Edible Medicinal and Non-Medicinal Plants

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Edible Medicinal and Non-Medicinal Plants

Volume 2, Fruits

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Contents

Combretaceae

Cucurbitaceae

Introduction

This book continues as volume 2 of a multi-compendium on *Edible Medicinal and Non-Medicinal Plants.* It covers edible fruits and seeds used fresh, cooked or processed into other by-products, or used as vegetables, spices, stimulants, edible oils and beverages. It encompasses species from the following families: Clusiaceae, Combretaceae, Cucurbitaceae, Dilleniaceae, Ebenaceae, Euphorbiaceae, Ericaceae and Fabaceae. However, not all the edible species in these families are included for want of coloured illustrations. The edible species dealt with in this work include to a larger extent lesser-known, wild and underutilized crops and also common and widely grown crops.

As in the first volume, topics covered include: taxonomy (botanical name and synonyms); common English and vernacular names; origin and distribution; agro-ecological requirements; edible plant parts and uses; plant botany; nutritive and medicinal/pharmacological properties with up-to-date research findings; traditional medicinal uses; other non-edible uses; and selected/cited references for further reading.

Clusiaceae

Most of the edible species in the family Clusiaceae (or Guttiferae) belonged to the *Garcinia* genus. The genus *Garcinia* is pantropical, comprising more than 250 species of evergreen, lactiferous, dioecious trees and shrubs that are a common flora of the moist, lowland tropical forests (Stevens 2007; Sweeney 2008). Centres of diversity of the genus have been reported to be in southeast Asia and Madagascar, and in the Guyana Highlands of the neotropics. Many species of *Rheedia* have been subsumed under *Garcinia*. Robson (1958) discussed the logical error in maintaining *Rheedia* separate from *Garcinia* asserting there is no basis in keeping them apart. Features thought to differentiate *Rheedia* from *Garcinia* such as the number of perianth parts and degree of fusion of the stamens are not constant in nor unique to *Rheedia* and occur in both genera (Hammel 1989; Adams 1970). Robson (1958) and later Adams (1970) argued for the inclusion of *Rheedia* in *Garcinia*, and this circumscription has been adopted in recent treatments.

One unique feature of plants in Clusiaceae is the presence of natural, secondary metabolites called xanthones. Xanthones is a family of three-membered ring phenolic compounds containing oxygen, with a yellow coloration and all of them have dibenzo-γ-pyrone or diphenylene ketone oxide, as the basic skeleton (Diderot et al. 2006; Na 2009) with the molecular formula $C_{13}H_8O_2$. Vieira and Kijjoa (2005) in their review of naturally occurring xanthones from January 2000 to December 2004, found among 515 xanthones reported during this period, of which 278 were new natural xanthones. These xanthones have been identified from 20 families of higher plants (122 species in 44 genera), fungi (19 species) and lichens (3 species). Since 1937 to 2009, 100 xanthones have been identified from Guttiferae (Han and Xu 2009), among which more than 40 are

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found in *Garcinia mangostana.* Xanthones are endowed with potent bioactivities, and provide a promising pharmacology for drug design and development (Chantarasriwong et al. 2010). Xanthones are potent antioxidants, substances that inhibit oxidation process during metabolism. Oxidation releases free radicals which are unstable molecules that cause damage to cell membranes and DNA leading to diseases like cancer, cardiovascular diseases, aging and more. Thus antioxidants scavenge these free radicals and protect cells from damage by them. Helping to fight cancer is just one of the many properties that different xanthones perform. In addition, some xanthones have shown significant antimicrobial, anti-inflammatory, antimicrobial, anti-hypercholesterolemic (cholesterol lowering), antithrombotic, immunopharmacological, antiviral, antimalarial, and antihypertensive biological profiles.

Of the edible *Garcinia* species, most notable ones from an economic standpoint are *Garcinia mangostana,* dubbed the Queen of fruits, and *Garcinia gummi-gutta,* source of hydroxycitric for weight loss. Both are rich in xanthones and also have other phytochemical such as flavonoids, tripenoid saponins and tannins and have potent bioactivities. Other lesser known edible *Garcinia* species covered in this volume also have pharmacologically active constituents but have been little exploited commercially as a fruit crop or for medicinal purposes. Among this group, *Garcina humilis,* known as Achacha or Bolivian mangosteen, has good commercial potential as a dessert fruit. Achacha has been introduced into Australia and is being cultivated commercially; the fruits are available in markets around Australia.

Combretaceae

Members of the Combretaceae family are widespread in the warm tropics and subtropics. This family comprises about 20 genera and 600 species of evergreen or deciduous trees, shrubs and woody lianas. Members of this family provide very valuable timber. Among the species that provides edible fruit noteworthy of mention are *Terminalia ferdinandiana, Terminalia kaernbachii* and *Terminalia catappa*. *Terminalia ferdinandiana is* most noted for its rich vitamin C content, containing around 5% vitamin C by weight, 50 times the concentration found in oranges. *Terminalia kaernbachii,* okari nut, an occasional timber species has potential as a high-value nut species. *Terminalia catappa,* Indian almond, possesses many bioactive metabolites that include flavonoids, triterpenoids and tannins that exhibit many pharmacological properties such as antinociceptive, antimicrobial, anti-diabetic, anticancer, and hepatoprotective, to mention some.

Cucurbitaceae

Cucurbitaceae is a major family for economically important species, particularly those with edible fruit such as cucumber, melon, gourds, pumpkin, zucchini, luffa and squashes. The family comprises 90 genera, 700 species, primarily in tropical and subtropical regions with a few representatives in temperate and cooler climates. The Cucurbitaceae are mostly prostrate or climbing, herbaceous annuals with characteristically coiled tendrils and five-angled stems. Some of the major edible species domesticated as food plants covered in this volume include *Citrullus lanatus* (watermelon), *Cucumis sativus* (cucumber), *Cucumis melo* (honey-dew melon, musk melon, cantaloupe), *Cucumis metuliferus* (African horned cucumber), *Cucurbita moschata* (pumpkin, butternut squash, squash), *Cucurbit pepo* (squash, pumpkin, zucchini), *Cucurbita filicifolia* (fig leaf gourd), *Momordica charantia* (bitter melon), spiny bitter gourd (*Momordica cochinchinensis), Sechium edule* (chayote), *Luffa acutangula, Luffa aegyptiaca* (luffa), *Lagenaria siceraria* (bottle gourd), *Benincasa hispida* (wax gourd), *Trichosanthes cucumerina* (snake gourd), *Coccinia grandis* (ivy gourd) and *Siraitia grosvenorii* (Arhat fruit, Buddha fruit, Luo han guo). Of these, three are more well known for their

medicinal value: *Momordica charantia* (bitter melon), *Momordica cochinchinensis* (gac) and *Siraitia grosvenorii* (luo han guo). Luo Han Guo is rich in mogrosides, a group of triterpene glycosides. Mogroside V, the major constituent in the fruit extract is more than 400 times as sweet as sucrose and is extremely low in calories. This fruit and mogroside V will be valuable as an advanced food ingredient and a natural sweetener substitute for sucrose in the near future, and might be valuable as a source of the chemopreventive agents in chemical carcinogenesis (Konoshima and Takasaki 2002). Gac fruit contains by far the highest content of β-carotene and lycopene of any known fruit or vegetable. The concentration of lycopene in the gac seed membrane has been reported to be about ten-times higher than that in known lycopene-rich fruit and vegetables. Gac also has other carotenoids like zeaxanthin and β-cryptoxanthin. Research has confirmed that the β-carotene (vitamin A) in gac fruit is highly bioavailable. Bitter melon contains bioactive compounds such as momordicins, cucubitacins, glycosides, terpenoid compounds and cytotoxic ribosome-inactivating proteins (RIPs). Together these compounds have shown various pharmacological and biological activities including antidiabetic, antiobesity, anticancer, antimicrobial, anti-HIV, antifeedant and antioviposition activities.

Dilleniaceae

The family Dilleniaceae comprises 10–12 genera with 400 species distributed in the tropical and subtropical regions in Asia to temperate Australia and Oceania. The genus *Dillenia* has about 100 species of which several have edible fruits. Of the *Dillenia* species with edible fruits, *Dillenia indica, D. serrata* and *D. philippinensis* have been used in traditional folkloric medicine in south and southeast Asia. Various plants parts of *D. indica* have exhibited antimicrobial, antidiarrhoeal, antiinflammatory and anticancer properties. *D. serrata* is also an important timber species.

Ebenaceae

Ebenaceae is a family of flowering plants, which includes ebony, a valuable timber species, and persimmon, a nutritious and economically-important fruit. The family comprises approximately 500 species of trees and erect shrubs in two genera, *Diospyros* and *Euclea*. The species are mostly evergreen and native to the warm tropics and subtropics, with a few deciduous species indigenous to temperate regions. *Diospyros* contains 450–500 species and has a pantropical distribution, with the greatest diversity of species in the Indo-Malayan region (Bakhuizen van den Brink 1936–1941; Kostermans 1977). Persimmon, *Diospyros kaki*, beside providing a nutritious and delicious fruit, also contain many bioactive phytochemicals that include tannins, proanthcyanidins, and flavoniods which impart a diverse array of pharmacological properties such as antioxidant activity, anticancer, antihypercholesterolemic, antidiabetic, cardioprotective, neuroprotective, antihypertensive, anti-skin whitening, and anti-aging activities.

Ericaceae

Ericaceae, the heather family, comprises about 125 genera and 4,000 species. The species are widely distributed in temperate and subarctic regions, and also found at high elevations in tropical regions. Plants are usually herbaceous or woody. Several genera and many species are ornamental viz. rhododendrons, azaleas and heathers. Edible berries are produced by some species in the genera: *Arctostaphylos, Gaylussacia* and *Vaccinium*. Within *Vaccinium*, the edible berries are: cranberry (sometimes called bearberry), blueberry, whortleberry, bilberry and huckleberry. Two species are covered in this volume, *Arbutus unedo* and *Vaccinium corymbosa*, blueberries. Blueberries are very nutritious and have many beneficial health attributes. Blueberries contain anthocyanins, potent antioxidant pigments, and various phytochemicals possibly having a role in reducing risks of some diseases, including

inflammation, cardiovascular and certain cancers. *Arbutus unedo* also produces edible fruit but is more well-known as an ornamental species.

Euphorbiaceae

The Euphorbiaceae, the spurge family, occurs mainly in the tropical Indo-Malayan region followed by tropical America. This one large family has been split or segregated into 14 families: Androstachydaceae, Antidesmataceae, Bischofiaceae, Hymenocardiaceae, Phyllanthaceae, Pedilanthaceae, Picrodendraceae, Porantheraceae, Putranjivaceae, Icinocarpaceae, Scepaceae, Stilaginaceae, Trewiaceae, and Uapacaceae. The Pandanaceae and Buxaceae, formerly included under Euphorbiaceae, are now well established as separate families. Many members of this family are economically important such as *Hevea brasiliensis* that produces rubber latex; *Ricinus communis* that provides castor oil; *Aleurites moluccana* candle nut; and *Manihot esculenta* whose tuberous roots are staple food in many tropical countries. Members of the families also include many ornamental species and weeds. Four species with edible fruit and medicinal properties, namely *Aleurites moluccana*, *Elateriospermum tapos*, *Hevea brasiliensis* and *Ricinus communis* are covered in this volume.

Fabaceae

Fabaceae or Leguminosae is the third largest family of flowering plants with 730 genera and over 19,400 species. It is commonly known as the legume family, pea family, bean family or pulse family. It consists of trees, shrubs or herbs, sometimes climbing or trailing species widespread throughout the tropics and temperate zone. Taxonomically, Fabaceae has been traditionally divided into three subfamilies, the Caesalpinioideae, Mimosoideae, and Papilionoideae. However, many scientists have ranked them as separate families, as in Caesalpiniaceae, Mimosaceae, and Papilionaceae. However, Lewis et al. (2005) maintained that there is increasing body of evidence from morphology, and molecular phylogenetic studies to support the legumes as being one monophyletic family. This view has been strengthened by the degree of interrelatedness of taxonomic groups within the legumes compared to that between legumes and its relatives, and also by recent molecular phylogenetic studies (Doyle et al. 2000; Kajita et al. 2001; Wojciechowski 2003; Wojciechowski et al. 2004). Such evidence has provided strong support for Fabaceae as a monophyletic family that is more closely linked to Polygalaceae, Surianaceae, and Quillajaceae, which together form the order Fabales (APG 2003).

Fabaceae is an economically important plant family. Legumes contribute significantly to the world's economy – through food and drink, pharmaceuticals and medicine, biotechnology, building and construction, textiles, furniture, horticulture, paper and pulp, fertilizers, chemicals, animal feed, timber, biodiesel, pest control, environmental management and ecotourism. There is a vast array of agricultural important plants, noteworthy of mention are: *Glycine max* (soybean), *Phaseolus* and *Vigna* spp. (various beans), *Pisum sativum* (pea), *Cicer arietinum* (chickpeas), *Medicago sativa* (alfalfa), *Arachis hypogaea* (peanut), *Lens culinaris* (lentils), *Lupinus* spp. (lupins), *Ceratonia siliqua* (carob), *Glycyrrhiza glabra* (licorice) and *Tamarindus indica* (tamarind). According to Graham and Vance (2003), grain legumes alone contribute 33% of the dietary protein nitrogen needs of humans, while soybeans and peanut provide more than 35% of the world's processed vegetable oil and a rich source of dietary protein for the poultry and pork industries. Except for alfafa, licorice and carob, the rest of the aforementioned are covered in this volume together with numerous lesser known legume species with edible fruit/seeds and some with medicinal value.

Health-wise, legumes are excellent sources of high quality proteins, low-glycemic index carbohydrates, essential minerals, dietary fibre and other bioactive phytochemicals. Soybeans have attracted the most scientific interest, mainly because they are a unique source of phytoestrogens known as isoflavones. Soyfoods and isoflavones

have received much attention for their potential role in preventing and treating cancer and osteoporosis (Messina 1999). Both beans and soybeans have reported protective and therapeutic effects that include lowering cholesterol levels, ameliorating diabetic state, and providing metabolic benefits that aid in weight control (Anderson et al. 1999).

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Calophyllum inophyllum

Scientific Name

***Calophyllum inophyllum* L.**

Synonyms

Balsaminaria inophyllum (L.) Lour., *Calophyllum bitangor* Roxb., *Calophyllum blumei* Wight, *Calophyllum calaba* Lam non L., *Calophyllum ovatifolium* Nor., *Calophyllum spurium* Choisy.

Family

Clusiaceae

Common/English Names

Alexandrian Laurel, Ball Nut, Ball Nut Tree, Beach Callophyllum, Beauty Leaf, Borneo Mahogany, Indian Laurel, India-Oil Nut, Laurelwood, Mastwood, Oi Nut Tree, Portia Tree, Poon, Poonay Oil Plant, Satin Touraga, Sweet-Scented Calophyllum

Vernacular Names

Burmese: Ponnyet, Ph'ong;
Chinese: Hai-Tang-Guo, Hong Hou Ke, Hu Tong;
Chuk: Rakich;
Cook Islands: Tamanu;
Fiji: Dilo;
French: Bintangor, Vintanina;
German: Alexandrischer Lorbeer, Rosenholz, Südsee-Eisenholz;
Guam: Daog, Daok;
Hawaiian: Kamani, Foraha, Tamanu;
India: Sultana-Champa, Sultanachampa, Sultanah-Champa, Sultanchampa, Surpan, Surpunika, Surpunka, Undi (Hindu), Hona, Honne, Honne Kaayi Mara, Honnu, Hoo Home, Hoo Honne, Huhome, Huhonne, Kallu Honne, Koove Mara, Mara, Naameru Mara, Namaeru, Nameru, Nameyru Mara, Ooma Mara, Pinekai, Pinnai, Pinnaykai, Ponneda, Ponnekayi, Srihonne, Suraganne-Mara, Suragonne, Sura Honne, Surahonnae Ponne, Surahonne, Surhonne, Sudaabu Mara, Voma, Uma, Vuma, Wuma (Kannada), Betan, Cerupunna, Ceruppuna, Cherupinna, Cherupuna, Cherupunna, Pine, Ponna, Ponnakam, Ponnakum, Pouna, Punna (Malayalam), Nagchampa, Pumag, Surangi, Undag, Undela, Undi, Ungam, Wundi (Marathi), Tungakesara (Oriya), Namaeruak, Panchakaeshera, Punnaga, Punnagah, Punnagavrikshaha, Punnaman, Tunga (Sanskrit), Arttakecam, Cayantakam, Cayantakamaram, Cimmantacikam, Culetam, Culetamaram, Curalam, Cuvetputpakam, Kecaram, Kopikakitam, Kopikakitamaram, Koppika, Koppikamaram, Kukattal, Kuruntutikam, Kuruntutikamaram, Macarrapattiram, Makapucurapi, Makapucurpimaram, Matukatitam, Matukatitamaram, Murunkai, Nagam, Nakam, Nameru, Narruti, Patalatturumam,

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Patumakecaram, Pillaicceti, Pinnai, Pitataru, Pitatarumaram, Punnacam, Punnacamaram, Punnagam, Punnai, Punnai-Maram, Pinmai, Punnakam, Punnagum, Punnaivirai, Pinnay Unnay, Pinnai, Purusa Akacciyam, Purusam, Purutaki, Purutakimaram, Purutam, Tamalai, Tankakecaram, Tevali, Tevalimaram, Vacanaikkenti, Viranankalkustampokki (Tamil), Naameru, Nameru, Ponna,Ponna Chettu, Ponna-Chettu, Ponnachettu, Ponna Vithulu, Ponnavittulu, Poona, Poonas, Poone, Pouna, Pumagamu, Puna, Punas, Punna, Punnaga, Punnagamu, Punnaagamu (Telugu);
Indonesia: Nyamplung (Java), Dingkaran (Sulawesi), Nyamplung (Sundanese), Punaga, Penago (Sumatra);
Kampuchea: Khtung, Kchyong;
Kiribati: Te Itai;
Kosrae: Eet;
Madagascar: Vintanina;
Malaysia: Bentagor Bunga, Bintagor, Bintangor Laut, Penaga, Penaga Laut, Penaga Air, Pudek, Senaga (Iban);
Maldives: Funa;
Marquesas: Tamanu;
Marshall Islands: Lukwej, Lueg;
Niuē: Fetau;
N. Marianas: Daog, Daok;
Palau: Btaches;
Papua New Guinea: Beach Calophyllum;
Philippines: Dagkaan (Bagobo), Dangkalan, Dingkalan (Bikol), Butalau (Cebu Bisaya), Bitaog, Pamitaogen (Iloko), Vutalau (Ivatan), Dangkalan, Langkagan (Maguindanao), Butalau (Manobo), Bitaog (Pampangan), Dangkalan (Panay Bisaya), Bitaoi (Pangasinan), Butulau (Samar-Leyte Bisaya), Bitaog (Sambali), Palo Maria De La Playa (Spanish), Palo Maria De La Playa (Sulu), Bitaog, Bitok, Bitong, Butulau, Dagkalan, Dangkalan, Dingkalan, Palo Maria De La Playa (Tagalog);
Pohnpei: Isou;
Portuguese: Loureiro De Alexandria;
Samoa: Fetau;
Society Islands: Tamnu;
Solomon Islands: Koila;
Spanish: Palo De Santa María, Palo María, Undi;
Sri Lanka: Domba-Gass;
Swahili: Motondoo, Mtondoo, Mkanja;
Tahiti: Ati, Tamanu;
Thailand: Kating, Kra Thing (General), Saraphee Naen (Northern), Naowakan (Nan);
Tonga: Feta U, Tamanu;
Vanuatu: Nambagura;
Vietnamese: Cong, Mù U;
Yap: Biyuch.

Origin/Distribution

Calophyllum inophyllum is a native of the old world tropics from East Africa, southern coastal India to Malesia, northern Australia and the Pacific islands. The species is widespread along the coasts of eastern Africa (from Kenya to northern Mozambique), Madagascar and other Indian Ocean islands, tropical Asia, northern Australia and the islands of the Pacific Ocean. Although it is considered wild in most of this area, it is often unclear where it is truly wild or a relict of former cultivation. In Réunion and Mauritius it has possibly been introduced. In Africa, it is locally planted outside the natural distribution area, e.g. in Guinea, Sierra Leone, Côte d'Ivoire, Ghana, Nigeria, Cameroon and Gabon, where seemingly wild trees and seedlings can be found near beaches. The species is also planted in southern China.

Agroecology

Calophyllum inophyllum occurs in maritime, littoral and riparian areas in the warm tropics and sub-tropics. It thrives in areas with mean annual temperature of 18–33°C, mean maximum temperatures of 22–37°C mean minimum temperatures of 12–17°C and mean annual rainfall of 1,000–5,000 mm occurring seasonally in winter or summer or uniformly throughout the year. It grows naturally on rocky and sandy sea shores, usually just above the high-tide mark and has also been cultivated successfully in inland areas at elevation from 0 to 800 m elevation. It is not suited to higher

elevations. It grows best in full sun but will tolerate light shade. It is a hardy robust tree that tolerates strong wind, salt spray, drought, and brief periods of waterlogged conditions but is susceptible to natural bush fires, cold weather (below 10°C) and frost. It occurs on a wide range of soils including clays, loams, calcareous, rocky and gravelly soils but performs best on well-drained, sandy soils. It is also tolerant of saline soils. A pH range of 4.4–7.4 is suitable for the tree.

Edible Plant Parts and Uses

Only the endospermum of the immature, unripe fruit is safe to be eaten. In Indonesia, the half-ripe fruit are sometimes pickled but only the endosperm is eaten (Burkill 1966); but caution is needed as toxic compounds may be present in the fruit and seeds. In Sabah, young sour fruit is pickled in sugar and eaten (Lee and Gibot 1986). The seed oil has also been reported to be edible after refinement and detoxification. Unlike most vegetable oils, Tamanu oil is not contained in fresh ripe fruits. It forms in the course of the nuts' desiccation.

Studies conducted by Venkatesan and Rege (1973) reported the possibility of using the meal remaining after defatting *Calophyllum inophyllum* seeds as a potential protein source in foods and feeds. Reasonably good correlation between chemical data and biological performance had been observed in case of undi (*C. inophyllum*) meal. The meal, when made nutritionally adequate by supplementation, was found capable of supporting normal growth rate in animal studies. Fat-free meal from undi and mowra (*Bassia latifolia*) seeds provided 25% or 50%, casein the remainder, of the dietary protein of rats. The undi meal was poor in methionine. The protein efficiency ratio of undi meal at the 50% level, alone or supplemented with histidine 0.09, lysine 0.14 and methionine 0.21% of diet, was 78.2, 91.3 and at the 25% level, without or with 1% methionine, was 98.1%, 100.6%, respectively, with 100% for the control diet of casein.

Plate 1 Bark, leaves and fruits

Botany

A medium to large, lowly branched evergreen, tree with a broad, spreading to irregular crown, gray bark and fissured trunk (Plate 1) and reaching heights of 8–30 m. It has milky white sap. Leaves are opposite, deep glossy green, glabrous, simple, coriaceous with broadly elliptic or obovate-elliptic lamina 10–20 cm long by 6–9 cm wide, rounded or emarginate apex, rounded or cuneate base, entire margin (Plate 1) and distinct parallel lateral veins, perpendicular to the mid rib. Flowers are white, fragrant, bisexual, 2.5 cm across and 8–14 mm long on sturdy pedicels and borne in racemose or paniculate, axillary inflorescences of 4–15 flowers. Flower has 8 white, suborbicular to obovate tepals, numerous (200 to >300) free stamens, superior, subglobose ovary with joined carpels, one locule and one solitary, peltate style. Fruit is globose to subglobose, 2.5–4 cm across, indehiscent drupe, light green (Plate 1) turning yellow to purplish brown and wrinkled when ripe and is found in clusters. The seed is large, brown 2–4 cm across and surrounded by a corky shell and thin pulp.

Nutritive/Medicinal Properties

Calophyllum inophyllum possess more significance as a timber tree with manifold medicinal attributes rather than for its infrequently eaten fruit. As such, no nutritive information has been published on the nutrient value of the fruit.

The physico-chemical properties and fatty acid composition of the kernel oils of *Calophyllum calaba* L. and *Calophyllum inophyllum* were reported by Crane et al. (2005). Oleic acid C18:1 (39.1–50%) was the predominant fatty acid followed by linoleic acid C18:2 (21.7–31.1%). Stearic C18:0 (13.4–14.3%) and palmitic C16:0 (11–13.7%) acids were the major saturates. The oils contained an appreciable amount of unsaturated fatty acids (70.8–73.10%). Most of the fatty acids were present as triacylglycerol (76.7–84%), 21 triacylglycerols were detected with predominantly unsaturated triacylglycerols. In both species, analysis of the unsaponifiable fractions revealed the preponderance of phytosterols, mainly stigmasterol (35.8–45.1%) and β-sitosterol (41.1–43.1%). Variations existed among the eight tocopherols and tocotrienols present in the two species; α-tocopherol (183 mg/kg) was the major tocopherol in *Calophyllum calaba* and δ-tocotrienol (236 mg/kg) was the dominant tocotrienol in *Calophyllum inophyllum*.

Total kernel lipids extracted from *Calophyllum inophyllum*, amounted to 60.1% of the dry kernel (Hemavathy and Prabhakar 1990). The total lipids consisted of 92.0% of neutral lipids, 6.4% glycolipids and 1.6% phospholipids. Neutral lipids consisted of triacylglycerols (82.3%), free fatty acids (7.4%) and small quantities of diacylglycerols, monoacylglycerols and sterols. At least four glycolipids and five phospholipids were identified. Acylmonogalactosyldiacylglycerol and monogalactosylmonoacylglycerol were the main glycolipids; while an acylated sterolglucoside and monogalactosyldiacylglycerol was present in small amounts. The phospholipids consisted of phosphatidylethanolamine and phosphatidylcholine as major phospholipids, and minor amounts of phosphatidic acid, phosphatidylserine and lysophosphatidylcholine.

Seventeen components out of 25 were identified in the pale yellow oil steam-distilled from *C. inophyllum* flowers (Samsudin et al. 1998). The major constituent of the oil was found to be a naphthalene derivative, l,2,3,4,4α,7-hexahydro-1,6-dimethyl-4-(l -methylethyl)naphthalene, which accounted for 24.50% of the oil. Other components identified were α-cubebene (6.83%), β-farnesene (6.53%), calerene (6.44%), β-selinene (5.28%), δ-cadinene (4.74%), α-farnesene (3.76%), β-bourbonene (3.01%), farnesol (2.59%), hexadecane (2.18%), β-sesquiphellandrene (2.12%), octadecanal (2.02%), nerolidol (0.95%), α-murelene (0.82%), copaene (0.77%) and zingiberene (0.46%).

Reviews reported by Su et al. (2008); Cechinel Filho et al. (2009) on *Calophyllum inophyllum*, revealed that various parts of the tree contained bioactive phytochemicals which included xanthones, coumarins, chromanones (flavonoids, biflavonoids), tripenes, tripenoids and steroids. Many of these compounds possessed biological activities that included anticancer (cytoxtoicity, antitumorous), antimicrobial, antimalarial, inhibition of HIV-1 reverse transcriptase, antisecretory and cytoprotective properties, inhibition of multidrug transport of P glycoproteins, inhibition of sulfotranferases, antinociceptive, molluscicidal and etc.

Phytochemicals in the Leaves

The following xanthones: inophyxanthone A [1, 3, 5-trihydroxy-2-(1, 1-dimethylallyl)xanthone], pancixanthone A, gerontoxanthone B, jacareubin and pyranojacareubin were isolated from *C. inophyllum* leaves (Li et al. 2009). Three new friedelane-type triterpenoids, 3,4-secofriedelan-3,28-dioic acid, 27-hydroxyacetate canophyllic acid and 3-oxo-27-hydroxyacetate friedelan-28-oic acid, were isolated from the leaves of *Calophyllum inophyllum* (Laure et al. 2005). Various pyranocoumarins, calophyllolide, inophyllums B, inophyllum C, inophyllum G(1), inophyllum G(2) and inophyllum P, were isolated from the leaves (Laure et al. 2008). Nine compounds were isolated from stems and leaves of *Calophyllum inophyllum*: 2-hydroxyxanthone; 4-hydroxyxanthone; 1, 5-dihydroxyxanthone; 1, 7-dihydroxyxanthone; 1, 3, 5-trihydroxy-2-methoxyxanthone; 6-deoxyjacareubin; flavonoids amentoflavone; kaempferol-3-O-α-L-rhamnoside; and quercetin-3-O-α-L-rhamnoside (Li et al. 2007). Two isomeric benzodipyranone (chromone) derivatives: (2*S*,3*R*)-2,3-dihydro-5-

hydroxy-2,3,8,8-tetramethyl-6-(1-phenylethenyl)-4H,8H-benzo [1,2-*b*:3,4-*b*′] dipyran-4-one along with (2*R*,3*R*)-2,3-dihydro-5-hydroxy-2,3,8,8-tetramethyl-6-(1-phenylethenyl)-4H,8H-benzo [1,2-*b*:3,4-*b*′] dipyran-4-one were isolated from the leaves of *Calophyllum inophyllum* (Khan et al. 1996). The chromone flavonoid epimers, inophynone and isoinophynone were isolated from leaves together with the sterol: cholesterol, triterpenes: friedelin, canophyllol and canophyllic acid (Ali et al. 1999); triterpenes friedelin, canophyllal, canophyllol and canophyllic acid (Govindachari et al. 1967).

The following pyranocoumarins: inophyllum A, inophyllum B, inophyllum C, and inophyllum E; and calophyllolide 1a, calophyllolide 2a, calophyllolide 3a, calophyllolide 3b, and calophyllolide 6, were isolated in considerably high yield in addition to a novel enantiomer of soulattrolide, inophyllum P (2a 2b), and two other novel compounds, inophyllums G-1 and G-2 from the leaves (Patil et al. 1993).

Phytochemicals in the Seeds

Fractionation of the ethanolic extract of the seeds of *Calophyllum inophyllum* resulted in the isolation of four novel pyranocoumarin derivatives, designated as inocalophyllin A, inocalophyllin B and their methyl esters in addition to the known calophyllolide (Shen et al. 2003). Bhushan et al. (1975) recorded calaustralin, a new 4-phenylcoumarin from the seed oil of *Calophyllum inophyllum*. Three new pyranocoumarin derivatives, tamanolide, tamanolide D and tamanolide P, were isolated from the seeds (Leu et al. 2009). Costatolide and inophyllum (Spino et al. 1998) and 5,7-dihydroxy-6-(2-methylbutyryl)-4-phenylcoumarin (Ravelonjato et al. 1992) were isolated from the seeds.

Phtyochemicals in the Wood, Bark and Root

The following xanthones were isolated from the heart wood: 2-(3-hydroxy-3-methylbutyl)-1,3,5,6-tetrahydroxyxanthone, jacareubin, 6-deoxyjacareubin, 2-(3-methylbut-2-enyl)-1,3,5,6-tetrahydroxyxanthone and 2-(3-methylbut-2-enyl)-1,3,5-trihydroxyxanthone (Goh and Jantan 1991); jacareubin, 1,7-dihydroxyxanthone (euxanthone), 1,5,6-trihydroxyxanthone, 1,6-dihydroxy-5-methoxyxanthone (buchanaxanthone), 6-desoxyjacareubin, 2-(3,3-dimethylallyl)-1,3,5-trihydroxyxanthone and 2-(3,3-dimethylallyl)-1,3,5,6-tetrahydroxyxanthone (the latter two isolated as their methyl ether derivatives) (Al-Jeboury and Locksley 1971). The following were also isolated from the heart wood: mesuaxanthone B and calophyllin B (Govindachari et al. 1968); 6-desoxyjacareubin, 2-(3,3-dimethylallyl)-1,3,5,6-tetrahydroxyxanthone, and jacareubin (Jackson et al. 1969); jacareubin; 1,7-dihydroxy-3,6-dimethoxyxanthone; 6-desoxyjacareubin; 6(3-methyl-2-butenyl)-1,5-dihydroxyxanthone (Kumar et al. 1976). Xanthones isolated from root bark and wood included: caloxanthones A and B, macluraxanthone and 1,5-dihydroxyxanthone (Iinuma et al. 1994b); caloxanthone D, caloxanthone E, 1,3,8-trihydroxy-7-methoxy-xanthone, 1,3-dihydroxy-7,8-methoxy-xanthone, 1,3,5-trihydroxy-2-methoxy-xanthone and 6-hydroxy-1,5-dimethoxy-xanthone (Iinuma et al. 1995). Chemical investigations on the root bark extracts of *Calophyllum inophyllum* yielded two new xanthones, inophyllin A and inophyllin B, three known xanthones, brasilixanthone B, tovopyrifolin C, caloxanthone B, one triterpene, friedelin and one triterpenoid, β-sitosterol (Ee et al. 2004, 2006, 2009).

From the root bark, a new xanthone named caloxanthone C and 4-hydroxyxanthone were isolated, and from the heartwood, a new xanthone 1-hydroxy-2-methoxyxanthone in addition to three known xanthones 1,2-dimethoxy-xanthone, 2-hydroxy- 1-methoxy-xanthone, and 6-deoxyjacareubin (Iinuma et al. 1994a); a polyphenolic compound flavanoid (−)-epicatechin was also isolated (Iinuma et al. 1994a). The study of the chemical constituents of the root bark and the nut of *Calophyllum inophyllum* resulted in the isolation and characterization of a xanthone derivative, named inoxanthone,

together with 12 known compounds: caloxanthones A, and B, macluraxanthone, 1,5-dihydroxyxanthone, calophynic acid (dihydro coumarin), brasiliensic acid, inophylloidic acid, friedelan-3-one, calaustralin (4-phenyl coumarin), calophyllolide, inophyllum C and inophyllum E (Yimdjo et al. 2004).

Two new prenylated xanthones, caloxanthone O and caloxanthone P were isolated from the twigs (Dai et al. 2010).

Biological activities of the phytochemicals from various parts of the tree include:

Antivira Activity

From a methanol/methylene chloride extract of *C. inophyllum*, inophyllums A, B, C, and E and calophyllolide (1a, 2a, 3a, 3b, and 6), in considerably greater yield were isolated in addition to a novel enantiomer of soulattrolide (4), inophyllum P (2b), and two other novel compounds, inophyllums G-1 (7) and G-2 (8) (Patil et al. 1993). Inophyllums B and P (2a and 2b) were found to inhibit HIV reverse transcriptase with IC_{50} values of 38 and 130 nM, respectively, and both were active against HIV-1 in cell culture (IC_{50} of 1.4 and 1.6 μM). Closely related inophyllums A, C, D, and E, including calophyllic acids, were significantly less active or totally inactive, indicating certain structural requirements in the chromanol ring. Altogether, 11 compounds of the inophyllum class were isolated from *C. inophyllum* and were described together with the SAR (structure-activity relationship) of these novel anti-HIV compounds. The seeds of *Calophyllum cerasiferum* and *Calophyllum inophyllum* were found to contain several known coumarins, among which were the potent HIV reverse transcriptase inhibitors costatolide and inophyllum (Spino et al. 1998).

Inophyllums isolated from *Calophyllum inophyllum* were found to be novel non-nucleoside inhibitors of human immunodeficiency virus (HIV) type 1 reverse transcriptase (Taylor et al. 1994; De Clercq 2000). Inhibition of avian myeloblastosis virus reverse transcriptase and Moloney murine leukemia virus reverse transcriptase by inophyllum B was demonstrated, suggesting that these inhibitors may be more promiscuous than other previously described non-nucleoside inhibitors. Inophyllums were active against HIV type 1 in cell culture with IC_{50} values of approximately 1.5 μM. These studies implied that the inophyllums had a novel mechanism of interaction with reverse transcriptase and as such could conceivably play a role in combination therapy.

Various pyranocoumarins, calophyllolide, inophyllums B, C, G(1), G(2) and P, from *Calophyllum inophyllum* leaves of French Polynesia (Austral, Marquesas, Society and Tuamotu archipelagos) were found to inhibit HIV-1 (Laure et al. 2008). The use of multivariate statistical analyses (PCA) showed geographical distribution of inophyllums and indicated those rich in HIV-1 active (+)-inophyllums. Inophyllum B and P contents (0.0–39.0 and 0.0–21.8 mg/kg, respectively) confirmed the chemodiversity of this species within the large area of French Polynesia. The study suggested the presence of interesting chemotypes which could be used as plant source for anti-HIV-1 drugs. A number of coumarins, xanthones and chromene acids from different *Calophyllum* species of Sri Lanka including *C. inophyllum* were found to be inactive in both the HIV-1 RT and whole virus systems (Dharmaratne et al. 2002). In contrast, cordatolide A and B demonstrated IC_{50} values of 19.3 and 11.7 μM, respectively, against HIV-1 replication in a novel green fluorescent protein (GFP)-based reporter cell assay (HOG.R5).

Anticancer Activity

Ten 4-phenylcoumarins isolated from *Calophyllum inophyllum* exhibited inhibitory activity against Epstein-Barr virus without showing any cytotoxicity (Itoigawa et al. 2001). Calocoumarin-A (5) showed more potent activity than any of the other compounds tested. Furthermore, calocoumarin-A exhibited a marked inhibitory effect on mouse skin tumour

promotion in an in vivo two-stage carcinogenesis test. The results indicated that some of these 4-phenylcoumarins might be valuable as potential cancer chemopreventive agents (anti-tumour-promoters). A new friedelane-type triterpene, along with seven known triterpenoids, was isolated from the stems and leaves of *Calophyllum inophyllum* (Li et al. 2010). Their structures were established as 3β, 23-epoxy-friedelan-28-oic acid, friedelin, epifriedelanol, canophyllal, canophyllol, canophyllic acid, 3-oxo-friedelan-28-oic acid, and oleanolic acid. The growth inhibitory effects of these triterpenoids on human leukemia HL-60 cells were also determined.

A new prenylated xanthone (**1**), named caloxanthone N, together with two known constituents, gerontoxanthone C (**2**) and 2-hydroxyxanthone (**3**), were isolated from the ethanolic extract of the twigs of *Calophyllum inophyllum (*Xiao et al. 2008). Compounds **1** and **2** exhibited cytotoxicity against chronic myelogenous leukemia cell line (K562) with IC_{50} values of 7.2 and 6.3 μg/ml, respectively. Two new prenylated xanthones, caloxanthone O (1) and caloxanthone P (2) were isolated from the ethanol extract of the twigs (Dai et al. 2010). Compound 1 exhibited cytotoxicity against human gastric cancer cell line (SGC-7901), with an IC_{50} value of 22.4 μg/mL while compound 2 was inactive (IC_{50}>100 μg/mL). Extract of *C. inophyllum* was one of 43 plant species that were found to exhibit in-vitro cell viability of a human leukaemia cell-line HL60 by more than 50% when exposed to 9.6 J/cm^2 of a broad spectrum light when tested at a concentration of 20 μg/mL (Ong et al. 2009). The results indicated that the plant extract could have potential for photodynamic therapy.

Antiplatelet Activity

Xanthone compounds isolated from *Calophyllum* and *Garcinia* species including *Calophyllum inophyllum* exhibited antagonistic activity against rabbit platelet activating factors (PAF) (Jantan et al. 2001). The compounds, 6-deoxyjacareubin, 2-(methylbut-2-enyl)-1,3,5-trihydoxyxanthone and 2-(3-methylbut-2-enyl)-1,3,5,6-tetrahydroxyxanthone isolated from *C. inophyllum* inhibited 3 H-PAF binding to rabbit platelets with IC_{50} values of 4.8, 29.0 and 44.0 μM, respectively. Calophyllolide, a nonsteroidal 1–4 phenyl coumarin isolated from *C. inophyllum* exhibited anti-blood coagulation activity (Arora et al. 1962). Xanthones from 3 Clusiaceae plants (*Hypericum patulum, Calophyllum inophyllum* and *C. austroindium*): guanandin; caloxanthone E; 1,3,5,6-tetrahydroxy-2-isoprenylxanthone; 6-deoxyjacareubin; and patulone showed strong inhibition of platelet activating factor (PAF)-induced hypotension, with inhibitory effects of more than 60% (Oku et al. 2005). Their ID_{50} values were greater than that of ginkgolide B (BN-52 021), a natural PAF-antagonist from the *Ginkgo biloba*.

Antimicrobial Activity

C. inophyllum oil exhibited antibacterial activity in-vitro against Gram negative bacteria (Bhat et al. 1954). Tamanu (*C. inophyllum*) oil demonstrated significant antimicrobial activity, as shown in antibacterial and antifungal tests (Sundaram et al. 1986; Mahmud et al. 1998). The oil was found to contain several powerful bactericide/fungicide agents, which demonstrated efficacy against various human and animal pathogens. These antimicrobial phytochemical agents included friedelin, canophyllol, canophyllic acid, and inophynone (Mahmud et al. 1998). Xanthones and coumarins in tamanu oil demonstrated antioxidant properties, specifically inhibiting lipid peroxidation (Mahmud et al. 1998). The antioxidant activity of tamanu oil was found to protect skin cells from damage by reactive oxygen species and other oxidative antagonists.

The following compounds from the root bark and the nut of *Calophyllum inophyllum*: a xanthone derivative, named inoxanthone, 3, together with 12 known compounds: caloxanthone A; caloxanthone B; macluraxanthone; 1,5-dihydroxyxanthone; calophynic acid; brasiliensic acid; inophylloidic acid; friedelan-3-one; calaustralin; calophyllolide; inophyllum C; and inophyllum E were evaluated for their antimicrobial

activity against *Staphylococcus aureus, Vibrio anguillarium, Escherichia coli*, and *Candida tropicalis* (Yimdjo et al. 2004). Their *in vitro* cytotoxicity against the KB cell line was also evaluated. At 20 μg per disc, caloxanthone A, calophynic acid, brasiliensic acid, inophylloidic acid, calophyllolide, inophyllum C and inophyllum E inhibited the growth of *S. aureus*.

UV Protection Activity

Calophyllum inophyllum oil was found to exhibit antioxidant and cytoprotective properties, and thus to have potential as a natural UV filter in ophthalmic preparations (Said et al. 2006). The oil, even at low concentration (1/10,000, v/v), exhibited significant ultra violet (UV) absorption properties (maximum at 300 nm) and was associated with an important sun protection factor (18–22). Oil concentrations up to 1% were not cytotoxic on human conjunctival epithelial cells, and *Calophyllum inophyllum* oil appeared to act as a cytoprotective agent against oxidative stress and DNA damage (85% of the DNA damage induced by UV radiations were inhibited with 1% Calophyllum oil) and did not induce in vivo ocular irritation in rabbits.

Wound Healing Activity

Dweck and Meadows (2002) reported that there was significant improvement in scars after 6 weeks of tamanu oil use in six subjects with visually obvious scars, which continued till 9 weeks of the study. The overall size of scars gradually decreased throughout the study. Scar length decreased by an average of 0.28 cm and scar width by an average of 0.12 cm. They reported that the oil was recommended for all kinds of burns (sunburns or chemical burns), most dermatoses, postsurgical cicatrization, certain skin allergies, acne, psoriasis, herpes, chilblains, skin cracks, diabetic sores, haemorrhoids, dry skin, insomnia, hair loss, etc. In cosmetology, it is used in the preparation of regenerative creams. Calophyllic acid and a lactone was found to be endowed with antibiotic properties which contributed to the oil's amazing cicatrising power (Dweck 2003).

Central Nervous System (CNS) Depressent Activity

The xanthones of *Calophyllum inophyllum* and *Mesua ferrea* namely, dehydrocycloguanandin (DCG), calophyllin-B (CPB), jacareubin (JR), 6-desoxy jacareubin (DJR), mesuaxantbone-A (MXA), mesuaxanthone-B (MXB) and euxanthone (EX) produced varying degrees of CNS depression characterised by ptosis, sedation, decreased spontaneous motor activity, loss of muscle tone, potentiation of pentobarbitone sleeping time and ether anaesthesia in mice and rats (Gopalakrishnan et al. 1980). None of the xanthones had any analgesic, antipyretic and anticonvulsant activities. The xanthones did not produce any pharmacological effect in the cardiovascular system of frogs and dogs.

Antiinflammatory Activity

Tamanu oil demonstrated significant anti-inflammatory activity which was partially due to the 4-phenyl coumarin calophyllolide (Bhalla et al. 1980). Calophyllolide, a nonsteroidal anti-inflammatory agent, was found to be effective in reducing the increased capillary permeability induced in mice by various chemical mediators involved in the inflammatory process viz. histamine (HA), 5-hydroxytryptamine (5-HT) and bradykinin (BK) (Saxena et al. 1982). Pretreatment with calophyllolide (p. o.) afforded significant protection against induced increase in capillary permeability by HA (PD50 144.1 mg/kg), 5-HT (PD50 250.0 mg/kg) and BK (PD50 133.5 mg/kg). The xanthones of *Calophyllum inophyllum* and *Mesua ferrea* namely, dehydrocycloguanandin (DCG), calophyllin-B (CPB), jacareubin (JR), 6-desoxy jacareubin (DJR), mesuaxantbone-A (MXA), mesuaxanthone-B (MXB) and euxanthone (EX) exhibited anti inflammatory activity both by intraperitoneal and

oral routes in normal and adrenalectomised rats as tested by carrageenin induced hind paw oedema, cotton pellet granuloma and granuloma pouch techniques, (Gopalakrishnan et al. 1980). The xanthones did not have any mast cell membrane stabilising effect, and the degranulating effect of compound 48/80, diazoxide and Won-X-100 on rat peritoneal mast cells in-vitro was not prevented.

Antiulcer Activity

The xanthones jacareubin and 6-desoxy jacareubin isolated from *Calophyllum inophyllum* exhibited antiulcer activity in rats (Gopalakrishnan et al. 1980).

Molluscicidal Activity

Of crude extracts of seeds, leaves and barks of *Calophyllum inophyllum*, the seed extract showed significant molluscicidal activity against *Biomphalaria glabrata* (Ravelonjato et al. 1992) . Among the coumarinic derivatives examined, 5,7-dihydroxy-6-(2-methylbutyryl)-4-phenylcoumarin presented an interesting molluscicidal activity.

Stable Fly Repellancy Activity

An enhancement in the protection time was produced by binary mixtures (PT, 2.68–2.04 h) of five essential oils (clove bud, clove leaf, thyme white, patchouli, and savory) and tamanu oil (0.25:2.0 mg/cm^2) compared with that of either the constituted essential oil or tamanu oil alone (PT, 0.56 h) in repellancy test against female stable fly, *Stomoxys calcitrans* in humans (Hieu et al. 2010b). The protection time of these binary mixtures was comparable with that of DEET the commonly used repellant. With the exception of savory essential oil, the other essential oils, tamanu oil, and binary mixtures did not induce any adverse effects on the human volunteers at 0.5 mg/cm^2. In another study, Hieu et al. (2010a) found that mixtures formulated from *Zanthoxylum piperitum* (pericarp steam distillate (ZP-SD), *Zanthoxylum armatum* seed oil (ZA-SO) and their constituents alone or in combination with *Calophyllum inophyllum* nut oil (CI-NO), or their bioactive constituents could be useful as potential repellents for the control of stable fly, *Stomoxys calcitrans* populations. The repellency of aerosols containing 2.5% ZP-SD or 2.5% ZA-SO and 2.5% CI-NO was comparable with that of 5% DEET aerosol.

Traditional Medicinal Uses

Various parts of the tree have been used in traditional herbal folk remedies in Asia and the Pacific islands (Burkill 1966; Chuah et al. 2007; CSIR 1950; Dweck and Meadows 2002; Kirtikar and Basu 1989; Lemmens 2003; Quisumbing 1978; Whistler 1992). Various parts has been reported to be used as a diuretic, for treatment of venereal disease, blood pressure, rheumatism, inflammation, eye diseases, varicose veins, haemorrhoids, chronic ulcers, skin infections and wounds (Su et al. 2008; Dai et al. 2010).

Plant

The plant is a virulent poison including the mature fruit and seed kernel. The milky juice causes blindness when brought in contact with the eyes and the sap, when brought into the circulation, causes death and is therefore used by the Samoans as an arrow poison.

Root

In Mauritius a root decoction is used to treat ulcers, boils and ophthalmia (inflamed eyes). A root infusion is used internally in conjunction with heated leaf poultice for side-stitch. The root decoction is used externally in combination with the leaf infusion taken internally for heat stroke.

Bark/Resin

Resin that oozes from the bark and bark itself have various medicinal uses. Bark can be used as

analgesic, antispasmodic, depurative, diuretic, emmolient and laxative and contains tannin. In India and Indo-China the pounded bark is applied in orchitis. In Indo-China, the bark is used against dysentery and intestinal colds. In Indonesia, the bark decoction is given after childbirth for vaginal discharges, passing of blood and in gonorrhoea. The latex and pounded bark are applied externally on wounds, ulcers and to treat phthisis, orchitis and lung affections, and internally as a purgative, after childbirth and to treat gonorrhoea. The gum that oozes from wounds is astringent and used as emetic and purgative and a decoction is given for internal haemorrhage and also used for the antiseptic treatments of wounds and ulcers. The oleoresin mixed with strips of the bark and leaves, and is steeped in water; the oil which rises to the surface is used as an application to sore eyes. The resin is sudorific and is useful for chronic catarrh and as cicatrizant for wounds, indolent ulcers and sores. The resin is employed in Indonesia, Philippines and Indochina as an application on wounds and a balsamic in phthisis. The oleoresin is taken internally for affections of the lungs.

Leaves

Boiled leaves provide a wash solution for skin rash, leg swellings, leg ulcers and wounds. Heat softened leaves are applied to boils, cuts, wounds, sores, pimples and skin ulcers, also for treating ocular irritation and microbial infection. In Madagascar, Linga and Fiji, a leaf lotion is used for sore eyes. Leaf solution is used as an astringent against haemorrhoids in the Philippines. Leaf infusion is used to treat sore eyes and dysentery. Leaves are used in inhalations to treat migraine and vertigo in Cambodia. The leaf infusion is taken internally of heat stroke in conjunction with an external application of the root decoction. For side stitch, the hot leaf poultice is applied externally in combination with the root decoction taken internally.

Flower/Fruit

The flowers are used as a heart tonic. An infusion of the fruit is pectoral and stimulates the mucous membrane of the lungs.

Seed/Seed Oil

Pounded seeds are applied on the abdomen for gastric pains, indigestion and colic in the Philippines. In Indonesia, pounded seed are used for itch. In Western India, the pounded seeds are mixed with cashew nuts, borax and sparrow droppings to boils to hasten maturation. In India, the seed oil is applied as a remedy for exanthematous eruptions, and as external application for scabies, liniment for rheumatism, arthritis and gout and as a treatment for gonorrhoea and gleet. The seed oil is rubefacient, analgesic, emetic and irritant and is applied externally as an analgesic against rheumatism and sciatica, and as a medication against swellings, ulcers, scabies, ringworm, boils, sores, and itch. In Malaysia and Polynesia, the seed oil is used as an external application for indigestion and colic and rheumatism. In the Philippines, the seed oil is used as a cicatrisant and as balsamic (soothing medicine) in pulmonary complaints. In Kenya, the seed oil is applied to glandular swellings in the neck and jaws. Fijian use the seed oil to massage their bodies. In Malaysia the seed oil is also used for ringworm. The oil has various other applications: hair/tonic/alopecia, relief of neuritis, nappy rash, minor wounds (lip chaps and skin cracks, atonic wound, physical and chemical burns. The seed oil is called Donba oil in Europe and is used for the treatment of rheumatism, itch and scabies.

Other Uses

Various parts of the tree have many other non-medicinal uses (Al-Jeboury and Locksley 1971; Burkill 1966; CSIR 1950; Dweck and Meadows 2002; Friday and Okano 2006; Lemmens 2005; Lim and Lemmens 1993).

Calophyllum inophyllum is planted as a roadside tree, shade tree, in hedges and as a wind break, and landscape ornamental plant in parks, gardens and coastal areas. The tree has been regarded as sacred in some Pacific islands, where it has been planted around altars and featured in old chants. It is also a useful timber tree. It provides valued, hard and strong wood for general construction and the construction of ships, canoes

and small boats, masts, keels, knees and pulley blocks, carpentry, flooring, panels, stairs, furniture and cabinet work, cart-wheel hubs, vessels, handicraft and musical instruments. . In Hawai'i it is traditionally used for food vessels and in Palau for storyboards. Latex from the cut bark can be used as a poison to kill rodents and stun fish. The bark is used as shingles/thatches for house walls in Yap. Latex from the cut bark has been made into a poison to kill rodents and stun fish. The bark contains tannins that have been used to strengthen fishing nets.

Flowers are used in leis (garlands), to scent hair, and to scent bark cloth. The mature fruit is burned for mosquito repellent. In ancient Hawai'i, a brownish-mauve dye for tapa or bark cloth (*kapa*) was made from the fruit husks. The stones (nuts) of the fruit are used as marbles. The nuts are hollowed out and the shells are used in making leis. The round thin shells are used as receptacles for 'buri sugar' a popular confection. In ancient times, whistles were made from the hollowed- out shells.

The seeds yield a thick, dark green oil for medicinal use or hair grease. The seed oil is used for illumination in oil lamps, varnishes, and as finishers for wooden bowls and wood. The purified oil can be used in soap production and as a carrier oil, skin moisturizer, skin creams and hair oil in cosmetics and also in aromatherapy.

The seed oil can be used as biodiesel. Studies conducted by Sahoo et al. (2007) in India demonstrated that non-edible filtered high viscous (72 cSt at 40°C) and high acid value (44 mg KOH/g) polanga (*Calophyllum inophyllum*) oil based mono esters (biodiesel) produced by triple stage transesterification process and blended with high speed diesel (HSD) were suitable for their use as a substitute fuel of diesel in a single cylinder diesel engine. HSD and polanga oil methyl ester (POME) fuel blends (20%, 40%, 60%, 80%, and 100%) were used for conducting the short-term engine performance tests at varying loads (0%, 20%, 40%, 60%, 80%, and 100%). The optimum engine operating condition based on lower brake specific fuel consumption and higher brake thermal efficiency was observed at 100% load for neat biodiesel. From emission point of view the neat polanga oil methyl ester was found to be the best fuel as it showed lesser exhaust emission as compared to high speed diesel. The fatty-acid methyl ester of *Calophyllum inophyllum* seed oil meets all of the major biodiesel requirements in the USA (ASTM D 6751–02, ASTM PS 121–99), Germany (DIN V 51606) and European Union (EN 14214) (Mohibbe Azam et al. 2005). The average oil yield is 11.7 kg-oil/tree or 4,680 kg-oil/ha. The yield of biodiesel from *C. inophyllum* oil using three stage process viz., pre-treatment, alkali catalyzed transesterification and post treatment and under the optimized conditions of methanol to oil molar ratio, catalyst concentration, temperature and time was found to be 89% (Venkanna and Venkataramana 2009). A two-step process was developed to produce biodiesel from *Calophyllum inophyllum* oil (Sathyaselvabala et al. 2011). This involved a pretreatment with phosphoric acid modified β-zeolite in acid catalyzed esterification process preceded by transesterification.

C. inophyllum oil has insecticidal activity and can be used as insecticides (Pawar et al. 2004). Extracts and purified extracts of seeds of *Calophyllum inophyllum* when evaluated against the second instar larvae reared on synthetic diet, exhibited high larval mortality of *Helicoverpa armigera*, prolongation of developmental period, morphological deformities and highly significant reduction in adult emergence. The reduction in larval weights in the treatments was also highly significant.

Comments

The seeds are recalcitrant and are damaged by drying and sub-zero temperatures.

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Garcinia atroviridis

Scientific Name

***Garcinia atroviridis* Griffith ex T. Anderson**.

Synonyms

None

Family

Clusiaceae

Common/English Name

Asam Gelugor, Som-Khaek

Vernacular Names

Indonesia: Asam Gelugor, Asam Potong;
Malaysia: Boh No, Nayo (Semang), Assam Gelugor, Asam Gelugo, Asam Keping (Malay);
Thailand: A Sa Ka Lu Ko (Malay), Cha Muang Chang, Som-Khaek, Ma-Khaam Khaek, Som-Ma-Won, Som-Pha-Ngum, Som-Khaai (Thai).

Origin/Distribution

The tree is a native of Peninsular Malaysia, Thailand, Myanmar and India (Assam). It is extensively cultivated in Myanmar and in southern Thailand.

Agroecology

A tropical species that occurs as individual trees in the humid, mixed lowland forest on the plains and to 600 m in the highlands of high rainfall areas in southeast Asia.

Edible Plant Parts and Uses

The ripe acid fruits which are a bright orange-yellow are sliced, dried and used in curries, as a sour relish or stewed in plenty of sugar and eaten. The dried fruit slices are used to give acidity to cooked dishes in place of tamarind (Plates 11 and 12). The dried rind is also used in herbal health teas. In Thailand presently, the products of som-khaek are becoming popular as health food, and a lot of som-khaek products are sold in the markets in different forms such as som-khaek tea, som-khaek capsules and som-khaek fruit slices. In Thailand the demand for som-khaek as health

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Plate 1 Habit of young tree of *Garcinia atroviridis*

Plate 2 Young shoot of *Garcinia atroviridis*

food is steadily increasing. Slices of dry fruit are sold at 200–300 baht (5–7.5 US dollars) for one kilogram throughout the year. The young tender leafy shoots and leaves are eaten fresh or cooked as ulam or as a sour relish (Plates 2–4) in Malaysia.

Plate 3 Leafy shoot consumed as vegetable

Plate 4 Bundles of young leafy shoot and leaves sold in a local market in Malaysia

Plate 5 Few-flowered raceme

Consumer preference studies conducted in Thailand revealed that a *Garcinia atroviridis* Tom-Yum mix was highly acceptable and preferred over the traditional commercial Tom Yum

Plate 6 Close-up of flowers

Plate 9 View of bottom-end of ripe fruit

Plate 7 Unripe green and ripe yellow fruit

Plate 10 Detached fruit segment showing the yellow-coloured flesh

Plate 8 Ripe fluted fruit of *Garcinia atroviridis*

Plate 11 Dried segments of *Garcinia atroviridis* used as sour relish

Plate 12 Dried cross-section slices of *Garcinia atroviridis* used as sour relish

mix (Siripongvutikorn et al. 2009). The *Garcinia* Tom-Yum mix could be used as a high acid seasoning to produce the Tom-Yum soup, a popular hot and sour Thai soup. The scientists assert that *its* unique taste and spiciness, and being low in fat and calories are features that will enhance its popularity worldwide.

Botany

Medium-sized, perennial tree growing to 27 m with 70 cm girth and a long trunk (Plate 1). Crown narrowly conical with numerous slender, terete drooping branches. Bole buttressed, bark is smooth, pale grey to black with transparent yellow latex. Leaves are coriaceous, oblong-lanceolate tapering to base and tip abruptly acuminate, 15 × 4 cm – 25 × 7 cm, on 15–25 mm long petioles, pinkish red when young and glossy dark green when mature (Plates 2–4). Flowers terminal at the end of twigs, pedicellate, with 4 yellow, spreading orbicular, concave sepals, 4 crimson, obovate, fleshy petals; males in short few-flowered racemes with numerous stamens in whorls round the pistillode on a fleshy receptacle (Plates 5 and 6). Female flowers are solitary, large with an ovoid ribbed, 8–16 celled ovary and a deep red, pileate, sub-tetragonal, convex stigma and staminodes attached to an annulus. Fruit green turning to bright yellow when ripe (Plates 7–9), depressed globose, 6–10 cm diameter with broadly sunken concave apex, with 12–16 ribs and shallow grooves giving it a fluted form with persistent petals and sepals and a thick rind (Plates 8–10). The fruits often separate off into pegs or segments. A mature fruit can weigh up to 2 kg. The fruit contains several flattened seeds 1.5 cm long, which are surrounded by acidic, bright orange pulp (arillode).

Nutritive/Medicinal Properties

The nutrient composition of the young leafy shoot per 100 g edible portion is as follows: energy 73 kcal, water 79.1 g, protein 1.8 g, fat 0.4 g, carbohydrate 15.5 g, fibre 2.6 g, ash 0.6 g, Ca 63 mg, P 19 mg, Fe 1.6 mg, Na 2 mg, K 83 mg, carotenes 459 μg, vitamin A 77 μg RE, vitamin B1 0.06 mg, vitamin B2 0.13 mg, niacin 0 mg, vitamin C 37.2 mg (Tee et al. 1997).

The nutrient composition of asam gelugor pieces per 100 g edible portion is as follows: energy 230 kcal, water 30.3 g, protein 2.7 g, fat 1.3 g, carbohydrate 51.9 g, fibre 12.2 g, ash 1.6 g, Ca 85 mg, P 38 mg, Fe 6.9 mg, Na 27 mg, K 351 mg, carotenes 155 μg, vitamin A 26 μg RE, vitamin B1 0.06 mg, vitamin B2 0.0 mg, niacin 0.4 mg, vitamin C 3.6 mg (Tee et al. 1997).

Scientific studies reporting on the pharmacological properties of *G. atroviridis* plant parts include the following:

Antioxidant Activity

Recent scientific studies showed that *Garcinia atroviridis* matured leaves had the highest antioxidant activity (92.34%, 2.47 mmol/l), followed by the young leaves (80.70%, 1.90 mmol/l) as determined by both DPPH (1,1-diphenyl-2-picrylhydrazyl) and ferric reducing antioxidant power (FRAP) assays respectively (Nursakinah et al. 2008). Measurement of the antioxidant activity of the young fruits (1.63 mmol/l) by FRAP assay showed significantly higher level compared to the matured fruits (1.47 mmol/l). However, DPPH assay showed that there was no significant difference between the antioxidant

activities of these two samples. Meanwhile, based on proximate analysis, matured leaves were found to contain the highest level of protein (2.16% (w/w)), carbohydrates (15.98% (w/w)) and ash (0.72% (w/w)) compared to other samples. Matured fruits had the highest moisture (90.52% (w/w)) content among all samples. The highest level of fat (0.30% (w/w)) was found in young fruits. The results indicated fruits and leaves of *G. atroviridis* to be good sources of antioxidants, for combating free radicals.

Antihyperlipidaemic/Anti-hyperclolesteromic/Antiobesity Activities

The fruit was reported to contain fruit acids such as citric acid, tartaric acid, malic acid, ascorbic acid and to exhibit antioxidant activity (Abdullah 1994). It was also reported to have saturated fatty acids such as pentadecanoic (15:0), octadecanoic (18:0, stearic acid), nonadecanoic (19:0, nonadecylic acid) and dodecanoic (12:0, lauric acid) acids. More importantly, it was reported to contain hydroxycitric acid (HCA) and flavonoids, which had been reported to have a hypolipidemic activity that can promote weight loss, by lowering lipogenesis and increasing glycogen development, thus lowering appetite. HCA is a potent metabolic regulator of obesity and lipid abnormalities in mammalian systems. (−)-hydroxycitric acid (HCA), the principal acid of Garcinia fruit (*Garcinia atroviridis* and *G. cambogia*) had been shown to be a competitive inhibitor of adenosine 5'-triphosphate (ATP) citrate lyase, the enzyme that catalyzes the extramitochondrial cleavage of citrate to oxaloacetate and acetyl CoA (Jena et al. 2002). This action was postulated to reduce the availability of acetyl CoA, required for the first step in the biosynthesis of fatty acids and cholesterol and lipogenesis during a lipogenic diet high in carbohydrates. Extensive animal studies indicated that (−)-HCA suppressed the fatty acid synthesis, lipogenesis, food intake, and induced weight loss. Studies conducted in Indonesia demonstrated that daily treatment with 2 ml of 2% potassium hydroxycitrate derived from gelugur fruit juice for two weeks reduced serum cholesterol LDL levels from 63 mg/day to 50 mg/day, increased HDL concentration from 35 to 63 mg/day and reduced body weight in rats (Achmadi 2001). The results indicated the benefit of gelugur fruit as food supplement for lowering serum cholesterol level and body weight reduction. In an obesity study conducted in Thailand, weight loss and fat storage of two groups of 25 obese women were monitored for 2 months (Roongpisuthipon et al. 2007). One group received water soluble calcium hydroxycitrate (HCA) as *Garcinia atroviridis* while the other group was given a placebo. All subjects were recommended a similar diet with 1000 Kcal/day.. The results indicated that the group administered HCA had significant weight loss due to a loss of fat storage. *G. atroviridis* was also found to reduce blood pressure in rats (Morat et al. 2003).

Studies conducted on guinea pigs demonstrated that the supplementation of *G. atroviridis* fruit extract lowered the total cholesterol and LDL-C levels in serum, and lipid deposition in the aorta of a high cholesterol diet animals (Amran et al. 2009). The findings indicated that *G. atroviridis* may be useful in preventing atherosclerosis or lowering the relative risk of atherosclerosis. The protective effect of *G. atroviridis* could be attributed to its antioxidant activity. The supplementation with *Garcinia atroviridis* was also found to reduce the DNA damage and deposition of lipids in the wall of the aorta in hypercholesteromic guinea pigs (Amran et al. 2010). Animals that consumed a cholesterol-enriched diet showed a significant increase in the percentage of DNA damage in the tail and in the tail moment and degree or peroxidation with increase in fat deposition in the aorta and number of foam cells. The results suggested that *G. atroviridis* could ameliorate oxidative stress and reduce atherosclerosis.

Antimicrobial Activity

Garcinia atroviridis plant parts have antimicrobial, anti-oxidant, anti-tumour and cytotoxic properties. The crude extracts (methanol) of the

leaves, fruits, roots, stem and trunk bark, of *Garcinia atroviridis* exhibited predominantly antibacterial activity with the root extract showing the strongest inhibition against the test bacteria at a minimum inhibitory dose (MID) of 15.6 μg/disc (Mackeen et al. 2000). Although all the extracts failed to inhibit the growth of most of the test fungi, significant antifungal activity against *Cladosporium herbarum* was exhibited by most notably the fruit (MID: 100 μg), and the leaf (MID: 400 μg) extracts. None of the extracts were significantly cytotoxic, and lethal towards brine shrimps. The root, leaf, trunk and stem bark extracts (except for the fruits) showed strong antioxidant activity exceeding that of the standard antioxidant, α-tocopherol. Antitumour-promoting activity (>95% inhibition) was shown by the fruit, leaf, stem and trunk bark extracts. The scientists also reported that two *Garcinia* acid derivatives, 2-(butoxycarbonylmethyl)-3-butoxycarbonyl-2-hydroxy-3-propanolide and 1',1"-dibutyl methyl hydroxycitrate, isolated from the fruit of *Garcinia atroviridis* (Mackeen et al. 2002) showed selective antifungal activity comparable to that of cycloheximide (MID: 0.5 μg/spot) only against *Cladosproium herbarum* at the MIDs of 0.4 and 0.8 μg/spot but were inactive against bacteria (*Bacillus subtilis*, methicillin-resistant *Staphylococcus aureus, Pseudomonas aeruginosa* and *Escherichia coli*), other fungi (*Alternaria* sp., *Fusarium moniliforme* and *Aspergillus ochraceous*) including the yeast *Candida albicans*. Separate studies revealed that the ethyl acetate and ethanol extracts of the fruit were active against 3 Gram-positive bacteria (*Staphylococcus aureus, Staphylococcus epidermidis* and *Bacillus subtilis*) and 4 Gram-negative bacteria (*Escherichia coli, Salmonella typhimurium, Salmonella enteritidis* and *Pseudomonas aeruginosa*) and 2 yeast strains (*Candida glabrata* and *Candida parapsilosis)* (Basri et al. 2005). Strongest inhibition zones were observed from ethyl acetate extract of *Garcinia atroviridis* against *Staphylococcus epidermidis* (25.27 mm) and *Staphylococcus aureus* (23.87 mm) compared to positive control (gentamycin at 10 μg/disc) with inhibition zones of 20.7 mm and 17.8 mm, respectively.

Anticancer Activity

Garcinia atrovridis was found to also contain anticancerous compounds. Two prenylated compounds, the benzoquinone, atrovirinone and the depsidone, atrovirisidone isolated from the roots of *Garcinia atroviridis* showed pharmacological activity (Permanana et al. 2001). Atrovirisidone showed some cytotoxicity against HeLa cells, while both compounds were mildly inhibitory toward *Bacillus cereus* and *Staphylococcus aureus*. Another prenylated depsidone, atrovirisidone B, together with naringenin and 3,8″-binaringenin were isolated from the roots of *Garcinia atroviridis*. Atrovirisidone B showed cytotoxic activity against human breast (MCF-7), human prostate (DU-145) and human lung (H-460) cancer cells (Permana et al. 2005) The roots also yielded a prenylated hydroquinone, 4-methylhydroatrovirinone, morelloflavone and its 7-O-_-D-glucopyranoside, fukugiside, together with 14-cis-docosenoic acid (Permana et al. 2003). The stem bark also yielded the xanthone, atroviridin (Kosin et al. 1998). Extract of *G. atroviridis* was one of 43 plant species that were found to exhibit in-vitro cell viability of a human leukaemia cell-line HL60 by more than 50% when exposed to 9.6 J/cm^2 of a broad spectrum light when tested at a concentration of 20 μg/ml (Ong et al. 2009). The results indicated that the plant extract could have potential for photodynamic therapy.

Antiinflammatory Activity

Studies revealed that *G. atroviridis* contained compounds which exhibited anti-inflammatory activity (Syahida et al. 2006). Atrovirinone a benzoquinone that was previously isolated from *Garcinia atroviridis*, was found to inhibit the production of both nitric oxide and prostaglandin E2 (PGE2) from LPS (lipopolysaccharide)-induced and IFN (Interferon)-gamma-induced RAW 264.7 cells and whole blood, with inhibitory concentration (IC_{50}) values of 4.62 and 9.33 μmol/l, respectively. Atrovirinone inhibited the generation of thromboxane B2 (TXB2) by both cyclooxygenase

(COX)-1 and the COX-2 pathway with IC_{50} values of 7.41 and 2.10 µmol/l, respectively. Atrovirinone also inhibited the generation of intracellular reactive oxygen species and the secretion of TNF-alpha (tumour necrosis factor – alpha) from RAW 264.7 cells in a dose-responsive fashion, with IC_{50} values of 5.99 and 11.56 µmol/l, respectively. Lipoxygenase activity was also moderately inhibited by atrovirinone. The results suggested that atrovirinone acted on important pro-inflammatory mediators possibly by the inhibition of the nuclear factor-kappa B pathway and also by the inhibition of the COX/lipoxygenase enzyme activity. Further studies showed that atrovirinone, inhibited the secretion of IL-1beta and IL-6 in a dose dependent manner whereas the secretion of IL-10, the anti inflammatory cytokine, was enhanced (Israf et al. 2010). The inhibition of proinflammatory cytokine synthesis and inducible enzyme expression was due to a dose-dependent inhibition of phosphorylation of p38 and ERK1/2. Atrovirinone also prevented phosphorylation of I-kappaBalpha, which resulted in a reduction of p65NF-kappaB nuclear translocation. The data suggested atrovirinone to be a potential antiinflammatory drug targeting both the MAPK and NF-kappaB pathway.

Antimalarial Activity

Garcinia atroviridis was found also to possess antimalarial activity (Syamsudin Dewi and Hernita 2004). Its leaf extract at an oral dose of 360 mg/kg BW administered to parasite (*Plasmodium berghei*) inoculated mice for 4 days exhibited statistically significant inhibition of the development of parasitemia in the inoculated mice.

Antinicotine Stress Activity

Studies showed that *G. atroviridis* extract could suppress harmful effect of nicotine-induced stress (Zaiton et al. 2005). At 0 hour, the *G. atroviridis* extract showed a higher percentage of normal embryos (13.5%) than their respective control (8.1%) and nicotine treated mice (0.5%). After 96 hours of in-vitro culture, the ethyl acetate extract of *G. atroviridis* administered together with nicotine showed high percentage of embryo (99.52%) in the form of hatched blastocyst compared to the control group. The embryos in the nicotine group did not develop any further after 24 hours of in-vitro culture. This study showed that nicotine retarded in-vitro embryo development and that *G. atroviridis* extract, suppressed this detrimental effect of nicotine-induced stress.

Traditional Medicinal Uses

In southeast Asian folkloric medicine, *G. atroviridis* is used as a postpartum medication agent as well as an agent to treat ear-ache, throat irritation, cough, dandruff and any stomach-ache associated with pregnancy. In Thailand, the traditional ethnomedical uses of som-khaek are as follows: the dried fruit is used for improving blood circulation, as an expectorant, treatment of coughs and as a laxative. In Peninsular Malaysia, the fruit is used in a lotion with vinegar to rub over the abdomen of a woman after confinement. Juice from the leaves is similarly applied to a woman after childbirth. A decoction of the leaves and roots is dropped into the ear for earache.

Other Uses

The fruit is used by dyers in south Thailand and Kelantan in Malaysia as a fixative with alum for lake dye on silk.

Comments

The fruit is propagated from seeds.

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Garcinia cowa

Scientific Name

***Garcinia cowa* Roxburgh ex DC.**

Synonyms

Garcinia kydia Roxb., *Garcinia lobulosa* Wall., *Garcinia roxburghii* Wight, *Garcinia umbellifera* Roxb. ex Wall., *Garcinia wallichii* Choisy, *Oxycarpus gangetica* Buchanan-Hamilton, *Stalagmitis cowa* (Roxb.) G. Don.

Family

Clusiaceae

Common/English Names

Cowa, Cowa Mangosteen

Vernacular Names

Burmese: Madow, Toungdalai;
Chinese: Yun Nan Shan Zhu Zi, Yun Shu;
India: Cuithekera, Kangach, Kujithekera (Assamese), Kau (Bengali), Cowa (Hindu), Bhava, Chenhek (Mizoram);
Indonesia: Kemenjing, Ki Ceuri (Java);
Japanese: Kowa Ganboji;
Malaysia: Kandis;
Nepalese: Kaphal;
Philippines: Pildis (Pampanggan), Paninginen (Sambali), Bilukau (Tagalog);
Thai: Cha Muang (Central Thailand), Ka Muang, Muang Som (Southern);
Vietnamese: Dọc, Tai Chua.

Origin/Distribution

Cowa mangosteen is indigenous to East India (Assam, Mizoram, Bengal, Bihar and Orissa), Nepal, Myanmar, Thailand, Kampuchea, Laos, Vietnam and northern Peninsular Malaysia. It is also found in the Anadaman, Nicobar Islands and south and west Yunnan in China.

Agroecology

In its native range, it is found wild frequently in evergreen and semi-evergreen, mixed forests on hills or along streams in deep valleys from (100-) 400–900 (−1,300) m altitudes. In Thailand, it is found in low sand dune forest behind the beach, in tropical evergreen forest, or in dry deciduous forest throughout the country.

Edible Plant Parts and Uses

The ripe fruit is edible but very acid. In spite of its sourness, the fruits are fondly eaten by local people especially in Mizoram. The fruits are also

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made into jams and preserves. The dried thinly sliced fruit pieces are sun dried and used for flavouring in various Malay cuisines especially in fish dishes. The young leaves and tender leafy shoots are cooked and eaten as a vegetables in Myanmar, Malaysia and Thailand. In Thailand, young, tender leaves are cooked in the famous dish "*tom mu chamuang*" (pork curry) of the provinces in the southeast. They are also often cooked with fish. In Vietnam, the fruits are an important sources of natural citric acid used for imparting an acidic flavour to fish and crab dished.

Botany

A small to medium–sized, multi-branched, evergreen, dioecious tree, 8–20 (−30 m) high with a girth of 15–30 cm and occasionally 90 cm. The bark is dark-brown with lemon-yellow exudates. The leaves are simple, opposite, 6–15 by 2.5–6 cm, entire, broadly lanceolate to lanceolate-elliptic, glossy green, thick, tapering to both ends, with 12–18 pairs of parallel secondary veins and borne on slender 1–1.5 cm petioles (Plates 1–2). Young leaves are soft, bronze to reddish coloured (Plate 1). Male flowers occur on short, slender peduncles in 3–8 flowered axillary or terminal umbels. Male flower has 4 subulate bracts, 4 yellow petals flushed with pink and twice as long as the 4 sepals, stamens in 4 connate fascicles forming a central capitate squarish mass of 40–50 anthers and no pistillode. Female flowers usually solitary, axillary with staminodes united in lower half and enveloping ovary base, ovary ovoid, 4-8-loculed; stigma radiately 4-8-ridged and papillate. Fruit sub-globose-globose, oblique, 5–6×4–5 cm in diameter, green and prominently ribbed when young (Plates 2–5), dull orange or yellow at maturity with 5–8 shallow grooves at least near the top (Plates 3–5). Stigma remnant sunken seated on small black persistent calyx. Seeds 2–4, large, trigonous, embedded in pale orange pulp.

Nutritive/Medicinal Properties

The major organic acid found in leaves, fruits, and dried rinds of *Garcinia cowa* was (−)-hydroxycitric acid in amounts of 1.7, 2.3, and 12.7%,

Plate 1 Bronze and reddish coloured young leaves

Plate 2 Young ribbed cowa fruits

Plate 3 Ripe and immature fruits

Plate 4 Ripe oblique, weakly ribbed fruit

Plate 5 Ripe, un-ribbed, glabrous fruit

respectively (Jena et al. 2002). (−)-hydroxycitric acid lactone, and oxalic and citric acids were also present in leaves, fruits, and rinds in minor quantities.

Xanthones isolated from *Garcinia cowa* stems included: 1,3,6-trihydroxy-7-methoxy-8-(3,7-dimethyl-2,6-octadienylxanthone (Lee and Chan 1977) and 7-O-methyl-garcinone E (Likhitwitayawuid et al. 1997). Five xanthones were isolated from the bark of *Garcinia cowa*, namely 7-O-methylgarcinone E (1), cowanin (2), cowanol (3), cowaxanthone (4), and β-mangostin (5) (Likhitwitayawuid et al. 1998). Two new xanthones, 1,5,6-trihydroxy-3-methoxy-4-(3-hydroxyl-3-methylbutyl)xanthone (1) and 1,5-dihydroxy-3-methoxy-6′,6′-dimethyl-2H-pyrano(2′,3′:6,7)-4-(3-methylbut-2-enyl)xanthone (2), were isolated together with six known xanthones: 1,3,5-trihydroxy-6′,6′-dimethyl-2H-pyrano(2′,3′:6,7)xanthone (3), dulxanthone A (4), 1,5,6-trihydroxy-3,7-dimethoxyxanthone (5), 1,7-dihydroxyxanthone (6), 1,3,5-trihydroxy-6-methoxyxanthone (7), 1,3,6,7-tetrahydroxyxanthone (8), from *Garcinia cowa* stems (Shen and Yang 2006).

Tetraoxygenated xanthones, cowaxanthones A–E, together with 10 previously reported tetraoxygenated xanthones, were isolated from the crude hexane extract of *Garcinia cowa* fruits (Panthong et al. 2006). A new tetraoxygenated xanthone, cowaxanthone F (1), as well as four known compounds, morelloflavone (2), volkensiflavone (3), morelloflavone-7″-O-glucoside (fukugiside, 4), and 1,6-dihydroxyxanthone (5), were isolated from the crude acetone extract of the twigs of *Garcinia cowa* (Panthong et al. 2009). Three new flavanone glycosides named garccowaside A, garccowaside B, garccowaside C were isolated from the ethanol extract of the stems of *Garcinia cowa* (Shen et al. 2007).

Five xanthones named cowagarcinone A-E and six previously reported xanthones (Cowaxanthone (1), cowanin (2), cowanol (3) and 1,3,6-trihydroxy-7-methoxy-2,5-bis(3-methyl-2-butenyl) xanthone (4), mangostinone (5) and fucaxanthone A (6) were isolated from the latex of *Garcinia cowa* (Mahabusarakam et al. 2005).

Some pharmacological properties of Cowa mangosteen are discussed below.

Antioxidant Activity

Of the five compounds isolated from the crude acetone extract of the twigs of *Garcinia cowa*: cowaxanthone F (1), morelloflavone (2), volkensiflavone (3), morelloflavone-7″-O-glucoside (fukugiside, 4), and 1,6-dihydroxyxanthone (5) only morelloflavone (2) and morelloflavone-7″O-glucoside (4) exhibited high antioxidant activity against diphenylpicrylhydrazyl (DPPH), hydroxyl, and superoxide radicals (Panthong et al. 2009). Both compounds showed equal potency with an IC_{50} value of 18 μmol/l, whereas the butylated hydroxytoluene (BHT) control had an IC_{50} value

of 136 μmol/l. Both compounds also exerted their inhibitory effects on the hydroxyl radical with IC_{50} value values of 0.56 and 0.74 mmol/l, respectively. In the superoxide anion assay, compound 4 (IC_{50} value 0.89 mmol/l) was less effective than compound 2 (IC_{50} value 0.27 mmol/l), however, both compounds showed better activity than the standard trolox (IC_{50} value 1.36 mmol/l).

Anticancer/Antiviral Activity

Methanol extract of *Garcinia cowa* leaves exhibited in-vitro antitumour promoting activity using the inhibition test of Epstein-Barr virus (EBV) activation in Raji cells induced by 12-O-hexadecanoylphorbol-13-acetate (Murakami et al. 1995). Dulxanthone A was found to be an active cytotoxic component in *Garcinia cowa* and to be a promising preventive and/or therapeutic agent against hepatoma (Tian et al. 2008). Dulxanthone A consistently induced S phase arrest and apoptosis in the most sensitive cell line HepG2. It induced cell cycle arrest at lower concentrations and triggered apoptosis at higher concentrations via up-regulation of p53 through the intrinsic mitochondrial pathway in HepG2 cells and downregulated cell cycle related proteins, such as cyclin A, cyclin B, cyclin E, cdc-2, p21 and p27.

The methanol extracts from *Garcinia cowa* showed moderate cytotoxic activity and selectivity towards non-small lung tumour cells and exhibited inhibition against NO production without affecting the viability of LPS and IFN-γ-induced RAW 264.7 macrophage cells (Jabit et al. 2009). An unusual polyprenylated acylphloroglucinol derivative unsubstituted at C-2 and C-6, garcicowin A, together with three other new (garcicowins B-D,) and nine known analogues, were isolated and characterized from the twigs of *Garcinia cowa* twigs (Xu et al. 2010). The isolated compounds demonstrated their selective cytotoxicity against two cancer cell lines (HT-29 and HCT116) and against normal colon cells (CCD-18Co). A new depsidone, cowadepsidone, isolated from *G. cowa* twigs exhibited The cytotoxicity against KB, MCF-7 and NCI-H187 cancer cell lines (Cheenpracha et al. 2011).

Antiinflammatory Activity

Eight tetraoxygenated xanthones from the fruits of *G. cowa*, cowaxanthones A-D (6–9), cowanin (15), α-mangostin (16), mangostanin (17), and cowanol (18), were also investigated for anti-inflammatory activity using ethyl phenylpropiolate (EPP)-induced ear edema (Panthong et al. 2009). Results revealed that cowaxanthones B-D (7–9), cowanin (15), and α-mangostin (16) exhibited significant antiinflammatory activity when compared to phenylbutazone, while cowaxanthone A (6), mangostanin (17), and cowanol (18) showed less activity.

Antimicrobial Activity

Five xanthones were isolated from *Garcinia cowa*: cowanin (1), cowanol (2), cowaxanthone (3), 1,3,6-trihydroxy-7-methoxy- 2-5-bis(3-methyl-2-butenyl)xanthone (4), and norcowanin (5) (na Pattalung et al. 1994). Xanthones 2 and 3 exhibited moderate antimicrobial activity against *Staphylococcus aureus.*

The hexane and chloroform extracts from the fruit rinds of *Garcinia cowa* inhibited the growth of *Aspergillus flavus* at 3,000 ppm the minimum inhibitory concentration (MIC) and aflatoxin production (Joseph et al. 2005). Both the extracts from *G. cowa* inhibited aflatoxin B1 production up to 100% at a lower concentration of 2,000 ppm. The hexane and chloroform extracts from *G. cowa* showed high antioxidant capacity by the formation of phosphomolybdenum complex at 100 ppm concentration and reducing power by potassium ferricyanide reduction method at various concentrations . The antiaflatoxigenic activities of the extracts from *G. cowa* may be due to their effective antioxidative properties, which could suppress the biosynthesis of aflatoxin.

Antimalarial Activity

Five xanthones from the bark of *Garcinia cowa*, namely 7-O-methylgarcinone E (1), cowanin (2), cowanol (3), cowaxanthone (4), and β-mangostin (5), were found to possess in-vitro anti-malarial activity against *Plasmodium falciparum* with IC_{50} values ranging from 1.50 to 3.00 μg/ml (Likhitwitayawuid et al. 1998).

Traditional Medicinal Uses

Garcinia cowa has been used in the folk medicine for various medicinal purposes in Thailand. The bark has been used as an antipyretic and antimicrobial agent (Mahabusarakam et al. 2005). The latex has been used as antipyretic agent (Na Pattalung et al. 1994). The fruits and leaves are used for the improvement of blood circulation, as an expectorant for the treatment of coughs and indigestion, and as a laxative, while the root is used for fever relief (Panthong et al. 2009). In Eastern India, the sun dried slices of this fruit are used to treat dysentery.

Other Uses

The bark is used for dying clothes yellow. Cowa tree also produces a yellow gum resin which resembles gamboges used in varnishes. In the Philippines grown as a grafting stock for the common mangosteen, *Garcinia mangostana*. The seeds yield approximately 9% oil.

Comments

The tree is propagated by seeds.

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Garcinia dulcis

Scientific Name

***Garcinia dulcis* (Roxb.) Kurz**

Synonyms

Garcinia elliptica Choisy, *Garcinia longifolia* Blume, *Stalagmitis dulcis* (Roxb.) Cambess., *Stalagmitis javanensis* (Blume) Spach, *Xanthochymus dulcis* Roxb., *Xanthochymus javanensis* Blume.

Family

Clusiaceae

Common/English Names

Baniti, Egg Tree, Gourka, Mundu, Rata Fruit

Vernacular Names

Dutch: Moendoe;
Indonesia: Mundu (Gorantalo), Baros, Kledeng, Moendo, Munder, Mundu, Mundur (Javanese), Monhdu (Madurese), Mundu (Lampong), Mundu (Malay), Mundu (Minangkabau), Mundu (Lingga), Patung-Patung (Makassar), Golodog-Panto, Jabura, Jawura, Mundu (Sundanese);
Malaysia: Mundu, Mendu;
Philippines: Bagalot (Bisaya), Buneg (Iloko), Baniti (Tagalog), Taklang-Anak;
Thailand: Ma Phut;
Vietnamese: Bứa Ngot, Tai.

Origin/Distribution

The species is indigenous to Peninsular Malaysia, southern Thailand, Java, Borneo and the Philippines. It is cultivated as a fruit tree in south-east Asia and introduced into tropical parts of America.

Agroecology

The species is found in the humid, tropical forest in coastal areas and inland up to 500 m altitude. It thrives in a moist, shady environment. It is not fastidious of soil types.

Edible Plant Parts and Uses

The soft yellow flesh has a butter-like consistency and pleasant acid flavour. It can be eaten fresh, or preserved and served in sherbets or made into fruit paste, jam or butter. The fruit can be cooked and candied. The seeds are of pleasant taste.

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Botany

A medium-size, evergreen, much branched perennial tree, 10–13 m high, with an upright growth habit. Bark is dark brown and rough and the branches are green, sparsely hairy angled (Plate 1) and orthotropic or horizontal and have a white latex. The leaves are opposite, simple, large, ovate, oval to oblong up to 10–30 cm long by 3–15 cm wide with acute apex and truncate base, entire margin, glossy green above and dull pale green below (Plates 1–3) and often sparsely hairy, but reddish-pink when young. The midrib is prominent with numerous veinlets arranged in parallel. Petioles are 1–2 cm long. Flowers are in small densely packed, axillary fascicle of 6–12. Flowers are pentamerous with 5 sepals and 5 yellowish-green or yellowish-white petals. Male flowers are smaller, 6 mm across with 5 adelphous stamens, yellow lobed central disk and a rudimentary pistil. Female flower has thick disk lobes, 5-lobed stigma, sessile and larger than 12 mm across. The fruits are globose to oblate, 5–8 cm in diameter, smooth, green when immature tuning yellow or deep yellow when ripe (Plates 4–6). The fruit is thin-skinned with a yellow, fibrous but soft pulp and 1–5 brown seeds, each 2.5 cm long.

Plate 1 Rough, dark brown bark and angled branches

Plate 3 Axillary fascicles of densely packed flowers and large, oblong leaves

Plate 2 Simple, large, ovate, oval to oblong leaves, glossy dark green above pale green below

Plate 4 Globose immature fruit

Plate 5 Close-up of fruit showing the remnant (knob) of the stigma

Plate 6 Ripe and unripe, globose fruit

Nutritive/Medicinal Properties

Ninety compounds were identified in the volatile aroma concentrate of the fruit, of which linalool, α-terpineol and hexadecanoic acid were found to be the major constituents (Pino et al. 2003).

Phenolic compounds viz. xanthones and flavonoids were isolated from various parts of the plant. These compounds exhibited antioxidant activity - radical scavenging and antibacterial activities. From the green fruit, the following were reported: dulcinoside, dulcisisoflavone, dulcisxanthone A and sphaerobioside acetate together with 22 known compounds (Deachathai et al. 2005). Dulcisflavan, dulcisxanthone B and isonormangostin together with 22 known compounds were isolated from the ripe fruit. Dulcisxanthones C–F (1–4) and dulcinone together with 22 known compounds were isolated from the flowers (Deachathai et al. 2006). Dulcisxanthone G, 1,3,6-trihydroxy-2-(2,3-dihydroxy-3-methylbutyl)-7-methoxy-8-(3-methyl-2-butenyl)xanthone, together with 13 known compounds were isolated from the seeds (Deachathai et al. 2008) and dulxanthone E, a pyranoxanthone, from the leaves (Kosela et al. 1999). A leaf extract was found to have hypocholesterolemic effects by lowering lipid levels in hypercholesterolemic rats.

A novel depsidone named garcinisidone-A, six new xanthones named assiguxanthone-A and -B and dulxanthone-A, -B, -C, and -D, and four new pyranoxanthones named latisxanthone-A, -B, -C, and -D, as well as some known xanthone, benzophenone, chromone, and biflavanone derivatives, were isolated from the stem bark (Ito et al. 1997). Ethanol extracts of the bark containing xanthanes, viz 1,7-dihydroxyxanthone, 12b-hydroxy-des-D-garcigerrin A, 1-O-methylsymphoxanthone, symphoxanthone and garciniaxanthone inhibited the growth of the malaria parasite, *Plasmodium falciparum* (Likhtiwitayawuid et al. 1998). From the bark of *Garcinia dulcis*, a new xanthone, dulciol A, was isolated in addition to two known xanthones [12b-hydroxydes-D-garcigerin and toxyloxanthone B]. Furthermore, from the roots of this plant, four novel xanthones with a 1,1-dimethylallyl group, dulciols B-E, were obtained, besides eight known xanthones [2; garciniaxanthones A, B and D; globuxanthone and subelliptenones C, D and F]. From the branches of *Garcinia dulcis* [1,4,6-trihydroxy-5-methoxy-7-(3-methylbut-2-enyl)xanthone] and the triterpenoid friedelin and the known flavonoids 3'-(3-methylbut-2-enyl) naringenin, I3,II8-biapigenin and podocarpusflavone A were isolated (Harrison et al. 1994).

From the roots of *Garcinia dulcis,* three new benzophenone-xanthone dimers named garciduols A-C were isolated in addition to a new xanthone, 1,3,6-trihydroxy-7-methoxyxanthone (IInuma et al. 1996b). Five known xanthones [2,5-dihydroxy-1-methoxy; 1,4,5-trihydroxy; 1,3,5-trihydroxy-;1,3,6-trihydroxy-5-methoxy; and 1,3,6-trihydroxy-8-isoprenyl-7-methoxyxanthone]

were also isolated from the roots (Iinuma et al. 1996a).

Morelloflavone, a biflavonoid extracted from *Garcinia dulcis*, has shown antioxidative, antiviral, anticancer, hypocholesterolemic and antiinflammatory properties.

Some of the pharmacological properties of *G. dulcis* plant parts are elaborated below.

Antioxidant Activity

Morelloflavone and a prenylated xanthone, camboginol, isolated from the fruits exhibited strong antioxidation effects in both Fe^{2+}-mediated and non-metal induced human low-density lipoprotein (LDL) oxidations (Hutadilok-Towatana et al. 2007). The well-known antioxidant, α-tocopherol (vitamin E), was found less potent than both compounds based on the same test systems.

Antiviral and Anticancer Activities

Morelloflavone demonstrated significant antiviral activity against HIV-1 (strain LAV-1) in phytohemagglutinin-stimulated primary human peripheral blood mononuclear cells (Lin et al. 1997). Studies showed that that morelloflavone could inhibit vascular endothelial growth factor (VEGF)-induced cell proliferation, migration, invasion, and capillary-like tube formation of primary cultured human umbilical vascular endothelial cells in a dose-dependent fashion. In addition, morelloflavone inhibited tumour growth and tumour angiogenesis of prostate cancer cells (PC-3) in xenograft mouse tumour model in-vivo, suggesting that morelloflavone inhibited tumorigenesis by targeting angiogenesis. Morelloflavone was found to exert antiangiogenic action by targeting the activation of Rho-GTPases (Rho-guanosine triphosphate hydrolase enzymes) and ERK (extracellular signal regulated kinases) signalling pathways (Pang et al. 2009). Angiogenesis is the pivotal step in tumour growth, invasiveness, and metastasis. The n-hexane extract of prenylated pyranoxanthonoids from the fruit also exhibited cytotoxic effects (Soemiati et al. 2002).

Antiinflammatory Activity

Morelloflavone exerted antiinflammatory effects in animal models, with a potent inhibition of 12-O-tetradecanoylphorbol 13-acetate (TPA)-induced ear inflammation in mice after topical administration (Gil et al. 1997). It irreversibly inhibited secretory phospholipase A2 (PLA2) in-vitro, with a high potency on the human recombinant synovial and bee venom enzymes (IC_{50} = 0.9 and 0.6 μM, respectively). Morelloflavone was shown to be an inhibitor of secretory PLA2 with selectivity for groups II and 111 enzymes and may have potential as a pharmacological tool.

Hypocholesterolemic Activity

Morelloflavone, from *Garcinia dulcis* was found to inhibit HMG-CoA (3-hydroxy-3-methylglutaryl-coenzyme A) reductase activity by competing with the enzyme whereas it was non-competitive towards NADPH (Tuansulong et al. 2011). Both flavonoid subunits of the compound, naringenin and luteolin, equally competed with HMG-CoA and were also non-competitive with NADPH (reduced form of nicotinamide adenine dinucleotide phosphate). The data suggested that each subunit of morelloflavone would occupy the active site of the enzyme, thereby blocking access of its substrate. The study suggested that this biflavonoid may serve as a new candidate for the future development of hypocholesterolemic agents.

Cardiovascular Activity

Pinkaew et al. (2009), found morelloflavone to be able prevent instent restenosis, the most ominous complication of percutaneous coronary intervention, caused by vascular smooth muscle cell (VSMC) migration into and proliferation in the intima. In endothelium-denudated mouse carotid

arteries, oral morelloflavone significantly decreased the degree of injury-induced neointimal hyperplasia, via the inhibition of VSMC migration, without inducing apoptosis or neointimal cell cycle arrest. The results indicated morelloflavone to be a viable oral agent for the prevention of restenosis, without compromising effects on the integrity and healing of the injured arteries. Restenosis is the reoccurrence of stenosis, a narrowing of a blood vessel, leading to restricted blood flow.

Traditional Medicinal Uses

The seeds are used medicinally in folkloric medicine in Java where it is pounded with or without vinegar and salt and applied externally for swellings and wounds. In Thailand, the crushed extract of the fruit is used as a relief expectorant, for coughs, and scurvy. The crushed extract from the root is used for the relief of fever, and to reduce poisoning and detoxification. The crushed extract from the bark is used for cleaning wounds.

Other Uses

The bark provides a dye for dyeing mats.

Comments

The fruit of this species is always mistaken for that of *Garcinia xanthochymus*.

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Garcinia forbesii

Scientific Name

***Garcinia forbesii* King**.

Synonyms

None

Family

Clusiaceae

Common Names

Red Mangosteen, Rose Kandis

Vernacular Names

Indonesia: Kandis, Mundar (Sumatra), Bunoh (Punam, Malinau, Kalimantan), Itan (Lun Daye, Mentarang, Kalimantan), Bua' Tetoh Telato (Merap, Malinau, Kalimantan) Aiti Kitung (Kenyah Uma' Lung, Kalimantan);
Malaysia: Assam Roi, Babata, Kandis (Sabah), Kandis (Peninsular Malaysia).

Origin/Distribution

Garcinia forbesii is native to Malaysia and Indonesia (Sumatra, Kalimantan).

Agroecology

Rose Kandis is strictly a tropical species, it is adapted to a hot, wet and humid climate. It occurs as an evergreen tree in the understorey of evergreen, tropical rain forests and lower and upper montane forests to 1,700 m elevation. It tolerates heavy shade and thrives in well-drained, organic matter rich soils.

Edible Plant Parts and Uses

The white, good-flavoured, acid-sweet, melting flesh is edible. In Sabah, the rind is dried and used as acidic flavouring for various cuisines.

Botany

A small to medium, evergreen, dioecious, perennial tree, reaching 18 m high with trunk diameter of 90 cm (Plates 1 and 2). The inner bark has

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Plate 1 Nine year old tree of Mundar tree with a drooping skirt of leaves

Plate 2 Mature tree habit of *Garcinia forbesii*

sparse yellow exudate. Leaves are borne on 2 cm, glabrous petioles, lamina is large, glossy green, ovate-elliptic (Plates 3, 4 and 5), 12–19 cm by 6–8 cm wide, tapering to shortly tipped apex and to the base, margin entire slightly recurved, secondary veins very fine, faint, parallel and straight, slightly raised on both surfaces. Flowers are unisexual, with 4 sepals and 4 petals. Male flowers are on short 3 mm pedicels in clusters behind leaves, 6 mm across with numerous stamens forming a central globose mass and with no pistillode. Female flowers are axillary, or behind the leaves, solitary and sessile. Fruit globose, 8 cm across, apple-like, light green ripening to pinkish-red or red with juicy, melting, white flesh, with deeply depressed at the base and remnant of stigma as a roundish, raised, papillose knob (Plate 6).

Nutritive/Medicinal Properties

Phytochemically, *Garcinia* species including *G. forbesii* are recognized as rich sources of xanthone and xanthonoid natural products with high pharmaceutical potential. Xanthones had been isolated and identified from various parts of *G. forbesii*. A new chromenoxanthone, forbexanthone, as well as the known compounds pyranojacareubin and 1,3,7-trihydroxy-2-(3-methylbut-2-enyl)-xanthone were isolated from the branches of *Garcinia forbesii* (Harrison et al. 1993). A caged natural product forbesione, a modified xanthone was also isolated from *Garcinia forbesii* (Leong et al. 1996) (Plate 7). Many naturally occurring xanthone compounds share a common caged structure, exemplified by

Plate 3 Fruiting rose kandis tree

Plate 6 White pulp of ripe fruit

Plate 4 Young, papillate rose kandis fruits

Plate 7 Tree label for *Garcinia forbesii*

Plate 5 Close-up immature and ripe, subsessile papillate fruits

the simplest among them, forbesione which also occurs in *Garcinia. gaudichaudii*. Forbesione was found to exhibit significant cytotoxicity against several cancer cell lines (Cao et al. 1998).

Rubraxanthone isolated from the bark of *G. forbesii* exhibited antimicrobial activity against the following bacteria tested: *Micrococcus luteus, Pseudomonas aeruginosa, Staphylococcus aureus, Staphylococcus epidermidis* and *Eschericia coli* (Alen et al. 2008).

Other Uses

The brown wood is heavy but lacks commercial value as it splits readily.

Comments

Its commercial potential is yet to be exploited.

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Garcinia gummi-gutta

Scientific Name

***Garcinia gummi-guta* (L.) N. Robson.**

Synonyms

Cambogia gummi-guta L., *Cambogia gutta* L., *Cambogia gutta* Lindl., *Garcinia affinis* Wight & Arn., *Garcinia cambogia* (Gaertn.) Desr. nom. illeg., *Garcinia conicarpa* Wight, *Garcinia gummi-gutta* var. *conicarpa* (Wight) N. P. Singh, *Garcinia elliptica* Wall., *Garcinia papilla* Wight, *Garcinia quaesita* Pierre, *Garcinia zeylanica* Roxb., *Mangostana cambogia* Gaertn. nom. supfl.

Family

Clusiaceae

Common/English Names

Bitter Kola, Brindali Berries, Brindall Berry, Brindle Berry, Gambooge, Garcinia Kola, Kokum Butter Oil Tree, Malabar Tamarind, Mangosteen Oil Tree, Red Mango

Vernacular Names

Chinese: Guan Mu;
Danish: Gummiharpiks (Product), Gummiguttræ;
Dutch: Geelhars, Guttegom (Product);
Eastonian: Gummigutigartsiinia;
French: Gamboge (Tree), Gomme-Gutte (Product), Mangoustanier Du Cambodge, Tamarinier De Malabar;
German: Gummigutt (Product), Gummiguttbaum, Gummitaz;
India: Bilatti-Amli, Goraka, Velaiti Imli (Hindu), Aesali, Aesalu Huli, Aradaalada Mara, Aradal, Aradala, Aradalada, Aradalaupagi, Arasina Pulige, Arasinapulige, Ardala, Esali, Esalpuli, Heela, Hile, Kadagolu, Karkapuli, Karkpuli, Mandu Huli, Manthey Huli, Manthulli, Manthuli, Mantulli, Munthe Huli, Muragi, Ontepuli, Opagi Mara, Otekayi, Punarpuli, Seeme Hunise, Seeme Kamboge, Simai Hunase, Upagi, Upagi Mara, Uppage, Vote Kaayi (Kannada), Mantapuli (Kodava), Coddam-Pulli, Coddampulli, Chigiri, Cikiri, Kadumpuli, Kodagam, Kodakapuli, Kodakkapuli, Kodampuli, Kodappuli, Kodapuli, Korugan, Kotakkappuli, Kotappuli, Kottukkappuli, Kurkapullie, Kurukkampuli, Kutampuli, Kutappuli, Marappuli, Penanga, Pinampuli, Pinar, Pinaru (Malayalam), Aradal, Darambo, Daraambaa, Dharamba, Dharambe (Marathi), Raktasrava (Oriya), Amla, Wethasa, Amla Wruksaka, Kankusta, Vrikshamla, Wrukshamla (Sanskrit), Cakkiraviriyam, Catpeti, Cattapeti, Cikiri, Cimaikkorukkappuli, Cimaikkorukkappulimaram, Cimaikkorukkayppuli, Goruka, Ilappuli, Kapavatamariyan, Kattimutantam, Kattimutantamaram, Kodakkapuli, Kodukkappuli, Korukka, Korukkaip-Puli, Korukkaippuli,

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Korukkampuli, Korukkay, Kotakan, Namalomalam, Punampuli, Takattaippokki, Takattaiyatakki (Tamil), Seemachinta, Simachinta, Simacinta, Vaadachinta, Vadachinte, Vadacinte, Vrksamla (Telugu);
Italian: Gomma Gutta, Gummi-Gutti (Product);
Japanese: Garushinia Kanbogia;
Norwegian: Malabartamarind;
Russian: Gartsiniia, Gartsiniia Kambodzha;
Spanish: Guta Gamba, Tamarindo Malabar;
Sri Lanka: Goraka, Heen Goraka, Kana Goraka, Rathu Goraka (Sinhala), Korakkaipili, Korakkaipulli, Murgal (Tamil);
Taiwan: Teng Huang Guo;
Thai: Som Khaek;
Ukrainian: Gartsiniia Kambodzhiiskaia, Gummigut;
Vietnamese: Cỏ Đuôi Lươn.

Origin/Distribution

This species has a restricted global distribution, occurring in Southern India and Sri Lanka. Within India, it has been recorded in Western Ghats of Maharashtra (Bombay, Konkan), Goa (Anmod, Colemrange, Sangeum), Karnataka (Chikmagalur, Dakshin and Uttar Kannada, Kodagu, Hassan, Shimoga), Kerala (Calicut, Cannanore, Palakkad, Nilambur, Thrissur and Thiruvananthapuram) and Tamil Nadu (Coimbatore, Nilgiri, Tirunelveli and Dharmapuri districts) in an altitude range of 400–900 m. It has been introduced elsewhere in the tropics.

Agroecology

In its natural habitat, the species occur as an understorey tree in the lowland tropical rainforests in the wet and intermediate zones up to 1,800 m. It occurs in areas with evenly distributed rainfall and a short dry period to initiate flowering. It thrives on deep, well-drained slightly acidic soil such as clayey loams and abhors calcareous soils.

Edible Plant Parts and Uses

The fruits are edible but excessively acidic to be eaten raw. It is valued for the sun-dried smoked rind which is widely used in India and Sri Lanka as a condiment for flavouring curries in place of tamarind or lime. The dried fruit rind of *Garcinia cambogia*, is a unique source of (−)-hydroxycitric acid (HCA), which exhibits a distinct sour taste and has been safely used for centuries in Southeastern Asia to make meals more filling. It goes well with fish curries. The dried rind is also used along with salt for curing fish. The fruit is also used as a substitute of Kokam butter.

Botany

Garcinia gummi-gutta is an evergreen, small to medium-sized tree, 5–20 m tall (Plate 1), about 70 cm dbh, with dark smooth, lactiferous bark and horizontal or drooping branches (Plates 2–3). Leaves are simple, entire, opposite, petiolate (1.2–2.2 cm long), coriaceous, glossy dark green, elliptic-ovate to obovate, 1–13 long, 2–8 cm wide, shortly acuminate tip, tapered based, sub-acute and glabrous. Flowers are either androecious or bisexual, thus it is an andromonoecious species. Male flowers occur in axillary clusters of 4–8, with long membranous sepals and concave, oblong petals which are twice as long as sepals, with monadelphous cluster of 16–18 stamens attached to a pistillode with a non-functional stigma. Hermaphrodite flowers occur solitary or in 2–3 flowered axillary or terminal clusters, with 4 greenish-white, 4–6 mm long persistent sepals and 4 greenish-white, pink, or reddish, fleshy, 5–10 mm long petals, stamens 8-12 – (20) free or in 2–3 bundles, ovary globose and superior crowned by a sessile, circular papillate stigma with 8–10 tuberculate stigmatic rays. The fruit is a fleshy, globose, sub-globose to ovoid berry, 7–10 cm in diameter, green turning yellow, orangey or reddish when ripe, fluted with 5–13 longitudinal grooves, not grooved to the tip (Plates 2–4).

Plate 1 Tree habit

Plate 2 Drooping branches and orangey-coloured fruits

The fruit is capped by the persistent calyx at the tem end and a rosette of 4–5 triangular remnants of the stigma at protruding nipple-shaped mamilla. Seeds 6-8-(13), smooth, pale brown, oval, 12 mm long, surrounded by a succulent reddish or whitish succulent aril.

Nutritive/Medicinal Properties

The major organic acid in *Garcinia cambogia* was found to be (−)-hydroxycitric acid (HCA), present in concentrations of 16–18% (Jayaprakasha and Sakariah 1998). Citric and malic acids were present in minor amounts. The major organic acid in commercially available extracts of *Garcinia cambogia* was found to be (−) hydroxycitric acid present to the extent of 51–55%. Tartaric, citric, and malic acids were present in small quantities (Jayaprakasha and Sakariah 2000). Two polyisoprenylated benzophenones, isoxanthochymol and camboginol were identified and quantified in the fruit rinds of *Garcinia cambogia* (Chattopadhyay and Kumar 2007).

Plate 3 Leaves and yellow-coloured fruit

Plate 4 Reddish-coloured fruits

Polyisoprenylated benzophenones such as garcinol, guttiferone I, guttiferone J, and guttiferone K, guttiferone M, guttiferone N, and the oxidized derivative of guttiferone K were found in the fruits of *G. cambogia* (Masullo et al. 2008). Oxy-guttiferone K represented the first example of tetracyclic xanthone derived from the oxidation of a polyisoprenylated benzophenone from natural source. The natural formation of oxy-guttiferone K wass in agreement with the previously described cyclization of garcinol by DPPH.

Some published reports on the pharmacological activities of *G. cambogia* plant parts are highlighted below.

Antiobesity Activity

The tropical plants *Garcinia cambogia* and *Hibiscus subdariffa* produce hydroxycitric acid (HCA), of which the absolute configurations are (2S,3S) and (2S,3R), respectively (Yamamda et al. 2007). (2S,3S)-HCA was found to be an inhibitor of ATP-citrate lyase, associated with fatty acid synthesis. (2S,3R)-HCA inhibited pancreatic α-amylase and intestinal α-glucosidase, leading to a reduction in carbohydrate metabolism. (−)-HCA was shown to be a potent inhibitor of ATP citrate lyase (EC 4.1.3.8), which catalyzes the extramitochondrial cleavage of citrate to oxaloacetate and acetyl-CoA: citrate + ATP + CoA -->acetyl-CoA + ADP + P(i) + oxaloacetate (Szutowicz et al. 1976; Jena et al. 2002). The inhibition of this reaction limited the availability of acetyl-CoA units required for fatty acid synthesis and lipogenesis during a lipogenic diet, i.e., a diet high in carbohydrates (Sullivan et al. 1974, 1977). Extensive animal studies indicated that (−)-HCA suppressed the fatty acid synthesis, lipogenesis, food intake, and induced weight loss.

(−)-hydroxycitric acid (HCA), a natural extract from the dried fruit rind of *Garcinia cambogia*, is a popular supplement for weight management. The dried fruit rind has been used for centuries as a condiment in Southeastern Asia to make food more filling and satisfying. A significant number of studies highlighted the efficacy of Super CitriMax (HCA-SX, a novel 60% calcium-potassium salt of HCA derived from *Garcinia cambogia*) in weight management (Shara et al. 2003, 2004). These studies also demonstrated that HCA-SX promoted fat oxidation, inhibited ATP-citrate lyase (a building block for fat synthesis), and lowered the level of leptin in obese subjects. Acute oral, acute dermal, primary dermal irritation and primary eye irritation toxicity studies demonstrated the safety of HCA-SX. However, no long-term safety of HCA-SX or any other (−)-hydroxycitric acid extract had been previously assessed. Results of studies in rats by Shara et al. (2003, 2004) indicated that treatment of HCA-SX over a period of 90 days resulted in a significant reduction in body weight, but did not cause any changes in hepatic and testicular lipid peroxidation, DNA fragmentation, or histopathological changes. In further animal studies, the Ohio group (Roy et al. 2004) observed that at doses relevant for human consumption dietary HCA-SX significantly curbed body weight growth. This response was associated with decreased abdominal fat leptin expression while plasma leptin levels remained unaffected. Functional characterization of HCA-SX-sensitive genes revealed that upregulation of genes encoding serotonin receptors represented a distinct effect of dietary HCA-SX supplementation.

In a 12-week randomized, double-blind, placebo-controlled trial *Garcinia cambogia* fruit extract containing HCA failed to produce significant weight loss and fat mass loss beyond that observed with placebo (Heymsfield et al. 1998).

Patients in both groups, HCA treated (n = 66) and placebo (n = 69) lost a significant amount of weight during the 12-week treatment period however, between-group weight loss differences were not statistically significant. There were no significant differences in estimated percentage of body fat mass loss between treatment groups, and the fraction of subject weight loss as fat was not influenced by treatment group.

The results of a clinical study of 60 human volunteers over a period of 8 weeks, demonstrated the safety, bioavailability and efficacy of HCA-SX (Supercitrimax – calcium-potassium salt of HCA derived from *Garcinia cambogia*) in weight management (Preuss et al. 2004). Subjects were given a 2,000 kcal diet/day, participated in a 30 minutes walking exercise program 5 days/week and given an oral dose of placebo or 4,666.7 mg HCA-SX (providing 2,800 mg HCA) in three equally divided doses 30–60 min before meals. At the end of 8 weeks, body weight and BMI (Body mass index) decreased by 5.4% and 5.2%, respectively. Food intake, total cholesterol, LDL, triglycerides and serum leptin levels were significantly reduced, while HDL and serotonin levels, and excretion of urinary fat metabolites (a biomarker of fat oxidation) significantly increased. No significant adverse effects were reported.

Studies suggested that chronic administration of (−)-hydroxycitrate (HCA) an active ingredient from fruit rind of *G. cambogia* promoted lipid oxidation and spared carbohydrate utilization in mice at rest and during running (Ishihara et al. 2000). Serum free fatty acid levels were significantly higher 100 minutes after administration in the HCA group, but the respiratory exchange ratio was not different from that in the control group. The concentration of glycogen in the gastrocnemius muscle was higher in the HCA group 16 hours after administration, and in an additional study, the maximum swimming time until fatigue, was slightly longer. The difference was significant on day 3 after 3 days of HCA or water administration. In other mice administered 10 mg HCA or water orally twice a day for 25 days, the respiratory exchange ratio on day 26 was significantly lower in the HCA group during both resting and exercising conditions.

High dose of *Garcinia cambogia* (154 mmol HCA/kg diet) showed significant suppression of epididymal fat accumulation in developing male Zucker obese rats, compared with the other groups (Saito et al. 2005). However, the diets containing 102 mmol HCA/kg diet and higher (778 and 1,244 mg HCA/kg BW/d, respectively) caused potent testicular atrophy and toxicity, whereas diets containing 51 mmol HCA/kg diet (389 mg HCA/kg BW/d) or less did not. Accordingly, 51 mmol HCA/kg diet (389 mg HCA/kg BW/d) was deemed to be the no observed adverse effect level (NOAEL).

Consumption of the *Garcinia cambogia* extract was found to effectively decrease the body weight gain, visceral fat accumulation, blood and hepatic lipid levels, and plasma insulin and leptin concentrations in a high-fat diet (HFD)-induced obesity mouse model (Kim et al. 2008a). The *Garcinia cambogia* extract reversed the HFD-stimulated alterations in the expression pattern of epididymal adipose tissue genes such as adipocyte protein aP2 (aP2), sterol regulatory element-binding factor 1c (SREBP1c), peroxisome proliferator-activated receptor gamma2 (PPARgamma2), and CCAT/enhancer-binding protein alpha (C/EBPalpha) (Kim et al. 2008a). The findings suggested that the *Garcinia cambogia* extract ameliorated HFD-induced obesity, probably by regulating multiple genes associated with adipogenesis, such as aP2, SREBP1c, PPARgamma2, and C/EBPalpha in the visceral fat tissue of mice. Kim et al. (2008b) also reported that a mixture composed of *Garcinia cambogia* extract, soypeptide, and l-carnitine (1.2:0.3:0.02, w/w/w) significantly reduced body weight gain and the accumulation of visceral fat mass in a rat model of high-fat diet (HFD)-induced obesity. The mixture significantly lowered hepatic lipid concentrations and serum glucose, insulin, c-peptide, and leptin levels in rats with HFD-induced obesity.

Vasques et al. (2008) conducted a double-blind randomized study involving 58 obese subjects to evaluate the pharmacotherapeutic efficacy of standardized extracts of *G. cambogia* (52.4% HCA) plus *Amorphallus konjac* (94.9% glucomannan) in the treatment of obesity. This combination

was based on the premise that hydroxycitric acid (HCA), the main compound of *Garcinia cambogia* extract, being a competitive blocker of ATP-citrate-lyase involved in inhibition of fatty acid biosynthesis and glucomannan fibers, which abound in *Amorphophallus konjac*, could reduce the absorption kinetics of dietary fat. The treatment had no significant effect on anthropometric parameters, resting energy expenditure (REE), triglycerides or glucose levels. However, a significant reduction was observed in total cholesterol (−32.0 mg/dL) and LDL-c levels (−28.7 mg/dL) in the treated group, the final levels being significantly lower than those of the placebo group. The results obtained suggested that the treatment had a significant hypocholesterolemic effect, without influencing the anthropometric or calorimetric parameters tested.

Garcinia cambogia fruit extract was found to prevent lipid droplet accumulation in fat cells without affecting adipose conversion (Hasegawa 2001). In week 3 of culture with insulin, the fat cells exhibited more numerous and larger intracytoplasmic lipid droplets (i.e., 30–40 μM^2). When *Garcini*a extract and insulin were added simultaneously, the accumulation of lipid droplets was inhibited and the peak droplet area markedly reduced. However, the activities of glycerophosphate dehydrogenase, a marker of adipose differentiation, were not significantly inhibited by the *Garcini*a extract. Ohia et al. (2001) found that hydroxycitric acid (HCA) extract from *G. cambogia* could increase the release of radio-labelled serotonin ([3H]-5-HT) from rat brain cortex in-vitro. When applied on its own, HCA (10 μM–1 mM) elicited a concentration-dependent increase in efflux of [3H]-5-HT reaching a maximum at 300 μM. Serotinin is found in the CNS and is involved in the regulation of appetite, mood, sleep, muscle contraction and other activities.

In addition, HCA supplementation had also been suggested as an ergogenic aid, especially because an increase in fat oxidative capacity would limit endogenous carbohydrate utilization during aerobic exercise (McCarty 1994, 1995a, b). The chief benefits of aerobic exercise were attributable to fat oxidation during exercise and a post-exercise reduction of respiratory quotient. The ability of exercise to selectively stimulate fat oxidation could be optimized if exercise is carried out post-absorptively (preferably during morning fasting metabolism), if caffeine and possibly hydroxycitrate/carnitine are taken prior to exercise, if the exercise regimen is of moderate intensity and extended duration, and if no calories are consumed for several hours following exercise. Pre-administration of (−)-hydroxycitrate, a potent inhibitor of citrate lyase, found in fruits of the genus *Garcinia*, may aid endurance during post-absorptive aerobic exercise by stimulating gluconeogenesis. Promotion of gluconeogenesis and liver glycogen storage may enhance satiety. Suggestions have also been made that increases in malonyl-CoA lead to insulin resistance in diabetic mice models. As such, a nutritional compound that could lower muscle malonyl- CoA concentration and increase fat oxidation would be extremely important.

Several studies reported that HCA did not have dietary or satiety efficacy. Mattes and Bormann (2000) found that the results of their double-blind, placebo-controlled parallel group study did not support a satiety effect of HCA. Forty-two participants ingested 400-mg caplets of *Garcinia cambogia* 30–60 min prior to meals for a total dose of 2.4 g/day (1.2 g/day HCA) for 12 weeks. 47 participants ingested matched placebos. Both groups lost body weight with the active group achieving a significantly greater reduction (3. 7 kg versus 2.4 kg). No effects of the HCA were observed on appetitive variables. The active treatment group did not exhibit better dietary compliance or significant correlations between appetitive variables and energy intake or weight change. Yonei et al. (2008) studied the effect of a dietary supplement with L-carnitine (600 mg/day) and *Garcinia cambogia* extract (500 mg/day as hydroxycitric acid) as main ingredients in 35 healthy volunteers in a double-blind test. Use of this supplement was found to significantly improve the level of lipid peroxides (−12.8%) in the blood as well as physical symptoms such as "tired eyes," "blurry eyes," "muscle pain/stiffness," "early satiety," "epigastralgia," "dizziness," "arthralgia" and "easily breaking

into a sweat." The Control Group showed a significantly favorable improvement rate, especially for "dizziness." In contrast, groups of subjects taking the test compounds registered a significant rise in total cholesterol (4.5%), fasting blood sugar (4.1%) and HbA1c (3.4%). The findings suggested that the consumption of the supplement could reduce the oxidative damage; however, the effect on QOL (quality of life) was equivocal and that *Garcinia cambogia* extract did not show dietary efficacy.

Studies by van Loon et al. (2000) showed that HCA, even when provided in large quantities, did not increase total fat oxidation in-vivo in endurance-trained humans such as cyclists. HCA concentrations increased after HCA ingestion. However, no significant differences in total fat and carbohydrate oxidation rates were observed between excercise trials. Additionally, plasma glucose, glycerol, and fatty acid concentrations did not differ between trials. Plasma lactate concentrations were significantly lower in the HCA administered than in the placebo after 30 minutes of exercise but at the end of the exercise period they did not differ between trials. In another double-blind placebo-controlled trial, 44 participants received either *G. cambogia* extract (1,667.3 mg/day equivalent to 1,000 mg HCA/day) or placebo for 12 weeks, compared to the placebo group, administration of *G. cambogia* extract did not significantly change the serum testosterone, estrone, and estradiol levels (Hayamizu et al. 2008). Similarly, hematology, serum triacylglycerol and serum clinical pathology parameters did not reveal any significant adverse effects. The results of this preliminary investigation indicated that ingestion of *G. cambogia* extract at dose levels commonly recommended for human use did not affect serum sex hormone levels and blood parameters despite the controversy over HCA related testicular toxicity in animal studies.

Antioxidant Activity

Two polyisoprenylated benzophenones from *G. cambogia* fruit, garcinol and guttiferone K were found to have protective effects against lipid and protein oxidation (Kolodziejczyk et al. 2009). Garcinol and guttiferone K (0.1–25 μg/ml), elicited a distinct reduction in the formation of carbonyl groups in plasma and platelet proteins together with the decrease of thiobarbituric acid reactive species (TBARS) caused by 100 μM peroxynitrite. However, garcinol and guttiferone K did not inhibit plasma and platelet protein nitration induced by peroxynitrite. The data indicated that garcinol and guttiferone K could be useful as prophylactic factors against diseases associated with oxidative stress.

Hypolipidemic Activity

Flavonoids from *Garcinia cambogia* were found to exert hypolipidaemic activity in rats (Koshy and Vijayalakshmi 2001). Lipid lowering activity was maximum in rats administered flavonoids (10 mg/kg BW/day) from *Garcinia cambogia*. A dose response study revealed biphasic activity. Higher doses were less effective in reducing lipid levels in serum and tissues, although devoid of toxic effects. Mahendran and Shyamala Devi (2001b) found that concomitant-treatment of the Male albino rats with *Garcinia cambogia* fruit extract for 45 days significantly inhibited the rise in lipid levels and also the peroxidative damage caused by ethanol, as reflected from the improved antioxidant status. The levels of serum AST, ALT and alkaline phosphatase, antioxidant enzymes, lipid peroxide, conjugated diene were maintained at near normalcy in *Garcinia cambogia* treated rats. This hypolipidemic property of *Garcinia cambogia* in turn reduced the peroxidative damage, enhanced by ethanol. They also found that the lipid levels and lipoprotein composition were maintained at near normalcy when dexamethasone administered rats were treated with *Garcinia cambogia* fruit extract in (Mahendran and Shyamala Devi 2001a). The sub cutaneous administration of dexamethasone (10 mg/kg body weight/day, for 8 days resulted in significant increase in the levels of triglycerides and cholesterol and free acids in both plasma and liver. The level of phospholipids

increased in the plasma but decreased significantly in liver tissue after dexamethasone administration as compared to those in normal rats. The activities of lecithin cholesterol acyl transferase and hepatic lipoprotein lipase were markedly reduced after dexamethasone per se administration. The levels of HDL-triglycerides and HDL-cholesterol remained unchanged, while the LDL and VLDL increased significantly in dexamethasone administered rats. This study revealed the undesirable alterations in lipid profile on dexamethasone administration and the hypolipidemic property of *Garcinia cambogia* fruit extract.

Separate studies showed that *G. cambogia* extract improved glucose metabolism and displayed leptin-like activity (Hayamizu et al. 2003). Treatment of 3.3% *Garcinia cambogia* extract for 4 weeks to sucrose-loaded mice was found to have no effect on body weight, fat pad weight or serum glucose level. In contrast, effects on serum total cholesterol, triglycerides, NEFA (non-essential fatty acids) were observed. Levels of serum insulin and leptin, as well as the leptin/WAT (white adipose tissue) ratio, were lower in the treated mice than in the control.

Oikawa et al. (2005) found that *Garcinia cambogia* supplementation for at least 4 weeks in mice did not cause a negative effect on skin properties irrespective of excessive sucrose (10%) intake. The collagen and triacylglycerol contents were not significantly different among the groups. Similarly, electron microscopy revealed no differences in the thickness of the dermis layer or the subcutaneous tissue layer. Mice administered the diet containing *Garcinia cambogia* tended to have lower total number of adipocytes, but not significantly.

Ethanolic extracts of *G. cambogia* seeds were found to have both haematologically enhancing and anti-obesity effects (Oluyemi et al. 2007). Analysis of the results showed a significant rise in RBC counts in both test groups (200 mg/kg and 400 mg/kg) and a reduction in weights of experimental animals compared with the control group. Decrease in the plasma level of very-low-density lipoprotein and increase in the level of chylomicrons occurred in a dose dependent manner. There was a small, but significant, decrease in the level of high-density lipoprotein and a significant rise in the level of LDL (low-density lipoprotein). There was significant dose-dependent decrease in the triacylglycerol pool of adipose tissue and the liver of the test groups, but a significant increase in the triacylglycerol pool of the gastrointestinal system.

Antiinflammatory Activity

Garcinia cambogia extract was found to have antiinflammatory activity and could provide a source for the search for new anti-inflammatory compounds useful in inflammatory bowel disease treatment (dos Reis et al. 2009). Administration of *G. cambogia* extract to ulcerative colitic rats significantly improved the macroscopic damage and caused appreciable reductions in increases in MPO (myeloperoxidase) activity, COX-2 (Cyclooxygenase-2) and iNOS (inducible Nitric Oxide Synthase) expression. Further, *Garcinia* extract treatment was able to reduce PGE2 (prostaglandin E2) and interleukin IL-1beta colonic levels. These antiinflammatory actions could be related to a reduction in DNA damage in isolated colonocytes. *Garcinia* extract caused neither mortality nor toxicity signals after oral administration.

Studies by Asgha et al. (2007) found that HCA-SX supplementation in obese Zucker rats reduced food-intake, body weight gain, and also mitigated the rises in inflammation, oxidative stress, and insulin resistance observed in untreated animals. Compared to controls, the levels of malondialdehyde (MDA), protein carbonyl (DNPH), and protein tyrosine nitration (tyr-NO(2) were lower in the liver and kidney of HCA-SX-treated animals. In addition, the levels of C-reactive protein and interleukin-6, markers of inflammation, were lower in the plasma of HCA-SX-supplemented animals compared to controls. Similarly, the levels of fasting plasma insulin, glucose, and triglycerides were lower. Interestingly, insulin resistance

did not develop in HCA-SX-supplemented rats. Food-intake and body weight gain was also lower in rats supplemented with HCA-SX compared to their control counterparts. It was concluded that HCA-SX may be used as an intervention to overcome obesity-related complications, including inflammation, oxidative stress, and insulin resistance.

Antiulcerogenic Activity

Oral pretreatment of rats with *Garcinia cambogia fruit* extract at 1 g/kg body weight, at days 7 and 15 prior to ulcer induction with hydrochloric acid and ethanol, significantly protected gastric mucosa against HCl-ethanol induced damage by decreasing the volume and acidity of gastric juice (Mahendran et al. 2002). Increased lipid peroxidation, decreased activity of antioxidant enzymes, altered levels of protein and glycoproteins in the ulcerated mucosa, and gastric juice were maintained at near normal levels in *G. cambogia* pretreated rats. The results suggested the anti-ulcer activity of *G. cambogia* could be attributed to its ability to decrease acidity and increase mucosal defense.

Toxicity Studies

In genotoxicity studies, (−)-hydroxycitric acid (HCA) did not induce mutagenic activity in the Ames test, and exhibited no significant mutagenic potency as indicated by chromosomal aberration tests (Lee and Lee 2007). However, HCA significantly and dose-dependently increased the number of MNPCEs (micronucleated polychromatic erythrocytes/1,000 polychromatic erythrocytes) and PCE/(PCE + NCE) ratios. These results suggested that HCA preferentially induced micronuclei proliferation.

Based on the results of toxicological animal study, the parental as well as the offspring no-observed-adverse-effect level for HCA-SX was found to be higher than 10,000 ppm in diet or equivalent to 1,018 and 1,524 mg/kg body weight/day in male and female rats, respectively (Deshmukh et al. 2008a). Compared to respective controls, HCA-SX exposure did not alter feed consumption or body weight at any of the exposure levels. HCA-SX exposure did not change reproductive performance as evaluated by sexual maturity, fertility and mating, gestation, parturition, litter properties, lactation, and development of the offspring. Based on the results of further developmental toxicity study, conducted in continuation of a two-generation reproductive toxicity study, HCA-SX was not found to be teratogenic in the Sprague-Dawley rat at the dietary exposure levels of 1,000, 3,000, and 10,000 ppm, equivalent to the dose levels of 103, 352, or 1,240 mg/kg/day, respectively (Deshmukh et al. 2008b). Despite a small (13%) decrease of maternal body weight gain during gestation period in the group receiving 10,000 ppm HCA-SX, no evidence of maternal toxicity, adverse effects on the parameters evaluated for the gravid uteri, external abnormalities in the fetuses, soft tissue abnormalities in the fetuses, or skeletal abnormalities in the fetuses were observed.

In-vivo toxicological animal studies by Ohia et al. (2002) demonstrated that HCA-SX(Super CitriMax) was a safe, natural supplement under the conditions it was tested. They also showed that HCA-SX could inhibit [3H]-5-HT uptake (and also increased 5-HT availability) in isolated rat brain cortical slices in a manner similar to that of serotonin receptor reuptake inhibitors (SRRI), fluoxetine plus clomipramine and thus may prove beneficial in controlling appetite, as well as treatment of depression, insomnia, migraine headaches and other serotonin-deficient conditions.

Traditional Medicinal Uses

A decoction of the fruit rind is used to cure rheumatism and bowel complaints in human beings. It is also used as a rinse for diseases of the mouth in cattle (Geetha 1994). A translucent yellow resin obtained from the tree is reported to have purgative properties.

Other Uses

The dried rind is used for polishing gold and silver, and as a substitute for acetic or formic acid in coagulating rubber latex.

Comments

The plant can be propagated from seeds, air-layering, cuttings, grafting and micropropagation.

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Garcinia hombroniana

Scientific Name

***Garcinia hombroniana* Pierre**

Synonyms

Garcinia opaca King

Family

Clusiaceae

Common/English Name

Seashore Mangosteen

Vernacular Names

Brunei: Luli;
Malaysia: Beraus, Manggis Hutan, Minjok;
Spanish: Mangostán De Playa;
Thailand: Wa.

Origin/Distribution

The species is native to Malaysia, Cambodia, Thailand and Vietnam. It is found along the east coast of Peninsular Malaysia, from Pahang to Kelantan. It is also found in Nicobar Islands. It is cultivated sporadically throughout the tropics. The fruit is being cultivated in Kerala and Tamil Nadu in India.

Agroecology

The species is tropical in ecological requirement. It naturally grows near seashores and riverine areas, in coastal primary and secondary forests and is salt tolerant and adapted to the sandy and rocky soils. In Peninsular Malaysia, it is also found inland on acid clay soils in lower montane forest on the main range up to 500 m elevation. It tolerates heavy rainfall and drought conditions.

Edible Plant Parts and Uses

Fruit pulp is scanty, sour but aromatic and pleasant and is eaten. It could probably be used to make juices, jams and jellies. The dried crimson rind is commercially important and widely used as sour relish in curries and culinary dishes requiring an acidulose base.

Botany

Usually a small, evergreen tree, reaching a height of (4.6–6 m) but can grow to 30 m tall. It has a straight trunk, with a girth of 180 cm and is densely branched. The tree has grey bark that peels off in little flakes revealing a paler grey to

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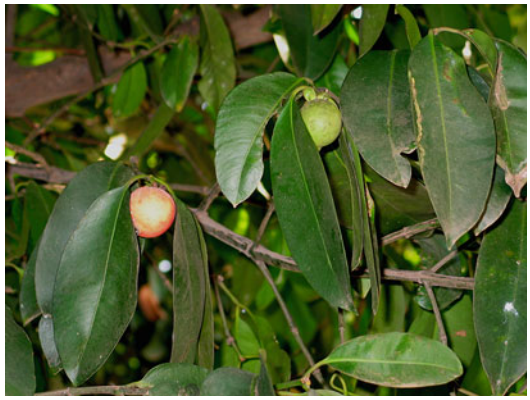

Plate 1 Large, glossy, dark- green leaves

Plate 3 Fruit with raised disc-like remnant of the stigma

Plate 2 Seashore mangosteen with persistent green calyx attached

buff new bark and has opaque white exudate. Young twigs are smooth and green, but older bark is dark brown and rough. Leaves are opposite, coriacious, bright green, glossy, ovate to ovate-oblong, 15–25 cm long and 5–13 cm wide, tapering apex and cuneate or rounded base with fine parallel secondary veins faintly looping to from a weal intramarginal nerve (Plate 1). Trees are dioecious. Each tree is either male or female. Flowers are whitish-cream, tetramerous with 4 sepals, 4 petals and pedicellate. The male flowers are small pale-yellow to cream-coloured, occur terminally in clusters of 1–3, sepals orbicular and red, stamens in a 4-lobed mass surrounding a pistillode, female flowers are solitary with green elliptic sepals and cream-coloured orbicular petals, with a short, broad ovary crowned by a large, sessile, pulviniform, lobed stigma and has no staminodes. The fruit is smooth, spherical and beaked, 5 cm across, with a pinkish-red or orangey-red peel and crowned by the disc-like remnant stigma and the green leathery calyx at the pedicel end (Plates 2–3). The interior is segmented, like the mangosteen but the pulp is white to creamy-white, scanty and acid-sweet although it has a good flavour. Most segments contain one flat seed.

Nutritive/Medicinal Properties

No nutritive information has been published on its edible fruit.

The methylene chloride extract from the pericarp of *Garcinia hombroniana* yielded three 17,14-friedolanostanes [(24*E*)-3α-hydroxy-17,14-friedolanostan-8,14,24-trien-26-oic acid, methyl (24*E*)-3α,23-dihydroxy-17,14-friedolanostan-8,14,24-trien-26-oate and methyl (24*E*)-3α,9,23-trihydroxy-17,14-friedolanostan-14,24-dien-26-oate] and two lanostanes [3β-hydroxy-23-oxo-9,16-lanostadien-26-oic acid and 3α-hydroxy-23-oxo-9,16-lanostadien-26-oic acid] (Rukachaisirikul et al. 2000).

The plant was found to be rich in bioactive tripenes (Rukachaisirikul et al. 2005). Five new triterpenes, one 17,14-friedolanostane (garcihombronane F), three 17,13-friedolanostanes

(garcihombronanes G-I), and one lanostane (garcihombronane J), were isolated from the leaves of *Garcinia hombroniana* together with nine known compounds including five triterpenes, two ionone-derived glycosides, and two flavonoid glucosides: namely methyl (24*E*)-3α,23α-dihydroxy-17,14-friedolanostan-8,14,24-trien-26-oate; methyl (24*E*)-3α,9α,23α-trihydroxy-17, 14-friedolanostan-14,24-dien-26-oate; 3β-hydroxy-23-oxo-9,16-lanostandien-26-oic acid; 3α-hydroxy-23-oxo-9,16-lanostandien-26-oic acid; lupeol; stigmasterol' riedelin; 8-(β-D-glucopyranosyl)-5,7-dihydroxy-2-(4-hydroxyphenyl)-4H-1-benzopyran-4-one; and a mixture of β-sitosterol glucoside and β-stigmasterol glucoside.

Methanolic extract from the bark of *G. hombroniana* was found to contain flavonoids, saponins, terpenoids and coumarins. The crude methanol extract displayed very good antioxidant activity by DPPH assay at EC_{50} of 2.21 μg/ml and also exhibited slightly inhibitory activity against gram positive bacteria including *Staphylococcus aureus*, *Staphylococcus epidermidis* and *Bacillus subtilis* at concentration of 100 mg/ml (Hofstaetter et al. 2007). The crude methanol extract were partitioned between chloroform and water and the water component had higher antioxidant activity with EC_{50} of 1.49 μg/ml than the chloroform component with EC_{50} 19.91 μg/ml. Further fractionation of the water component yielded 4 fractions F4, F5, F6 and F8 among which F4 was most abundant and exhibited antioxidant activity at EC_{50} of 1.08 μg/ml. The methanol extract of its leaves and stem at a concentration of 18.2 ug/ml were reported to have inhibitory effect (46.3% and 29.2% respectively) on PAF (platelet activating factor) receptor binding to rabbit platelets (Jantan et al. 2005).

Decoction of the root was reported to be administered after childbirth as a preventive medicine and the leaves have been prescribed to relieve itching in traditional medicine in Peninsular Malaysia.

Other Uses

The tree is an attractive ornamental and may be use as a rootstock for mangosteen, *Garcinia mangostana*. Timber is reported to be used for house building, house posts and oars.

Comments

The species is easily propagated from seeds.

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Garcinia humilis

Scientific Name

***Garcinia humulis* (Vahl) C. D. Adams**

Synonyms

Mammea humilis Vahl (basionym), *Mammea humilis* var. *macrophylla* Mart., *Mammea humilis* var. *plumier* Griseb., *Mammea humilis* var. *vahlii* Griseb., *Rheedia achachairu* Rusby, *Rheedia lateriflora* L., non Blume, *Rheedia sieberi* Choisy, *Rheedia sessiliflora* Planch. ex Vesque.

Family

Clusiaceae

Common/English Names

Achacha, Bolivian Mangosteen, Hatsland Rheedia, Hatstand Tree, Low Garcinia, Wild Manimee

Vernacular Names

Bolivia: Shashairu (Chiquitanos), Pacurí (Chiriguanos), Ibaguazú (Guarayos), Cachicheruqui (Mojenos), Tiquidea (Siriono), Achacha, Achachairú (Spanish);
Grenada: Abricot, Abricot Montagne, Abricot St. Domingue, Abricotier De St. Domingue, Bois Chica, Bois L'onguent, Bois Mulâtre, Garcinia Abricot (French);
Haiti: Abricot, Abricot Bâtard, Abricot Bord De Mer, Arbricotier De St-Domingue, Garcinia Abricot (French).

Origin/Distribution

The species is found in Bolivia and Guyana, Panama and in the Caribbean: Antilles, Dominica, Trinidad Grenada and Haiti. It has been introduced into Australia and is being developed into a commercial crop.

Agroecology

A tropical, under storey species but will also grow in the warmer parts of the subtropics. It occurs in the Amazonian rainforests in Bolivia and Guyana and also found in the lowland forests in the Caribbean from 150 to 600 m altitude. It thrives in areas with average annual temperatures of 23–25°C and mean annual rainfall of 1,400–2,500 mm. It does best in moist, well-drained, alluvial soils rich in organic matter with pH 4.7–6.6. It requires some shade during the seedling stage but grows well in full sun. It is intolerant of saline soils and is moderately drought tolerant.

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Edible Plant Parts and Uses

The white slightly acidic to sweet pulp is pleasantly mellow and refreshing and is eaten fresh out of hand when ripe. The pulp is also used in jams, beverages, sorbets and ice-cream. The rind is not bitter and is utilised for beverage and wine. The thin rind is extracted in a juicer to make a delicious, refreshing drink by adding sugar.

Botany

A small, evergreen tree, 6–10 m with pyramidal shaped canopy and stem of 40 cm diameter with a yellowish sap. Leaves are opposite, large, glossy dark-green, coriaceous, simple, elliptic to lanceolate 15–28 by 4–8 cm, with entire margin and acute to acuminate apex. Juvenile leaves are pinkish-bronze, turning yellowish-green then to dark green. Flowers, hermaphrodite and male, both white and on with 2 cm long pedicels. Hermaphrodite flowers in axillary fascicle of 4–5 flowers, flower 17–36 mm long with, 20–34 stamens, 2 sepals, 4 white, imbricate petals and an ovoid ovary. Male flowers 9.5–12 mm long, with 26–28 stamens and a vestigial ovary. Fruit smooth, bluish-green when young turning deep golden yellow to orange, ovoid to ellipsoid, 5.5–6 cm long by 4.4–5 cm across at the equatorial diameter, rind 0.8–1.5 mm thick (Plates 1–4).

Plate 1 Orange, ovoid to ellipsoid achacha fruits

Seeds 2–3, brown, oval, polyembryonic, large 3.0–3.5 by 1.5–2 cm (Plates 3–4) embedded in white acidic sweet pulp (Plates 2–3). Seeds exude yellow sap when cut.

Plate 2 Achacha fruit with rind removed showing the white pulp

Plate 3 Whole and longitudinal section of fruit showing the seed

Plate 4 Whole fruit and seeds with pulp removed

Nutritive/Medicinal Properties

Nutrient composition of the pulp per 100 g edible pulp had been reported as: water 83.9 g, protein 0.4 g, fat 0.5 g, total carbohydrate 14.2 g, fibre 0.6 g, ash 0.3 g and P 20.8 mg (Ardaya et al. 1995). The fruit has been reported to comprise 40% pulp, 47% peels and 12% seeds.

Guttiferone I, a new prenylated benzophenone, was isolated from the bark and stem of *Garcinia humilis* (Herath et al. 2005). The compound was found to be an agonist of Liver X receptors (LXR). The IC_{50} value for this compound in the LXRalpha-SPA binding assay was 3.4 μM. Liver X receptors are nuclear hormone receptors that play a critical role in cholesterol homeostasis. They regulate the expression of the ABCA1 gene, which mediates the efflux of cholesterol out of cells. LXR agonists are expected to increase cholesterol efflux, lower LDL, and raise HDL levels.

The fruit rind when made into a drink, help to suppress hunger and has been reported to be used for healing the skin.

Other Uses

In Trinidad, young trees have been cut, branches trimmed so the stem and shortened limbs form a natural hat-stand (Morton 1981).

Comments

In Australia, during the fruiting season the fruits are available in local markets.

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Garcinia intermedia

Scientific Name

***Garcinia intermedia* (Pittier) Hammel**.

Synonyms

Calophyllum edule Seem., *Rheedia edulis* (Seem.) Planch. & Triana, *Rheedia intermedia* Pittier (Basionym), *Rheedia macrophylla* var. *benthamiana* Vesque, *Rheedia tonduziana* Engl.

Family

Clusiaceae

Common/English Names

Cherry Mangosteen, Intermediate Garcinia, Lemon Drop Mangosteen, Monkey Fruit, Waika Plum (Belize), Wild Lemon, Wild–Lemon Rheedia

Vernacular Names

Belize: Jocomico (Spanish), Ka-Re-Ché (Maya), Waika Plum (English);
Brazil: Achachairu (Portuguese);
Costa Rica: Jorco, Jorcol;
El Salvador: Chaparrón;
French: Garcinia Intermédiaire;
Guatemala: Arrayán, Crauel, Eche Amarilla, Jocomico, Jocote De Mico, Limoncillo, Mameyito, Palo Bayo;
Honduras: Caimito, Caimito De Montaña, Fruta De Mico, Jacomico, Jocomico, Jocote De Mico, Pacuri, Sakipa, Sastra;
Nicaragua: Jocomico;
Panama: Cero, Chaparrón, Sastra.

Origin/Distribution

The species is native to Mexico (Jalisco, Michoacan, Oaxaca, Veracruz) and Central America (Belize, Costa Rica, El Salvador; Honduras, Nicaragua, Panama). It is also found in Ecuador and Columbia. It is cultivated sporadically throughout the tropics including in Australia.

Agroecology

In its native range, it occurs as an evergreen understory tree in most primary forest habitats, excluding the extreme coastal zone. The tree is very adaptable, growing well in different soils and environments from near sea level to 1,220 m elevation. It grows well in full sun or shade, but fruits better in full sun. It flowers and fruits sporadically throughout the year.

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Edible Plant Parts and Uses

The white, aromatic pulp from ripe fruit is edible, pleasantly acid-sweet and is consumed fresh and made into juices, jams and jellies.

Botany

A small, evergreen, dioecious tree with a straight, dark brown trunk of 20 cm girth, growing to 5–6 m high and yellow latex. The upper half of the tree is thickly covered with thin, horizontal branches oriented at right angles to the bole. The young branchlets have smooth, green bark. Leaves are opposite, simple, entire, leathery, elliptic-lanceolate, 7.5–13 cm long by 2.5–5 cm wide, with tapering base and acute apex, glossy green above and paler green below with a distinct mid-rib and fine, parallel secondary veins (Plates 1, 2, 4). Leaf petiole is green and 0.8–1 cm long. Flowers are small, 5 mm across, greenish-white, imperfect with male and female flowers occurring in axillary clusters of 1–15 in separate trees. Each flower consists of five pale, greenish-white petals that are folded back around the pedestal and either a central, globular cluster of about 20 short stamens (male) or a globular green ovary topped with a brown stigma (female). Several vestigial staminate appendages are also present

Plate 1 Clusters of lemon-drop mangosteen fruits and foliage

Plate 2 Unripe fruit and leaves

Plate 3 Close-up of unripe fruit

Plate 4 Ripening lemon-drop mangosteen fruits and leaves

Plate 5 Ripe lemon-drop mangosteen fruits

in the female flower. Fruit globose to sub-globose-ovoid, 2.5 cm in diameter, green (Plates 2 and 3) turning to deep yellow to orange when ripe (Plates 1, 4, 5). The fruit has a thin peel and pulpy, sub-acid-sweet white aril enclosing 1–2, large, laterally flattened, almond-shaped seeds 1.5–1.8 cm long.

Nutritive/Medicinal Properties

No published information is available on the nutritive food value of the fruit.

The following bioactive compounds, the polyisoprenylated benzophenone derivative, (1R,5R,7R,8 S)-(+)-3-(10-(3,4-dihydroxy phenyl)-10-hydroxymethylene)-8-methyl-1,5,7-tris (3-methyl-2-butenyl)-8-(4-methyl-3-pentenyl) -bicyclo[3.3.1]nonane-2,4,9-trione named guttiferone A and the xanthone 8-desoxygartanin were isolated along with the biflavonoids, podocarpusflavone A, amentoflavone, and friedelin were isolated from the leaves of *G. intermedia* (Abe et al. 2004). These compounds exhibited trypanocidal activity against epimastigotes of *Trypanosoma cruzi*, the etiologic agent of Chagas' disease.

Guttiferone A and other benzophenones isolated from other Clusiaceae species exhibited HIV-inhibitory; these compound inhibited the cytopathic effect of in-vitro HIV infection (Gustafson et al. 1992). Guttiferone A also showed particularly strong leishmanicidal activity in vitro, with IC_{50} values (0.2 μM and 0.16 μM, respectively) comparable to that of the reference compound, miltefosine (0.46 μM) (Lenta et al. 2007). Guttiferone A also showed potent anticholinesterase properties towards acetylcholinesterase (AChE) and butylcholinesterase (AChE) with IC 50 of 2.77 μM which was more active than galanthamine (IC_{50} = 8.5 μM) against BChE (Lenta et al. 2007). Guttiferone A also exhibited antimicrobial activity activity against *Staphylococcus aureus* and *Bacillus cereus* with IC_{50} values of 2.4 μg/ml and 2.4 μg/ml, respectively (Naldoni et al. 2009).

The biflavones podocarpusflavone A and amentoflavone had been reported to exhibit strong inhibitory activity on several phosphodiesterases (PDE) isoforms (Chaaabi et al. 2007). Among the biflavones, amentoflavone and podocarpusflavone A showed the best PDE inhibitory activity, and were even more active than the respective reference inhibitors (Rolipram) for PDE1, PDE2, PDE4 and PDE5 isoforms. Rolipram is a PDE4-inhibitor. Like most PDE4-inhibitors, it was found to be an antiinflammatory drug (Griswold et al. 1993). PDE inhibitors also possessed antipsychotic activity (Maxewell et al. 2004).

Other Uses

The wood is resistant to termites, and is used to make posts, cabinet work, carpentry, flooring, furniture, general construction and tool handles. The tree is an attractive ornamental, especially when in fruit.

Comments

The species has been introduced into Indonesia and Sabah, Malaysia.

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Garcinia livingstonei

Scientific Name

***Garcinia livingstonei* T. Anderson**.

Synonyms

Garcinia angolensis Vesque, *Garcinia baikieana* Vesque, *Garcinia bussei* Engl. *Garcinia ferrandii* Chiov., *Garcinia pallidinervia* Engl., *Garcinia pendula* Engl.

Family

Clusiaceae

Common/English Names

African Mangosteen, Gupenja, Imbe, Inbe, Lowveld Mangosteen, Mwausungulu, Pama, Veld Mangosteen, Wild Mangosteen, Wild Plum

Vernacular Names

Czech: Garcínie Livingstonova;
French: Mangoustan Du Congo;
Ghana: Kulitia (Dagaari), Abriva (Gbe-Vhe), Lepenabul (Konkomba), Kulitia (Moore), Kombauadai (Wala);
Guinea: Guessé-Guessé, Kouru, Sungala (Manding-Maninka);
Malawi: Mphimbi (Chewa), Ntundura (Yao);
Mali: Sumé Sunsu (Manding-Bambara), Ko Rokna Ko (Tree), Sungala (Maninka);
Mozambique: Bimbi, Himbi, Muhimbi, Meto, Veto, Ntabaza, Petapelo, Mutotola;
Senegal: Pratone, Pratond (Konyagi), Kõkumõ, Sumésunsu (Manding-Bambara), Mãdãhõ, Sungala (Maninka);
South Africa: Geelmelkhout, Laeveldse Geelmelkhout (Afrikaans), Mokongono, Mokononga (Pedi), Mmimbi (Tsonga), Umphimbi, Ugobandlovu (Zulu);
Swahili: Mpekechu, Mutumbi;
Tanzania: Mchamvya, Mpekechu, Mpekeso, Mpeketo, Mtobozi;
Uganda: Etungan (Karamojong);
Upper Volta: Sumé Sunsu (Manding-Bambara);
Zambia: Mulyanganga (Bemba), Kikole (Kaonde), Muchindu, Mukwananga, Mutugwa (Lozi), Mukwananga, Mutugwa, Mukoningo, Mulongwe, Musunka (Tonga), Mpule (Nyanja);
Zanzibar: Mutumbi;
Zimbawe: Himbi, Munhinzwa.

Origin/Distribution

The species is native to a broad area of tropical Africa: from Natal (Zululand), Swaziland and Transvaal to Kenya, Uganda and Somalia Zanzibar; westward to Bechuanaland Protectorate, Southwest Africa (Caprivi Strip), Angola, Northern Rhodesia and Belgian Congo (Katanga). It also occurs from French Guinea to Nigeria.

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It has been introduced for trial purposes in Indonesia, India, Singapore, northern Australia and elsewhere in the tropics.

Agroecology

Imbe thrives in a climate of warm winters and hot summers and is found from sea level to 1,050 m elevation. It naturally occurs where mean annual temperature is 20–22.5°C and frost never occurs but the tree has been reported to withstand brief periods of light frost without serious injury. It is found in areas with rainfall ranging from 200 to above 1,000 mm. Imbe is quite tolerant of drought, bush fires and heavy rain. It has been reported to withstand dry periods of up to 5 months. Imbe occurs on a wide range of soil types from acid sandy maritime soils, alluvial soils along riverbanks to alkaline and rocky soils. It grows in open coastal and riverine forests and in South Africa veld and frequently in riparian and munga, mopane woodland and termite mounds in Zambia. The tree does respond to good cultural practices.

Edible Plant Parts and Uses

The fruit has an acid-sweet juicy pulp with an apricot-like flavour. The pulp is eaten fresh or cooked with porridge. The fruits are also made into drinks, preserves, jams, pies, and assorted desserts. In East Africa and in Mozambique, it is also made into fermented beverages and alcohol. Some examples include a purplish, claret-like wine and a liqueur made by soaking the fruits in alcohol and thickening the extract with syrup.

Botany

It is an evergreen, glabrous, dioecious (male and female tree), much-branched tree, growing to 4.5–18 m tall, with rough, grey-brown, scaly bark (Plates 1–2, 5) and a dense spreading crown. It has an interesting branching pattern, with three lateral branches being produced at right angles to the trunk at each node and has grey-brown bark which exudes a yellow-red latex when bruised. The leaves are borne in opposite pairs or whorls of 3–4, each leaf being blue-green, coriaceous, petiolate. Lamina is very variable, lanceolate or oblanceolate to oblong or obovate (or

Plate 1 Young imbe fruits

Plate 2 Young imbefruits, subsessile, old leaves and trunk

Plate 3 New leafy shoots of imbe

Plate 4 Leaves and fruit of imbe

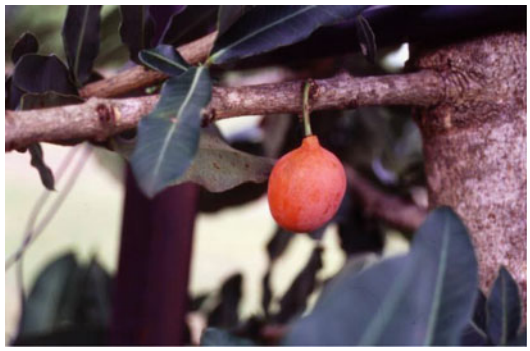

Plate 5 Rough scaly, grey brown bark of imbe

Plate 6 Orange, globose, fruit of imbe arising from the branches

rarely ± orbicular), 6–11 cm long by 3–5.5 cm wide, emarginate or rounded to acute or apiculate at the apex, cuneate to rounded at the base, sometimes with shallowly crenate margin and waxy (Plates 2 and 3). Flowers are polygamous, in fascicles of 5–15 or more in the axils of the older leaves and on the old wood with 4–20 (35) mm. long pedicels varying in thickness. Sepals are unequal, 4 in 2 opposite and decussate pairs. Petals usually 5 but sometimes up to 8, are 3–7 (9) mm long, obovate to orbicular, greenish-white to cream or pale yellow, with translucent, orange or reddish longitudinal glandular lines. Male flowers have numerous apparently free stamens inserted in a fleshy cushion formed by the united fasciclodes. Female flowers with fewer staminodes inserted in a fleshy fasciclodal ring below the ovary; ovary is globose, 2 (3)-locular, surmounted by a bilobed fleshy stigma. Berry is obovoid to globose, 2·5–3 cm. in diameter, green turning to orange-yellow, orange to reddish-orange (Plates 4–6), 1–2 seeded and thin skin filled with yellow latex. Seeds are cylindric or plano-ovoid, 1·5–2 cm. long surrounded by acid-sweet, juicy orange pulp.

Nutritive/Medicinal Properties

The juicy fruit pulp is acid-sweet, pleasant tasting and refreshing. Fruits have been reported to be rich in carbohydrates (mainly sugars) and have moderate mineral content (FAO 1988).

Many of the phytochemicals from the plant exhibit various pharmacological activities.

Anticancer Activity

Thirteen known compounds, including seven benzophenones [guttiferone A (1), guttiferone K (2), xanthochymol (3), guttiferone E (4), cycloxanthochymol (5), isoxanthochymol (6), and gambogenone (7)], five biflavonoids [amentoflavone (8), 3,8″-biapigenin (9), (+)-volkensiflavone (10), (+)-morelloflavone (11), and (+)-fukugiside (12)], and the xanthone derivative alloathyriol (13), were identified from the fruits of *Garcinia livingstonei* (Yang et al. 2010). Benzophenones 1 and 2 exhibited strong cytotoxic activity against HCT-116 and HT-29 human colon cancer cell lines with IC_{50} values between 5 and 10 μM, and somewhat weaker activity with SW-480 cells (IC_{50} values ranging from 18 to 25 μM). The fruit

extract of *G. livingstoneii* showed moderate to mild cytotoxic activities against A549, DU145, KB and Kbivin human vincristine resistant nasopharygneal cancer cell lines with 50% cytotoxic (CC_{50}) values ranging from 5.7 to 20.0 μg/ml (Magadula and Suleimani 2010).

Antiviral Activity

Recent scientific studies reported *G. livingstonei* to be a rich source of guttiferones, polyisoprenylated benzophenone derivatives. The guttiferones A–E and were found to inhibit in-vitro the cytopathic effects of HIV infection (Gustafson et al. 1992). The fruit extract of *G. livingstonei* showed significant anti–HIV−1 activity with EC_{50} value of 2.25 μg/ml (Magadula and Suleimani 2010). Root and stem extract of *G. livingstonei* showed in-vitro inhibitory effect against HIV (Magadula and Tewtrakul 2010). At 30 μg/ml concentration the root and stem extracts exhibited 44.5% and 34.3% inhibition and at 100 μg/ml, had inhibition of 87% and 89.5% respectively.

Central Nervous System Activity

Guttiferone A also showed potent anticholinesterase properties towards acetylcholinesterase (AChE) and butylcholinesterase (AChE) with IC 50 of 2.77 μM which was more active than galanthamine (IC_{50} = 8.5 μM) against BChE (Lenta et al. 2007).

Antimicrobial Activity

Guttiferone A also had antimicrobial activity. It presented activity against *Staphylococcus aureus* and *Bacillus cereus* with IC_{50} values of 2.4 μg/ml and 2.4 μg/ml, respectively (Naldoni et al. 2009).

Antiparasitic Activity

From the root bark *of Garcinia livingstonei*, three xanthone dimers were isolated: Garcilivin A-C were structurally related to 1,4,5-trihydroxy-3-(3-methylbut-2-enyl)-9 H-xanthen-9-one (Sordat-Diserens et al. 1992a, b). The dimeric xanthone garcilivin A showed a higher and non-selective antiparasitic activity and cytotoxicity (IC_{50} 2.0 μM against MRC-5 (human lung fibroblast) cells) than its diastereoisomer garcilivin C (IC_{50} 52.3 μM).

Guttiferone A exhibited trypanocidal activity against epimastigotes of *Trypanosoma cruzi*, the etiologic agent of Chagas' disease (Abe et al. 2004). Guttiferone A also showed particularly strong leishmanicidal activity in-vitro, with IC_{50} values (0.2 μM and 0.16 μM, respectively) comparable to that of the reference compound, miltefosine (0.46 μM) (Lenta et al. 2007). Also a new biflavonoid, ent-naringeninyl-(I-3a,II-8)-4′-O-methylnaringenin, along with five known xanthones and two known biflavonoids, were isolated from the root bark (Mbwambo et al. 2006). This new compound showed moderate activity against *Plasmodium falciparum*. Anti-trypanosomal activity (IC_{50} 0.87 μM) was observed for the xanthone 1,4,5-trihydroxy-3-(3-methylbut-2-enyl)-9*H*-xanthen-9-one.

The tree is used in traditional medicine, and in particular the powdered root is used as an aphrodisiac and an infusion made from roots has been used to treat abdominal pains during pregnancy and after giving birth. Extracts from flowers and leaves have been reported to have antibiotic properties. The fruit has been used to treat mumps.

Other Uses

Imbe is also used as a shade tree and ornamental landscape tree – the stiff, unsymmetrical growth and the grey-green stiff foliage give the tree an unusual and striking appearance. The tree has a bulbous base underground which holds the soil and acts as erosion control. The tree is also used for fuel-wood. Imbe is occasionally used as a grafting root stock for mangosteen, *Garcinia mangostana*. Leaves and young shoots are used as fodder by browsing animals. The wood although susceptible to borers has been used as a general-purpose timber for implements, fencing posts and rails. The yellow oily sap is used in the

manufacture of arrow poison and to decorate arrows.

In Zimbabwe, the tree is revered socially, its deep root system and the fact the tree is not easily ripped up characterises immortality and resistance. For this reason a *himbe* plant is among the gifts offered to a newlywed couple to bless that the new bride will never leave her husband's house.

Comments

The species is propagated by seed, air layering or grafting.

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Garcinia macrophylla

Scientific Name

***Garcinia macrophylla* Mart.**

Synonyms

Garcinia gardneriana (Planch. & Triana) Zappi (Plate 3), *Rheedia benthamiana* Planch. & Triana, *Rheedia gardneriana* Planch. & Triana, *Rheedia gardneriana* var. *parvifolia* Engler, *Rheedia macrantha* Standl. & Steyerm., *Rheedia macrophylla* (Mart.) Planch. & Triana, *Rheedia magnifolia* Pittier, *Rheedia sagotiana* Engl., *Rheedia spruceana Engler.*

Family

Clusiaceae

Common/English Name

Big leaf Garcinia

Vernacular Names

Bolivia: Achachairú, Achachairú Grande, Chachairu, Cahchairu Grande (Spanish);
Brazil: Bacuri, Bacuri-Da-Várzea, Bacupari, Bacuride Cerca, Bacuripari, Bacuripari-Verdadeiro, Bacopare (Portuguese);
French: Garcinia Á Grandes Feuilles;
Paraguay: Pacuriazú, Pacuri-Acu (Spanish);
Peru: Charichula, Charichuelo, Renaquillo (Spanish);
Suriname: Pakoeli;
Venezuela: Baro ehuhi (Yanomamí), Cotoiba, Cozoiba, Cozoiba picuda, Wadanidi-ishadu (Yekwana).

Origin/Distribution

The species is reported to have originated in Amazonia - Brazil, Bolivia, Columbia, Ecuador, Peru, Venezuela, French Guiana, Guyana and Suriname.

Agroecology

In it native Amazonia, it occurs as an under-storey tree in the evergreen lowland forests to lower montane forests, at altitudes of 50–400 m. It flourishes in the Amazonian climatic regime with mean annual temperatures of 26–28°C and mean annual rainfall of 1,500–4,000 mm. Young trees are killed by light frost and older trees will tolerate brief periods of light frost. The tree grows in light to moderate shade but will tolerate full sun and wind exposure. It grows best on well-drained nutrient rich soils but will grow on deep, well drained, nutrient poor oxisols and ultisols.

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Edible Plant Parts and Uses

The white pulp surrounding the seeds is acid-sweet and edible. The pulp can be mashed or blended in water to give a refreshing drink.

Botany

A dioecious, evergreen, tree, 5–15 m high with cylindrical trunk 30–50 cm diameter, rough, dark-brown mottled bark and densely-branched crown, pyramidal to sub-cylindrical in shape. The bark exudes a yellow latex when cut. Leaves are opposite, simple, glabrous, coriaceous, glossy, dark green, large, oblong-lanceolate to elliptic-oblong, 20–45 cm long by 8–18 cm wide, with acute apex, rounded to cuneate base, entire margin and a distinct mid-rib with numerous 45–50 parallel veins and borne on 2–3 cm petioles (Plates 1–2). Inflorescence of 3–5 (−10) flowered fascicles borne together on a thickened, woody pad in the leaf axils (Plates 1–2). Flowers unisexual, white and scented. Male flowers on slender pedicels up to 4 cm long with 2 broadly ovate sepals; 4 imbricate, obovate white petals; numerous stamens with kidney-shaped anthers surrounding a central, nectariferous disc. Female flowers in fewer-flowered fascicles, on shorter and thicker pedicels; sepals and petals as in male flowers; stamens fewer, smaller and reduced with sterile anthers; ovary ovoid to spherical, inserted on a large disc with 4 one-seeded loculi; and a large, fleshy, weakly-4-lobed stigma. Fruit ovoid to ellipsoid, up to 10 cm long and 7 cm across, smooth to rugose, yellow, thick rind exuding a yellow latex when cut; pulp white, mucilaginous, juicy, acid sweet but scanty, surrounding 1–4 ellipsoid seeds up to 2.5 cm long.

Plate 1 Flower buds and open flowers

Plate 2 Large, glossy, leathery leaves

Plate 3 Tree Label

Nutritive/Medicinal Properties

No information has been published on its nutritive food value.

Phytochemicals

A novel tetraisoprenylated benzophenone isolated from pericarp of fruits of *Rheedia gardneriana*, was identified as 15-epiclusianone, 1-benzoyl-6-hydroxy-14,14-dimethyl-3,5,15-tri(3-methyl-2-butenyl)-bicyclo[3.3.1]non-1-ene-4,6-dione (dos Santos et al. 2001). Xanthones, polyprenylated benzophenones and biflavonoids,

and 3 new 1,3,5,6-tetraoxigenated xanthones namely rheediaxanthone A, B and C were isolated in addition to macluraxanthone from the roots (Delle Monache et al. 1983).

8-Deoxygartanin and two new xanthones, 1,5-dihydroxy-6′,6′-dimethyl-2H-pyrano-(2′,3′:3,2)-6″,6″-dimethyl-2H-pyrano(2″,3″:6,7)-xanthone and 1,5,6-trihydroxy-6′,6′-dimethyl-2H-pyrano(2′,3′:3,2)-7-(3-methylprop-2-enyl)-xanthone, had been isolated from the roots of *Rheedia gardneriana* (Delle Monache et al. 1984). The latter of the two new xanthones was assigned the trivial name 7-prenyljacareubin while the former, the trivial name rheediaxanthone-A. Xanthones 1,5-Dihydroxyxanthone; 1,7-dihydroxyxanthone;1,6-dihydroxy-5-methoxyxanthone, and lupeol, betulin and β-sitosterol were isolated from *Rheedia gardneriana* (Braz Filho et al. 1970).

Twenty-eight volatile components representing 93.7% of the total oil were found in the oil extracted from *G. macrophylla* flowers (Andrade et al. 2007). The volatile components comprised 60.8% oxygen-containing monoterpenes, 20.2% of oxygen-containing sesquiterpenes, 9.1% fatty acid derivatives, 3.6% benzoids and 4.4% unidentified compounds. Seven major components identified (representing 73.2% of the oil) were (Z)-linalool oxide (4.1%), (E)-linalool oxide (4.5%), linalool (13.3%), hotrienol (24.8%), phenyl ethanol (2.5%), pinocampheol (8.7%) and seline-11-en-4α-ol (15.3%). Forty-seven compounds were identified from the oil from leaves, representing 96.6% of the total oil (Andrade et al. 2007). The oil was characterised by a predominance of sesquiterpene hydrocarbons (69.3%) and fatty acid derivatives (22.6%) and minor percentages of oxygen-containing sesquiterpenes and benzoid compounds (1%). The eight major components (comprising 77.5 of the oil) were (Z)-3-hexen-1-ol (15.7%), 1-hexanol (3.2%), α-copane (16.2%), β-caryophyllene (18%), α-humulene (4%), alloaromadendrene (9%), γ-cadinene (8.8%) and δ-cadinene (3.6%).

Higher yield of the bioactive biflavonoids from *Rheedia gardneriana* leaves were obtained using chitin modified with benzaldehyde (CH-Bz) as adsorbent in column chromatography than that achieved with silica gel and chitosan (Girardi et al. 2005).

Some of the plant's pharmacological attributes are elaborated below.

Antiinflammatory Activity

Studies showed that hydroalcoholic extracts from *Garcinia gardneriana* from the leaves, bark and seeds reduced carrageenan-induced mouse paw inflammation, in addition to reducing the myeloperoxidase activity in the stimulated tissues (Castardo et al. 2008). The reduction of neutrophil infiltration by treatment with the leaf extract was confirmed by histology. The leaf extract also reduced the paw oedema evoked by bradykinin, histamine, prostaglandin E2 and 12-O-tetradecanoylphorbol acetate. The leaf extract partially decreased substance P and compound 48/80-caused paw oedema, without any influence on the arachidonic acid-induced oedema. Both of the isolated biflavonoid compounds, fukugetin and GB-2a, prevented the carrageenan-induced paw oedema. The results illustrated important antiinflammatory effects of *Garcinia gardneriana* hydroalcoholic extracts through its interaction with different intracellular signaling pathways, without interfering with the formation of arachidonic acid (AA) metabolites. The results confirmed its popular traditional use and highlighted its promise in the development of new antiinflammatory drugs.

Recent studies by Otuki et al. (2011) revealed the antiinflammatory effect of *G. gardneriana* leaves for topical usage. The leaf extract was able to reduce (70 %, and ID_{50} 0.33 mg/ear) ear oedema, while the seeds (51 %) and the wood (60 %) extracts were less effective. Two leaf bioflavonoids fukugetin (or morelloflavone) and 13-naringenin-II 8-eriodictyol (GB-2a), were found to be responsible for the antiinflammatory effect.

Analgesic Activity

A new biflavonoid identified as I3-naringenin-II8-4′-OMe-eriodictyol was isolated from *Rheedia gardneriana* leaves (Cechinel Filho et al. 2000).

This compound showed potent and concentration-related analgesic action in both experimental models, with ID_{50}'s values of 4.5 μmol/kg against the writhing test and 8.2 and 6.8 μmol/kg against the first and second phase of the formalin test, respectively. It was several times more potent than some well-known analgesic drugs used as reference. Biflavonoids with analgesic and anti-inflammatory activities had been isolated from *R. gardeneriana* leaves (Bittar et al. 2000).

Vasodilator/Vasoconstrictor Activity

Studies showed that at low concentrations up to 10 μM, 7-epiclusianone, a prenylated benzophenone from *Rheedia gardneriana*, induced concentration-dependent and an endothelium-dependent vasodilator effect in rat aortic rings (Cruz et al. 2006). At concentrations greater than 10 μM, and in conditions where NO synthase was inhibited, 7-epiclusianone induced a vasocontractile effect in rat aortic rings. Nitric oxide appeared to participate in the vasodilation, while endothelial cyclooxygenase- and 5-lipoxygenase-derived products played a role in the vasoconstrictor effect.

Anti cancer Activity

The benzophenone, guttiferone A (1), and a new guttiferone analogue, guttiferone G (2) and friedelin were isolated from twigs of *Garcinia macrophylla* (Williams et al. 2003). Compounds 1 and 2 were weakly cytotoxic in the A2780 human ovarian carcinoma cell line, with IC_{50} values of 6.8 and 8.0 μg/mL, respectively.

Antimicrobial Activity

Biflavonoids, volkensiflavone (1), fukugetin (2), fukugiside (3), GB2a-I-7-O-glucoside (4) and epicatechin (5) were isolated from the hydroalcoholic extract of *Rheedia gardneriana* leaves (Verdi et al. 2004). Compounds 1–5, were evaluated for The lethality to brine shrimp larvae, *Artemia salina* and antibacterial activity of compound 1–5 and some derivatives of 1 and 2 were found against Gram positive and negative bacteria. *R. gardneriana* seed extract exhibited antimicrobial activity against *Streptococcus mutans*, the oral pathogen (Samarão et al. 2010). The crude extract gave similar inhibition as the control, 0.12% chlorhexidine digluconate solution. Among its various fraction i.e. dichloromethane, ethanol-water, methanol, and hexane, the ethanol –water fraction showed no antibacterial activity.

Studies found that 7-epiclusianone a new prenylated benzophenone isolated from *Rheedia gardneriana* exhibited antibacterial activity against *Streptococcus mutans* (Murata et al. 2008). The compound was found to disrupt the extracellular and intracellular sugar metabolism of *S. mutans*. It did not affect bacterial viability but inhibited F-ATPase activity. The biomass (dry-weight), extracellular insoluble polysaccharide concentration and acidogenicity of the biofilms were significantly reduced by the test compound. The researchers asserted that it had potential as a novel, naturally occurring compound to prevent biofilm-related oral diseases.

Antiparasitic Activity

7-Epiclusianone, isolated from *Rheedia gardneriana*, was found to be active in-vitro against trypomastigotes of *Trypanosoma cruzi* but inactive in-vivo in experimentally infected mice (Alves et al. 1999). It was also active against *Artemia salina*, but inactive against the fungus *Cladosporium sphaerospermum* and the snail *Biomphalaria glabrata*.

Other Uses

It may have potential to be used as a rootstock for mangosteen and other *Garcinia* spp.

Comments

*Garicnia gardneriana (*Planch. & Triana) Zappi is listed as a synonym of *G. macrophylla* Mart. (Grin 2010; Grandter 2005; Tropicos 2011).

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Garcinia madruno

Scientific Name

***Garcinia madruno* (Kunth) Hammel**.

Synonyms

Calophyllum madruno Kunth, *Chloromyron verticillatum* Pers., *Garcinia acuminata* Planch. & Triana, *Garcinia floribunda* Miq., *Garcinia portoricensis* (Urb.) Alain, *Rheedia acuminata* (Ruiz & Pav.) Planch. & Triana, *Rheedia acuminata* (Spreng.) Triana & Planch., *Rheedia acuminata* var. *floribunda* (Miq.) Vesque, *Rheedia floribunda* (Miq.) Planch. & Triana), *Rheedia hessi* Britton, *Rheedia kappleri* Eyma, *Rheedia madruno* (Kunth) Planch. & Triana, *Rheedia madruno* subsp. *ovata* Pittier, *Rheedia portoricensis* Urb., *Rheedia rostrata* Miers & Vesque, *Rheedia spruceana* Engl., *Verticillaria acuminata* Ruiz & Pav.

Family

Clusiaceae

Common/English Names

Costa Rica Garcinia, Madruno, Garcinia Madruno, Madruno Garcinia, Panama Garcinia

Vernacular Names

Brazil: Bacuri, Bacuri-Azedo, Bacuri-Coroa, Bacuri-De-Anta, Bacuri-De-Espinhos, Bacuripari, Bacuripari-Selvagem, Bacuri-Verdadeiro, Bacurizinho, Bocupar, Limaozinho (Portuguese);
Costa Rica: Cerillo, Jorco, Madroña (Spanish);
Bolivia: Kamururu, Naranjita, Naranjito, Ocoró (Spanish);
French: Madruno;
German: Marienbalsam;
Panama: Cero, Fruta De Mono, Machari, Madroño, Satra, Satro (Spanish);
Peru: Charichuelo, Charichuela (Spanish), Ompiquiritoqui (Campa Asháninca);
Puerto Rico: Guayabacoa, Palo De Cruz (Spanish);
Venezuela: Cozoiba, Cozoiba Negra, Cozoiba Rebalsera Madroño, Naranjita, Peramán De Agua (Spanish).

Origin/Distribution

The species is indigenous to Central America – Costa Rica, Panama, and south America in Amazonia – Venezuela, Guyana, French Guiana, Suriname, Ecuador, Bolivia, Peru Bolivia, Brazil and Colombia.

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Agroecology

A tropical species found as an understorey tree in riparian locations in wet tropical rainforests from 100 to 1,000 m elevation and mean annual rainfall from 1,000 to 3,000 mm or more with a pronounced dry season. It prefers well-drained, alluvial soils but is hardy to most soil conditions.

Edible Plant Parts and Uses

White, juicy, acid-sweet pulp is eaten fresh or made into juice, jams or jellies.

Botany

A dioecious, evergreen, small to medium-sized understory tree, 9–15 m high with a straight trunk with rough, gray bark and an open loose crown when young but with age the crown becomes more symmetrical (Plate 1). Plant parts have a yellow latex which exude out when bruised. Leaves are opposite, simple, entire on 10–14 mm long petiole, lamina elliptic to elliptic-oblong, 10–20 cm long 5–12 cm wide, apex shortly acuminate, base rounded to cuneate with prominent marginal veins, coracious, glabrous, smooth and glossy above, glabrous, juvenile leaves pale bronze becoming green with age (Plate 2) Flowers creamy-white, unisexual borne singly or in fascicles (up to 14 flowers) on young branches in the axils of recently fallen leaves; calyx 5 imbricate sepals and 5 imbricate, creamy-white petals, stamens numerous free, variously fasciculate, ovary 4–5 locules with 0–1ovule per locule. Male flowers without ovary. Fruit spherical, ovoid, oval to ellipsoid, 5–8 cm long and a little less wide, green (Plate 3) turning to yellow when ripe with a thick rind, verrucose, densely tuberculate like a rough lemon (Plates 4–6) containing 1–3, oblong, brown seeds enveloped by the white fleshy, juicy, mucilaginous, acid sweet pulp (Plate 6).

Plate 1 Habit of a young tree

Plate 2 Juvenile and mature leaf flushes

Nutritive/Medicinal Properties

No information has been published on its nutritive food value.

The biflavonoid fraction in *G. madruno* fruit was found to have antioxidant activity (Osorio et al. 2009). Morelloflavone, volkensiflavone and

Plate 3 Immature verrucose, tuberculate, green fruit

Plate 6 Thick rind and white acid-sweet pulp

Plate 4 Clusters of ripe fruits

Plate 5 Ripe madruno fruits

amentoflavone were identified in the biflavonoid fraction. The ethyl-acetate extract containing the biflavonoid fraction was found to be the major contributor to the free radical-scavenging activity of *G. madruno*. The DPPH activity for the biflavonoid fraction was 4.50 μg/ml. Lipid peroxidation, induced with $CuSO_4$, was significantly reduced in the presence of the biflavonoid fraction (CE_{50} = 11.85 μg/ml). Morelloflavone was found to be the main biflavonoid in the fraction responsible for its protection against lipid peroxidation and free radical-scavenging activity. The data suggested the biflavonoid fraction of *G. madruno* to be an excellent candidate for use as an antioxidant. Other bioflavonoids identified from *G. madruno* included fukugiside, madrunoudeaside and spicataside (Durango 2008).

G. madruno extract was found to exhibit moderate antibacterial activity against Gram-negative (*Escherichia coli* and *Pseudomonas aeruginosa*) and Gram-positive (*Staphylococcus aureus* and *Enterococcus faecalis*) but had no activity against brine shrimp nauplii (Suffredini et al. 2006).

Other Uses

Has potential as rootstock for other *Garcinia* species and for breeding purposes.

Comments

Garicnia acuminata Planch. & Triana is listed as a synonym of *Garcinia madruno* (Grin 2010; Grandter 2005; Tropicos 2011).

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Garcinia malaccensis

Scientific Name

***Garcinia malaccensis* Hook. f.**

Synonyms

Garcinia cornea Roxb.

Family

Clusiaceae

Common/English Names

Forest Mangosteen, Jungle Mangosteen

Vernacular Names

Malaysia: Manggis Burung, Manggis Hutan.

Origin/Distribution

The species is a native of Peninsular Malaysia, Sumatra and Brunei.

Agroecology

The species is adapted to a hot, wet and humid tropical climate. It occurs in the tropical rainforests in the lowlands and hillsides to 540 m altitude. It thrives in full or partial shade in well-drained, organic rich soils.

Edible Plant Parts and Uses

The white flesh is flavoursome, acid-sweet and good to eat.

Botany

A small to medium evergreen, under-storey tree reaching 24 m tall with a girth of 90 cm. The inner bark has opaque yellow latex. The leaves have long petioles up to 20 mm, leathery, ovate to ovate oblong, 6.5–25.5 cm long by 3.5–7 cm broad, dark glossy green, leathery with broadly tapering apex and broadly wedge-shaped base and smooth entire margin with finely transverse striate veins (Plates 1–2) . Flowers are unisexual and terminal and have 4 orbicular sepals and 4 lanceolate petals. Male flowers are borne in terminal fascicles of 4–6, on slender 2 cm long

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Plate 1 Glossy, large leaves and immature fruit with prominent 4-lobed calyx at the pedicel end

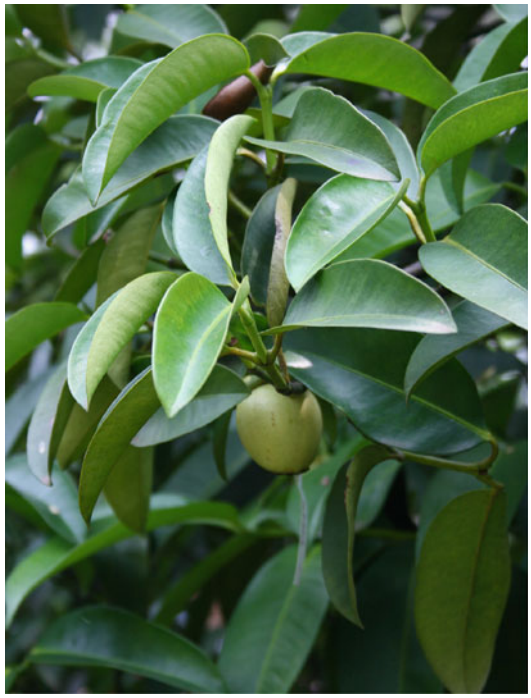

Plate 2 Fruit with adpressed remnant of stigma on the short terminal beak and leaves with finely transverse striations

pedicels with numerous stamens in a conical mass surrounding a pistillode, filaments short and anther adnate and 2-celled, sepals are orbicular and concave, petals dull red, broadly ovate and shortly clawed. Female flowers are solitary, rose-coloured, terminal, stigma with deep separated lobes and corrugated surface, with no staminode, ovary globose, 8-celled, stigma sessile

Plate 3 Ripe fruit of *G. malaccensis* (Sobir)

large and convex enveloping half the ovary. Fruit is a depressed globose to ovoid berry to 4.5 cm across, hard leathery, green (Plates 1–2) ripening pinkish red to purple red with adpressed remnant of stigma on a short terminal beak and the large persistent calyx at the base of the fruit (Plate 3).

Nutritive/Medicinal Properties

No published information is available on its nutritive values.

The extracts from *Garcinia cowa* Roxb. (stem), *Garcinia bancana* Miq. (stem) and *Garcinia malaccensis* Hook.f. (leaf) showed moderate activity and selectivity towards non-small lung tumour cells (Jabit et al. 2009). The extracts from *Garcinia bancana* (stem), *Garcinia malaccensis* (stem), *Garcinia prainiana* King (leaf), *Garcinia rostrata* Hassk.ex Hook.f. (stem and leaf), *Garcinia cowa* (stem) and *Garcinia nervosa* Miq. (leaf) exhibited inhibition against NO (nitric oxide) production without affecting the viability of LPS and IFN-γ-induced RAW 264.7 macrophage cells. Among these, the most promising extracts were *G. bancana* (stem) and *G. malaccensis* (stem), as they showed the highest selectivity indices (>50) for NO inhibition. The data provided evidence that some of the *Garcinia* species could potentially contain potent and selective cytotoxic and anti-inflammatory agents.

Other Uses

Its timber has no commercial value as it splits after drying.

Comments

Studies reported that *Garcinia mangostana*, the common mangosteen could be a hybrid of two closely related facultative agamospermic species *Garcinia malaccensis* and *Garcinia hombroniana* (Richards 1990). *G. mangostana* shares some similar characteristics with *G. malaccensis* and *G. hombroniana*. *G. mangostana* resembles *G. malaccensis* in latex colour, fruit colour and possession of a sessile stigma. *G. mangostana* resembles *G. hombroniana* in possessing a smooth fruit surface, a smooth stigma surface, distinctly lobed stamen/staminode mass and in having a globose fruit. Recent studies using molecular techniques such as RAPD (Random Amplified Polymorphic DNA), AFLP (Amplified Fragment Length Polymorphism) analyses and isozyme markers have provided more evidence to the proposal that *G. mangostana* is a natural hybrid of both species (Sobir et al. 2008).

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Garcinia mangostana

Scientific Name

***Garcinia mangostana* L.**

Synonyms

Mangostana garcinia Gaertn.

Family

Clusiaceae

Common/English Names

King's-fruit, Mangosteen, Purple Mangosteen

Vernacular Names

Brazil: Mangostão (Portuguese);
Chinese: Dao Nian Zi, Mang Ji Shi;
Czech: Garcínie Mangostan;
Danish: Mangostan;
Dutch: Manggis, Manggistan;
French: Mangostan, Mangostanier, Mangoustan, Mangoustanier;
German: Mangostane (Tree), Mangostin, Mangostanbaum, Mangostan, Wohlriechende Mangostane (Fruit);
India: Mangosteen Hannu (Kannada), Shulampuli, Sula Puli (Malayalam), Mankustan, Mangusthan, Mengustan (Tamil);
Indonesia: Manggoita (Aceh), Bagustang, Manggastan, Manggusta (Alfoersch, North Sulawesi), Manggis, Manggista, Manggusta (Bali), Manggis, Manggisto, Manggous, Manggusta (Batak), Manggusta (Bima), Manggisi (Boeginese, Sulawesi), Manggusta (Boeol, Manado, Sulawesi), Sungkup (Dyak), Malung (Punan Malinau, East Kalimantan), Kitong (Lundanye, East Kalimantan), Bua Tiu' (Merap, East Kalimantan), Kitung (Kenyah Uma', East Kalimantan), Epiko (Enggano, Sumatra), Guste, Manggi, Mangi (Gajo, Sumatra), Manggusta (Gorontalo, Sulawesi), Manggis (Java), Bahutang, Basitang, Basitangi, Busutang (N. Halmaheira), Mangustang (S. Halmaheira), Mangos (Koeboe), Manggus, Mangos (Lampong, Sumatra), Mangghis (Madurese), Kirasa, Manggisi, Mangkosota (Makasar), Manggis, Manggistan, Manggusta, Manggustan (Malay), Lakopa, Malakopa (Mentawi, Sumatra), Manggih (Minangkabau), Magi (Nias), Mangis, Makis (Roti, Timor), Manggustang (Sangir, Sulawesi), Manggu (Sundanese), Mangustang (Ternate);
Italian: Garcinia, Mangostana (Fruit), Mangostano (Tree);
Japanese: Mangosuchin,Mangoosutin, Mangosutin;
Korean: Mang Ko Seu T'in;
Laotian: Kok Mak Mang Kout;

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Malaysia: Masta, Mesta, Ple Semeta (Semang), Gamus, Gamush (Sakai), Manggis (Malay);
Philippines: Manggis (Sulu), Mangostan (Tagalog);
Portuguese: Mangostão;
Russian: Мангустан Mangustan;
Slovašcina: Mangostan;
Spanish: Mangostán (Tree), Mangustán (Fruit);
Sri Lanka: Mangoos, Maengus (Sinhala);
Thailand: Mang Khút, Mangkhut, Mangkut;
Vietnamese: Cây Măng Cụt, Măng Cụt, Trái Măng Cụt.

Origin/Distribution

Mangosteen is native to the Malay archipelago in the old world tropics but the exact location is uncertain. It has been recorded wild in south Trengganu and Ulu Kemaman in Malaya and in the Sunda Islands and Moluccas (Maluku) in Indonesia. It closely resembles its nearest wild relatives indigenous to the Malay peninsular, *Garcinia hombriana* Pierre and *Garcinia malaccensis* T. Anderson. There is suggestion that *G. mangostana* is an allotetrapliod derived from these two species in which case the origin is in the Malayan Peninsula (Richards 1990). Recent studies using molecular techniques such as RAPD (Random Amplified Polymorphic DNA), AFLP (Amplified Fragment Length Polymorphism) analyses and isozyme markers have provided more evidence to the proposal that *G. mangostana* is a natural hybrid of both species (Soubir et al. 2008). Corner suggested that the tree may have been first domesticated in Thailand, or Burma. It is now cultivated widely in southeast Asia but during the last three centuries it has been introduced to India, Sri Lanka, the New World tropics, to Northern Australia and to the Pacific islands.

Agroecology

Mangosteen is strictly a tropical fruit species. In its native range, it is found in undisturbed mixed dipterocarp forests up to 200 m altitude on hillsides and ridges. It also occurs in secondary forests probably present as a pre-disturbance remnant tree or planted. It is widely cultivated within 18° north and south of the equator but it is predominantly grown within 10° from the equator. It is usually cultivated in the lowlands below 600 m but has been grown up to 1,000 m in the tropics. It thrives in a warm to hot, wet and humid tropics with a uniform temperature and a short dry season for flower induction. Its optimum range is from 20°C to 32°C with a lower limit of 10°C and an upper limit of 38–40°C. Temperatures below 20°C will retard growth and temperatures below 10°C is detrimental and below 4°C will kill the tree. Temperatures above 38°C will burn the leaves. It ordinarily requires high atmospheric humidity and an annual rainfall of over 1,500 mm. Mangosteen is shade-loving and humidity-loving and thrives better in partial shade or with protection from other trees, it requires shading during the early years of its establishment. It is intolerant of salt sprays and strong winds.

Mangosteen does best on deep, fertile, friable soil, rich in organic matter. In south east Asia, it is grown mainly on sandy loams, fairly well-drained lateritic soils and volcanic soils. In India, the most productive trees are on clay containing much coarse material and a little silt. Limestone and sandy alluvial soils are unsuitable and sand low in humus contributes to low yields and it is intolerant of saline soils. Mangosteen abhors prolonged water-logged conditions and requires irrigation under dry conditions.

Edible Plant Parts and Uses

The arillodes of ripe fruits are extremely delicious and mangosteen is dubbed the "Queen of fruits" being one of the best tropical fruits. Mangosteen arils are usually eaten fresh as table fruit or dessert. The fleshy arillodes are sometimes canned, but they are said to lose their delicate flavour in canning, especially if pasteurized for as much as 10 min. Tests have shown that it is best to use a 40% syrup and sterilise for only 5 min. The more acid fruits are best for preserving. The Malays make a conserve called *halwa manggis* by boiling the arils of unripe fruits with

sugar. In the Philippines, a preserve is made by simply boiling the segments in brown sugar, and the seeds may be included to enrich the flavor. In Indonesia, the fruit is eaten ripe and unripe. Unripe fruits are called *blebar* (Java). The aril is also used to prepare delicacies such as *kolak* (mashed fruit cooked with sugar, coconut milk and water), *jenang* or *dodol* (cooked with flour or glutinous rice), and *lempog* (cooked with glutinous rice and coconut).

The seeds are sometimes eaten alone after boiling or roasting.

The rind is rich in pectin. After treatment with 6% sodium chloride to eliminate astringency, the rind is made into a purplish jelly.

Mangosteen is being promoted and marketed as a novel class of functional foods sometimes dubbed "superfruits". It is being promoted on a combination of the following features: (1) fruit appeal, such as taste, fragrance and visual qualities, (2) nutrient richness, (3) antioxidant strength and (4) potential impact for lowering risk against human diseases. Mangosteen xanthone juice is now widely marketed as a health drink based on its health benefits.

Plate 1 Leaf and mangosteen fruit

Plate 2 Flower with the 6-lobed stigma crowning the ovary in the centre

Plate 3 Maturity stages of mangosteen fruit

Botany

A medium sized, evergreen, lactiferous tree 6–25 cm tall with a 25–35 cm diameter trunk and black bark and a pyramidal crown formed by the symmetrical branches. All parts of the tree exude yellowish latex when bruised. Leaves are opposite, shortly petiolate, thickly coriaceous, ovate-elliptic-oblong, 15–25 cm by 7–13 cm, simple, entire margin, base acute to obtuse or rounded, apex tapering or acuminate, glabrous, glossy dark green above and paler green beneath, pinnati-nerved with prominent mid rib and evenly spaced lateral nerves (Plate 1). Flowers are large, fleshy, 4–5 cm across, unisexual, dioecious, only female flowers have been found. Flowers occur on short, stout pedicels 1.2 cm diameter, in pairs or solitary at apices of branchlets. There are 4 green sepals and 4 ovate, thick, fleshy petals, yellowish-green and glabrous on the outside, glabrous, yellowish-red inside, numerous staminodes 1.5 cm long, arranged in 1–3 fascicles, ovary yellowish, sessile, subglobose 5-8-loculed; style nearly absent; stigma sessile 5- or 6-lobed (Plate 2). Fruit is a berry, globose to subglobose, 4–7 cm diameter, smooth, turning from pale green to pink to

Plate 4 Ripe mangosteen fruit with large green persistent calyx lobes

Plate 5 White juicy, sweet arillode of mangosteen fruit

maroon to dark purple-black when ripe (Plates 1 and 3), crowned by the persistent, sessile, lobed stigma and seated on the persistent green calyx (Plate 4); with 1 cm thick pericarp. Seeds are apomictic (formed without fertilization), 4 or 5 or more, ovoid-oblong, laterally compressed, enclosed by the white, juicy arillode (Plate 5).

Nutritive/Medicinal Properties

Food value per 100 g edible portion of *Garcinia mangostana* was reported as : energy 34 kcal, moisture 87.6%, protein 0.6 g, fat 1.0 g, total carbohydrate 5.6 g, fibre 5.1 g, ash 0.1 g, Ca 7 mg, P 13 mg, Fe 1.0 mg, Na 7 mg, K 45 mg, vitamin B1 (thiamin) 0.03 mg, vitamin B2 (riboflavin) 0.03 mg, niacin 0.3 mg, ascorbic acid (vitamin C) 4.2 mg (Tee et al. 1997). Another analysis (Dignan et al. 1994) reported the following food value of mangosteen flesh per 100 g edible portion: water 88 g, energy 55 kJ (55 kcal), protein 0.6 g, total fat 1 g, available carbohydrate 1 g, dietary fibre 5.1 g, Na 7 mg, Ca 7 mg, Fe 1 mg, thiamin 0.03 mg, riboflavin 0.03 mg, niacin traces, vitamin C 4.2 mg.

The main volatile components of the edible arils are hexyl acetate, hexenol and α-copaene imparting caramel, grass and butter notes as part of the mangosteen fragrance (MacLeod and Pieris 1982).

Proximate analysis showed mangosteen seeds to have high amounts of carbohydrate and oil (21.68%) but with a low protein content (Ajayi et al. 2007). The seed flour was found to be a good source of minerals with considerable amounts of potassium (7,071 mg/kg), magnesium (865 mg/kg) and calcium (454 mg/kg). Fatty acid composition of the seed oil indicated that the oil contained one essential fatty acids in small amount: linoleic acid (1.30%). The major fatty acids were palmitic acid (49.5%) and oleic acid (34.0%). The oil was golden-orange in colour, with a specific gravity of 0.98 and remained liquid at room temperature 25°C. Its acid value, saponification number, iodine value, percent free fatty acid and peroxide value compared well with those of conventional edible oils. The researchers found that weanling albino rats appeared to suffer no toxicological effects when fed with mangosteen seed oil in their diet for 8 weeks. Weekly monitoring of the rats showed good physical appearance and steady weight increase. Histological examination revealed that the kidney of some of the rats had some degrees of pathology which included diffuse glomerular and tubular degeneration. No lesion was found in the heart and liver of the rats. They suggested that mangosteen seed oil could be useful as an edible oil and for industrial applications.

Other Phytochemicals

Mangosteen is rich in phytochemicals especially in a variety of oxygenated and prenylated

xanthones (Bennet and Lee 1989; Perez et al. 2000; El-Seedi et al. 2009).

From the fruit hull (pericarp) the following xanthones and phytochemcials were isolated: γ-mangostin (Jefferson et al. 1970); 5,9-dihydroxy-8-methoxy-2,2-dimethyl-7-isopre- nyl-2H,6H-pyrano [3,2-b] xanthen-6-one (Sen et al. 1980); two new trioxygenated xanthones with a 3,3-dimethyl allyl side chain: 1,5-dihydroxy-2-(3-methylbut-2-enyl)-3-methoxy-xanthone; 1,7-dihydroxy-2-(3-methylbut-2-enyl)-3-methoxyxanthone (Sen et al. 1981); three new tetraoxygenated xanthones (garcinones A, B and C), (Sen et al. 1982); garcinone D (Sen et al. 1986); garcinone E (Dutta et al. 1987); gartanin, 8-deoxygartanin, BR-xanthone, mangostin, β-mangostin, γ-mangostin, garcinone-D, euxanthone,compound xanthone 7 and its derivative xanthione, and also derivatives of mangostin di-*O*-ethylmangostin, di-*O*-acetylmangostin, 3-isomangostin (Gopalakrishnan et al. 1997); 1-isomangostin, 1-isomangostin hydrate, 3-isomangostin, 3-isomangostin hydrate, calabaxanthone, demethylcalabaxanthone, 2-(γ,γ-dimethylallyl)-1,7-dihydroxy-3-methoxyxanthone, and 2,8-bis(γ,γ-dimethylallyl)-1,3,7-trihydroxyxanthone (Mahabusarakam et al. 1987); two new xanthones, a bis-pyrano xanthone, BR-xanthone-A and 1-methoxy-2,4,5-trihydroxyxanthone, BR-xanthone-B in addition to known xanthones (Balasubramanian and Rajagopalan 1988); a new xanthone with a geranyl group, mangostinone, in addition to seven known xanthones, α-, β- and γ-mangostins, gartanin, garcinone E, 1,5-dihydroxy-2-(3-methylbut-2-enyl)-3-methoxy- and 1,7-dihydroxy-2-(3-methylbut-2-enyl)-3-methoxyxanthone (Asai et al. 1995); caloxanthone A, macluraxanthone and 1,7-dihydroxyxanthone (Iinuma et al. 1996); a new polyoxygenated xanthone mangostanol and α-mangostin, γ-mangostin, gartanin, 8-deoxygartnin, 5,9-dihydroxy-2,2-dimethyl-8-methoxy-7-(3-methylbut-2-enyl)-2H,6H-pyrano[3,2-b]xanthen-6-one, garcinone E and 2-(γ,γ-dimethylallyl)-1,7-dihydroxy-3-methoxyxanthone and epicatechin (Chairungsrilerd et al. 1996c); 2,7-di-isoprenyl-1,3,8-trihydroxy-4-methyl xanthone and 2,8-diisoprenyl-7- carboxy-1,3,-trihydroxy-4-methyl xanthone (Gopalakrishnan and Balaganesan 2000); garcimangosone A, garcimangosone B, garcimangosone C, garcimangosone D, tovophyllin A, tovophyllin B and 1,3,6,7-tetrahydroxy-8-isoprenyl-9H-xanthen-9-one (Huang et al. 2001); mangostenol, mangostenone A and mangostenone B along with the known xanthones, trapezifolixanthone, tovophyllin B, α-mangostin, β-mangostin, garcinone B, mangostinone, mangostanol, and the flavonoid epicatechin (Suksamrarn et al. 2002); compound 7 and mangostanine (Suksamrarn et al. 2003); 2-isoprenyl-1,7-dihydroxy-3-methoxyxanthone (Matsumoto et al. 2003); three new prenylated xanthones, mangostenones C, D, and E, together with 16 known xanthones, were isolated from the young fruit (7-week maturity stage) (Suksamran et al. 2006); two new highly oxygenated prenylated xanthones, 8-hydroxycudraxanthone G and mangostingone [7-methoxy-2-(3-methyl-2-butenyl)-8-(3-methyl-2-oxo-3-butenyl)-1,3,6-trihydroxyxanthone], together with 12 known xanthones, cudraxanthone G 8-deoxygartanin, garcimangosone B, garcinone D, garcinone E, gartanin, 1-isomangostin, α-mangostin, γ-mangostin, mangostinone, smeathxanthone A, and tovophyllin A (Jung et al. 2006); α-mangostin, β-mangostin,3-isomangostin,gartanin,9-hydroxycalabaxanthone, and 8-desoxygartanin (Walker 2007); three major phenolic compounds, 1,3,6,7-tetrahydroxy-2,8-(3-methyl-2-butenyl), 1,3,6-trihydroxy-7-methoxy-2,8-(3-methyl-2-butenyl) xanthone and epicatechin (Yu et al. 2007); 14 prenylated xanthones: garcinone C, garcinone D, garcinone E, α-mangostin, β-mangostin, γ-mangostin, gartanin, 8-deoxygartanin, mangostenone A, calabaxanthone, demethylcalabaxanthone, 11-hydroxy-1-isomangostin, tovophyllin B and 1,6-dihydroxy-7-methoxy-8-)3-methylbut-2-enyl)-6,6-dimethylpyrano (2′,3′:3,2) xanthone (Chaivisuthangkura et al. 2009); three prenylated xanthones: α-mangostin, β-mangostin and 1,6-hydroxy-7-methoxy-8-isoprenyl-6′,6′-dimethylpyranone (2′,3′,3,2) xanthone (Ahmat et al. 2010); two new prenylated xanthones and a new prenylated tetrahydroxanthone, garcimangosxanthone A-C (1–3), along with 14 known xanthones (Zhang et al. 2010) and

recently a new antioxidant xanthone, 1,3,6-trihydroxy-2,5-bis(3-methylbut-2-enyl)-6′,6′-dimethyl-4′,5′-dihydropyrano[2′,3′:7,8] xanthone, along with five known xanthones (Zhao et al. 2010).

Oligomeric proanthocyanidins extracted from mangosteen pericarps were found to be predominated by procyanidins together with a few prodelphinidin units along with small amounts of stereoisomers of afzelechin/epiafzelechin, catechin/epicatechin, and gallocatechin/epigallocatechin (Fu et al. 2007). Depolymerization with benzylmercaptan resulted in epicatechin thioether as the major product. Anthocyanin concentrations in the outer pericarp of mangosteen fruit were higher than in the inner pericarp and increased to a maximum at the final colour stage (purple black) (Palapol et al. 2009). The anthocyanins in the outer pericarp mainly consisted of five compounds, cyanidin-sophoroside, cyanidin-glucoside, cyanidin-glucoside-pentoside, cyanidin-glucoside-X, cyanidin-X2 and cyanidin-X, where X denoted an unidentified residue of m/z 190, a mass which did not correspond to any common sugar residue. Cyanidin-3-sophoroside and cyanidin-3-glucoside were the main compounds and the only ones that increased with fruit colour development.

From the fruit arillodes the following xanthones were isolated: 2-(γ,γ-dimethylallyl)-1,7-dihydroxy-3-methoxyxanthone, demethylcalabaxanthone, 1,3,7-trihydroxy-2,8-di-(3-methylbut-2-enyl) xanthone and 2,8 bis (γ,γ-dimethylallyl)-1, 3, 7-trihydroxyxanthone, mangostin, gartanin, β-mangostin, γ-mangostin and calabaxanthone (Mahabusarakam et al. 1987).

From the whole fruit the following xanthones were isolated: gartanin and 8-deoxygartanin (from ripe fruit) and mangostin and β-mangostin (from partially ripe fruit) (Govindachari and Muthukumaraswamy 1971); thwaitesixanthone, mangostinone, mangostenone C, mangostenone D, mangostenone E, mangostanol, mangostanin, gartanin, garcinone B, garcinone C, garcinone D, garcinone E, compound 7, demethylcalabaxanthone, 11-hydroxyl-1-isomangostin (Suksamran et al. 2006); 1-isomangostin (Sundaram et al. 1983); 1,2-dihydro-1,8,10-trihydroxy-2-(2-hydroxypropan-2-yl)-9-(3-methylbut-2-enyl)furo[3,2-a]xanthen-11-one and 6-deoxy-7-demethylmangostanin, along with three known compounds, 1,3,7-trihydroxy-2,8-di-(3-methylbut-2-enyl)xanthone, mangostanin and α-mangostin (Chin et al. 2008).

Six naturally occurring xanthones: 3-isomangostin, 8-desoxygartanin, gartanin, α-mangostin, 9-hydroxycalabaxanthone and β-mangostin were qualitatively and quantitatively determined in *G. mangostana* by high-performance liquid chromatographic method using photodiode array and electrospray ionization mass spectrometry (Ji et al. 2007). Cyclization of mangostin with p-toluenesulfonic acid afforded 1-isomangostin, 3-isomangostin, and a new cyclization product, bicyclomangostin (Mahabusarakam et al. 1998).

From the seed cases, the following xanthones were isolated: 2 new xanthones mangostenone F, mangostenone G plus 12 known ones (Ryu et al. 2010).

From mangosteen heart wood the following phytochemicals and xanthone were isolated: 1,3,6,7-tetrahydroxyxanthone (Norathyriol) and 1,3,6,7-tetrahydroxy-O-glucosylxanthone (Holloway and Scheinmann 1975); a number of known triterpenoids and xanthones as well as a new biphenyl, 3,4′,5-dihydroxy-3′,4,5-trimethoxybiphenyl (Nilar and Harrison 2002); 12 new xanthones: garciniafuran (4) (5 mg), 1-hydroxy-8-(2-hydroxy-3 -methylbut-3-enyl)-3,6,7-trimethoxy-2-(3-methylbut-2-enyl)-xanthone (6) (2.3 mg), (16E)-1-hydroxy-8-(3-hydroxy-3-methylbut −1-enyl)-3,6,7-trimethoxy-2-(3-methylbut-2-enyl)-xanthone (12) (2 mg) and 1-hydroxy-2-(2-hydroxy-3-methylbut-3-enyl)-3,6,7-trimethoxy-8-(3-methylbut-2-enyl)-xanthone (9) (2 mg), b-mangostin (2) (54 mg), 1,6-dihydroxy-2-(2-hydroxy-3-methylbut-3-enyl)-3,7-dimethoxy-8-(3-methylbut-2-enyl)-xanthone (8) (11 mg), (16E)-1,6-dihydroxy-8-(3-hydroxy-3-methylbut-1-enyl)-3,7-dimethoxy-2-(3-methylbut-2-enyl)-xanthone(11) (10 mg) and 1,6-dihydroxy-8-(2-hydroxy-3-methylbut-3-enyl)-3,7-dimethoxy-2-(3-methylbut-2-enyl)-xanthone (7) (11 mg), 1,3-dihydroxy-2-(2-hydroxy-3-methylbut-3-enyl)-6,7-dimethoxy-8-(3-methylbut-2-enyl)-xanthone (10) (7 mg) and mangostanin (13)

(30 mg), 6- O-methylmangostanin (14) (4 mg), 1,6-dihydroxy-3,7-dimethoxy-2-(3-methylbut-2-enyl)-xanthone (19) (8 mg) and 1,6-dihydroxy-3,7-dimethoxy-2-(3-methylbut-2-enyl)- 8-(2-oxo-3-methylbut-3-enyl)-xanthone (21) (7 mg). (Nilar and Harrison 2002); dulxanthone D, 1,3,7-trihydroxy-2-methoxyxanthone, 1,3,5-trihydroxy-13,13-dimethyl-2H-pyran[7,6-b]xanthen-9-one and a new diprenylated xanthone (mangoxanthone) and a new benzophenone (3′,6-dihydroxy-2,4,4′-trimethoxybenzophenone) (Nguyen et al. 2005) and one new diprenylated xanthone (mangoxanthone) and a newbenzophenone (3′,6-dihydroxy-2,4,4′-trimethoxybenzophenone) as well as the known xanthonesdulxanthone D, 1,3,7-trihydroxy-2-methoxyxanthone, 1,3,5-trihydroxy-13,13-dimethyl-2H-pyran[7,6-b]xanthen-9-one (Nguyen et al. 2005).

From the stem bark, the following xanthones were isolated: mangosharin (2,6-dihydroxy-8-methoxy-5-(3-methylbut-2-enyl)-xanthone) and six prenylated xanthones, α-mangostin, β-mangostin, garcinone D, 1,6-dihydroxy-3,7-dimethoxy-2-(3-methylbut-2-enyl)-xanthone, mangostanol and 5,9-dihydroxy-8- methoxy-2,2-dimethyl-7-(3-methylbut-2-enyl)-2H,6H-pyrano-[3,2-b]-xanthene-6-one (Ee et al. 2006a); a new xanthone, 11-hydroxy-3-O-methyl-1-isomangostin together with 10 known compounds, 11-hydroxy-1-isomangostin, 11 α-mangostanin, 3-isomangostin, α-mangostin, β-mangostin, garcinone D, 9-hydroxycalabaxanthone, 8-deoxygartanin, gartanin, and cratoxyxanthone (Han et al. 2009).

From mangosteen root bark, six xanthones were isolated: α-mangostin, β-mangostin, γ-mangostin, garcinone–D, mangostanol and gartanin (Ee et al. 2006b). From the root bark, stem bark and the latex collected from the green mangosteen fruit, the following xanthones were isolated: α -mangostin, β-mangostin, γ-mangostin, garcinone-E, methoxy-β-mangostin and a new geranylated biphenyl derivative 3-hydroxy-4-geranyl-5-methoxybiphenyl were reported (Dharmaratne et al. 2005).

From the leaves the following xanthone and phytochemicals were isolated: two new xanthones, 1,5,8-trihydroxy-3-methoxy-2[3-methyl-2-butenyl] xanthone and 1,6-dihydroxy-3-methoxy-2 [3-methyl-2-butenyl] along with the known xanthone gartanin (Parveen and Khan 1988); a new triterpene, 3β-hydroxy-26-nor-9,19-cyclolanost-23-en-25-one (Parveen et al. 1991) and 2-ethyl-3-methylmaleimide N-β-d-glucopyranoside (Krajewsk et al. 1996).

Recent scientific studies have demonstrated that various extracts of mangosteen have antioxidant, anticancer, antiviral, antiinflammatory, cardioprotective, antimicrobial, antiamoebic, larvicidal and other pharmacological cum biological activities. However, much more preclinical and clinical trials are warranted before they can be recommended for medicinal therapy. Many bioactive chemicals such as xanthones, benzophenone, flavonoids have been isolated from the fruits, leaves and stem. The medicinal properties can be attributable to a larger extent to xanthones, the most bioactive constituents. Prenylated xanthones isolated from mangosteen have been extensively studied; some members of these compounds possess antioxidant, antitumoral, antiallergic, antiinflammatory, antibacterial, antifungal and antiviral properties (Pedraza-Chaverri et al. 2008). Xanthones have been isolated from pericarp, whole fruit, heartwood, stem-bark, root- bark and leaves. The most studied xanthones are α-, β-, and γ-mangostins, garcinone E, 8-deoxygartanin, and gartanin (Pedraza-Chaverri et al. 2008).

Antioxidant Activity

The ethanol extract and water-soluble fraction from the unripe mangosteen fruits exhibited potent antioxidative activity with EC_{50} values of 5.13 and 4.73 μg/ml, respectively (Feng et al. 2004). The water-soluble fraction of the unripe fruits possessed the highest activity with an EC_{50} value of 3.60 μg/ml. The main antioxidative constituent in the water-soluble fraction of the unripe fruits was identified as (−)-epicatechin and its content was approximately three times higher than that in the water-soluble fraction from ripe fruit hulls, resulting in a potent antioxidative activity in the unripe fruits. The isolated

proanthocyanidins from mangosteen pericarps were found to be potent peroxyl radical scavengers as evidenced by the high oxygen radical scavenging capacity at 1.7 × 10 (4) μmol TE/g, much higher than that of pine bark and grape seed extracts (Fu et al. 2007).

All extracts (water, 50% ethanol, 95% ethanol and ethyl acetate) of mangosteen fruit hull exhibited antioxidative activity (Weecharangsan et al. 2006). The water and 50% ethanol extracts showed high free-radical scavenging activity with IC_{50} values of 34.98 and 30.76 μg/ml, respectively. The antioxidant activities (IC_{50}) of mangosteen peel, leaves, and bark extracts, as evaluated by DPPH method, were 5.94, 9.44, and 6.46 μg/ml, respectively (Palakawong et al. 2010).

Fan and Su (1997) found that using the ferric thiocyanate method, antioxidative efficiency of α-mangostin and γ-mangostin isolated from mangosteen fruit hull, was in the order γ-mangostin > BHA > α-tocopherol > α-mangostin > control. γ-mangostin showed strong activities in all the antioxidative assays, especially in superoxide, anion scavenging efficiency. α-Mangostin had weak antioxidative activity in the ferric thiocyanate method and a low hydrogen peroxide-scavenging effect, but showed no activity in other antioxidative assay. Because the only difference between the structures of the 2 isolated compounds was the methyl group, it was postulated that the adjacent hydroxy groups on C-6 and C-7 of xanthone contributed to strong antioxidative activity. The prenylated xanthone, mangostin, had been shown to inhibit the oxidation of low density lipoprotein (Mahabusarakam et al. 2000). Studies showed that structural modification of mangostin could have a profound effect on antioxidant activity. Derivatisation of the C-3 and C-6 hydroxyl groups with either methyl, acetate, propane diol or nitrile was found to appreciably reduce antioxidant activity. In contrast, derivatisation of C-3 and C-6 with aminoethyl derivatives enhanced antioxidant activity. Cyclisation of the prenyl chains had little influence on antioxidant activity.

Two new highly oxygenated prenylated xanthones, 8-hydroxycudraxanthone G (1) and mangostingone [7-methoxy-2-(3-methyl-2-butenyl)-8-(3-methyl-2-oxo-3-butenyl)-1,3,6-trihydroxyxanthone, 2], together with 12 known xanthones, cudraxanthone G (3), 8-deoxygartanin (4), garcimangosone B (5), garcinone D (6), garcinone E (7), gartanin (8), 1-isomangostin (9), α-mangostin (10), γ-mangostin (11), mangostinone (12), smeathxanthone A (13), and tovophyllin A (14) were isolated from a CH2Cl2-soluble extract of the pericarp (Jung et al. 2006). Among the compounds 1, 8, 10, 11, and 13 exhibited the most potent antioxidant activity. Three major phenolic components were identified from mangosteen fruit hulls, P1 (1,3,6,7-tetrahydroxy-2,8-(3-methyl-2-butenyl)), P2 [1,3,6-trihydroxy -7-methoxy-2,8-(3-methyl-2-butenyl) xanthone] and P3 (epicatechin) (Yu et al. 2007). The three phenolic compounds exhibited different antioxidant activities in these antioxidant tests - the free radical scavenging capability and total antioxidant activity in a linoleic acid peroxidation. The hydroxyl radical and 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging capabilities and the activity against linoleic acid peroxidation of P1 were greater than those of P2 and P3, while the superoxide anion radical scavenging activity of P3 was greater than that of P1, but was close to that of P2 or α-tocopherol.

A dichloromethane-soluble extract of mangosteen fruit yielded five bioactive compounds, including two xanthones, 1,2-dihydro-1,8,10-trihydroxy-2-(2-hydroxypropan-2-yl)-9-(3-methylbut-2-enyl)furo[3,2-a]xanthen-11-one (1) and 6-deoxy-7-demethylmangostanin (2), along with three known compounds, 1,3,7-trihydroxy-2,8-di-(3-methylbut-2-enyl)xanthone (3), mangostanin (4), and α-mangostin (5) (Chin et al. 2008). Compounds 1–4 induced quinone reductase (concentration to double enzyme induction, 0.68–2.2 μg/ml) in Hepa 1c1c7 cells and γ-mangostin (6) exhibited hydroxyl radical-scavenging activity (IC_{50}, 0.20 μg/ml).

Studies showed that mangostin inhibited the oxidation of low density lipoprotein (LDL) which play an important role in atherosclerosis (Williams et al. 1995). Mangostin prolonged the lagtime to both metal ion (Cu^{2+}) dependent and independent oxidation of LDL in a dose dependent manner

over 5–50 μM. an inhibition of thiobarbituric reactive substances TBARS formation was observed with 100 μM mangostin at 4 h but not at 24 h. Similar results were observed in the presence of 50 μM mangostin. Mangostin, at 100 μM, retarded the relative electrophoretic mobility of LDL at both 4 and 24 h after Cu^{2+} induced oxidation. Mangostin (100 μM) significantly inhibited the consumption of α-tocopherol in the LDL during Cu^{2+} initiated oxidation over a 75 min period. The study suggested that mangostin acted as a free radical scavenger to protect the low density lipoprotein (LDL) from oxidative damage.

Recent studies by Kondo et al. (2009) demonstrated the bioavailability of antioxidants from a xanthone-rich mangosteen product and its in-vivo antioxidant effects in human volunteers after the acute consumption of 59 ml of the supplement containing mangosteen, aloe vera, green tea, and multivitamins. Results indicated that α-mangostin and vitamins B(2) and B(5) were bioavailable, with observed C(max) at t(max) of around 1 hour. The antioxidant capacity measured with the oxygen radical absorbance capacity (ORAC) assay was increased with a maximum effect of 18% after 2 hours, and the increased antioxidant level lasted at least 4 hours. Ngawhirunpat et al. (2010) found that mangosteen extracts, especially the water extract, acted as antioxidant and cytoprotective agents against oxidative damage, which was attributed partly to its phenolic compounds such as α-mangostin, epicatechin, and tannin in mangosteen. When added simultaneously with hydrogen peroxide (200 μM) to keratinocyte cells, the water extract (50 μg/ml), epicatechin (200 μM), and tannin (200 μM) effectively protected cells from oxidative damage, but the methanol extract, hexane extract, and α-mangostin did not. The methanol extract and hexane extract showed moderate cytotoxicity, whereas α-mangostin exhibited strong cytotoxicity. A new xanthone, 1,3,6-trihydroxy-2,5-bis(3-methylbut-2-enyl)-6′,6′-dimethyl-4′,5′-dihydropyrano[2′,3′:7,8] xanthone, along with five known xanthones isolated from mangosteen fruit hull were found to have strong DPPH radical-scavenging activity (Zhao et al. 2010).

Anticancer Activity

Of the ethanolic extracts of nine selected Thai medicinal plants, mangosteen extract exhibited the most potent antiproliferative activity against SKBR3 human breast adenocarcinoma cell line using MTT assay (Moongkarndi et al. 2004b). Studies reported that the crude methanolic extract from mangosteen fruit pericarp showed a dose-dependent inhibition of human breast cancer cell (SKBR3) proliferation with ED_{50} of 9.25 μg/ml (Moongkarndi et al. 2004a). The antiproliferative effect of the extract was associated with apoptosis on breast cancer cell line reflected by morphological changes and oligonucleosomal DNA fragments. In addition, the extract at various concentrations and incubation times were also found to inhibit ROS (reactive oxygen species) production. These investigations showed that the methanolic extract from mangosteen pericarp had strong antiproliferation, apoptotic and potent antioxidation effects.

Alpha-mangostin and γ-mangostin were found to inhibit both DNA topoisomerases I and II (Tosa et al. 1997). Topoisomerase inhibitors are a new class of anticancer agents with a mechanism of action aimed at interrupting DNA replication in cancer cells. Alpha-mangostin from mangosteen fruit hull, was also found to inhibit 7,12-dimethylbenz[α]anthracene-induced preneoplastic lesions in a mouse mammary organ culture assay with an IC_{50} of 1.0 μg/ml (2.44 μM) (Jung et al. 2006). Four prenylated xanthones from the fruit pericarp: α-mangostin, β-mangostin, γ-mangostin, and methoxy-β-mangostin were found to exhibit anti-proliferative effects in various human cancer cells (Akao et al. 2008). These xanthones differed in the number of hydroxyl and methoxy groups. Except for methoxy-β-mangostin, the other three xanthones strongly inhibited cell growth at low concentrations from 5 to 20 μM in human colon cancer DLD-1 cells. The study showed that that the antiproliferative effects of the xanthones were associated with cell-cycle arrest. In another study, α-mangostin was found to exhibit in-vitro cytotoxicity against human colon cancer DLD-1 cells. The number of viable cells was consistently

decreased by the treatment with α-mangostin at more than 20 μM (Nakagawa et al. 2007). Alpha-mangostin preferentially targeted mitochondria in the early phase, resulting in apoptosis. The co-treatment with α-mangostin and fluorouracil (5-FU), both at 2.5 μM, augmented growth inhibition compared with the treatment with 5 μM of α-mangostin or 5 μM 5-FU alone. These findings indicated the unique mechanisms of α-mangostin-induced apoptosis and its action as an effective chemosensitizer. The researchers asserted that the results could provide a relevant basis for the development of xanthones as an agent for cancer prevention and the combination therapy with anti-cancer drugs. Alpha mangostin was found to be cytotoxic in-vitro against human leukemia HL-60, human breast adenocarcinoma MCF-7 and human cervical cancer HeLa cancer cell lines (Ahmat et al. 2010).

In a separate study, α-mangostin, was shown to have antioxidant and anticarcinogen properties. Alpha-mangostin displayed antimetastatic effect in the human prostate carcinoma cell line PC-3 (Hung et al. 2009). Alpha-mangostin exhibited an inhibitory effect on the abilities of adhesion, migration, and invasion by cell-matrix adhesion assay, wound healing assay, and Boyden chamber assay. These results demonstrated that α-mangostin could mediate PC-3 cells metastasis by reduction of matrix metalloproteinase-2 (MMP-2), matrix metalloproteinase-9 (MMP-9), and urokinase-plasminogen activator (u-PA) expression through the suppression of the Jun N-terminal kinase 1 and 2 (JNK1/2) signalling pathway and inhibition of nuclear factor kappa B (NF-kappaB) and AP-1 (activator protein −1) binding activity. In-vitro studies showed that γ-mangostin exhibited potent antiproliferative activity toward human malignant glioblastomas (MGs) including U87 MG and GBM 8401 (Chang et al. 2010). Gliomas are a common type of primary brain tumour with glioblastoma multiforme accounting for the majority of human brain tumours. Gamma-mangostin induced apoptosis, which in turn mediated cytotoxicity in human MG cells. The results indicated γ-mangostin to be a potential leading compound for the development of an anti-brain tumour agent.

Dietary administration of crude α-mangostin derivative in mangosteen pericarp at both doses 0.02% and 0.05% crude α-mangostin significantly inhibited the induction and/or development of aberrant crypt foci (ACF) in rats (Nabandith et al. 2004). The study showed that α-mangostin had a chemopreventative effect on putative preneoplastic lesions involved in rat colon carcinogenesis.

Extracts of the stem and root bark of *G. mangostana* and of α-mangostin, mangostanol, and garcinone D exhibited cytotoxic effects against the CEM-SS cell line (leukaemic T lymphocytes) (Ee et al. 2006b, 2008). The hexane and chloroform extracts of the root bark of *G. mangostana* as well as the hexane extract of the stem bark were found to be active against the CEM-SS cell line. Gamma-mangostin showed good activity with a very low IC_{50} value of 4.7 μg/ml, while α-mangostin, mangostanol, and garcinone D showed significant activities with IC_{50} values of 5.5, 9.6, and 3.2 μg/ml, respectively. A new xanthone, 11-hydroxy-3-O-methyl-1-isomangostin (1) was isolated from mangosteen stem bark (Han et al. 2009). In addition, ten other known compounds, 11-hydroxy-1-isomangostin (2), 11α-mangostanin (3), 3-isomangostin (4), α-mangostin (5), β-mangostin (6), garcinone D (7), 9-hydroxycalabaxanthone (8), 8-deoxygartanin (9), gartanin (10), and cratoxyxanthone (11), were isolated. Compounds 4–8 exhibited cytotoxicity against the human colon cancer, HT-29 cell line with ED_{50} values of 4.9, 1.7, 1.7, 2.3, and 9.1 μM, respectively. In an ELISA NF-kappaB assay, compounds 5–7, 9, and 10 inhibited p65 activation with IC_{50} values of 15.9, 12.1, 3.2, 11.3, and 19.0 μM, respectively, and 6 showed p50 inhibitory activity with an IC_{50} value of 7.5 μM. Alpha-mangostin was further tested in an in vivo hollow fiber assay, using HT-29, LNCaP, and MCF-7 cells, but it was found to be inactive at the highest dose tested (20 mg/kg).

In one study, six xanthones α, β and γ mangostins, mangostinone, garcinone E and 2-isoprenyl-1,7-dihydroxy-3-methoxy xanthone exhibited cell growth inhibition of human leukemia cell line HL60 (Matusmoto et al. 2003). All xanthones displayed growth inhibitory effects. Among them,

α-mangostin showed complete inhibition at 10 μM through the induction of apoptosis. Alpha manostin also showed inhibitory activity against other leukamia cell lines: K562, NB4 and U937 with IC_{50} of 5–10 μM. In further studies, the scientists found that α-mangostin preferentially targeted mitochondria in the early phase, resulting in induction of capase 9 and 3 apoptosis in human leukemia HL60 cells (Matsumoto et al. 2004). These results indicated that α-mangostin and its analogs could be potential candidates for preventive and therapeutic application for cancer treatment. Extract of *G. mangostana* was one of 43 plant species that were found to exhibit in-vitro cell viability of a human leukaemia cell-line HL60 by more than 50% when exposed to 9.6 J/cm^2 of a broad spectrum light when tested at a concentration of 20 μg/ml (Ong et al. 2009). The results indicated that the plant extract could have potential for photodynamic therapy.

Studies reported that garcinone E one of six xanthones from mangosteen pericarp had potent cytotoxic effect on all hepatocellular carcinomas (HCC) cell lines as well as on the other gastric and lung cancer cell lines (Ho et al. 2002). The studies indicated that garcinone E may be potentially useful for the treatment of certain types of cancer.

Three new prenylated xanthones, mangostenones C (1), D (2), and E (3), together with 16 known xanthones 4–19, were isolated from the young fruit (7-week maturity stage) of *Garcinia mangostana* (Suksamrarn et al. 2006) Compound 1 showed cytotoxic properties against three human cancer cell lines, epidermoid carcinoma of the mouth (KB), breast cancer (BC-1), and small cell lung cancer (NCI-H187), with IC_{50} values of 2.8, 3.53, and 3.72 μg/ml, respectively. Among the isolates, α-mangostin (12), the major metabolite, exhibited the most potent effects against the BC-1 cells with an IC_{50} value of 0.92 μg/ml, an activity greater than that of the standard drug ellipticine (IC_{50} = 1.46 μg/ml). Compound 12 also showed the highest activity against KB cells, while gartanin (10) displayed the strongest activity against the NCI-H187 cells at the respective IC_{50} values of 2.08 μg/ml and 1.08 μg/ml. Two new prenylated xanthones and a new prenylated tetrahydroxanthone, garcimangosxanthone A-C (1–3), along with 14 known xanthones were isolated from the pericarp of *Garcinia mangostana* (Zhang et al. 2010). Compounds 1 and 2 exhibited in-vitro cytotoxicity against A549 (lung cancer), LAC (lung adenocarcinoma) and A375 (melanoma) cell lines with IC_{50} values of 5.7–24.9 μM, which were comparable to those of doxorubicin.

Xanthones also have activity against breast cancer. Alpha-mangostin was found to inhibit 7,12-dimethylbenz[α]anthracene (DMBA)-induced preneoplastic lesions in a mouse mammary organ culture assay with an IC_{50} of 1.0 μg/ml (2.44 μM) (Jung et al. 2006). In another study, among the 12 xanthones from mangosteen pericarp, garcinone D, garcinone E, α-mangostin, and γ-mangostin displayed dose-dependent inhibitory activity in noncellular, enzyme-based microsomal aromatase inhibition assay (Balunas et al. 2008). In a follow-up cell-based assay using SK-BR-3 breast cancer cells that expressed high levels of aromatase, the most potent of these four xanthones was γ-mangostin. Further studies are warranted to determine their possible role in breast cancer chemoprevention. Three prenylated xanthones: α-mangostin, β-mangostin and 1,6-dihydroxy-7-methoxy-8-isoprenyl-6′, 6′-dimethylpyrano (2′,3′,3,2) xanthone were isolated from mangosteen fruit pericarp (Norizan et al. 2010). Alpha-mangostin was found to be cytotoxic against Hl-60, MCF-7 and HeLa cancer cell lines. Of 8 xanthone derivatives isolated from mangosteen fruit pericarp, 3 compounds showed potent death receptor 5 (DR5) promoter activity (Kikuchi et al. 2010). The combined treatment with gartanin and tumour necrosis factor (TNF)-related apoptosis-inducing ligand (TRAIL) showed a potentiation effect in sensitizing TRAIL-resistant human gastric adenocarcinoma (AGS) cells.

Three major phenolics were purified and identified as P1 [1,3,6,7-tetrahydroxy-2,8-(3-methyl-2-butenyl) xanthone], P2 [1,3,6-trihydroxy-7-methoxy-2,8-(3-methyl-2-butenyl) xanthone] and P3 (epicatechin), purified from mangosteen fruit pericarp exhibited strong antioxidant activities (Yu et al. 2009). In-vitro cell

proliferation trials indicated that P1 and P3 exhibited good immunomodulatory activities at 7.5 μg/ml concentration. Furthermore, P1 and P3 showed good cytotoxicities against human breast cancer cells (MCF-7) and human colon cancer cells (LOVO). P1 exhibited the maximal cytotoxicity of 73.06% against MCF-7 cells and of 46.27% against LOVO cells at 62.5 μg/ml concentration. The cytotoxicities of P1, P2, P3 and paclitaxel against normal embryonic lung fibroblast cells (HELF) were in a decreasing order: paclitaxel > P3 > P1 > P2. The results suggested that P1 and P3 could be used as a potential anticancer agent.

Mangosteen xanthones were found to inhibit in-vitro the proliferation of human colorectal adenocarcinoma cell line, COLO 205 and to also induce their death by apoptosis that involved the activation of the caspase cascade (Watanapokasin et al. 2010). In-vivo study, using a mouse subcutaneous tumour model with COLO 205 cells showed that, at relatively low doses, the growth of tumours was suppressed upon intratumoral administration of mangosteen xanthones. At a higher dose of mangosteen xanthones, the size of tumours was reduced gradually, and, in some mice, the disappearance of tumours was noted.

Antimicrobial Activity

The extracts of mangosteen peel, leaves, and bark exhibited antimicrobial activity (Palakawong et al. 2010). The minimum inhibitory concentration (MIC) values of mangosteen peel, leaves, and bark extracted against Gram-positive bacteria, *Listeria monocytogenes* and *Staphylococcus aureus* ranged from 0.025 to 0.78 mg/ml. Mangosteen pericarp extract exhibited antibacterial activity against *Staphylococcus aureus, Micrococcus luteus* and *Staphylococcus albus* (Vishnu Priya et al. 2010b). The MIC values for *Staphylococcus aureus* was 200 μg/ml and 50 μg/ml for both *Micrococcus luteus* and *Staphylococcus albus.*

Sundaram et al. (1983) found that α-mangostin and four of its derivatives exhibited antibacterial and antifungal activities. Among the bacteria, *Staphylococcus aureus, Pseudomonas aeruginosa, Salmonella typhimurium* and *Bacillus subtilis* were highly susceptible to xanthones, whereas *Proteus* sp., *Klebsiella* sp. and *Escherichia coli* were only moderately susceptible. Among the fungi, *Epidermophyton floccosum, Alternaria solani, Mucor* sp., *Rhizopus* sp. and *Cunninghamella echinulata* were highly susceptible to the xanthones whereas *Trichophyton mentagrophytes, Microsporum canis, Aspergillus niger, Aspergillus flavus, Penicillium* sp., *Fusarium roseum* and *Curvularia lunata* were only moderately susceptible. The order of the antimicrobial effectiveness was as follows: a-mangostin > isomangostin > 3-O-methyl mangostin > 3,6-di-O-methyl mangostin. Mangostin triacetate exerted no antimicrobial activity. Of the following compounds mangostin, gartanin, γ-mangostin, 1-isomangostin and 3-isomangostin from mangosteen, mangostin exhibited the highest antimicrobial activity against both normal and penicillin-resistant strains of *Staphylcoccus aure*us (Mahabusarakam et al. 1986). Mangostin, γ-mangostin, and gartanin exhibited moderate activity against *Trichophyton mentagrophytes* and *Microsporum gypseum* but showed no activity against *Candida albicans* and *Cryptococcus neoformans*.

Phongpaichit et al. (1994) found that the mangostin mixture exhibited the most potent effect against Methicillin-resistant *Staphylococcus aureus* (MRSA) isolated from patients in Songklanagarind Hospital and Maharaj Nakorn Chiang Mai Hospital with MIC value of 1.48 μg/ml which was in accord with vancomycin, an antimicrobial agent used as a positive control whereas Penicillin G (another control) had a MIC of >50 μg/ml Further α- and γ-mangostins also had an effect against MRSA, with MIC values of 3.12 and 2.26 μg/ml, respectively. The MIC value of α-mangostin against MRSA was 8 μg/ml. Mangostin inhibited the growth of all *Enterococcus* spp. isolated from patients in Maharaj Nakorn Chiang Mai Hospital, with an MIC value of 1 μg/ml.

Garcinia mangostana fruit rind extract containing the xanthone, mangostin displayed potent antimicrobial effect (Chomnawang et al. 2005). The MIC values were the same (0.039 mg/ml) for

both bacterial species and the MBC values were 0.039 and 0.156 mg/ml against *Propionibacterium acnes* and *Staphylococcus epidermidis*, respectively. Both bacteria have been recognized as pus-forming bacteria triggering an inflammation in acne. *Garcinia mangostana* extract possessed also highly significant antioxidant activity and reduced reactive oxygen species production. *Garcinia mangostana* extract was highly effective in scavenging free radicals and was able to suppress the production of pro-inflammatory cytokines by *Propionibacterium acnes* (Chomnawang et al. 2007). In addition, *Garcinia mangostana* extracts could reduce the TNF-alpha (tumour necrosis factor α) production. This study identified *G. mangostana* to be a promising source of anti-inflammatory agent which could be useful in treatment of acne vulgaris. In another study, α- and β-mangostins and garcinone B, isolated from the fruit hulls, edible arils and seeds, exhibited strong inhibitory effect against *Mycobacterium tuberculosis* with the minimum inhibitory concentration (MIC) value of 6.25 μg/ml (Suksamrarn et al. 2003). *Garcinia mangostana* also exhibited inhibitory activity against Methicillin-resistant *Staphylococcus aureus* (MRSA), a major nosocomial pathogen which causes severe morbidity and mortality worldwide. Its potent inhibitory activity was attributed to the prenylated xanthone, α-mangostin (MIC and MBC values of 1.95 and 3.91 μg/ml, respectively) (Chomnawang et al. 2009).

Alpha mangostin from mangosteen was found to exhibit potent antibacterial against methicillin-resistant *Staphylococcus aureus* (MRSA) and methicillin-sensitive *Staphylococcus aureus* with minimum inhibitory concentration (MIC) of 1.57–12.5 μg/ml (Iinuma et al. 1996). The anti-MRSA activity of α-mangostin was clearly increased by the presence of vancomycin. The strong in-vitro antibacterial activity of xanthone derivative against both methicillin-resistant and suggested the compound might find wide pharmaceutical use. In another study, ethanolic extracts of *Garcinia mangostana, Punica granatum* and *Quercus infectoria* were found most effective of 10 Thai medicinal plants against methicillin-resistant *Staphylococcus aureus* (MRSA) with MICs of 0.05–0.4, 0.2–0.4 and 0.2–0.4 mg/ml, respectively, and for *Staphylococcus aureus* ATCC 25923 of 0.1, 0.2 and 0.1 mg/ml, respectively (Voravuthikunchai and Kitpipit 2005). MBCs for MRSA isolates were 0.1–0.4, 1.6–3.2 and 0.4–1.6 mg/ml, and for *Staphylococcus aureus* ATCC 25923 were 0.4, 3.2 and 1.6 mg/ml, respectively. Another separate study reported that α-mangostin, isolated from mangosteen stem bark was found to be active against vancomycin resistant *Enterococci* (VRE) and methicillin resistant *Staphylococcus aureus* (MRSA), with MIC values of 6.25 and 6.25–12.5 μg/ml, respectively (Sakagami et al. 2005). The studies also showed synergism between α-mangostin and gentamicin (GM) against VRE, and α-mangostin and vancomycin hydrochloride (VCM) against MRSA. Further studies showed partial synergism between α-mangostin and commercially available antibiotics such as ampicillin and minocycline.

The young mangosteen fruit rind extract was found to contain significantly higher levels of phenolics and tannins and promoted higher free radical scavenging activity than the mature fruit rind extract (Pothitiratet al. 2009). In contrast, the latter extract contained higher contents of flavonoids and α-mangostin xanthone and elicited higher anti-acne producing bacteria activity than the young fruit rind extract. Soxhlet extraction of 95% ethanol extract of mangosteen fruit rind yielded the maximum contents of crude extract (26.60% dry weight) and α-mangostin (13.51%, w/w of crude extract), and also exerted the highest anti-acne activity with MIC 7.81 and 15.63 μg/m land MBC 15.53 and 31.25 μg/ml against *Propionibacterium* acnes and *Staphylococcus epidermidis*, respectively (Pothitirat et al. 2010). Ethanol 50% yielded maximum amounts of total phenolic compounds (26.96 g gallic acid equivalents/100 g extract) and total tannins (46.83 g tannic acid equivalents/100 g extract), and also exhibited the most effective DPPH-scavenging activity (EC_{50} 12.84 μg/ml). The results suggested that ethanol 50% should be the appropriate solvent for extracting free radical-scavenging components, phenolic compounds, and tannins, while 95% ethanol

is recommended for extraction of α-mangostin, a major anti-acne component from mangosteen.

Thai scientists found that polysaccharides in the fruit pericarp extract composed mainly of D-galacturonic acid and a small amount of neutral sugar (L-arabinose as the major one and L-rhamnose and D-galactose as the minor ones) could stimulate phagocytic cells and kill intracellular bacterium, *Salmonella enteritidis* (Chanarat et al. 1997).

The latex of *G. mangostana* was found to consist of more than 75% of xanthones which included α-mangostin, β-mangostin, γ-mangostin, garcinone-E, methoxy-β-mangostin and a new geranylated biphenyl derivative 3-hydroxy-4-geranyl-5-methoxybiphenyl (Dharmaratne et al. 2005). The xanthones had been reported to have strong antibacterial (anti-MRSA and -VRE), antifungal, antiinflammatory and a number of other biological activities.

Mangosteen pericarp extract was also found to be inhibitory to oral pathogens (Rassameemasmaung et al. 2008). In one study, clinical improvement compared to baseline was found in the following groups: subjects in the test group received periodontal treatment consisting of scaling, root planing and subgingival application of GM gel (mangosteen pericarp gel) while those in the control group received scaling and root planing without GM gel application. The test group exhibited significantly higher reduction in mean probing pocket depth (PPD), bleeding on probing (BOP), Gingival Index (GI) than the control group at the third month after treatment. Subgingival microbial composition changed from diseased state to that compatible with health after treatment in both groups. The studies showed that mangosteen pericarp gel could enhance the clinical effects of periodontal treatment. Herbal mouthwash containing the pericarp extract of *G. mangostana* was found useful as an adjunct in treating oral malodour based on determinations of volatile sulfur compound (VSC) levels, plaque index (PI) and papillary bleeding index (PBI) in gingivitis subjects and the recurrence of these parameters after periodontal treatment (Rassameemasmaung et al. 2007). The mangosteen fruit pericarp extract was found to be effective against two strains of *Streptococcus mutans* (Torrungruang, et al. 2007). The MIC and MBC for the strain ATCC 25175 were 0.625 μg/ml. The respective values for the strain KPSK2 were 0.625 and 1.25 μg/ml. The MIC and MBC were comparable to those of chlorhexidine, an antiseptic commonly used in dental plaque control.

Kaomongkolgit et al. (2009) showed that α-mangostin was effective against *Candida albicans*, the minimum inhibitory concentration (MIC) and minimum fungicidal concentration (MFC) were 1,000 and 2,000 μg/ml, respectively. The *C. albicans* killing activity of α-mangostin was more effective than clotrimazole and nystatin. The cytotoxicity of α-mangostin was determined and it was found that α-mangostin at 4,000 μg/ml was not toxic to human gingival fibroblast. The strong antifungal activity and low toxicity of α-mangostin make it a promising agent for treatment of oral candidiasis.

Alpha-mangostin, isolated from mangosteen fruit hull was metabolised by fungi to yield 4 metabolites which were identified as mangostin 3-sulfate (2), mangostanin 6-sulfate (3), 17,18-dihydroxymangostanin 6-sulfate (4)and isomangostanin 3-sulfate (5). (Arunrattiyakorn et al. 2011). Of the isolated metabolites, metabolite 2 exhibited significant antimycobacterial activity against *Mycobacterium tuberculosis.*

Antiviral Activity

The ethanol extract of *Garcinia mangostana* showed potent inhibitory activity against HIV-1 protease (Chen et al. 1996). The xanthone, mangostin produced an $IC_{50} = 5.12$ μM and γ-mangostin and $IC_{50} = 4.81$ μM. A series of xanthones 1–12 was isolated from the seed-cases of *Garcinia mangostana* and evaluated for bacterial neuraminidase inhibitory activity (Ryu et al. 2010). Neuraminidase inhibitors are a class of antiviral drugs targeted at the influenza virus, which work by blocking the function of the viral neuraminidase. Compounds 11 and 12 emerged to be new xanthones (mangostenone F, mangostenone G). The IC_{50} values of compounds 1–12

were determined to range between 0.27 and 65.7 μM. The most potent neuraminidase inhibitor compound 10 which had an IC_{50} of 270 μM features a 5,8-diol moiety on the B ring. Interestingly, structure-activity studies revealed that these xanthones showed different kinetic inhibition mechanisms depending upon the arrangement of hydroxyl groups in the B ring. Compound 6 possessing a 6,7-diol motif on the B-ring operated under the enzyme isomerization model whereas compound 10 possessing a 5,8-diol unit displayed simple reversible slow-binding inhibition.

Antiinflammatory and Antiallergy Activities

Xanthones also have antiinflammatory properties. Of mangostin and its derivatives 3-0-methyl mangostin (MM), 3,6-di-O-methyl mangostin (DM), 1-isomangostin (IM), mangostin triacetate (MT), mangostin 3,6-di-O-(tetra acetyl) glucoside (MTG) and mangostin-6,6-di-O-glucoside (MOG), mangostin, IM and MT produced pronounced antiinflammatory activity both by intraperitoneal and oral routes in rats as tested by carrageenin induced hind paw oedema, cotton pellet implantation and granuloma pouch techniques (Shankaranarayan et al. 1979). Antiinflammatory activity for M, IM and MT was observed even in bilaterally adrenalectomised rats. M, IM and MT did not produce any mast cell membrane stabilising effect and the degranulation effect of polymyxin B, diazoxide and Triton X-100 on rat peritoneal mast cells in-vitro was not prevented. M, IM and MT did not alter the prothrombin time of albino rats. Mangostin a major xanthone from mangosteen rind was found to interfere with one or more discrete phases in the sequence of events leading to immunopathological and inflammatory responses as indicated by its ability to inhibit systemic anaphylaxis, Schultz-Dales' reaction and immunocytoadherence in guinea pigs and rats and adjuvant-induced arthritis in rats (Gopalakrishnan et al. 1980).

Mangostanol, and α- and γ-mangostin from mangosteen pericarp, showed moderate inhibitory effects on cAMP phosphodiesterase (Chairungsrilerd et al. 1996c). cAMP phosphodiesterase is a predominant isoenzyme in the majority of inflammatory cells, with the exception of platelets, implicated in inflammatory airways disease.

The xanthones, α- and γ-mangostin exhibited anti-inflammatory properties in several murine models (Bumrungpert et al. 2009). Alpha- and γ-mangostin decreased the induction by LPS (lipopolysaccharide) of inflammatory genes, including tumour necrosis factor-α, interleukin (IL)-1beta, IL-6, IL-8, monocyte chemoattractant protein-1, and Toll-like receptor-2. Gamma-mangostin was more effective than α- mangostin on an equimolar basis. The data demonstrated that γ-mangostin mitigated LPS-mediated inflammation and insulin resistance in human adipocytes, possibly by inhibiting the activation of MAPK, NF-kappaB, and AP-1 (activator protein −1). Bumrungpert et al. (2010) found that α and γ-mangostin attenuated lipopolysaccharide (LPS)-induced expression of inflammatory genes, including tumour necrosis factor-α, interleukin-6, and interferon gamma-inducible protein-10 in a dose-dependent manner in human macrophage (MPhi). They also found that α- and γ-mangostin attenuated LPS-activated mitogen-activated protein kinases (MAPK) and activator protein (AP)-1, but only γ-mangostin reduced nuclear factor-kappaB (NF-kappaB). In addition, α- and γ- mangostin attenuated LPS suppression of PPARgamma gene expression in a dose-dependent manner. Taken together, the data demonstrated that mangostin attenuated LPS-mediated inflammation in macrophage MPhi and insulin resistance in adipocytes, possibly by preventing the activation of MAPK, NF-kappaB, and AP-1, which are central to inflammatory cytokine production in white adipose tissue. Obesity-associated inflammation is characterized by recruitment of human macrophages (MPhi) into white adipose tissue (WAT) and production of inflammatory cytokines, leading to the development of insulin resistance.

Mangosteen extract was reported to posses potent nitric oxide inhibitory effect with an IC_{50} value of 1.0 μg/ml in RAW264.7 macrophage

cells (Tewtrakul et al. 2009). The isolated compounds from the extract including α-mangostin and γ-mangostin, possessed marked inhibitory effect against nitric oxide release with IC_{50} values of 3.1 and 6.0 μM, respectively. The extract exhibited potent inhibitory effect on PGE2 (prostaglandin E2) release (IC_{50} = 6.0 μg/ml), whereas those of α- and γ-mangostins were 13.9 and 13.5 μM, respectively. However, mangostins possessed only moderate effects towards tumour necrosis factor (TNF-α) and interleukin −4 (IL-4) releases with IC_{50} values ranging from 31.8 to 64.8 μM. Both extract and α-mangostin suppressed transcription of gene encoding inducible nitric oxide synthase (iNOS) and cyclooxygenase-2 (COX-2) in dose-dependent manners, whereas γ-mangostin had only an inhibitory effect on transcription of iNOS. The present study supported the Thai traditional use of *Garcinia mangostana* fruit hull for treatment of inflammatory-related diseases through the inhibition of NO and PGE2 releases, but moderate effect through TNF-α and IL-4.

Japanese studies showed that all extracts (100% ethanol, 70% ethanol, 40% ethanol and water) of mangosteen fruit hull potently inhibited A23187-induced prostaglandin E2 synthesis in C6 rat glioma cells (Nakatani et al. 2002a). The 40% ethanol extract of mangosteen inhibited the prostaglandin E2 synthesis in a concentration dependent manner with relatively lower concentrations than the histamine release. It inhibited IgE-mediated histamine release from RBL-2H3 cells with greater potency than the water extract of *Rubus suavissimus* that had been used as an anti-allergy crude drug in Japan. In addition, passive cutaneous anaphylaxis (PCA) reactions in rats were significantly inhibited by this ethanol extract as well as by the water extract of *Rubus suavissimus*. The results suggested that the 40% ethanol extract of mangosteen had potent inhibitory activities of both histamine release and prostaglandin E2 synthesis. In a separate study, the scientists found that γ-mangostin had a potent inhibitory activity of prostaglandin E2 (PGE2) release induced by A23187, a Ca2+ ionophore in C6 rat glioma (Nakatani et al. 2002b). The inhibition was concentration-dependent, with the IC_{50} value of about 5 μM. Gamma-mangostin concentration-dependently inhibited also the conversion of arachidonic acid to PGE2 in microsomal preparations, showing its possible inhibition of cyclooxygenase (COX). In enzyme assay in-vitro, γ-mangostin inhibited the activities of both constitutive COX (COX-1) and inducible COX (COX-2) in a concentration-dependent manner, with the IC_{50} values of about 0.8 and 2 μM, respectively. This study demonstrated that γ-mangostin, a xanthone derivative, directly inhibited COX activity.

In another study, γ-mangostin purified from the fruit hull was found to have an effect on spontaneous prostaglandin E2 (PGE2) release and inducible cyclooxygenase (COX-2) gene expression in C6 rat glioma cells (Nakatani et al. 2004). An 18-hour treatment with γ-mangostin potently inhibited spontaneous PGE2 release in a concentration-dependent manner with the IC_{50} value of about 2 μM, without affecting the cell viability even at 30 μM. γ-mangostin reduced the lipopolysaccharide LPS-inducible activation of NF-kappaB- and human COX-2 gene promoter region-dependent transcription. Gamma-mangostin also inhibited rat carrageenan-induced paw edema. These results suggested that γ-mangostin directly inhibited IkappaB kinase (IKK) activity, and thereby prevented COX-2 gene transcription, an NF-kappaB target gene, probably to decrease the inflammatory agent-stimulated PGE2 production in-vivo. These studies confirmed α- and γ-mangostins from *G. mangostana* to be bioactive substances with anti-inflammatory effects and to be useful lead compounds for anti-inflammatory drug development.

Alpha- and γ-mangostins, isolated from the fruit hull of *G. mangostana*, significantly inhibited nitric oxide (NO) and PGE(2) production from lipopolysaccharide (LPS)-stimulated RAW 264.7 cells and possessed antiinflammatory effects. (Chen et al. 2008). The IC_{50} values for the inhibition of NO production by α- and γ-mangostins were 12.4 and 10.1 μM, respectively. The data show that expression of iNOS was inhibited by α- and γ-mangostins in LPS-stimulated RAW 264.7 cells, but not by COX-2. However, the level of PGE(2) production was reduced by

the two xanthones. In an in-vivo study, α-mangostin significantly inhibited mice carrageenan-induced paw edema.

A crude ethanol extract of *G. mangostana* (CEM) at intragastric (i.g.) doses of 0.5, 1, and 3 g/kg clearly exhibited antinociceptive effects in the hot-plate and acetic acid-induced writhing tests in mice (Cui et al. 2010). Two isolated compounds, α-mangostin and γ-mangostin, exhibited analgesic effects at doses of 25 and 50 mg/kg (i.g.) in the hot-plate and formalin tests, respectively. CEM at doses of 0.5, 1, and 3 g/kg significantly inhibited xylene-induced release of inflammatory mediators. CEM, α-mangostin, and γ-mangostin each dose-dependently demonstrated the ability to scavenge reactive oxygen species. The results demonstrated that CEM and mangostins possessed potent peripheral and central antinociceptive effects in mice and suggested that xanthones may be developed as novel analgesics and antiinflammatory drugs.

Mangosteen hull extract and its consituents α-mangostin and γ-mangostin also acted as histaminergic and a serotonergic receptor blocking agent (Chairungsrilerd et al. 1996a; Furukawa et al. 1997). A crude methanolic extract of the fruit hull of *Garcinia mangostana* was found to inhibit the contraction of the isolated rabbit aorta induced by histamine and serotonin (Furukawa et al. 1997). The results suggested that α-mangostin acted as a selective and competitive histamine H1 receptor antagonist and that γ-mangostin acted as a selective and competitive 5-HT2A receptor antagonist. Chairungsrilerd et al. (1996a) also found that the crude methanolic extract of the fruit hull of mangosteen, inhibited the contractions of isolated thoracic rabbit aorta induced by histamine and serotonin. Xanthones also had an effect on cell degranulation in rat basophilic leukemia RBL-2H3 cells. These xanthones suppressed the release of histamine from IgE-sensitized RBL-2H3 cells. All the xanthones tested significantly suppressed the signalling involving Syk (Spleen tyrosine kinase) and PLC gammas (phospholipase C gamma) pathways. Further, they showed that in the isolated rabbit thoracic aorta and guinea-pig trachea, α-mangostin dose-dependently inhibited histamine-induced contractions in the presence or absence of cimetidine, a histamine H2 receptor antagonist (Chairungsrilerd et al. 1996b). Alpha-mangostin also dose-dependently inhibited the binding of [3H]mepyramine, a specific histamine H1 receptor antagonist to rat aortic smooth muscle cells. Kinetic analysis of [3H]mepyramine binding indicated the competitive inhibition by α-mangostin. These results suggested α-mangostin to be a novel competitive histamine H1 receptor antagonist in smooth muscle cells. Subsequent studies reported that γ-mangostin caused a parallel rightwards shift of the concentration/response curve for the contraction elicited by 5-hydroxytryptamine (5-HT) in the rabbit aorta without affecting the contractile responses to KCl, phenylephrine (α1) or histamine (Chairungsrilerd et al. 1998a; b). The perfusion pressure response of rat coronary artery to 5-HT (5-HT2A) was reduced dose-dependently by γ-mangostin ($IC_50 = 0.32$ μM). 5-HT amplified, ADP-induced aggregation of rabbit platelets (5-HT2A) was inhibited by γ-mangostin ($IC_{50} = 0.29$ μM) whereas that induced by thrombin was not affected, nor did γ-mangostin affect 5-HT-induced contraction of the guinea-pigileum. Gamma-mangostin inhibited [3H]spiperone binding to cultured rat aortic myocytes ($IC_{50} = 3.5$ μM). The results suggested γa-mangostin to be a novel competitive antagonist, free from a nitrogen atom, for the 5-HT2A receptors in vascular smooth muscles and platelets. Chairungsrilerd et al. (1998a) further showed that γ-mangostin (10–40 nmol/mouse), suppressed 5-fluoro-α-methyltryptamine -induced head-twitch response in mice by blocking 5-HT2A (5-hydroxy-tryptamine2A) receptors not by blocking the release of 5-HT from the central neurone. Gamma-mangostin was found to be a promising 5-HT2A receptor antagonist in the central nervous system.

Cardioprotective and Cardiovascular Activities

Of mangostin and its derivatives 3-0-methyl mangostin (MM), 3,6-di-O-methyl mangostin (DM),

1-isomangostin (IM), mangostin triacetate (MT), mangostin 3,6-di-O-(tetra acetyl) glucoside (MTG) and mangostin-6,6-di-O-glucoside (MOG), only MOG produced significant effects on the cardiovascular system of frogs and dogs (Shankaranarayan et al. 1979). MOG produced myocardial stimulation and a rise in blood pressure which was partially blocked by propranolol.

Alpha-mangostin exerted a protective effect of on lipid peroxidation and antioxidant tissue defense system during isoproterenol (ISO)-induced myocardial infarction in rats (Sampath and Vijayaraghavan 2007). Induction of rats with ISO (150 mg/kg body weight, ip) for 2 days resulted in a marked elevation in lipid peroxidation, serum marker enzymes (lactate dehydrogenase (LDH), creatine phosphokinase (CPK), glutamic-oxaloacetic transaminase (GOT) and glutamic-pyruvic transaminase (GPT) and a significant decrease in the activities of endogenous antioxidants (superoxide dismutase (SOD), catalase (Cat), glu- tathione peroxidase (GPX), Glutathione S-transferase (GST) and Glutathione (GSH). Pre-treatment with α-mangostin (200 mg/kg of body weight per day) orally for 6 days prior to the ISO administration and 2 days along with ISO administration significantly attenuated these changes when compared to the individual treatment groups. In subsequent studies (Sampath and Vijayaraghavan 2008; Sampath and Kannan 2009), the scientists reported that induction of rats with isoproterenol (150 mg/kg body wt, i.p.) for 2 days resulted in a significant increase in the activities of serum and cardiac lysosomal hydrolases (β-d-glucuronidase, β-d-galactosidase, β-d-Nacetylglucosaminidase, acid phosphatase and cathepsin-D) and cardiac TNF-α and COX-2 expressions in ISO-intoxicated rats. Pre-co-treatment with α-mangostin (200 mg/kg body wt.) orally for 8 days significantly attenuated these abnormalities and restored the levels to near normalcy when compared to ISO intoxicated group of rats. Cardiac endothelial nitric oxide synthase (eNOS) expression and NO level were significantly suppressed in ISO-intoxicated rats. Pretreatment with α-mangostin extenuated ISO-induced diminution of eNOS expression and NO level. The data indicated that the ameliorative potential of α-mangostin against ISO-induced biochemical and morphological changes in mitochondria, might be mediated through the NO pathway and by its ability at quenching free radicals. They concluded that α-mangostin preserved the myocardial membrane integrity and extenuated anomalous TNF-alpha and COX-2 expressions by mitigating ISO-induced oxidative stress and cellular damage effectively. Oxidative stress can play a key role in myocardial necrosis.

Anti-obesity Activity

In a pilot, dose-finding study, a proprietary mangosteen juice blend (XanGo Juice) was found to reduce C-reactive protein (CRP) levels (increased change from baseline) in obese patients compared to placebo for those taking the highest dose of 18 oz per day (Udani et al. 2009). Other markers of inflammation (inflammatory cytokines) and a marker for lipid peroxidation (F2 isoprostane) did not show any significant differences when compared with placebo. There was a trend towards a decrease in BMI (body mass index) in the juice groups. There were no side effects reported in any of the groups and none of the laboratory or EKG (electrocardiogram) safety assessments indicated clinically significant changes for any subject. Thirteen phenolic compounds (1–13) mainly xanthones and benzophenones, isolated from mangosteen hull were found to possess strong inhibitory activity of fatty acid synthase (FAS) with the IC_{50} values ranging from 1.24 to 91.07 μM (Jiang et al. 2010). The study indicated that two types of natural products, xanthones and benzophenones, could be considered as promising FAS inhibitors for obesity therapy.

Immune system and CNS (Central Nervous System) Activity

Mangostin from mangosteen rind and its derivatives such as 3-0-methyl mangostin (MM),

3,6-di-O-methyl mangostin (DM), 1-isomangostin (IM), mangostin triacetate (MT), mangostin 3,6-di-O-(tetra acetyl) glucoside (MTG) and mangostin-6,6-di-O-glucoside (MOG) were screened for various pharmacological effects in experimental animals (Shankaranarayan et al. 1979). With the exception of DOM, all the compounds produced CNS depression characterised by ptosis, sedation, decreased motor activity, potentiation of pentobarbital sleeping time and ether anaesthesia in mice and rats. None of the compounds exhibited analgesic, antipyretic and anticonvulsant effects.

Both water and 50% ethanol extracts of mangosteen fruit hull exhibited potent neuroprotective activity on NG108–15 cells (Weecharangsan et al. 2006). The highest activity was observed at the concentration of 50 μg/ml for both the water and 50% ethanol extracts. For cytotoxicity test, none of the extracts was toxic to the cells except at the high concentration of 100 μg/ml.

Results of studies suggested that a xanthone derivative of *Garcinia mangostana* prevented doxorubicin-induced central nervous system toxicity in mice, partly by inhibition of doxorubicin-mediated increases in circulating f tumour necrosis factor-alpha (Tangpong et al. 2011). The levels of the pro-apoptotic proteins p53 and Bax and the anti-apoptotic protein Bcl-xL were significantly increased in doxorubicin -treated mice compared with the control group. The results indicted the potential of the xanthone as a good candidate for prevention of systemic effects resulting from reactive oxygen generating anticancer therapeutics.

Xanthone constituents, 1-isomangostin and garcinone from the fruits of *Garcinia mangostana* were found to have anticomplement activity (Quan et al. 2010). These xanthones have potential to be used in anticomplement therapy in diseases.

Protective Activity Against Alzheimer's Disease

Mangosteen extract (ME) was found to exert significant protective effects against Beta-amyloid (A beta) -induced cytotoxicity, increased reactive oxygen species (ROS), and increased caspase activity in SK-N-SH (human neuroblastoma cell line) cells (Moongkarndi et al. 2010). Beta-amyloid (A beta) plays a key role in the pathogenesis of Alzheimer's disease (AD) by inducing neurotoxicity and cell death mainly through production of reactive oxygen species (ROS). Treating SK-N-SH cells with 5–20 μM A beta(1–42) for 24 h caused morphologically cytotoxic changes, decreased cell viability and increased ROS level, whereas preincubation with 50–400 μg/ml mangosteen extract 30 min before the induction by A beta(1–42) successfully prevented such cytotoxic effects in a dose-dependent manner (completely at 400 μg/ml). The A beta-induced increase in caspase-3 activity was also preventable by 400 μg/ml mangosteen extract. Moreover, proteomic analysis revealed some proteins that might be responsible for these protective effects by the mangosteen extract. Further characterizations of these proteins may lead to identification of novel therapeutic targets for successful prevention and/or decreasing the severity of Alzheimer's disease.

Antiulcerogenic Activity

Mangosteen fruit extract also has antiulcerogenic activity (Nainwal et al. 2010). In the ethanol-induced ulcer protocol, *Garcinia mangostana* crude extract (250 and 500 mg/kg) was found to significantly reduced the lesion index, the total lesion area and the percentage of lesion, in comparison with control group. In indomethacin-induced ulcer only the treatments with 500 mg/kg of *Garcinia mangostana* extract and 100 mg/kg of cimetidine gave similar significant reduction. In the gastric secretion determination model, using ligated pylorus, the treatment with *Garcinia mangostana* crude extract (250 and 500 mg/kg) and cimetidine (100 mg/kg), reduced the volume of gastric juice, total acidity and raised gastric pH appreciably. Mangostin from the fruit rind, produced significant antiulcer activity in rats (Shankaranarayan et al. 1979).

Larvicidal Activity

All crude extracts of a new xanthone, mangosharin (2,6-dihydroxy-8-methoxy-5-(3-methylbut-2-enyl)-xanthone) and other prenylated xanthones, α-mangostin 1 and β-mangostin α-mangostin, β-mangostin, garcinone D, 1,6-dihydroxy-3,7-dimethoxy-2-(3-methylbut-2-enyl)-xanthone, mangostanol and 5,9-dihydroxy-8- methoxy-2,2-dimethyl-7-(3-methylbut-2-enyl)-2H,6H-pyrano-[3,2-b]-xanthene-6-one isolated from mangosteen stem displayed good toxicity against the larvae of *Aedes aegypti* (Ee et al. 2006).

Antiplasmodial Activity

Mangostin, the major xanthone of *Garcinia mangostana*, exhibited moderate in-vitro antiplasmodial activity against *Plasmodium falciparum* but prenylated xanthones containing alkylamino functional groups exhibited quite potent antiplasmodial activity (Mahabusarakam et al. 2006).

Sarcoplasmic Reticulum Ca(2+)-pumping ATPase Inhibitory Activity

Alpha-mangostin, was found to dose-dependently inhibited the activities of both Ca(2+)-ATPase and Ca(2+)-transport of the sarcoplasmic reticulum from rabbit skeletal muscle with an IC_{50} value of 5 μM. Neither Ca2+ release nor other enzyme activities were affected by α-mangostin (Furukawa et al. 1996). The researchers asserted that α-mangostin may become a useful pharmacological tool for clarifying the physiological functions of Ca(2+)-pumping ATPase and sarcoplasmic reticulum. Of eight xanthones, α-mangostin from mangosteen fruit hull, exerted the most potent apoptotic effect PC12 rat pheochromocytoma cells with the EC(50) value of 4 μM in a time and dose-dependent maaner (Sato et al. 1983). Alpha-mangostin-treated PC12 cells exhibited typical apoptotic DNA fragmentation and caspase-3 cleavage. Further, α-mangostin markedly inhibited the sarco(endo)plasmic reticulum Ca(2+)-ATPase There was a correlation between the Ca(2+)-ATPase inhibitory effects and the apoptotic effects of the xanthone derivatives. In contrast, c-Jun NH(2)-terminal kinase (JNK/SAPK), one of the signalling molecules of endoplasmic reticulum (ER) stress, was activated with α-mangostin treatment. These results suggested that α-mangostin inhibited Ca(2+)-ATPase to cause apoptosis through the mitochondrial pathway.

Protein Kinase Inhibition Activity

The hull of the fruit of the mangosteen also contained four inhibitors of plant Ca^{2+}-dependent protein kinase (Jinsart et al. 1992). Mangostin and γ mangostin xanthones also inhibited avian myosin light chain kinase and rat liver cyclic AMP-dependent protein kinase. This represented the first report of inhibition of plant and animal second messenger-regulated protein kinases by plant-derived xanthones.

Toxicity Studies

Toxicity study (14 days) of mangosteen fruit pericarp showed that there was neither death nor alterations in the body weight, relative organ weight, cytoarchitecture of organs, clinical biochemistry, serum marker enzymes and hematological parameters in the *G. mangostana* treated groups of rats when compared to the control (Vishnu Priya et al. 2010a).

Adverse Effect

A possible adverse effect may occur from chronic consumption of mangosteen juice containing xanthones. A patient with severe latic acidosis possibly attributable to a year of daily use (to lose weight, dose not described) of mangosteen juice

infused with xanthones was reported in a medical case in 2008 (Wong and Klemmer 2008).

Traditional Medicinal Uses

In Thai folk medicine, the fruit hulls of *G. mangostana* are used for healing skin infections and wounds and for the relief of diarrhea (Mahabusarakam et al. 1987). Mangosteen fruit hull is used by people in Southeast Asia as a traditional medicine for the treatment of abdominal pain, dysentery, wound infections, diarrhoea, suppuration, and chronic ulcer (Cui et al. 2010). Traditionally, mangosteen is famous for its anti-inflammatory properties and is used in the treatment of skin infections and wounds. Other applications include the therapy of various conditions such as dysentery, different urinary disorders, cystitis and gonorrhoea. In Malaysia, the dried and sliced rind has been used medicinally as an astringent, or in a decoction administered for dysentery. In Indonesia it is used as a lotion. An infusion of the leaves along with unripe bananas and a dash of benzoin are applied to wounds after circumcision and to other wounds. A decoction of the root is drunk for irregular menstruation (dysmenorrhoea). The fruit is said to purge and ripe fruits recommended to allay thirst in fever. In India, that the bark and young leaves are employed in diarrhoea, dysentery, and affections of the genito-urinary tracts, and also as a wash for aphthae of the mouth. The rind is used as an astringent medicine for diarrhoea and dysentery. It has been found very useful in chronic diarrhoea in children. The rind is made into an ointment and is applied on eczema and other skin disorders. The rind decoction is taken to relieve diarrhoea and cystitis, gonorrhoea and gleet and is applied externally as an astringent lotion. Filipinos employ a decoction of the leaves and bark as a febrifuge and to treat thrush, diarrhoea, dysentery and urinary disorders. A bark extract called “amibiasine”, has been marketed for the treatment of amoebic dysentery. Nutraceutical products derived from *G. mangostana* are now distributed increasingly all over the world.

Other Uses

The fruit rind contains 7–14% catechin, tannin and rosin, and together with tannin from the bark is used for tanning leather in China. It also yields a black dye. A wood tar prepared from the stem may be used for blackening teeth. The wood is dark-brown, heavy, almost sinks in water, and is moderately durable. It has been used to make handles for spears handles, also rice pounders, and is employed in construction and cabinetwork. Twigs are used as chewsticks in Ghana.

Several xanthones viz. gartanin, α-mangostin, γ-mangostin, garcinone-D, BR-xanthone and xanthione, euxanthone, isolated from the fruit hulls of *Garcinia mangostana* exhibited antifungal activity against three phytopathogenic fungi, *Fusarium oxysporum vasinfectum, Alternaria tenuis* and *Dreschlera oryzae* (Gopalakrishnan et al. 1997) and could have potential use as fungicides .

Comments

Mangosteen is usually propagated from seeds but it takes more than 10 years to bear fruit. Mangosteen is also grown from grafted seedlings which bears earlier than those raised from seeds but are less prolific.

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Garcinia nervosa

Scientific Name

***Garcinia nervosa* Miq.**

Synonyms

Garcinia andersonii Hook.f, *Garcinia spectabilis* Pierre

Family

Clusiaceae

Common/English Name

Pear Mangosteen

Vernacular Names

Indonesia: Anglau, Asam Garam, Buradgis, Gatatan, Kabal, Kandis Gajah, Pokok Lapan Taun, Selapan;
Malaysia: Kandis Gajah (Peninsular), Kandis Daun Besar (Sabah);
Nicobar: Kintul (Shompen Tribe), Payuh;
Thailand: Cha Muang Nam, Ma Phut Pa.

Origin/Distribution

The species is indigenous to Peninsular Malaysia, Sumatra, Rhiau, Borneo and the Philippines. It is also found in the Nicobar islands.

Agroecology

An uncommon lowland species sometimes found in coastal forest and riverine area in its native range. It is scattered on all types of topography and soil but most trees are distributed very well on the flatland and well-drained alluvium soils rather than other areas.

Edible Plant Parts and Uses

The pulp is edible but sour.

Botany

A small to medium, evergreen, lactiferous tree to 20 m, with a 90 cm girth, narrowly conical crown and strongly angles branches (Plate 1). Petiole 3–4 cm, lamina oblong-ovate 30–50 cm long by 9–15 cm wide, simple, drooping, broadly acuminate, base shallowly cordate, coriaceous, margin

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Plate 1 Habit of young tree with large, drooping leaves

Plate 2 Angled branching

Plate 3 Tree label

slightly recurved, prominently veined, with prominent sunken rib and lateral nerves (Plates 1–2). Flowers in big axillary clusters, pentamerous on 2 cm pedicel, sepals pubescent inside. Male flowers cram wide, campanulate, 1 cm across, stamens in 5 fascicles, pistillode reduced. Female flowers with 5 staminodes alternating with a thick, fleshy disc of 5 glands. Fruit is usually pear-shaped sometimes round, about 8 cm across, with persistent raised stigma comprising 5 deeply spaced lobes. Fruit green ripening to pale yellow, s containing 5 red seeds covered with thin white, sour flesh.

Nutritive/Medicinal Properties

No nutritive values have been published on its edible fruit.

A new isoflavone, 5,7,4′-trihydroxy-2′,3′,6′-trimethoxyisoflavone, nervosin, along with two known isoflavones, irigenin (5,7,3′-trihydroxy-6,4′,5′-trimethoxyisoflavone) and 7-methyltectorigenin (5,4′-dihydroxy-6,7-di-methoxyisoflavone) were isolated from the leaves of *Garcinia nervosa* (Ilyas et al. 1994). Biflavonoids were also found in the leaves; e I-5, II-5, I-7, II-7, I-3′, I-4′, II-4′-heptahydroxy-[I-3, II-8]-flavanonylflavone (Babu et al. 1988) and I-3, II-3, I-5, II-5, I-7, II-7, I-4′, II-4′-octahydroxy [I-2′, II-2′] biflavone (Parveen et al. 2004). Ilyas et al. (2002) also isolated a novel chalcone 5′-bromo-2′-hydroxy-4,4′,6′-trimethoxy-chalcone, isoliquiritigenin-4, 4′-dimethyl ether (2′-hydroxy-4,4′-dimethoxy chalcone) and 2′-hydroxy-3,4,4′,6′-tetramethoxy dihydrochalcone the leaves. The chalcone 5′-bromo-2′-hydroxy-4,4′,6′-trimethoxychalcone from *Garcinia nervosa* and its isomer 3′-bromo-2′-hydroxy- 4,4′,6′-trimethoxychalcone were also synthesised (Parab et al. 2010).

Xanthone compounds: isocowanin (8-geranyl-4-(3,3-dimethylallyl)-7-methoxy-1,3,6-trihydroxyxanthone), isocowanol (8-geranyl-4-(3-hydroxymethyl-3-methylallyl)-7-methoxy-1,3,6-trihydroxyxanthone) and nervosaxanthone (4,8-di(3,3-dimethylallyl)-2-(1,1-dimethylallyl)-1,3,5,6-tetrahydroxyxanthone) were isolated from the stem bark (Ampofo and Waterman 1986). The stem bark of *Garcinia nervosa* also

afforded two xanthons, dulxanthon G and dulxanthon J (Elya et al. 2007).

The extract from *G. nervosa* leaves was found to exhibit inhibition against NO (nitric oxide) production without affecting the viability of LPS (lipopolysaccharide) and IFN (interferon)-γ-induced RAW 264.7 macrophage cells (Jabit et al. 2009).

In Nicobar folkloric medicine, the leaf paste is applied on the body to relieve body pain; root decoctions are used for washing uterus after child birth by the Shompen tribe (Elanchezhian et al. 2007).

Other Uses

The wood is pale brown, hard but satisfactory to work, durable if sheltered and contains resin. In the Nicobar Islands, the branches are used as canoe paddles, the trunk is used as posts for frame work of huts and leg support for the stage frame.

Comments

The species occurs scattered in lowland tropical forest and yet some have wrongly referred to it as mountain mangosteen.

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Garcinia nitida

Scientific Name

***Garcinia nitida* Pierre**.

Synonyms

None

Family

Clusiaceae

Common/English Name

Asam Kandis, Brunei Cherry

Vernacular Names

Brunei: Asam aur-aur;
Peninsular Malaysia: Asam Kandis;
Sabah: Asam Alui-Alui;
Sarawak: Kandis.

Origin/Distribution

The species is indigenous to Borneo.

Agroecology

It occurs as an under-storey tree in tropical rainforest in the same climatic and agro-ecological zone as the mangosteen, *G. mangostana*.

Edible Plant Parts and Uses

Fruit pulp of ripe fruit is edible but acidic and is more used for cooking to impart an acidulose base to dishes. The rind is dried and used as acidic flavouring especially with sea food.

Botany

Small evergreen, branched, erect tree, with a dense crown and drooping branches. Leaves are alternate to opposite, large, oval-elliptic to obovate with acuminate tip, cuneate base, simple entire margin, glossy green, glabrous on 2–3 cm long petiole, furrowed above (Plates 1–3). Flowers are tetramerous and dioecious. Female flower solitary and axillary with many staminodes and ovoid superior ovary; male flowers in 2–3 flowered axillary fascicles, stamens in a single 4-lobed mass around a central pistillode. Fruit is subsessile, subglobose to globose, 2.5–4 cm across, smooth, pale green turning pink to pinkish red when ripe (Plates 1, 2 and 4) with white acidic flesh.

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Plate 1 Fruting tree

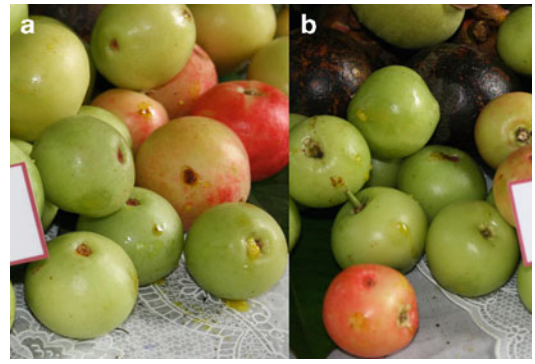

Plate 4 (**a**) and (**b**) Ripe and unripe, fruits with short peduncles

Plate 2 Close-up of fruit and leaves

Plate 3 Dark-green large leaves

The tree yields bioactive compounds with anticancer properties. The stem bark extracts of *Garcinia nitida* yielded two triterpenoids, stigmasterol and stigmasterol acetate plus a total of five xanthones, inophyllin B, osajaxanthone, 1,3,7-trihydroxy-2,4-bis (3-methylbut-2-enyl) xanthone, rubraxanthone and 3-isomangostin (Ee et al. 2005, 2007; Lim 2005).

The crude hexane and chloroform extracts of *Garcinia nitida* were found to show significant growth inhibitory activities CEM-SS (T-lymphoblastic leukemia) cell line with IC_{50} values of less than 30 μg/ml (Ee et al. 2005; Lim 2005). Rubraxanthone gave moderate inhibitory activity with IC_{50} value 9.4 μg/ml y towards the CEM-SS cell line. The human breast cancer cell line, MDA-MB-231 cell line, was found to be very susceptible towards most of the prenylated xanthones tested: inophyllin B (IC_{50} = 1.4 μg/ml), and 1,3,7-trihydroxy-2,4-bis(3-methylbut-2enyl) xanthone (IC_{50} = 2.2 μg/ml).

The pure compound, rubraxanthone exhibited potent larvicidal activity with LC_{50} value of 15.5 ppm against the larvae of *Aedes aegypti* (Lim 2005).

Nutritive/Medicinal Properties

No information has been published on the nutritive value of the edible fruit.

Other Uses

The species could have potential use as a rootstock for mangosteen and breeding purposes.

Comments

The common name, Brunei cherry or asam aur-aur, has pink to reddish fruit and has been erroneously identified as *Garcinia parvifolia* which has yellow to orangey-yellow fruits.

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Garcinia parvifolia

Scientific Name

***Garcinia parvifolia* (Miq.) Miq.**

Synonyms

Garcinia dioica Blume, *Garcinia globulosa* Ridley

Family

Clusiaceae

Common/English Names

Cherry Mangosteen, Kandis, Yellow Kandis

Vernacular Names

Borneo: Entelang, Ete, Gandis, Kandis, Kedundong, Kumanjing, Kundong;
Indonesia: Kemenjing, Memenjing, Walung (Javanese), Kijeri, Jeri (Sundanese), Badang (Bali);
Japanese: Garushinia Dioika;
Malaysia: Kandis (Peninsular, Sabah, Sarawak).

Origin/Distribution

Garcinia parviflora is indigenous to the Old world tropics – Thailand, Peninsular Malaysia, Sumatra, Java, Borneo (Sarawak, Brunei, Sabah, West-, Central- and East-Kalimantan), Celebes, Moluccas and New Guinea.

Agroecology

Garcinia parviflora is a tropical species found wild in peat swamp forests, primary or secondary undisturbed mixed dipterocarp forests in the lowlands and humid submontane, mixed or teak forests, up to an altitude of 1,000 m. It occurs on hillsides and ridges, and also on well-drained, alluvial sites and along rivers.

Edible Plant Parts and Uses

In Indonesia, the young reddish leaves are eaten raw as *lalap*, they have a sour taste and are often used in *sayor* as a substitute for tamarind. The young leaves are also pounded with other ingredients to a jelly which is eaten as *rujuk*. The ripe fruits are also eaten and the arils have a pleasant and agreeable sub-acid taste. It is used in curries or as a flavouring with rice. The fruit is used fresh or preserved by sun-drying for subsequent use.

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Botany

An evergreen, small to medium-sized, sub-canopy, perennial tree, 5–25 m high with a bole of 23 cm and with black widely patent branches and exuding yellow latex when bruised. Leaves are opposite, shortly petiolate, oblong or lanceolate-oblong, entire, simple, penni-veined, glabrous, base acute to decurrent, apex acuminate, dark green above, paler green below, glabrous, 3.5–17 cm long, 2–7 cm wide, petiole 0.5–1.5 cm long with a shallow furrow on the anterior side. Flowers are unisexual – monoecious, bisexual or polygamous, pale yellow or orange coloured, 0.5–1 cm across, pedicellate, solitary or in axillary fascicles of 2–12. Sepals 4, yellow to pale orange coloured, 2.5–3 mm long, petals larger 3.5–6 mm long by 2–3 mm wide. Male flower without pistillodes, female flowers with 7–12 staminodes. Fruit is depressed globose, pale-green turning to yellow or orangey-yellow when ripe 2.5–3.5 by 3.5–4 cm across, crowned by sunken remains of the small stigma (Plates 1–3) with thin skin. Seeds small, 5–8 enclosed in the white, sub-acidic arils.

Nutritive/Medicinal Properties

Nutritive food composition of the fruit or leaves has not been published.

Plate 1 Unripe and ripe depressed globose fruit crowned by sunken remains of the small stigma

Plate 2 Ripe fruits and leaves

Plate 3 Fruits with four persistent yellow/pale orange sepals

Garcinia species including *G. parvifolia* are recognized as rich sources of xanthone and xanthonoid natural products with high pharmaceutical and medicinal potential. The following xanthones were isolated from the bark: 1,3,6-trihydroxy-8-geranyl-7-methoxyxanthone (rubraxanthone); 1,3,6-trihydroxy-8-(7-hydroxy-3,7-dimethyl-2,5-octadieyl)-7-methoxyxanthone; 1,3,6-trihydroxy-8-(6,7-epoxy-3,7-dimethyl-2-octenyl)-7-methoxyxanthone; and 1,3,7-trihydroxy-2,4-diisoprenylxanthone, parvixanthones A–I (Iinuma et al. 1996b). Nine xanthones, parvixanthones A-I (1–9), isolated from the dried bark of *Garcinia parvifolia,* were found to have a common 1,3,6,7-oxygenated pattern for their xanthone nucleus, but various oxygenated

isoprenyl or geranyl substituent groups (Xu et al. 2001). Investigation of *Garcinia parvifolia'* s twigs afforded six new compounds: two xanthones (1 and 2), one phenol derivative (3), two chromanols (4 and 5) and one chromenol (6), together with two known compounds: garcidepsidone B (7) and the xanthone (8) (Naklue and Rukachaisirikul 2005). Seven phloroglucinols, named parvifoliols A-G, two depsidones, named parvifolidones A, B, and three xanthones, named parvifolixanthones A-C, were isolated from the twigs of *Garcinia parvifolia* along with seven known compounds: garcidepsidone B, mangostinone, rubraxanthone, dulxanthone D, 1,3,5,6-tetrahydroxyxanthone, norathyriol, and (2E,6E,10E)-(+)-4b-hydroxy-3-methyl-5b-(3,7,11,15-tetramethylhexadeca-2,6,10,14-tetraenyl)cyclohex-2-en-1-one (Rukachaisirikul et al. 2006).

Parvifoliquinone, a new benzoquinone derivative, was isolated from the leaves together with six known compounds: parvifoliol B, C (phloroglucinols); parvifoliol E (benzopyran derivative), garcidepsidone B (depsidone), nigrolineaisoflavone A (isoflavone-like compound), and mangostinone (xanthone) (Rukachaisirikul et al. 2008).

The phytochemicals in various plant parts and associated pharmacological properties are elaborated below.

Antioxidant Activity

Seven phloroglucinols, named parvifoliols A-G, two depsidones, named parvifolidones A, B, and three xanthones, named parvifolixanthones A-C, were isolated from the twigs of *Garcinia parvifolia* along with seven known compounds: garcidepsidone B, mangostinone, rubraxanthone, dulxanthone D, 1,3,5,6-tetrahydroxyxanthone, norathyriol, and (2E,6E,10E)-(+)-4b-hydroxy-3-methyl-5b-(3,7,11,15-tetramethylhexad eca-2,6,10,14-tetraenyl)cyclohex-2-en-1-one (Rukachaisirikul et al. 2006). Some of them demonstrated antibacterial and antioxidant activities. Crude extracts of n-hexane, ethyl acetate and methanol of the root, stem bark, fruit and leaf of *Garcinia parvifolia* demonstrated antioxidant, activity (Syamsudin and Kumala 2007; Syamsudin et al. 2007a). All extracts of different plant parts showed anti-oxidant activities with $IC_{50} < 200$ mg/ml although weaker anti-oxidant activity compared to vitamin C and quercetin (positive controls).

Anticancer Activity

Leaf extracts of *Garcinia parvifolia* provided relatively high yields of four novel, cytotoxic prenylated depsidones (Xu et al. 2000). The crude hexane and acetone extracts of *Garcinia parvifolia* were found to be cytotoxic to CEM-SS cell line with IC_{50} values of less than 30 μg/ml meanwhile, the crude chloroform extract gave a significant activity with an IC_{50} value of 6.5 μg/ml (Lin 2005). Two known xanthones, parvixanthone A and rubraxanthone, isolated from *G. parvifolia* were to be cytotoxic to L1210 murine leukemic cells, with IC_{50} values in the range of 3–8 μg/ml (Kardono et al. 2006). Crude extracts of n-hexane, ethyl acetate and methanol of the root, stem bark, fruit and leaf of *Garcinia parvifolia* demonstrated cytotoxic activity (Syamsudin and Kumala 2007; Syamsudin et al. 2007a). All extracts also showed cytotoxic activity with values of $LC_{50} > 1{,}000$ m g/ml.

Antimicrobial Activity

Rubraxanthone was also isolated as the major constituent from the latex of *G. parvifolia* (Pattalung et al. 1988). The compound displayed strong activities against normal and penicillin-resistant strains *Staphylococcus aureus*, and showed moderate activities against fungi, *Trichophyton mentagrophytes* and *Microsporum gypseum*.

Rubraxanthone was found to have a structure similar to that of α-mangostin, and showed the highest activity against methicillin-resistant *Staphylococcus aureus* strains (MIC = 0.31 – 1.25 μg/ml), an activity which was greater than

that of the antibiotic vancomycin (3.13–6.25 μg/ml) (Iinuma et al. 1996b). Crude extracts of n-hexane, ethyl acetate and methanol of the root, stem bark, fruit and leaf of *Garcinia parvifolia* demonstrated varying antimicrobial activity (Syamsudin and Kumala 2007; Syamsudin et al. 2007a). The n-hexane extract of leaf and fruit did not show antimicrobial activity, while n-hexane and ethyl acetate extracts of stem bark, root and fruit exhibited strongest antimicrobial activity, especially against *Staphyloccocus aureus*. The antibacterial activity against methicillin-resistant *Staphylococcus aureus* of parvifoliquinone, parvifoliols B, C, E, garcidepsidone B, nigrolineaisoflavone A, and mangostinone, isolated from the leaves were determined (Rukachaisirikul et al. 2008).

Antiplatelet Activity

Rubraxanthone also has anti-platelet activity. Rubraxanthone showed a strong inhibition on platelet-activating factor (PAF) binding to rabbit platelets with IC_{50} value of 18.2 μM (Jantan et al. 2002). The IC_{50} values of isocowanol, macluraxanthone, 6-deoxyjacareubin, 2-(3-methylbut-2-enyl)-1,3,5-trihydroxyxanthone, 2-(3-methylbut-2-enyl)-1,3,5,6-tetrahydroxyxanthone and 1,3,5-trihydroxy-6,6′-dimethylpyrano (2′,3′:6,7)-4-(1,1-dimethylprop-2-enyl)-xanthone were also determined for comparison. The results revealed that a geranyl group substituted at C-8 in the xanthone structure was beneficial to the binding while a hydroxylated prenyl group at C-4 resulted in a significant loss in binding to the PAF receptor.

Antiplasmodial Activity

Crude extracts of n-hexane, ethyl acetate and methanol of the root, stem bark, fruit and leaf of *Garcinia parvifolia* demonstrated anti-plasmodial, activity (Syamsudin and Kumala 2007; Syamsudin et al. 2007a). Although most of the extracts showed anti-plasmodial activity, extract of roots and stem bark gave the strongest anti-plasmodial activities (IC_{50} 7.88 and 4.11 mg/ml). In another study, the active fraction (n-hexane extract with methanol) of *G. parvifolia* was active against *Plasmodium berghei* in mice with an ED_{50} of 74.45 mg/kg body weight/day (Syamsudin et al. 2007b, c). In addition, the active fraction was also relatively safe as expressed by the LD_{50} of 8.0 mg/kg body weight. Separate studies showed that at the dose of 200 mg/kg/day of an active fraction of the stem bark, the number of *Plasmodium berghei* parasite in mice blood was reduced by 54.90% (Syamsudin et al. 2008). The reduction of the number of parasite which circulated in the blood occurred at the doses of 50 and 100 mg/kg/day, although its activity was much lower than the malaria drug of chloroquine. Macrophages activity (87.19%) increased at the dose of 200 mg/kg/day, compared to the control group (52.99%), these indicated that the fraction of *G. parvifolia* induced immune response. The increase of the phagocyte activity of the macrophage was stimulated by the active fractions of *G. parvifolia* (dose dependent) that was administered to the *P. berghei*-infected mice.

Larvicidal Activity

The crude hexane and acetone extracts of *Garcinia parvifolia* showed moderate activities against *Aedes aegypti* larvae by giving LC_{50} values of less than 100 μg/ml while pure rubraxanthone showed potent activity against the larvae with a LC_{50} value of 15.49 μg/ml (Lin 2005).

Other Uses

Its wood lacks commercial value as it splits easily and is susceptible to termite attack. The tree provides a source of resin.

Comments

The colour of the fruit of *Garcinia parvifolia* Miq. (synonym *Garcinia dioica* Blume) as described by Backer and Bakhuizen van den

Brink (1963), Ochse and Bakhuizen van den Brink (1980), Burkill (1966), and Slik (2006) is pale orange but the fruit identified as Asam aur-aur (*Garcinia parvifolia*) in Brunei or kundong in Sarawak is crimson in colour and subscribes more to *Garcinia nitida*.

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Garcinia prainiana

Scientific Name

***Garcinia prainiana* King.**

Synonyms

None

Family

Clusiaceae

Common/English Names

Button Mangosteen, Cherapu

Vernacular Names

Malaysia: Chepu, Cherapu, Cherupu, Kechupu, Menchupu, Chekau, Chupak (Peninsular).

Origin/Distribution

Button mangosteen is indigenous to Peninsular Malaysia and southern Thailand.

Agroecology

It grows in similar agroecological tropical conditions as the common mangosteen. It thrives in areas with annual rainfall above 1,500 mm that is well distributed and warm temperatures of 25–35°C. It occurs in many soil types but prefers soils that are porous, deep, wet but well-drained, slightly acid, clay loams rich in organic matter with pH from 5.5 to 6.8. It occurs wild in lowland forests and on hill sides and ridges up to 900 m altitude. It is also cultivated in villages.

Edible Plant Parts and Uses

The pale orange pulp of the ripe fruit is acid-sweet and has a flavor similar to but different from mangosteen. Fruits are used as food flavouring and to make jams.

Botany

A small, evergreen tree growing to 10 m high with a narrow, dense and bushy crown with rough, greyish-brown bark (Plate 5). It has white latex. The leaves are sub-sessile, large, ovate-oblong (Plates 1 and 2), 10–23 cm long, 4.5–11.5 cm

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Plate 1 Pink flowers and large green, ovate-oblong leaves

Plate 4 Cluster of developing fruits

Plate 2 Flowers formed in dense clusters at apex of lateral shoots

Plate 5 Close-up of developing young fruit

Plate 3 An opened flower

Plate 6 Fruit and branch with rough bark

wide, coriaceous, simple with entire margin, tapering apex and with distinct lateral veins raised below, faint above. Flowers are pentamerous, pinkish, 2 cm wide and formed in dense, round clusters on terminal shoots or on leafless lateral shoots (Plates 1–3). Male flowers have stamens in 5 bundles around a pistillode. The fruits are depressed globose and smooth, 2.5–5 cm wide, ripening to orange-yellow, with a thin leathery, smooth rind and with a persistent stigma as a blackish button-like, raised dome-shaped papillose and with persistent sepals and calyx in the stem end (Plates 4–6). Seeds are embedded in the subacid but sweet pale orange pulp.

Nutritive/Medicinal Properties

In a study conducted in Malaysia (Khoo et al. 2008), the total carotene content (mg/100 g) of selected underutilized tropical fruit in decreasing order was jentik-jentik (*Baccaurea polyneura*) 19.83 mg>Cerapu 2 (*Garcinia prainiana*) 15.81 mg>durian nyekak 2 (*Durio kutejensis)* 14.97 mg>tampoi kuning (*Baccaurea reticulata*) 13.71 mg>durian nyekak (1) 11.16 mg>cerapu 1 6.89 mg>bacang 1 (*Mangifera foetida*) 4.81>kuini (*Mangifera odorata*) 3.95 mg>jambu susu (*Syzygium malaccense*) 3.35 mg>bacang (2) 3.25 mg>durian daun (*Durio lowianus*) 3.04 mg>bacang (3) 2.58 mg>tampoi putih (*Baccaurea macrocarpa*) 1.47 mg>jambu mawar (*Syzygium jambos*) 1.41 mg. Beta carotene content was determined by HPLC to be the highest in jentik-jentik 17,46 mg followed by cerapu (2) 14.59 mg, durian nyekak (2) 10.99 mg, tampoi kuning 10.72 mg, durian nyekak (1) 7.57 mg and cerapu (1) 5.58 mg. These underutilized fruits were found to have acceptable amounts of carotenoids that could serve as potential antioxidant fruits.

Ikram et al. (2009) found *Garcinia prainiana, Phyllanthus emblica, Sandoricum koetjape* and *Syzygium jambos* to have high antioxidant capacity as assayed by β-carotene bleaching, ferric reducing antioxidant potential (FRAP) and 2,2-diphenyl-1-picryl hydrazyl (DPPH) assays and thus have the potential to be sources of antioxidants. In another study, the methanol extract of *Garcinia prainiana* leaves exhibited inhibition against nitric oxide (NO) production without affecting the viability of LPS (lipopolysaccharides) and IFN-γ-induced RAW 264.7 macrophage cells (Jabit et al. 2009).

Other Uses

Its wood has been used for house construction.

Comments

The plant is propagated from seeds which germinate rather slowly.

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Garcinia schomburgkiana

Scientific Name

Garcinia schomburgkiana Pierre

Synonyms

None

Family

Clusiaceae

Common/English Name

Ma Dan

Vernacular Names

Khmer: Tro-Meng, Tro-Moung;
Thai: Ma Dan;
Vietnamese: Bứa Dồng, Cây Bứa Dồng, Cây Thuốc.

Origin/Distribution

The species is indigenous to Southeast Asia-Thailand, Kampuchea, Laos and Vietnam.

Agroecology

In its native range, it is commonly found growing wild near rivers, streams and swamps in dry evergreen forest. It is also grown in gardens for home uses.

Edible Plant Parts and Uses

Young tender leaves and fruits are consumed raw or cooked. The fruit of madan can be eaten fresh but is sour. It is commonly used in a sauce of shrimp paste and chilli and eaten with vegetables and fish. It can be julienned and used as a side dish in various Thai salads such as salty crab salad. The fruit can be processed to make preserved fruit in syrup, pickled fruit, salted fruit and dried fruit. The fermented fruit is stuffed with minced pork to make a soup, or it can be made into a sweet.

The young tender leaf is used as a vegetable accompaniment to many Thai dishes and can be eaten either raw or cooked.

Botany

A small, evergreen, perennial tree, 3–7 m high. Leaves simple, opposite, elliptic-lanceolate or elliptic-ovate, 2–3 cm wide, 5–9 cm long, apex subacute, base cuneate, margin entire, glossy

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Plate 1 Madan fruit and leaf

dark green (Plate 1). Flowers unisexual, monoecious borne in 3-6-flowered axillary clusters. Flowers consist of four pinkish petals, which are 3 mm wide and 6.5 mm long, stamens in four fascicles. Fruits are obliquely ellipsoid to ellipsoid-oblong, 5–7 cm long, and 2–3 cm wide, glossy green (Plate 1) ripening yellow.

Nutritive/Medicinal Properties

Poomopamorn and Kumkong (1997) reported the proximate composition of madan fruit and leaves per 100 g fresh weight as: fruit – 7.3 g carbohydrate, 0.3 g protein, 0.1 g fat, 0.4 g fibre, 17 mg Ca, 7 g P, 432 IU vitamin A, 0.04 mg riboflavin, and 5 mg vitamin C.

leaves: 6.5 g carbohydrate, 0.3 g protein, 0.1 g fat, 103 mg Ca, 8 g P, 225 IU vitamin A, 0.01 mg thaimin, 0.04 mg riboflavin, 0.02 mg niacin and 16 mg vitamin C.

The amount of vitamin C found in *Garcinia schomburgkiana* herbal fruit juice was reported as 4.6 mg/100 g (Suntornsuk et al. 2002). The stability of vitamin C during the first 4 weeks was remarkably improved after freeze-dried process. A mixture of four compounds, viz. clusiacitran A, clusiacitran B, fluorinated clusiacitran A and fluorinated clusiacitran B isolated from *Garcinia schomburgkiana* (Fun et al. 2006).

The traditional ethnomedicinal uses of madan's leaves, root and fruit are as an expectorant, treatment of coughs, improvement of menstrual blood quality, treatment of diabetes and as a laxative (Poomopamorn and Kumkong 1997). Leaf and fruit are macerated with saline water and drank as expectorant or mucolytic to relieve-cough and treat abnormal menstruation. Stem extract is used for accelerating lochial discharge (Chuakul and Saralamp 2002).

Other Uses

No other non-edible and non-medicinal uses have been recorded for the species.

Comments

The plant is propagated from seeds which germinate readily and also by air-layering.

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Garcinia spicata

Scientific Name

***Garcinia spicata* (Wight & Arn.) Hook. F.**

Synonyms

Garcinia ovalifolius, Hook.f., *Garcinia ovalifolius*, Hook.f. var. *spicata*, *Stalagmites ovalifolius* G.Don., *Xanthochymus ovalifolius* Roxb., *Xanthochymus spicatus* Wight & Arn. (basionym).

Family

Clusiaceae

Common/English Name

Gamboge Tree

Vernacular Names

India: Haldi (Marathi), Manja nangu (Malayalam), Kokpttai (Tamil).

Origin/Distribution

The tree is indigenous to India and Sri Lanka.

Agroecology

The species is tropical in requirement. It occurs as an understorey tree in the warm humid forest in Southern India and Sri Lanka. It is found up to 1,000 m altitude.

Edible Plant Parts and Uses

The fruit has been reported as edible (Rath and Priyadarshini 2005) but not very palatable. The fruit has been reported to have slight unpleasant odour which was weaker than that of *Garcinia subelliptica* and the flesh not as firm and crunchy as *G. subelliptica*. The flesh was described as less flavourful, less sweet, slightly astringent and sappy.

Botany

Medium-sized evergreen, lactiferous tree. Leaves are opposite, ovate to elliptic oblong with obtuse tips and tapering bases, 8–22 cm by 4.5–8.5 cm, entire, simple with numerous lateral nerves and oblique transverse nervules on 0.6–1.3 cm long petioles and orientated obliquely vertical (Plates 1–3). Young leaves are bronze in colour turning to glossy dark green (Plate 3). Inflorescence in axillary clusters. Female flowers on long pedicels in fascicles and male flowers on shorter pedicel in spike with fascicles of flowers

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Plate 1 Large, obliquely-vertical leaves and axillary flower fascicles

Plate 2 Bronzed-coloured, juvenile leaves

Plate 3 Densely packed foliage

along the length of the spike. Flowers 0.8–1.3 cm across. Male flower s with 4, coriaceous, orbicular, sepal and 4 membranous, orbicular, concave petals, stamens in 5 spathulate fascicles, anthers few and didymous. Females flowers with similar sepals and petals, 5 small staminodes; 3–4 celled, globose ovary with a very short style and 5-lobed stigma. Fruit 4 cm long, size of walnut, subglobose to broadly oblong, glabrous, deep green (Plates 3–5) ripening to orange yellow, 1–3 seeded.

Nutritive/Medicinal Properties

No information has been published on its nutritive value as the fruit is edible but not very palatable.

From the fresh bark of *Garcinia spicata*, (±) – fukugetin, (+)-fukugetin, (±)-3′-O-methyl fukugetin and fukugiside (morelloflavone-7″-*O*-glucoside) (Konoshima et al. 1969; Konoshima and Ikeshiro 1970). From the plant two new compounds dl-volkensiflavone and spicataside, a biflavonoid glycoside along with GB-Ia

Plate 4 Immature green angular-sub-globose fruit

Plate 5 Close-up of developing fruit

(3-8″-binaringenine), and GB 2a (3-8″-naringenileriodictiol) were isolated (Konoshima et al. 1970).

Leaf extract of *Garcinia spicata* afforded an unidentified long chain carboxylic acid, friedelin, friedelan-3β-ol, sitosterol and the biflavanones GB-1, GB-1a, GB-2a and morelloflavone (Gunatilaka et al. 1984).

No medicinal use of the tree has been reported.

Other Uses

It may have potential as an ornamental tree and use as border and screen plant.

Comments

The plant is propagated from seeds.

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Garcinia xanthochymus

Scientific Name

***Garcinia xanthochymus* Hook. f. ex T. Anderson**

Synonyms

Garcinia pictoria (Roxb.) Engl., *Garcinia tinctoria* (DC.) Dunn, *Garcinia tinctoria* W. Wight, *Xanthochymus pictorius* Roxb., *Xanthochymus tinctorius* DC.

Family

Clusiaceae

Common/English Names

False Mangosteen, Gamboge Tree, Himalayan Garcinia, Mysore Gamboge, Sour mangosteen, Yellow Mangosteen

Vernacular Names

Burmese: Daungyan, Dawyan-Ban, Hmandaw, Madaw;
Chinese: Da Ye Teng Huang;
Czech: Garcínie Žlutá;
French: Gamboge Des Teinturiers, Mangoustan Amer;
India: Dampel, Tezpur, Tepur Tenga, Tamal Hindi Tepor (Assamese), Chalata (Bengali), Aruak (Garo), Dampel, Ota, Tamal, Jharambi, Tumul (Hindu), Deavkai, Devagarige, Devajarige, Devangi, Gansargi, Gurse, Hirekanigu, Janagijavangi, Neralemavu, Devanahuli, Garigehuli, Bettada Huise, Chikka Kamarak Mara, Devamba, Devarige, Gurchi, Hiraykanagilu, Jorige Julimara, Kaapicche, Kandaali, Moogurchi, Neeve, Nerale Maavu, Thamaari, Devagarike, Divarige, Gurce, Hirekanigina, Janagi, Jarige, Nellamavu, Vate, Arisinagurgi, Chikka Kamaraak Mara, Daevachaarige, Daevagarige, Daevajaaarige, Deevaarige, Dhaarige Huli, Gansurgi, Gurche, Hireganigala, Jaavangi, Jeeraka, Jerikana Mara, Kaadu Jeeraka, Mothimurukalu, Naeralemaavu, Nelamaavu (Kannada), Pinar, Anavaya, Samudrapacca, Samudrapochu, Tamalam, Thamalam (Malayalam), Heibung (Manipuri), Jharambi, Ota, Otanche, Dharambo (Marathi), Thehmusaw (Mizoram), Tapinchha (Oriya), Avika, Bhavana, Bhavishya, Bhavya, Kalakhanda, Kusumodar, Lamphala, Pichchalabija, Samputanga, Tamala, Tamalaki, Tapinjha, Vakrashodana (Sanskrit), Kulavi, Malaippachai, Malaippuli, Pachilai, Pachumbadi, Tabinjam, Tamalam, Chitaka-Maraku, Pacchilai, Makki, Paccilai, Camuttirappaccai, Cetanam, Cikatimaram, Colaikotukkayppuli2, Ilai1, Kakacimpi, Kokottai2, Malaippaccai, Malaivecikacceti, Malaivecikam, Malinam, Mattilai, Mekantam 1, Paccilaimaram1, Pallinarkulali, Talilam, Tamal, Tamalatalam,

T.K. Lim, *Edible Medicinal And Non-Medicinal Plants: Volume 2, Fruits*,
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Tampincam, Tapincam, Tokki, Nakam (Tamil), Ivarumamidi, Jwara, Memaditamalamu, Sikatimramu, Sitakamraku, Tamalamu, Iwara Mamidi, Lollorimanu, Cikatimranu, Chikatimanu, Chikatimraku, Chitakamraku, Inoramamedee, Ishvaramamidi, Isvaramamidi, Ivurumamidi, Iwaramemadee, Iwaramemadi, Tamala, Cheekatimraaku, Ivarumaamidi, Seethakamraku, Thamaalamu (Telugu);
Malaysia: Asam Kandis, Kandis;
Thailand: Mada Luang (Chiang Mai), Mada (Northern), Chakasa (Karen);
Sri Lanka: Cochin Goraka, Kolon, Jamala, Rata Goraka (Sinhala);
Vietnamese: Bứa Nhuộm.

Plate 1 Dark brown, rough bark with horizontal branches

Plate 2 Subglobose, oblique and pointed fruit

Origin/Distribution

Yellow mangosteen is believed to have originated in India and Myanmar and southwards into Thailand. It is cultivated and has become semi-naturalised in many southeast Asian countries and elsewhere in the tropics.

Agroecology

It is a tropical fruit species that occurs as understorey tree in the dense humid forests of valleys or on hills from 100 to 1,400 m altitude. It is adapted to a moist, shady environment and well-drained soils rich in humus and organic matter.

Edible Plant Parts and Uses

The pleasant acid fruit flesh can be eaten fresh, preserved or made into sherbets or jams. The young shoots are edible and have a sour taste. The fruits are also cooked and eaten.

Botany

A medium sized, branched evergreen perennial, up to 17 m high. The tree has a short and straight trunk and rough, brown bark (Plate 1) with white latex. On exposure to air the latex turns pale brown. Branches numerous, slender, decussate, horizontal (Plate 1) but usually ± distally pendulous, twigs distinctly angled The leaves are opposite, lanceolate, elliptic to lanceolate oblong (Plate 3–4), 12–25 cm long and 4–7 cm wide. The leaf is pale green when young and becomes dark green and shiny on the upper surface and glabrous. The lower leaf surface is pale green, leaves are pinkish when young. The midrib is prominent with numerous veinlets arranged in parallel. The thick petiole is short being only 2 cm long. Flowers are white, small, 1 cm across, pentamerous, sepals 5, petals 3 large, 2 small and borne in fascicles of 4–12 on 2–3.5 cm long pedicel from leafless axils. Female flower with 5 staminode fascicles, each fascicle with 2–5 staminodes; strongly rugose.

Plate 3 Subglobose pointed immature fruit with persistent stigma

Plate 4 Lanceolate, elliptic to lanceolate-oblong, glossy green leaves

Plate 5 Ripe, deep yellow, oblique fruit with deep yellow, acid flesh

Ovary is globose, usually 5-loculed; style short, 1 mm; stigma peltate, apex concave, 5-cleft. Fruits are subglobose to ovoid and often oblique and pointed (Plates 2–5), up to 9 cm diameter and crowned by the persistent stigma. The fruit is green when immature turning to a deep yellow to orangey yellow colour when ripe (Plate 5). It is soft with a thin skin and deep yellow acid pulp and has 1–4 brown, smooth, oblong or ovoid seeds, 2.5 cm long.

Nutritive/Medicinal Properties

No information has been published on the nutritive value of the edible fruits.

Phenolic compounds isolated from the fruits, stem/twig bark and leaves of *Garcinia xanthochymus* exhibited antioxidant, cytotoxic, anti cancer, antiinflammatory and antimicrobial activities.

From the fresh leaves of *G. xanthochymus* (±) – fukugetin, fukugiside (morelloflavone-7″-*O*-glucoside), dl-volkensiflavone, GB-Ia (3-8″-binaringenine), and GB 2a(3-8″-naringenileriodictiol), GB-2 and a new biflavone glycoside, xanthochymusside were isolated (Konoshima et al. 1970). Two novel xanthones, 1,6-dihydroxy-4,5-dimethoxyxanthone and 1,5,6-trihydroxy-7,8-di(3-methyl-2-butenyl)-6′,6′-dimethylpyrano(2′,3′:3,4)xanthone were isolated from the bark of *Garcinia xanthochymus* (Zhong et al. 2007). Several new xanthones 1,2,5-trihydroxy-6-methoxyxanthone, 1,4,6-trihydroxy-5-methoxyxanthone, 1,2,7-trihydroxy-4-(1,1-dimethylallyl) xanthone (Zhong et al. 2008), and Garcinexanthones A-E (Chen et al. 2008) were isolated from the bark.

Some pharmacological properties of the plant reported are:

Antioxidant Activity

Five new xanthones, garcinenone A, B, C, D and E, along with seven known compounds were isolated from the ethyl-acetate-soluble extract of the bark of *Garcinia xanthochymus* (Zhong et al. 2009). Jacareubin; 1,4,6-trihydroxy-5-methoxy-7-(3-methyl-2-butenyl)xanthone; subeliptenone B and symphoxanthone were obtained from this

plant for the first time. The isolated compounds exhibited potent antioxidant activity in the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging test with IC_{50} values in the 6.0–23.2 μmol/L. These results suggested that *G. xanthochymus* could be a promising rich source of natural antioxidant.

Garcinia wine was prepared by fermentation of ameliorated must of *Garcinia xanthochymus* using *Saccharomyces cerevisiae* (Rai et al. 2010). The wine had higher amount of residual sugars contributing to the calorific value. The aldehydes and esters content in the final wine were 0.034% and 0.26%, respectively. There was reduction of citric acid and oxalic acid (antinutritional factor) and synthesis of aspartic acid and glutamic acid. *Garcinia* beverage was accepted on sensory analysis with high score for desirable attributes and overall quality with alcohol content of 6.1%. There was increase in total phenolics (0.039% gallic acid equivalent) and reducing power on fermentation but decrease in 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity.

Anticancer Activity

Studies reported that polyisoprenylated benzophenones derived from *Garcinia xanthochymus* fruit had antioxidant and cytotoxic activity in-vitro on different colon cells and antitumour activity in rodent models (Baggett et al. 2005). Methanol extract of *Garcinia xanthochymus* fruit yielded two new benzophenones, guttiferone H and gambogenone. Guttiferone H displayed cytotoxicity in the SW-480 colon cancer cell line (IC_{50} = 12 μM). Gambogenone displayed cytotoxicity in the SW-480 colon cancer cell line (IC_{50} = 188 μM). Both compounds induced apoptosis in SW-480 colon cancer cells and displayed antioxidant activity in the 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay (IC_{50} = 64 and 38.7 μM, respectively). Eleven known compounds, aristophenone A, alloathyriol, amentoflavone, 3,8″-biapigenin, cycloxanthochymol, (±)-fukugetin, (±)-fukugiside, guttiferone E, isoxanthochymol, (±)-volkensiflavone, and xanthochymol were isolated and tested against SW-480 colon cancer cells and in the DPPH assay. Three *Garcinia*-derived benzophenones: xanthochymol, guttiferone E and guttiferone H, appeared to inhibit the growth of human colon cancer cells lines – HCT116, HT29 and SW480, at least in part, by activating the endoplasmic reticulum stress response and inhibiting the mTOR (mammalian target of rapamycin) cell survival pathway (Protiva et al. 2008). mTOR inhibition is a new therapeutic target in cancer. These combined effects may contribute to the anticancer activity of these novel compounds.

Other studies reported that three new hydroxylated xanthones with prenyl or geranyl substituents, compounds 1–3, isolated from the twig bark of *Garcinia xanthochymus*, along with four known compounds 1,4,5,6-tetrahydroxy-7,8-diprenylxanthone, 1,3,5,6-tetrahydroxy-4,7,8-triprenylxanthone, garciniaxanthone E and 6-prenylapigenin, showed moderate cytotoxicities against breast cancer (MDA-MB-435S) and lung adenocarcinoma (A549) cell lines, but lacked antifungal activity against *Candida albicans* (Han et al. 2007).

Nerve Growth Factor (NGF) – Potentiating Activity

Studies reported that prenylated xanthones: 1,3,5,6-tetrahydroxy-4,7,8-tri(3-methyl-2-butenyl) xanthone (3 μM) and garciniaxanthone E; 1,4,5,6-tetrahydroxy-7,8-di(3-methylbut-2-enyl) xanthone (10 μM) isolated from the wood elicited marked enhancement of nerve growth factor-mediated neurite outgrowth in PC12D cells (Ohizumi et al. 2003). Two prenylated xanthones, 1,4,5,6-tetrahydroxy-7,8-di(3-methylbut-2-enyl) xanthone (1) and 1,2,6-trihydroxy-5-methoxy-7-(3-methylbut-2-enyl)xanthone (2), were isolated from the wood of *Garcinia xanthochymus* along with a known xanthone, 12b-hydroxy-des-Đ-garcigerrin A (3). Compound 1 (10 μM), 2 (10–30 μM) and 3 (10 μM) showed a markedly enhancing activity of nerve growth factor (NGF)-mediated neurite outgrowth on PC12D

cells (Chanmahasathien et al. 2003a, b). Five xanthones isolated from *Garcinia xanthochymus* 1,4,5,6-tetrahydroxy-7,8-di(3-methylbut-2-enyl) xanthone, 1,2,6-trihydroxy-5-methoxy-7-(3-methylbut-2-enyl)xanthone, 1,3,5,6-tetrahydroxy-4,7,8-tri(3-methyl-2-butenyl)xanthone, 12b-hydroxy-des-D-garcigerrin A, and garciniaxanthone E were found to have nerve growth factor (NGF)-potentiating activities (Li and Ohizumi 2004). The compounds elicited marked enhancement of NGF-mediated neurite outgrowth in PC12D cells. These substances may contribute to the basic study and the medicinal development for the neurodegenerative disorder.

Antiinflammatory and Antimicrobial Activities

Using the carrageenan-induced rat paw edema method, various extracts of *G. xanthochymus* leaves exhibited antiinflammatory activity (Pal et al. 2005). The equivalent percentage inhibition of inflammatory activity of petroleum ether extract and methanolic extract was 86.4% and 80.7%, respectively compared to standard ibuprofen, which was statistically significant. Xanthochymol, the benzophenone isolated from the fruit was also reported to demonstrate antimicrobial activity (Baslas and Kumar 1980).

Traditional Medicinal Uses

In traditional folkloric Asian medicine, the fruit is used as anthelmintic and cardiotonic and is regarded to improve appetite.

Other Uses

The species is sometimes used as grafting root stock for *Garcinia mangostana*. The trees are tapped and yield an inferior gamboges paint used in water colours and a dye used in dyeing Buddhist priests' robes. The tree yields a yellowish-white, heavy and hard timber.

Comments

The plant is propagated from seeds which germinate readily.

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Mammea americana

Scientific Name

***Mammea americana* L.**

Synonyms

Mammea emarginata Moc. & Sessé ex Choisy, *Potamocharis mamei* Rottb.

Family

Clusiaceae, also placed in Calophyllaceae

Common/English Names

Mamey Tree, Mammee, Mammee Apple, Mammey-Apple, Marmalade Tree, South American Apricot, Santo Domingo Apricot, St. Domingo Apricot, Tropical Apricot

Vernacular Names

Brazil: Abricó, Abricó-De-São-Domingos, Abricó-Do-Pará, Abricó-Selvagem, Abricoteiro (Portuguese);
Czech: Mamej Americká;
Danish: Mammeaæble;
Eastonian: Ameerika Mammea, Vili: Mammea;
French: Abricot, Abricot D' Amerique, Abricot De Saint Domingue, Abricot De Saint-Dominque, Abricot Des Antilles, Abricot Pays, Abricotier d'Amérique, Abricotier De Saint Domingue, Abricotier Des Antilles, Abricotier Sauvage, Mammée Américaine;
German: Mammi, Mammiapfel;
Portuguese: Abricó, Abrico Do Pará, Abrico Selvagem, Abricote, Abricoteiro (Tree), Pecego De Sao Domingos, Pessego De São Domingo;
Spanish: Albaricoque De Santo Domingo, Albricoque, Mamao, Mamey Amarillo, Mamey De Cartagena, Mamey De Santo Domingo, Mamey Dominicano, Mameyo, Martín Sapote, Mata Serrano, Zapote De Santo Domingo, Zapote De Niño, Zapote De Santo Domingo, Zapote Domingo, Zapote Mame, Zapote Mamey.

Origin/Distribution

Mammea americana is a native of West Indies – Dominican Republic, Haiti, Jamaica, Puerto Rico and the lesser Antilles. It has been introduced into the tropics of the New and Old World. The tree has naturalized in other islands in pre-historic times by the native people to whom it was an important food item. It is now common in semi-cultivation in Central and northern South America and is grown as a fruit tree in many other moist, tropical areas. It is exotic to Bahamas, Barbados, Bermuda, Brazil, Colombia, Costa

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Rica, Ecuador, El Salvador, French Guiana, Guatemala, Guyana, Mexico, Panama, Surinam, United States of America (Hawaii and Florida), Venezuela, Virgin Islands (US). It is of very restricted occurrence in West Africa (particularly Sierra Leone), Zanzibar, southeast Asia (Java in Indonesia, Sabah in Malaysia, the Philippines), Queensland in Australia and Hawaii.

Agroecology

The mammey apple is confined to wet and warm tropical or subtropical climates in areas with mean annual temperatures of 27–30°c and with mean annual rainfall of 150–4,000 mm. The tree is frost sensitive and is killed by sub-zero temperatures. In Central America, the species is grown from near sea-level to 1,000 m elevation. The species thrives in deep, rich, well-drained soil, but is tolerant of shallow, sandy terrain, and it grows in limestone areas of Jamaica, as well as oolitic limestone of the Bahamas and southeastern Florida.

Edible Plant Parts and Uses

The pulp of ripe fruit is eaten fresh either plain, with a dash of lime or lemon juice and sugar, in fruit salads, or served with cream and sugar or wine. In Jamaica, the pulp may be steeped in wine and sugar for a while prior to consumption. In the Dominican Republic, the fresh pulp, blended with sugar, is made into frozen sherbet. The juice or sirup of stewed flesh, is seasoned with sugar and lemon juice to make "ade". In the Bahamas, the pulp may be steeped in salt water before cooking with much sugar to prepare a kind of jam. Slightly under-ripe fruits, rich in pectin, are made into jelly. In El Salvador, a mamey-flavoured carbonated drink called *kolashanpan* is considered by most as the national soda. In the French West Indies, an aromatic liqueur, *Eau de Créole*, or *Crème de Créole*, is distilled from the flowers. This liqueur is believed to be tonic or digestive. Sliced mamey pulp may also be cooked in pies or tarts, and may be seasoned with cinnamon or ginger. Canned, sliced mamey pulp has been exported from Cuba in the past. The mamey is widely made into preserves such as spiced marmalade and pastes (resembling guava paste) and used as a filler for products made of other fruits. Wine is processed from the fruit and fermented "toddy" from the sap of the tree in Brazil.

Botany

An evergreen, medium-sized tree, 10–20 m tall with a short trunk of 90–120 cm diameter and oval shaped canopy of densely foliaged ascending branches (Plate 1). The trunk exudes a yellow latex when bruised. Leaves are simple, opposite, coriaceous, glabrous, glossy dark-green, broadly elliptic, up to 20 cm long and 10 cm wide (Plates 3 and 4). Flowers are fragrant, with 4–6 white petals and orange stamens or pistils, 2.5–4 cm wide

Plate 1 Tree habit

Plate 2 Flower bud and opened flower

Plate 5 Close-up of ripe mammey apple fruit

Plate 3 Leaves and flower buds

Plate 6 Orangey-yellow pulp of ripe mammey apple fruit

Plate 4 Fruits amongst the dense canopy

when fully open, borne singly or in clusters of 2 or 3 on axils of young branches (Plates 2 and 3). Flowers may be staminate, pistillate or hermaphrodite occurring on the same tree or on separate trees. The fruit is a berry not a drupe (Mourão and Beltrati 2000), subglobose to globose, 10–20 cm across, greyish brown with a rugose, thick, leathery rind and borne on a short stout peduncle (Plates 4–6). The fruits contain 2–4 russet-brown, ovoid to ellipsoid, exalbuminous seeds embedded in yellow to orangey–yellow, non-fibrous, fragrant, firm, sub-acid pulp (Plate 6). The embryo is pseudo-conferruminate, with two massive food-storing cotyledons, rich in starch.

Nutritive/Medicinal Properties

The nutritive value of raw mammey apple per 100 g edible portion was reported as: water 86.20 g, energy 51 kcal (213 kJ), protein 0.50 g, total lipid (fat) 0.50 g, ash 0.30 g, carbohydrate, 12.50 g, total dietary fibre 3.0 g, Ca 11 mg, Fe 0.70 mg, Mg 16 mg, P 11 mg, K 47 mg, Na 15 mg, Zn 0.10 mg, Cu 0.086 mg, Se 0.6 µg, vitamin C 14.0 mg, thiamin 0.020 mg, riboflavin

0.040 mg, niacin 0.400 mg, pantothenic acid 0.103 mg, vitamin B-6 0.100 mg, total folate 14 μg, vitamin A12 μg RAE, vitamin A 230 IU, total saturated fatty acids 0.136 g, 16:0 (palmitic) 0.042 g, 18:0 (stearic) 0.094 g, total monounsaturated fatty acids 0.205 g, 18:1 undifferentiated (oleic) 0.205 g, total polyunsaturated fatty acids 0.079 g, 18:2 undifferentiated (linoleic) 0.079 g, tryptophan 0.005 g, lysine 0.037 g, and methionine 0.006 g (USDA 2010). A total of 60 different carotenoids, all-trans-β-carotene being the major carotenoid were found in the fruits of buriti (*Mauritia vinifera*), mamey (*Mammea americana*), marimari (*Geoffrola striata*), peach palm (*Bactris gasipaes*), physalis (*Physalis angulata*), and tucuma (*Astrocaryum aculeatum*) (de Rosso and Mercadante 2007). The presence of apo-10'-β-carotenol, found in mamey, was not previously reported in foods. In addition, β-zeacarotene was identified for the first time. The total carotenoid content ranged from 38 μg/g in marimari to 514 μg/g in buriti. All fruits analyzed were found to be good sources of provitamin A.

β-Ionone (22%), 2-methylbutyric acid (12.5%), E-farnesol (4.6%), and nerolidol (3.8%) were as the major components s of the volatile fraction of the fresh fruit of *Mammea americana* (Sagrero-Nieves et al. 1989). In total, 51 volatile constituents (40 of which are identified for the first time in mammee apple) were identified in mammee fruit pulp with methyl 3-hydroxy-2(*S*)-methyl propanoate pure enantiomer and 2-methyl butanoic acid with ee 98.5% *S* being the major components (Morales and Duque 2002). In total 19 glycosidically bound aroma compounds were identified. The identified aglycones were mainly carboxylic acids (51%), C13-norisoprenoids (17.2%), hydroxy esters (10.5%), aliphatic alcohols (6.9%), phenyl propane derivatives (7.9%), and unknown (6.5%). The above mentioned bound volatiles were comprised mainly by 2-methyl butanoic acid, 4-hydroxy-β-ionone and 4-oxo-β-ionol. Additionally, with the aid of capillary GC-MS of trifluoroacetylated derivatives eight glucosides were identified: glucopyranosyl methylbutanoate (two isomers), glucopyranosyl methylbutenoate (two isomers), methyl 3-*O*-β-D-glucopyranosyl 2-methylpropanoate, methyl 3-*O*-β-D-glucopyranosyl 2-methylbutanoate, 4-oxo-β-ionyl 9-*O*-β-D-glucopyranoside and 4-oxo-7,8-dihydro-β-ionyl 9-*O*-β-D-glucopyranoside.

The phenylcoumarin named mammeigin (or mammea A/AA cycle D) [systematic name: 5-hydroxy-8,8-dimethyl-6-(3-methylbutanoyl)-4-phenyl-2*H*,8*H*-pyrano[2,3-*f*] chromen-2-one] was isolated and characterised from mamey seed oil (Finnegan and Mueller 1965). Four closely related 4-alkyl-5,7-dihydroxycoumarins were isolated from *Mammea americana* seeds (Crombie et al. 1967a). All four compounds were found to have 3-methylbut-2-enyl groups at the 6-position and three, mammea B/BA, B/BB, and B/BC were found to have 4-n-propyl substituents. They were differentiated by possession of a 3-methylbutyryl, a 2-methylbutyryl, or an unsubstituted butyryl group at the 8-position. Mammea C/BB was similar to B/BB except that it had a 4-n-pentyl group. Three of the compounds, mammea B/BA, B/BB, and B/BC, were also found in the related species *Mammea africana*. Five 4-phenyl-5,7-dioxygenated coumarins were also isolated from *Mammea americana* seeds (Crombie et al. 1967b). Two of them, A/AA and A/A cyclo D, were shown to be identical with mammeisin and mammeigin, respectively. The three new isomeric coumarins A/BA, A/AB, and A/BB were shown, to possess 3-methylbut-2-enyl groups at position 6 (A/BA and A/BB) or 8 (A/AB) and to have a 3-methylbutyryl (A/BA) or a 2-methylbutyryl (A/AB and A/BB) group in the remaining phloroglucinol position. 2-methoxyxanthone and the triterpene friedelin were also isolated. Other coumarin components of mamey seed oil included mammein, mammeisin and cyclomammein, a putative mamey seed oil constituent, which was obtained from mammein by treatment with peracids, and produced upon air oxidation of the latter (Finnegan and Merkel 1972). Six new 4-n-propylcoumarins, with 5,6-annulation and a higher oxidation level than the closely related mammeas B/BA, B/BB, and B/BC, were identified in the seed-extract from *Mammea americana* (Crombie et al. 1972a). A group of three (VIa–c) contained an α-(hydroxyisopropyl) dihydrofuran ring and were differentiated by 3-methylbutyryl, 2-meth-

ylbutyryl, and butyryl substituents at the coumarin C-8. They were deacylated to a common product (VIIIa). Compounds (VIa–c) were also obtained by partial synthesis from mammea B/BA, B/BB, and B/BC, respectively. Two further similar compounds contained a cyclic peroxide feature (XVa and b). The sixth compound was a hydroperoxide (XVI). Six new coumarins of the 4-n-propyl series and two of the 4-phenyl series were identified from *Mammea americana* (Crombie et al. 1972b). Three of the former, mammea B/AA, B/AB, and B/AC, possessed the 5,7-dihydroxy-4-n-propylcoumarin core carrying an 8-(3-methylbut-2-enyl), grouping, and could be differentiated by the 6-acyl substituent, which was 3-methylbutyryl (Ia), 2-methylbutyryl (Ib), or butyryl (Ic). The other three 4-n-propyl compounds had the same core but a 7,8-fused α-(hydroxyisopropyl) dihydrofuran system. The same three acyl variations were present, but at position 6 (VIIa–c). The two 4-phenylcoumarins also had a 7,8-fused α-(hydroxyisopropyl)dihydrofuran system and possessed either a 6-(3-methylbutyryl) or a 6-(2-methylbutyryl) substituent (VIa and b). None of the crystalline coumarins reported earlier had insecticidal activity able to account for that of the crude light petroleum extract of *Mammea americana* (Crombie et al. 1972c). A crystalline mixture, shown to be of the two 4-alkyl-5,7-di-hydroxycoumarins (Xa and b), differing only in the possession of an 8-(3-methylbutyryl) or an 8-(2-methylbutyryl) substituent, was isolated and found to have more insecticidal activity than the most effective non-crystalline fractions from which it was derived. The distinguishing feature of the insecticides, relative to the already known extractives, was the presence of a 4-(1-acetoxypropyl) side-chain. Ethanol extract of mamey seed residues afforded 2- and 4-hydroxyxanthone along with 1,7-dihydroxyxanthone (euxanthone) and the previously unknown 1,5-dihydroxyxanthone (Finnegan and Patel 1972).

Ten major mammea coumarins, mammea E/BD (1), mammea E/BC (2), mammea E/BA (3), mammea E/BB (4), mammea B/BA hydroxycyclo F (5), mammea B/BD (6), mammea B/BC (7), mammea B/BA (8), mammea B/BB (9), and mammea B/BA cyclo F (10), were isolated and identified from the seed nucleus of *Mammea americana* (Yang et al. 2006). The total content (w/w%) of the 10 major mammea coumarins was determined to be highest in the root (0.75%), followed by the leaf (0.64%), seed nucleus (0.48%), fruit skin (0.11%), stem (0.08%), seed coat (0.02%), and fruit flesh (<0.01%). The leaf and seed nucleus were found to be rich and sustainable natural sources of mammea coumarins. Mammea coumarins are isoprenylated derivatives of the lactones of the 2-hydroxy-Z-cinnamic acids that are bioactive and have limited distribution in three Clusiaceae genera.

Mamey wax, isolated from the seed oil of *Mammea americana* was shown to be a mixture of saturated, long straight-chain fatty esters with carbon contents ranging from C_{38} to C_{54} with the major constituent being the symmetrical C_{48} homolog, tetracosanyl tetracosanoate (Finnegan and Eisenbraun 1964).

Anticancer Activity

Significant antitumour activity against Sarcoma 180 grown in stationary cell culture was exhibited by mammein (4-n-propyl-5,7-dihydroxy-6-isopentenyl-8-isovalerylcoumarin), constituent of *M. americana* and certain of its congeners: the 8-α-methylbutyryl isomer (neomammein) and the 8-n-butyryl homolog (normammein), as well as by various degradation and synthetic intermediates (Finnegan et al. 1972). A number of related xanthones and benzophenones *from Mammea americana* seeds showed significant inhibitory activity of sarcoma 180 (Finnegan et al. 1973). Four hydroxyxanthones isolated from a polar extract of *Mammea americana* seeds did not account for the inhibitory activity of the extract. Three new isoprenylated coumarins, mammea B/BA hydroxycyclo F (1), mammea E/BC (2), and mammea E/BD (3) plus 12 known isoprenylated coumarins, mammea A/AA (4), mammea A/AA cyclo D (5), mammea A/AA cyclo F (6), mammea A/AC cyclo D (7), mammea A/AD cyclo D (8), mammea B/BA (9), mammea B/BA cyclo F (10), mammea

B/BB (11), mammea B/BC (12), mammea B/BD (13), mammea E/BA (14), and mammea E/BB (15), as well as two known flavanols, (+)-catechin (16) and (−)-epicatechin (17) were identified from *Mammea americana* seeds (Yang et al. 2005). All 15 isoprenylated coumarins exhibited significant cytotoxic activities in the SW-480, HT-29, and HCT-116 human colon cancer cell lines (IC_{50} ranges of 13.9–88.1, 11.2–85.3, and 10.7–76.7 μM, in the three cell lines, respectively) at concentrations comparable to 5-fluorouracil (IC_{50} = 53.0, 46.1, and 45.1 μM), a drug frequently used for human colon cancer treatment. In the SW-480 cell line, the three new coumarins, 1–3, also exhibited dose-dependent increases in sub-diploid cells by flow cytometry, indicating that they induced apoptosis. Compounds 2–4, 9, and 11–15 displayed high antioxidant activity in the DPPH assay (IC_{50} range of 86–135 μM), compounds 1, 5–8, and 10, however, had no antioxidant activity (IC_{50} > 200 μg/ml) in the DPPH assay.

Mammea-type coumarins isolated from *Mammea americana* were found to inhibit the activation of HIF-1 (hypoxia-inducible factor-1) in human breast and prostate tumour cells (Du et al. 2011). Bioassay-guided fractionation of the active extract yielded 14 mammea-type coumarins including three new compounds, mammea F/BB (1), mammea F/BA (2), and mammea C/AA (3) besides mammea E/BB (15). Acetylation of mammea F/BB afforded a triacetoxylated product (A-2) that suppressed HIF-1 activation with enhanced potency in both T47D (human ductal breast epithelial tumour cell line) with IC_{50} 0.83 μM for hypoxia-induced and PC-3 (human prostate cancer) cells with IC_{50} 0.94 μM for hypoxia-induced. Coumarins possessing a 6-prenyl-8-(3-methyloxobutyl) substituent pattern displayed increased HIF-1 inhibitory effects. The O-methylated derivatives were less active at inhibiting HIF-1 and suppressing cell proliferation/viability. Mechanistic studies indicated that these compounds acted as anionic protonophores that potently uncoupled mitochondrial electron transport and disrupted hypoxic signalling.

Antimicrobial Activity

Of 50 plants screened six crude plant extracts tested for their anti-*Mycobacterium tuberculosis* activity yielded positive results with varying degrees of inhibition (Frame et al. 1998). *Mammea americana* showed the greatest inhibitory activity at 50 μg per disc. the bactericidal inhibitory activity of *M. americana* extract was comparable to streptomycin. *Mammea americana* and *Calophyllum brasiliense* plant extracts were among 17 Mexican medicinal plants that showed activity against *Escherichia coli* and *Staphylococcus aureus* (Yasunaka et al. 2005). Both plant extracts were highly active against *Staphylococcus aureus*. Coumarins (mammea A/BA and mammea A/AA) and xanthones, namely jacareubin and 1,3,5,6-tetrahydroxy-2-(3,3-dimethylallyl) xanthone, were isolated as the principle compounds from the plants.

Antiulcerogenic Activity

The results of studies by Toma et al. (2005) suggested that ethanolic and dichloromethane extracts of *M. americana* fruit possessed excellent antisecretory and/or gastrotective effect in all gastric ulcer models. The results further suggested that the antiulcerogenic compound(s) present in *M. americana* may be clustered in the apolar fraction. In the HCl/ethanol-induced gastric-ulcer model, ethanolic and dichloromethane extracts of *Mammea americana* fruit exerted significant inhibition of the ulcerative lesion index by 54% (12.0 mm) and 86% (3.7 mm), respectively, compared to the control value (26.0 mm). In the nonsteroidal antiinflammatory drugs (NSAID)/cholinomimetic-induced lesion model, both ethanolic and dichloromethane extracts showed antiulcerogenic effects with significant reduction in the damage to these gastric lesions of 36% (8.3 mm) and 42% (7.5 mm), respectively, as compared to the control group (13.0 mm). In the gastric ulcer induced by hypothermic-restraint stress, both extracts also showed significant activity, and inhibited the gastric lesion index by 58% and

75%, respectively. The ethanolic and dichloromethane extracts also altered gastric juice parameters as well as those of cimetidine, decreased gastric acid secretion significantly, increased pH values and significantly promoted reduced acid output. In all gastric-ulcer-induced models, the methanol extract did not show any significant antiulcerogenic activity, nor did it change gastric-juice parameters.

Trypanocidal Activity

Several mammea-type coumarins, isolated from the leaves of *Calophyllum brasiliense* and mammea A/AA from the fruit peels of *Mammea americana* exhibited in-vitro activity against epimastigotes and trypomastigotes of *Trypanosoma cruzi*, the etiologic agent of Chagas disease (Reyes-Chilpa et al. 2008). The most potent compounds were mammea A/BA, A/BB, A/AA, A/BD and B/BA, with MC100 values in the range of 15–90 μg/ml. Several active coumarins were also tested against normal human lymphocytes in-vitro, which showed that mammea A/AA and A/BA were not toxic. The results suggested that mammea-type coumarins could be a valuable source of trypanocidal compounds.

Molluscicidal Activity

Mammea americana plant extract was found to have molluscicidal activity against *Biomphalaria glabrata*, the intermediate host of *Schistosoma mansoni* (Meléndez and Capriles 2002). At 50 ppm, the extract killed all snails, indicating its potential as molluscides for the relatively cheap control of human schistosomiasis.

Traditional Medicinal Uses

In Central America, South America and the Caribbean, mammey has been used in traditional folk medicine for problems of scalp infections, diarrhoea, digestive and eye infections. Pulverised mammey seeds are used against parasitic skin diseases in Venezuela, and to control ectoparasites in dogs in Trinidad and Tobago (Lans et al. 2000). In Brzail, the pulverised seeds are regarded as a convulsant and an infusion is used for anthelmintic infestation in adults. In Trinidad and Tobago, the pulverised seeds are mixed with rum or coconut oil to treat head lice and chiggers. In the French West Indies, an aromatic liqueur called *Eau de Creole,* or *Creme de Creole,* distilled from the flowers is employed as a tonic or digestive. An infusion of the fresh or dry leaves is administered for intermittent fever.

Other Uses

The large spreading lateral roots of mammey apple may help to prevent soil erosion. It is often planted as a shade, barrier, support and windbreak tree. The glossy, dark-green, leaves and dense foliage make it a beautiful ornamental tree and it is often planted for shade around houses, parks and along avenues. The tree also provides useful timber. The heartwood is reddish or purple-brown and the sapwood much lighter. The wood is strong, fine-grained, easy to work, fairly decay-resistant and is employed for cabinetwork, pillars, rafters, decorative features of fine houses, interior sheathing, turnery and fence posts. The tree is also used for fuel. The tannin from the bark is sometimes used for home treatment of leather.

All parts of the mammey tree have insecticidal properties. Infusions of the pulverised seeds and gum from the bark and green fruit rind are used as insecticides to kill ticks, fleas and jiggers. Extracts of the fruit, bark, leaves or roots are toxic to moths, beetle larvae, cut-worms, mole crickets and also to bugs. Seed extracts are toxic to fish, chicks and hogs.

Comments

Mammea americana is often confused with the sapote, or *mamey colorado, Pouteria sapota,* which is commonly called *mammey* in Cuba.

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Terminalia catappa

Scientific Name

***Terminalia catappa* L.**

Synonyms

Badamia commersonii Gaertn., *Buceras catappa* Hitchc., *Catappa domestica* Rumph., *Juglans catappa* (L.) Lour., *Myrobalanus catappa* (L.) Kuntze, *Phytolacca javanica* Osbeck, *Terminalia badamia* Tul., *Terminalia catappa* var. *chlorocarpa* Hassk., *Terminalia catappa* var. *macrocarpa* Hassk., *Terminalia catappa* var. *rhodocarpa* Hassk., *Terminalia catappa* var. *subcordata* (Humb. & Bonpl. ex Willd.) DC., *Terminalia dichotoma* Miq., *Terminalia intermedia* Bertero ex Spreng., *Terminalia latifolia* Blanco, *Terminalia procera* Roxb., *Terminalia mauritiana* Blanco, *Terminalia moluccana* Lam., *Terminalia myrobalana* Roth, *Terminalia ovatifolia* Noronha, *Terminalia paraensis* Mart., *Terminalia procera* Roxb., *Terminalia rubrigemmis* Tul., *Terminalia subcordata* Humb. & Bonpl. ex Willd.

Family

Combretaceae

Common/English Names

Barbados Almond, Bastard Almond, Beach Almond, Bengal Almond, Catappa, Coastal Almond, Country Almond, Demarara Almond, False Kamani, Fiji Almond, Indian Almond, Katapang, Java Almond, Malabar Almond, Malay Almond, Sea Almond, Singapore Almond, Story Tree, Talisay Tree, Tavola Nut, Tropical Almond, Water Almond, West Indian Almond, Umbrella Tree

Vernacular Names

Andaman Islands: White Bombay, White Bombway;
Australia: Kotamba;
Banaban: Te Kunikun;
Benin: Ebelebo;
Brazil: Amendoeira, Amendoeira Da India, Guarda Sol, Castanhola, Chapéu-De-Sol (Portuguese);
Brunei Darussalam: Telisai, Terminalia;
Burmese: Badan;
Carolinian: Talisei, Tipapop, Tipop;
Chamorro: Talisai;
Chinese: Lan Ren Shu, Lan Ren;
Chuukese: Aas, Ahaah, As, Asaas, Asas, Sif;
Columbia: Kotamba;

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Cook Islands: Kauariki, Kauariki, Kaukauariki, Kavariki, Taraire (Maori);
Costa Rica: Alconorque;
Danish: Indisk Mandel;
Dutch: Wilde Amandel , Amandel Boom;
Eastonian: Mandliterminaalia;
El Salvador: Almendro Des Pais;
Fijian: Sivi, Tavali, Tatavola, Tavola, Tavola Lato, Tivi, Tiviloa;
French: Amandier Des Antilles, Amandier Des Indes, Amandier De l'Inde, Amandier De La Martinique, Amandier Tropical, Badamier, Myrobolan;
French Guiana: Amandeir De Cayenne;
Futuna: Telie;
Gabon: Amandier Des Tropiques;
German: Indischer Mandelbaum, Katappenbaum, Seemandelbaum, Seemandelbaumblätter;
Ghana: Abrofo-Nkate;
Haiti: Amandier Des Indes, Zanmande (Creole);
Hawaiian: Kamani, False Kamani, Kamani Haole, Kamani 'Ula;
I-Kiribati: Te Kunikun, Te Tarin;
India: Baangla Baadaam, Desi Baadaam (Bengali), Baadaam, Deshi Badam, Hijli Badam, Jangli Badam, Patee Badam (Hindu), Kadubadami, Taree (Kannada), Ketapag (Malayalam), Jangli Badam (Marathi), Desiyobadamo (Oriya), Desabadama, Inguda, Kshudrabija (Sanskrit), Inkuti, Nattu Vadam, Nattuvadumai, Saraparuppu, Vaatumai, Vadumai, Vatha Kottai (Tamil), Badamu, Nalu Badami, Tapasataruvu (Telugu);
Indonesia: Ketapang (Java), Katapang (Sundanese), Katapieng (Sumatra);
Japanese: Kobatein, Momo Tamana;
Kapingamarangi: Kekapin, Kekepin, Tikekapin, Tikekepin;
Khmer: Barang, Châmbak Barang, Kapang, Pareang Prang;
Kosraean: Sarf, Shufehf, Srifaf, Srofaf;
Kwara'Ae: Alita, Alite;
Laotian: Hu Kwang, Huu Kwaang, Hou Kouang, Sômz Moox Dông;
Malaysia: Telisai (Sabah), Jelawai Ketapang, Ketapang, Lintak (Peninsular);
Marquesas: Ma'I'I, Koa'I'I, Koua'I'I, Ta'Ie;
Marshallese: Kotal, Kotel, Kotõl, Kutil;
Nauruan: Etetah, Eteto;
Nepalese: Kaathe Badaam;
Nicobar Islands: White Bombay, White Bombway;
Nigeria: Ebelebo (*Bini*);
Niuean: Selie, Telie;
Pakistan: Jangli Badam;
Palauan: Mia, Miich;
Papiamento: Amandel;
Papua New Guinea: La Badame, Talis, Talise, Reddish-Brown Terminalia, Jara Almond;
Peru: Castana;
Philippines: Talisai (Bagobo), Dalinsi (Bikol), Dalisai (Ibanag), Logo, Lugo (Iloko), Savidug (Ivatan), Banilak, Dalasa, Hitam, Kalisai (Pampangan), Salaisai, Talisai (Sambali), Almendras, Almendro (Spanish), Taisai (Sulu),Taisi, Talisai (Tagalog), Taisi (Yakan);
Pingelapan: Tepop;
Pohnpeian: Dipwoapw, Thipwopu, Thipwopw, Tipop, Uhsass;
Portuguese: Amendoeira, Amendoeira Da India;
Rakahanga-Manihiki: Kauariki;
Rodrigues Island: Badamier;
Rotuman: Salisa;
Russian: Terminaliia Katappa;
Samoan: Talie;
Societies: 'Autara'A, 'Aua, 'Auari'I, 'Auari'Iroa;
Solomon Islands: Alite, Saori;
Spanish: Almendra, Almendrillo, Almendro, Almendro De La India, Almendron, Mirobalano, Polidrupa;
Sri Lanka: Kottamba, Kottang (Sinhalese);
Surinam: Amandelboom;
Tahitian: Auari'I-Roa, Autara, Autara'A, Autera'A, Taraire;
Taiwan: Lan Ren;
Thai: Hukwang, Taa Pang, Khon, Dat Mue;
Tokelau: Telie;
Tongan: Telie;
Tuamotuan: Autara'A;
Tuvaluan: Telie, Te Ipe;
Ulithian: Kel;
'Uvea: Telie;
Vanuatu: Natapoa (Bislama);
Vietnamese: Bàng, Bang Bien, Bang Nu'o'c;
Woleaian: Gil, Gil Gul, Gul, Keel;
Yapese: Kasas, Kel, Ker.

Origin/Distribution

The species has been spread widely by humans and the native range is uncertain. It has long been naturalised in a broad belt extending from the Indian subcontinent through southeast Asia, Northern Australia, New Guinea to the Pacific Islands. The tree is found throughout the South Pacific region, including the Solomon Islands, Vanuatu, and Fiji. It is present on nearly all the high archipelagos of Polynesia and Micronesia. More recently, the tree has also been introduced to parts of Africa and the Americas.

Agroecology

Sea Almond thrives in a maritime subtropical and tropical environment where there is little variation in diurnal or seasonal temperatures and where rainfall ranges from 1,000 to 3,000 mm annually, uniformly distributed or mainly in summers. It thrives well in areas with mean annual temperatures of 23–28°C and will tolerate temperature down to 5–7°C and it is frost intolerant. It naturally occurs on various coastal soils but is also found inland in dry or open forest near streams and in clearings at elevations of less than 300–400 m and also in semi-arid conditions. The tree is tolerant of strong winds, salt spray, and moderately high salinity in the root zone. It is adapted to a wide range of soils with a wide pH range from 4 to 8, including light textured soils, raised sandy and rocky beaches, brackish, saline and alkaline sands over limestone, but requires good drainage when grown on heavier, clayey soils. It abhors waterlogged soils. It does best in full sun and in freely drained, well-aerated, sandy soils but will withstand flooding as occurs in Florida.

Edible Plant Parts and Uses

Kernels of ripe fruit are eaten fresh or roasted. The kernels are usually consumed fresh shortly after extraction from the shell as it starts to mould within 1–2 days at ambient temperatures. The kernels can be preserved by smoking and consumed up to a year later. In some areas the kernels are consumed as snack food by children, with the fleshy outer flesh also sometimes being eaten. The sun-dried kernels also yield 38–55% oil of acceptable flavour, edible like almond oil nut but the yellow oil becomes turbid on standing (Howes 1948; Hedrick 1972; Rosengarten 1984; Morton 1985). In the Philippines, a wine is processed by fermenting mature fruits.

Botany

A medium to large, unarmed, semi-deciduous, monoecious tree, 25–40 m high, with spreading, symmetrical crown and whorls of horizontal branches, forming tiers resembling a pagoda framework. The trunk is cylindrical 20–47 cm diameter, crooked or straight, occasionally shallowly buttressed, with greyish-brown, rough flaky (sometimes fissured) bark. Leaves are produced at the end of branches in a spiral manner (Plate 1–2). Leaves are large, broadly obovate, (10-) 20–43 cm long, (6-) 12–21 cm wide, brown puberulent, when young becoming glabrous, glossy dark green, coriaceous, apex acuminate to emarginate, base subcordate, margin entire, lateral veins 10–12 pairs, petioles 1–2 cm long. Flowers are white or cream coloured, fragrant, small, 4–6 mm across, apetalous, in 1- several, axillary or terminal spikes, 10–25 cm long. Within a spike the majority of the flowers are male, with only a few bisexual flowers

Plate 1 Leaf and fruit of water almond

Plate 2 Glossy large leaves

Plate 3 Ripening water almond fruits

Plate 4 Close-up of water almond fruit

positioned toward the base. Perfect flowers with calyx tube distinctly narrowed above ovary, 5 lobed with teeth 1–1.5 mm long, stamens 10 free joined to perianth, ovary 1-loculed, style solitary; staminate flowers apparently on slender pedicels 1.5–2.5 mm long. The fruit is an indehiscent, glabrous drupe 5–7 cm long by 3–5.5 cm broad, ellipsoid, somewhat compressed, narrowly winged along lateral margins, green at first, then yellow and finally red or purplish when ripe (Plates 1–4), mesocarp firm to leathery, fibrous containing a single seed, 1–10 mm diameter. The seed consists of two delicate and intricately entwined cotyledons enclosed in an inconspicuous cream coloured, rarely red, testa.

Nutritive/Medicinal Properties

The nutritive value of raw tavola per 100 g edible portion (2%) collected from Fiji and Vanuatu (in brackets) was reported as follows: energy 414 kcal, 1,734 kJ (258 kcal, 1,080 kJ). water 30.7 g (51.6 g), protein 15,9 g (9.6 g), fat 39.9 g (24.0 g), sugars 0.2 g (2.4 g), starch <0.1 g (<0.1 g), ash 3.5 g (3.5 g), dietary fibre 7.5 g (5.9 g), β-carotene equivalent <5 μg (9 μg), thiamin 0.09 mg (0.11 mg), riboflavin 0.05 mg (<0.02 mg), niacin 0.6 mg (0.8 mg), vitamin C 4 mg (11 mg), Na 6 mg (8 mg), K 688 mg (567 mg), Ca 230 mg (83 mg), Fe 4.6 mg (3.2 mg), Mg 335 mg (257 mg), Zn 4.9 mg (3.4 mg), cu 2.0 mg (1.1 mg), Mn 1.2 mg (0.8 mg) (English et al 1996). The inedible portion is the husk covering the seed (nut). The edible fleshy outer cover (50–55%) of two different varieties, red and yellow of *Terminalia catappa* fruit in their ripe and unripe stages, were analyzed for proximate and mineral composition along with phytochemicals (Dikshit and Samudrasok 2011). Per 100 g sample, the red variety was shown to be a rich source of protein (1.95 g vs. 1.65 g) while the yellow variety had higher levels of carbohydrate and ash (12.03 g vs. 6.14 g and 1.21 g vs. 0.70 g respectively). Of the phytochemicals, β-carotene and vitamin C were found to be present in higher quantities in the red variety (2,090 μg versus 754 μg and 138.6 mg versus 105.4 mg), wherein the former increased while the latter decreased with ripening of the fruit.

Air-dried kernels were reported to contain 52.0% fat, 25.4% protein, 14.6% fibre, 6% glucose and a small percentage of ash. Indian almond oil was reported to contain glycerides of palmitic acid 34.4%, oleic acid 32.1%, linoleic acid 27.5% and stearic acid 6%; it closely resembled sweet almond, cotton seed, kapok

and groundnut oils and could substitute for them for dietetic and industrial uses (Morton 1985).

The optimal oil yield from milled seeds of *Terminalia catappa* using petroleum ether in a Soxhlet extractor was 56.71% with a viscosity of 40.79 centipoises (Omeje et al. 2008). Other parameters of the oil were as follows: specific gravity -0.9248, refractive index -1.4646, acid value -3.35, peroxide value -8.6, saponification value -166.2, and unsaponifiable matter -1.46. The crude oil extract was water-degummed, bleached and deodorized to generate refined oil. Autoxidation of the crude and refined oil extract was performed at five different temperatures of 0°C, 20°C, 40°C, 60°C and 80°C and also in the presence of pure α-tocopherol at a concentration of 1.0% (w/v) by measuring peroxide value variations over 96 h. In all evaluations, the refined oil exhibited lower tendency towards autoxidation but not at temperatures above 60°C. The use of Arrhenius equation revealed generally very low activation energies of 0.0261 cal/deg-mol and 0.0122 cal/deg-mol for crude oil and antioxidant-treated crude oil, respectively and 0.0690 cal/deg-mol and 0.0177 cal/deg-mol for the refined oil. The data indicated *T. catappa* seed oil to be a potential pharmaceutical oil with excellent characteristics.

Other Phytochemicals

The supercritical fluid extracted flavour components during the roasting of *Terminalia catappa* nuts revealed 74 aroma active compounds made up of 27 hydrocarbons, 12 aldehydes, 11 ketones, 7 acids, 4 esters, 3 alcohols, 5 furan derivatives, a pyrazine, and 2 unknown compounds (Lasekan and Abbas 2010). While low amounts of acrylamide (8–86 μg/kg) were obtained in the roasted nuts, significant increases occurred in concentration with increased roasting temperature and time. Carboxylic acids were the most abundant volatiles in the roasted almond nuts and less significant amount of acrylamide was generated with mild roasting and shorter roasting period. The fruit of *T. catappa* was reported to contain corilagin, brevifolin-carboxylic-acid, β-carotene, cyanidin-3-glucoside, ellagic-acid, gallic-acid, glucose, pentosans, tannin (Duke 1994+). Other phytochemicals are also mentioned below.

The leaves were found to be rich in tannins, flavonoid glycosides, other phenolic compounds, triterpenoids and squalene. The leaves were found to contain four new hydrolyzable tannins named terflavins A and B, tergallagin and tercatain , together with eight known tannins: punicalin, punicalagin, chebulagic acid, geraniin, granatin B, 1-desgalloyleugeniin, corilagin and 2,3-[(S)-4,4′, 5,5′, 6,6′-hexahydroxydiphenoyl]-D-glucose (Tanaka et al. 1986). Six phenolic compounds were identified in the leaves: p-hydroxybenzoic acid, 4-hydroxyphenylpropionic acid, m-coumaric acid, 3,4-dihydroxybenzoic acid, p-coumaric acid and gallic acid (Chyau et al. 2006). Leaves were also found to contain flavonoid glycosides, apigenin 6-C-(2²-O-galloyl)-β-D-glucopyranoside and apigenin 8-C-(2²-O-galloyl)-β-D-glucopyranoside, together with four known flavone glycosides, isovitexin, vitexin, isoorientin, and rutin (Lin et al 2000). Leaves also contained triterpenoids: ursolic acid and 2α,3β,23-trihydroxyurs-12-en-28-oic acid (Fan et al. 2004). A total of 18 compounds were identified in the volatile aromatic components of leaf extracts (Mau et al. 2003). Among them, three highest amounts of compounds were ethyl acetate, 6,10,14-trimethyl-2-pentadecanone and phytol. Although (*E*,*E*)-2,4-decadienal with oily odour was not high in content, it was odour significant due to its odour value of 18,572–31,714. β-Ionone with the highest odour value of 82,857–445,715 was described as a fruity, floral aroma. *Terminalia catappa* leaf color ranges from red to yellow and it was found to be a potential source of natural pigments (López-Hernández et al. 2001). Seven pigments were identified in the leaf extracts: violaxanthin, violeoxanthin, lutein epoxide, lutein, two lutein isomers and β-cryptoxanthin.

Chemical investigation of the dichloromethane and n-butanol soluble fraction from the methanol extracts of the bark of *Terminalia catappa* yielded β-sitosterol, oleanolic acid, betulinic acid, β-sitosterol-D-glucoside,28-O-β-D-glucopyranosylarjunolic

acid and arjunolic acid (Diyabalanage et al. 1997). Coliragin and ellagic acid were identified in the acetone extracts of the bark, leaves and fruit (Rayudu and Rajadurai 1966). The following phytochemicals were reported from the bark of *Terminalia catappa*: gallic acid, 2,3-(S)-HHDP-D-glucose, punicalagin, corilagin, tercatain, casuarinin, castalagin, grandinin , castalin ,3-methoxy-4-hydroxyphenol-1-O-β-D-(6é-Ogalloyl)-glucoside, 3,5-dimethoxy-4-hydroxyphenol-1-O-β-D-(6é-O-galloyl)-glucoside, (+)-catechin, (−)-epicatechin, 3,3',4-tri-omethyl-ellagic-acid, 3,3'-di-o-methyl-ellagic-acid, (−)-epicatechin-3-O-gallate,(−)-epigallocatechin-3-O-gallate, procyanidin B-1, 3é-O-galloyl procyanidin B-2, acutissimin A, eugenigrandin A, arjunolic-acid, arjunolic-acid-28-o-β-d-glucoside, β-sitosterol, β-sitosterol, betulinic-acid, daucosterol, ellagic-acid, leucocyanidin , oleanolic acid, oxalic-acid (Duke 1994+).

Various parts of the plant have been reported to have various pharmacological activities:

Antioxidant Activity

T. catappa leaves were found to have potent antioxidant activity. Aqueous extracts from leaves of three different maturity stages: green, yellow fallen and red fallen showed high antioxidant activities and moderate scavenging abilities on hydroxyl radicals at 1 mg/ml (Chyau et al. 2006). EC_{50} values in antioxidant activity were 0.549–0.557 mg/ml whereas those in scavenging ability on hydroxyl radicals were 0.631–0.686 mg/ml for aqueous extracts. EC_{50} values in reducing power were 0.15–0.23 mg/ml. EC_{50} values in scavenging abilities on superoxide anion and 1,1-diphenyl-2-picrylhydryl (DPPH) radicals were 0.36–0.44 and 10.4–35.3 mg/ml, respectively. EC_{50} values in chelating abilities on ferrous and cupric ions were 0.41–2.50 and 8.96–9.89 mg/ml, respectively. Based on the results obtained, the aqueous extracts displayed higher antioxidant properties. Six phenolic compounds identified in the aqueous extract were 4-hydroxyphenylpropionic acid, *m*-coumaric acid, *p*-hydroxybenzoic acid, 3,4-dihydroxybenzoic acid, *p*-coumaric acid and gallic acid. The scientists suggested that the aqueous extracts from three different leaf maturity types may have potential as antioxidant supplement for application in food products or as a drink. In earlier studies, the scientists also compared solvent extracts prepared from green, yellow fallen and red fallen leaves of *Terminalia catappa* for their antioxidant activities including reducing power, scavenging and chelating effects (Chyau et al. 2002). The yields were consistently in the order of yellow fallen (6.34–10.50%) > red fallen (5.12–9.98%) > green leaf extracts (2.36–6.08%) for four solvents used. Higher yields were obtained from extraction with ethyl acetate or methanol than with dichloromethane or pentane. For three different leaf types, the antioxidant activities were in the order methanol > ethyl acetate > dichloromethane > pentane extracts and all showed a parabolic-like curve with the maximum at 0.1–0.5 mg/ml of solvent extract. Reducing powers of three methanolic extracts and their scavenging effects on DPPH radicals were excellent at 0.5 and 0.1 mg/ml, respectively. At 30 mg/ml, chelating effects of methanolic extracts from green, yellow fallen and red fallen leaves on ferrous ions were 77.3%, 48.6% and 48.3%, respectively.

Leaves also contain flavonoid glycosides: apigenin 6-C-(2²-O-galloyl)-b-D-glucopyranoside and apigenin 8-C-(2²-O-galloyl)-b-D-glucopyranoside. Both compounds showed significant antioxidative effects (Lin et al. 2000). Their IC_{50} were 2.1 and 4.5 mm, respectively. The tannin components of *T. catappa* extract exhibited their ability to prevent lipid peroxidation, superoxide formation and their free radical scavenging activity (Lin et al. 2001a). Punicalagin and punicalin isolated from the leaves were the most abundant components and had the strongest anti-oxidative effects of this group of tannins.

Separate studies showed that supercritical CO_2 extracts of *T. catappa* leaves exhibited potent antioxidative and DPPH scavenging activities that increased with leaf maturity. Its squalene contents also increased with increasing leaf maturity (Ko et al. 2002). The leaf extracts displayed potent inhibition of conjugated diene hydroperoxide (CDHP) formation in a pork fat storage system. However, the seed extracts only exhibited potent inhibition of

CDHP formation and very low DPPH scavenging activity. Supercritical carbon dioxide extraction at 2,000 psi and 40°C resulted in the extracts with better antioxidant activity whereas lower inhibition of peroxidation was observed with the extracts prepared from the extraction at 4,000 psi and 40°C (Mau et al. 2003). With respect to the antioxidant activity by the 1,3-diethyl-2-thiobarbituric acid method, the extracts from yellow fallen and red fallen leaves exhibited higher inhibition of peroxidation than those from green leaves.

Hepatoprotective Activity

Various scientific studies have shown that the leaves have hepatoprotective and antiheptotoxic activities which are associated with the antioxidant activities of the phytochemicals.

In the acute hepatic damage test, notable elevation in the activity of serum alanine aminotransferase (ALT) and aspartate aminotransferase (AST) (5.7-fold and 2.0-fold) induced by CCl^4 were reversed and significant morphological changes were attenuated by pre-treatment with 50 and 100 mg/kg of chloroform extract of *Terminalia catappa* leaves (Gao et al. 2004). In the hepatocyte injury experiment, the increases in ALT and AST levels (1.9-fold and 2.1-fold) in the medium of primary cultured hepatocytes induced by D-GalN were thwarted by pre-treatment with 0.05, 0.1, 0.5 g/L of the extract. Further, Ca^{2+}-induced mitochondrial swelling was dose-dependently prevented by 50–500 μM ursolic acid and asiatic acid. Both ursolic acid and asiatic acid, at concentrations ranging from 50 to 500 μM, exhibited dose-dependent superoxide anion and hydroxyl radical scavenging activity. The study concluded that leaf extract had hepatoprotective activity and the mechanism was related to protection of liver mitochondria and hepatocytes and the scavenging action on free radicals. Separate studies showed that increases in the activity of serum aspartate aminotransferase and alanine aminotransferase and the level of liver lipid peroxidation (2.0-fold, 5.7-fold and 2.8-fold) induced by CCl^4 were significantly inhibited by oral pre-treatment with 20, 50 or 100 mg/kg of *Terminalia catappa* leaves extract (Tang et al. 2006). Morphological observation further confirmed the hepatoprotective effects of the leaf extract. Additionally, the disruption of mitochondrial membrane potential (14.8%), intramitochondrial Ca^{2+} overload (2.1-fold) and inhibition of mitochondrial Ca^{2+}–ATPase activity (42.0%) in the liver of CCl^{4-}insulted mice were effectively inhibited by pre-treatment with the leaf extract.

A water extract of the leaves of *T. catappa* showed a strong radical scavenging action for 1,1-diphenyl-2-picrylhydrazyl and superoxide (O^{2-}) anion (Kinoshita et al. 2007). Chebulagic acid and corilagin were isolated as the active components from *T. catappa* leaves. Both antioxidants exhibited potent scavenging activity for O^{2-} and peroxyl radicals and also inhibited reactive oxygen species production from leukocytes stimulated by phorbol-12-myristate acetate. Galactosamine (GalN, 600 mg/kg, s.c.,) and lipopolysaccharide (LPS, 0.5 μg/kg, i.p.)-induced hepatotoxicity of rats as evidenced by an elevation of serum alanine aminotransferase and aspartate aminotransferase and glutathione S-transferase (GST) activities were significantly reduced when the leaf extract or corilagin was given intraperitoneally to rats prior to GalN/LPS treatment. Increase of free radical formation and lipid peroxidation in mitochondria caused by GalN/LPS treatment were also decreased by pretreatment with the herb/corilagin. In addition, apoptotic events such as DNA fragmentation and the increase in caspase-3 activity in the liver observed with GalN/LPS treatment were inhibited by the pretreatment with the herb/corilagin. These results showed that the leaf extract of *T. catappa* and its antioxidant, corilagin were protective against GalN/LPS-induced liver injury through suppression of oxidative stress and apoptosis.

Terminalia catappa chloroform leaf extract was also found to have hepatoprotective activity and the mechanisms underlying its protective effects was shown to be related to the suppression of the over expression of interleukin IL-6 gene in liver (Tang et al. 2003). CCl_4-treated mice produced an increase in serum ALT activity and in IL-6 mRNA level, however the increases were

reverted by oral pre-treatment of the chloroform extract. In addition, histological changes such as the infiltration of numerous inflammatory cells and hepatocyte swelling in injured mice were effectively mitigated by the pre-treatment of the extract.

Treatment with *T. catappa* water extracts showed antihepatotoxic activity against CCl_4-induced toxicity in the rat liver (Lin et al. 1997). The crude drug also exhibited anti-oxidant effects in $FeC1_2$-Ascorbic acid induced lipid peroxidation in the rat liver homogenate. Further, the superoxide radical scavenger effect of *T. catappa* was demonstrated using electron spin resonance (ESR) and spin-trapping technique. The results indicated that *T. catappa* possessed good antihepatotoxic activity and superoxide radical scavenger activity. Studies also showed that punicalagin and punicalin isolated from the leaves of *Terminalia catappa* exerted antihepatotoxic activity, antioxidant activity at low doses (Lin et al. 2001b). The levels of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) were increased by acetaminophen administration but reduced by punicalagin and punicalin. Histological changes around the hepatic central vein and oxidative damage induced by acetaminophen were also restored by both compounds.

Anticancer Activity

Morioka et al. (2005) found that oral administration of *Terminalia catappa* (TC) at two doses, 0.02% and 0.1% significantly decreased the numbers of both aberrant crypt foci (ACF)/colon/rat and β-catenin accumulated crypts (BCAC)/cm^2/rat, when compared with the control group. Colonic proliferating cell nuclear antigen (PCNA) labelling index in TC treated and control rats was also significantly lower than that in rats injected with azoxymethane. These results suggested that *Terminalia catappa* had a potent short-term chemopreventive effect on biomarkers of colon carcinogenesis and this effect may be associated with the inhibition of the development of ACF and BCACs.

Another study reported that *T. catappa* leaf extract exerted a dose-dependent inhibitory effect on the invasion and motility of highly metastatic A549 and Lewis lung carcinoma (LLC) cells (Chu et al. 2007). The leaf extract treatment was found to decrease the expressions of matrix metalloproteinase-2, matrix metalloproteinase-9, urokinase plasminogen activator and their endogenous inhibitors, in a concentration-dependent manner. Moreover, the inhibitory effect of the extract on the growth and metastasis of LLC cells in-vivo was confirmed. These results indicated that the leaf extract could be used as a potential antimetastatic agent.

Further studies showed that *T. catappa* leaf extract and punicalagin, the major tannin component of the leaves exhibited chemopreventive effect against H-ras induced transformation which could have resulted from inhibition of the intracellular redox status and JNK-1/p38 (stress activated protein kinases) activation (Chen and Li 2006). The leaf extract and punicalagin inhibited the proliferation of H-Ras-transformed NIH3T3 cells (a mouse embryonic fibroblast cell line) in a dose-dependent manner. Punicalagin treatments lowered the intracellular superoxide level, which modulated downstream signaling of Ras protein and the levels of phosphorylated JNK-1 and p38. In a recent study, the ethanol extract of *T. catappa* leaves (TCE) was found to significantly suppress the cell migration/invasion capacities of SCC-4 oral cancer cells (Yang et al. 2010). Additionally, the activities and protein levels of MMP-2, MMP-9 and u-PA were all suppressed by TCE. TCE also inhibited phosphorylation of ERK1/2, JNK1/2 and Akt while the expression of nuclear protein NF-kappaB, c-Jun and c-Fos were also suppressed. TCE also reduced the DNA-binding activity with AP-1 and NF-kappaB. That data suggested that TCE may serve as a powerful chemopreventive agent against oral cancer metastasis.

Antimutagenic Activity

Super critical carbon dioxide ($SC\text{-}CO_2$) extracts of *Terminalia catappa* leaves at a dose of 0.5 mg/

plate exhibited antimutagenicity and toxicity (Ko et al. 2003). Mutagenicity was not detected using the Ames test. The antimutagenic activity of SC-CO2 extracts increased with decreases of extraction temperature (60°C, 50°C, and 40°C) and pressure (4,000, 3,000, and 2,000 psi). The most potent antimutagenicity was observed in extracts obtained at 40°C and 2,000 psi. The SC-CO2 extracts were more cytotoxic to human hepatoma Huh 7 cells than to normal Chang liver cells.

Anticlastogenic Activity

The water extract of the leaves of *Terminalia catappa* was found to inhibit mitomycin C-induced micronuclei in CHO-K1 cells (Liu et al. 1996). The simultaneous and pre-treatment of CHO-K1 cells with *T. catappa* extract (75 and 150 μg/ml) reduced mitomycin C-induced micronuclei. In addition, gastric intubation of *T. catappa* extract (4.8 and 24 mg/animal per day) to male ICR mice for 8 days significantly suppressed mitomycin C-induced micronuclei in peripheral blood. In addition, *T. catappa* inhibited lipid peroxidation in-vitro and 12-O-tetradecanoylphorbol-13-acetate (TPA)-induced hydrogen peroxide formation in human mononuclear leukocytes in a dose-dependent manner. The anticlastogenic effects of *T. catappa* in-vitro and in-vivo was suggested to be attributed to its antioxidative potential.

Anti-HIV Activity

T. catappa was one of 15 plants screened among 100 plants, that exhibited anti-HIV activity. Studies reported that punicalin and punicalagin isolated from the leaves, inhibited HIV replication in infected H9 lymphocytes with little cytotoxicity (Nonaka et al. 1990). Two compounds, punicalin and punicacortein C, inhibited purified HIV reverse transcriptase with ID_{50} of 8 and 5 μM, respectively. All tannins appeared to inhibit virus-cell interactions.

Antigenotoxic Activity

Terminalia catappa leaf water extract (TCE) and its major tannin component, punicalagin, exhibited prophylactic effects on bleomycin-induced genotoxicity in cultured Chinese hamster ovary cells (Chen et al. 2000). Pre-treatment with TCE or punicalagin prevented bleomycin-induced HGPRT (hypoxanthine-guanine phosphoribosyl transferase) gene mutations and DNA strand breaks. TCE and punicalagin inhibited the generation of bleomycin-induced intracellular free radicals, identified as superoxides and hydrogen peroxides. The effectiveness of TCE and punicalagin against bleomycin-induced genotoxicity could be, at least in part, be attributed to their antioxidative potentials.

Antidiabetic, Hypoglycaemic Activity

Studies reported that all the three extracts: petroleum ether, methanol, and aqueous of *Terminalia catappa* fruit produced a significant antidiabetic activity at concentration levels 1/5 of their lethal doses in alloxan-induced diabetic rats when tested using fasting blood sugar levels and serum biochemical analysis (Nagappa et al. 2003). Simultaneous histological studies of the pancreas of these animals showed comparable regeneration by methanolic and aqueous extracts which were earlier necrosed by alloxan. Similar results were obtained for aqueous and cold extract of *Terminalia catappa* leaves. Both extract exhibited significant antihyperglycemic activities in alloxan-induced diabetic rats (Ahmed et al. 2005). These extracts produced improvement in parameters like body weight and lipid profile as well as regeneration of β-cells of pancreas and so might be of value in diabetes treatment.

A separate study reported 70% ethanol leaf extract (300 mg/kg/day) exhibited significant antihyperglycemic activity in glucose loaded rats and in alloxan induced diabetic rats with significant improvement in body weight, protein, albumin, haemoglobin level and decrease in blood glucose and urea (Tenpe et al. 2007). Results

showed that *T. catappa* had good glucose lowering property when administered to alloxan induced diabetic rats. Another study found that the leaves contained an α-glucosidase inhibitor which had an IC_{50} of 3.43 ug/ml (Anam et al. 2009). α-glucosidase is the key enzyme which catalyses the final step in the digestive process of carbohydrates in mammalian Hence, α-glucosidase inhibitors can retard the liberation of D-glucose of oligosaccharides and disaccharides from dietary complex carbohydrates and delay glucose absorption, resulting in reduced postprandial plasma glucose levels and suppressed postprandial hyperglycaemia. The studies indicated that the leaves had potential to be developed into a physiological functional food or lead compounds for antidiabetic agents.

Antiinflammatory Activity

Terminalia catappa leaf ethanolic extract was reported to exhibit strong antiinflammatory activity using 12-O-tetradecanoylphorbol-13-acetate (TPA)-induced ear edema in acute and chronic models (Fan et al. 2004). The studies found that the triterpenic acids: ursolic acid and 2α,3β,23-trihydroxyurs-12-en-28-oic acid, isolated from the chloroform fraction were responsible for the antiinflammatory activity of *T. catappa* leaves.

In another study, punicalagin and punicalin isolated from the leaves of *Terminalia catappa* were found to have antiinflammatory activities (Lin et al. 1999). The edema rates were augmented by carrageenan administration and decreased by drug treatment. After 4 hours of carrageenan administration, the best effect group was the punicalagin (10 mg/kg) treated group (inhibition rate, 58.15%), and the second was the punicalagin (5 mg/kg)-treated group (inhibition rate, 39.15%). The data showed that both punicalagin and punicalin exerted antiinflammatory activity, but treatment with larger doses of punicalin may induce some cell damages.

The ethanolic extract of *Terminalia catappa* (TCSE) leaves was found to exhibit analgesic and anti-inflammatory (Annegowda et al. 2010). In the formalin induced pain test, 80 mg/kg (p.o.) dose of TCSE extract inhibited both the phases of animal's nociception, but TCSE extracts (40 mg/kg, per os) inhibited only the late phase. TCSE extract at 80 mg/kg, per os showed a significant increase in the reaction time in the hot plate test at the time intervals of 60, 90 and 120 minutes. In contrast, both the doses of TCSE extracts did not elicit any analgesic effect in the tail flick test. TCSE extracts showed moderate ABTS free radical scavenging activity compared to the standard gallic acid and higher activity compared to BHT (88.07%, 96.35% and 68.76% of inhibition, respectively) but showed less ability to chelate ferrous ion.

Antimicrobial Activity

The chloroform extract of the bark showed prominent antimicrobial activity against *Staphylococcus aureus* and *Escherichia coli* as compared to other tested microorganisms, while petroleum ether extract was devoid of antimicrobial activity (Pawar and Pal 2002). The methanolic extract exhibited MIC of 0.065 mg/ml against *E. coli* and chloroform extract exhibited MIC of 0.4 mg/ml against *S. aureus*. The chloroform and methanolic extracts showed good antimicrobial activity against Gram positive and Gram negative microorganisms. In a separate study, methanolic leaf extract was found to be considerably more effective than aqueous extract in inhibiting the microbial strains comprising 10 Gram positive, 12 Gram negative bacteria and one fungus, *Candida tropicalis*. In another study, the extracts derived from *Terminalia catappa* leaves were screened for their antibacterial activity against species of *Corynebacteria, Staphylococci, Streptococci, Enterococci, Escherichia, Salmonella* and *Shigella* (Naz et al. 2007). The results indicated that crude ethanolic extract, aqueous fraction of crude extract and its subfractions (petroleum ether and ethylacetate) possessed prominent antibacterial activity. Phytochemical analysis of the five fractions yielded ferulic acid, vanillic acid, pelargonidin,

cyanidin, myricetin, quercetin and gallic acid. Studies conducted in Indonesia reported that *Terminalia catappa* was one of six plants which demonstrated high antibacterial and antifungal activities, out of 20 plant species screened (Goun et al. 2003).

Aphrodisiac Activity

The kernel of *T. catappa* seeds was found to have aphrodisiac activity and may be useful in the treatment of certain forms of sexual inadequacies, such as premature ejaculation (Ratnasooriya et al. 2000). The 1,500 mg/kg dose seeds in a suspension of its kernel in 1% methyl cellulose, had a marked aphrodisiac action (prolongation of ejaculation latency) in rats but no effect on libido (mounting, intromission and ejaculation), sexual vigour (mounting-and-intromission frequency), or sexual performance (intercopulatory interval). In contrast, the higher dose (3,000 mg/kg) reversibly inhibited all the parameters of sexual behaviour other than mounting-and-intromission frequency and copulatory efficiency. The effects of high dose were not due to general toxicity, liver toxicity, haemotoxicity, stress, muscle deficiency, muscle incoordination, analgesia, hypoglycaemia nor reduction in blood testosterone level. They were found to be due to distinct sedation.

Antinociceptive Activity

In an investigation of analgesic, antihyperalgesic and antiinflammatory activities of *T. catappa*, the 10 and 15 ml/kg doses of tender leaf water extract significantly elevated the reaction time and altered the percent maximum possible effect at 3 hours post treatment in the hot plate test (Ratnasooriya et al. 2002). In contrast, none of the doses exhibited analgesic activity in the tail flick test. Further, in female animals, the 10 ml/kg dose induced a significant analgesia as in males, and this effect was not affected by the stage of the oestrous cycle. The antinociceptive action of the extract was not obstructed by naloxone nor by metachlopramide. Further, the extract was devoid of sedative activity. In the carrageenan study, the extract showed neither antiinflammatory nor antihyperalgesic activities. In the formalin pain test, the extract significantly reduced the pain in the early phase but not in the late phase. It was concluded that *T. catappa* leaf extract was useful as an analgesic but not as an antihyperalgesic in mild to moderate pain, supporting its folkloric use in Sri Lanka.

Angiotensin-Converting Enzyme (ACE) Inhibition

Plants that were popularly used as antihypertensive and/or diuretics were evaluated for ACE inhibition. The following plants were found to have significant ACE inhibition rates: *Calophyllum brasiliense, Combretum fruticosum, Leea rubra, Phoenix roebelinii* and *Terminalia catappa* (Braga et al. 2007). ACE is an exopeptidase, a circulating enzyme that participates in the body's renin-angiotensin system (RAS) which mediates extracellular volume and arterial vasoconstriction.

Toxicological Evaluation

In a short-term toxicological evaluation, the oils of *Calophyllum inophyllum, Pentaclethra macrophylla* and *Terminalia catappa* were fed to rats (Ajayi et al. 2008). Weekly monitoring of the rats showed good physical appearance and steady weight gain, with no mortality recorded for the period of the study. Haematological analysis of the rats indicated that they were not anaemic. Histopathological examination of the sections of the heart, liver, kidney and spleen revealed moderate (*T. catappa* oil) to severe fatty change and necrosis in the liver. Glomerulonephrotic changes in the kidneys of rats fed with *T. catappa* oil were moderate, while it was severe in the group fed with *P. macrophylla* oil. Severe myocardiac necrosis as well as atherosclerotic clefts in vasa vasori was observed in the vasa vasori of the hearts of rats fed with *P. macrophylla* oil. This change was moderate in the heart of rats fed with

C. inophyllum, while no such observation was made in the group fed with *T. catappa* oil. There was a significant difference in the plasma cholesterol levels of the rats fed with *C. inophyllum* and *T. catappa* oils when compared with the control rats, while those fed with *P. macrophylla* oil had no significant difference. The oil of *T. catappa* appeared more suitable for consumption than the oils from *C. inophyllum* and *P. macrophylla*. Fatty acid analysis of the oils showed that they had high amounts of unsaturated fatty acids with linoleic and oleic acids as the main ones.

Traditional Medicinal Uses

In folkloric medicine, the fruit is considered bitter, acrid, astringent purgative and aphrodisiac. The fruit is useful in bronchitis and bowels and for diabetes. The leaves are maturant and emollient; the juice of leaves is used in the preparation of ointment for scabies, leprosy and other cutaneous diseases in India. Leaves are used as anthelminthic to expel parasitic worms. Leaves mixed with oil are rubbed onto the breast to relieve mammary pain. Leaves are applied to rheumatic joints. Leaves macerated in oil has been used for tonsillitis in Nigeria. In Taiwan. Leaves are popular folk medicine for preventing hepatoma and treating hepatitis and for dermatitis. In Suriname, a tea made from the leaves is prescribed against dysentery and diarrhoea. In Sri Lankan folklore, juice of tender leaves are used for pains, including headaches. Leaves act as sudorifics and applied to rheumatic joints and for dysentery in Indo China. An infusion of the young leaves or scraped bark is occasionally taken as a potion for treating mouth infections in Tonga and Samoa and is used in the Cook Islands to bathe fractures. Juice from young leaves is used in the Philippines to cure headache and colic. In India, the bark is used as a diuretic and cardiotonic. In Nigeria, stems and bark, and seeds used for sexual dysfunction. Bark is used as astringent for gastric ailments, bilious diarrhoea and dysentery etc. from India throughout southeast Asia. In Indonesia, the bark is used for thrush. In the Philippines, the bark decoction has been used for the treatment of gonorrhoea and stomach cramps.

Other Uses

Terminalia catappa is widely planted along the coast in tropical regions of the world for its 'umbrella-wide' shade, ornamental purposes, and edible nuts. It has a spreading, fibrous root system and plays an important role in stabilization of sandy beaches. In south east Asia, the tree is grown in coastal villages and as avenue trees inland. It also furnishes an excellent, strong, solid and durable, reddish hardwood which is well suited for conversion into furniture, flooring and interior building timbers. Larger logs are suitable for veneer and plywood manufacture. The wood has high water resistance; it has been utilized in Polynesia for making canoes. In Malacca, Malaysia the timber has been used for house and boat construction, also for carts, planks and troughs. In the south Pacific islands the wood is also used for crafts and tools such as kava bowls, tool handles, clubs, walking sticks, paddles, and drums. The wood is also suitable for furniture, veneer and cabinetwork, boxes, crates, bridge timbers, pillars, cross-ties, flooring, beams, poles and plywood. The wood is also used as fuel wood. The bark, leaves, fruit shells and roots are rich in tannins which may be used for staining/dyeing fabrics including tapa, tanning leather, and ink-making. The leaves are sometimes used to wrap and carry food in the Pacific. In Thailand, the leaves have been employed by Betta fish breeders to lower the pH and heavy metals of the water. Leaves are used as feed for the Tassar-silkworm (*Antheracea mylitta* Drury). Oilcake is used as pig feed. Kernel oil is used for making soap but its industrial use is limited by the difficulty in extracting the kernel. Studies reported that the oil was obtained from the kernels of the *Terminalia catappa* fruit, with yields around 49% (% mass) had quite similar fatty acid composition to that of conventional oils (Dos Santos et al. 2008). The crude oil of *T. catappa* was trans-esterified, using a conventional catalyst and methanol to produce biodiesel. The physicochemical properties of *T. catappa* biodiesel were found to be in the acceptable range for use as biodiesel in diesel engines.

Comments

The plant is easily propagated from freshly collected seeds. Seeds stored at ambient conditions for longer than 8 weeks lose their viability.

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Terminalia ferdinandiana

Scientific Name

***Terminalia ferdinandiana* Exell**

Synonyms

Myrobalanus edulis Kuntze, *Terminalia edulis* F. Muell. nom. illeg., *Terminalia latipes* subsp. *psilocarpa* Pedley, *Terminalia prostrata* Pedley

Family

Combretaceae

Common/English Names

Billy Goat Plum, Green Plum, Gubinge, Kakadu Plum, Salty Plum, Wild Plum

Vernacular Names

Australia: Gubinge, Manmohpan, Marnybi, Murunga (Aboriginal), Arangal, Madoorr, Gubinge (Bardi People) Kabinyn (Nyul Nyul) and Gabiny (Yawuru).

Origin/Distribution

The species is native to Australia, concentrated to the top half of the Northern Territory to eastern Arnhem Land and the Kimberley region of north-western Australia.

Agroecology

It occurs in the tropical belt of Northern Australia and is found in sand plains behind beaches, dry creek beds, flood plains, cliff tops, ridges, coastal vine thickets, mangrove edges and woodlands. It grows on red sand, sandy clay, black peat, sandstone, ironstone, granite.

Edible Plant Parts and Uses

Kakadu plum is a traditional food of some Australian Aboriginal communities in north-western and northern Australia who eat the fresh ripe fruits, seeds, and prepare a drink from the fruits. Fresh or dried fruits can also be soaked in water for a day or two to make a refreshing drink. Kakadu plum is also used in modern cuisine. The flesh of the fruit is used for jams, preserves, relishes, sauces, juices and ice cream flavouring. Kakadu

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Plate 1 Tree habit (C. Ham)

Plate 2 Harvested Kakadu plums (C. Ham)

Plate 3 Ripe Kakadu plum fruit and seed

Plate 4 Vacuumed packed and frozen Kakadu plum (C. Ham)

plum being the edible fruit with the highest content of vitamin C 2,000–3,000 mg/100 g has great potential to be use in the form of Kakadu Plum concentrate as a natural source of vitamin C similar to that of acerola cherry, rose hips, and blackcurrant extracts, in dietary health supplements. The gum from some local *Terminalia* species including Kakadu plum has also been eaten – cooked in sand, chewed directly or pounded into a powder which after soaking formed an edible jelly.

Botany

A slender, spreading tree, to 10 m high with rough cream-grey bark becoming flaky in lager trees (Plate 1). Leaves are light green, very large, leathery, glabrous, broadly elliptical to ovate, 15–22 cm long by 12–20 cm wide, with distinct veins and spirally arranged towards the ends of the branches. The flowers are small, creamy-white, perfumed, and borne on spikes 20 cm long in leaf axils. Fruit fleshy, void with a short beaked, 2 cm long by 1 cm wide, yellow-green with reddish tint, containing one large seed (Plate 2–4).

Nutritive/Medicinal Properties

The nutrient composition of ripe raw Kakadu plum per 100 g edible portion was reported as: energy 89 kJ, moisture 76.2 g, nitrogen 0.13 g, protein 0.8 g, fat 0.5 g, ash 1.0 g, dietary fibre 7.1 g, Ca 62 mg, Cu 0.9 mg, Fe 2.4 mg, Mg 40 mg, P 24 mg, K 261 mg, Na 13 mg, Zn 0.7 mg, thiamin 0.05 mg, riboflavin 0.04 mg, and niacin derived from protein or tryptophan 0.1 mg and vitamin C 2,907 mg (Brand Miller et al. 1993).

Kakadu plum is most noted for its rich vitamin C content, containing around 5% vitamin C by weight, 50 times the concentration found in oranges (Peerzada et al. 1990). There are no reports of unsafe or toxic levels of antinutrients in the fruit (Hegarty et al. 2001). The reported values for oxalates, cyanogens and saponins in the Kakadu Plum fruit do not exceed those recorded for widely consumed foods and the value for alkaloids is below that of common citrus fruits.

Kakadu plum has traditionally been used by Australian Aborigines as an antiseptic and a soothing balm for aching limbs and feet. A preparation from the inner bark is used to treat sores, boils, backache, ringworm and leprosy sores.

Other Uses

Today, the Kakadu plum is more commonly sold as an ingredient for cosmetics but it is slowly entering new markets as a nutraceutical in food supplements and fortified beverages.

Comments

The plant is readily propagated from seeds.

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Terminalia kaernbachii

Scientific Name

***Terminalia kaernbachii* Warb.**

Synonyms

Terminalia okari C.T. White

Family

Combretaceae

Common/English Names

Okari, Okari Nut

Vernacular Names

French: Noix d'Okari, Noyer d'Okari;
Japan: Buraun taamineria;
Papua New Guinea: okari (Tok Pisin), Makame (Barai), sarigi (Pole), topo (Podopa), yumu (Foi), uka (Kaluli), favie (Onobasalo), tukai'o (Etoro), iuwa (Hawalisi);
Solomon Islands: Bush Alite, okari.

Origin/Distribution

The species is indigenous to Indonesian Irian Jaya (West Papua), the Aru Islands, Papua New Guinea (Madang, Morobe, Western, Gulf, Central, Northern and Bougainville) and the Solomon Islands. It was introduced to Queensland (Australia).

Agroecology

Okari occurs scattered in lowland rainforest and riverine forest, in areas with a wide range of rainfall of 2,000–7,000 mm per annum. Wild populations of this species are known from many areas in Irian Jaya, Papua New Guinea and from the Solomon Islands, where it is also widely cultivated in forests and semi-cultivated areas. It does poorly near the ocean and grows best inland in lowland and intermediate altitudes below 1,000 m. It tolerates poorly drained soils.

Edible Plant Parts and Uses

This ripe fruit is split open with an axe to reveal the edible kernel that is inside the hard shell. The shell has ridges and holes in it. The palatable kernels are the largest known in the family

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Combretaceae. The kernel is excellent and is regarded as one of the best-flavoured, tropical nuts that can be eaten raw or cooked. It is common in markets during the fruiting season.

Botany

Okari is a small, mid-canopy, tree 20–30 m tall, with a spreading crown, straight and cylindrical trunk and grey bark. Twigs are often massive, hairy when young, with leaves crowded towards the tips (Plate 1). Leaves are spirally arranged, simple, obovate or narrow obovate, 15–28 cm long by 6–13 cm broad (Plates 1–3). Inflorescences are axillary with flowers on unbranched axis. Flowers are unisexual and bisexual, unisexual with male and female flowers on the same plant, stalked, 10 mm across; outer perianth triangular and hairy; inner perianth 5 and pale green, some partly joined; stamens 10, free and attached to the perianth; ovary inferior, carpels joined (when more than one), locule 1; style solitary, 20 mm long. Fruit is a large, ellipsoid, slightly flattened convex, simple, indehiscent, drupe, up to 9–11 cm long by 6–8 cm wide and 5–6 cm thick, covered with short reddish-brown hairs, green when young turning red (Plates 3–4), fleshy, and glabrous when ripe, containing a massive woody stone (nut) with large edible, white to creamy-white kernel, reaching 7–8 cm long by 3–4 cm wide, and covered by a thin, brown layer of skin (Plates 5–6).

Plate 1 Dense foliage with leaves crowded towards the end of twigs

Plate 2 Leaves at the apex of a young sapling

Plate 3 Immature okari nut fruit

Plate 4 Close up of okari nut fruit

Plate 5 Okari nut kernels on sale in PNG market

Plate 6 Creamy-white kernel covered with a brown skin

Nutritive/Medicinal Properties

Little is known or published about its nutritive value. Kernels weigh from 2.5 to 10 g in weight and is a favourite article of diet among the natives, almond flavoured, mild and pleasant. The kernel was found to be source of about 50 g of a sweet, colourless, non-drying, edible oil, considered less oily than *Canarium* (Exell 1954; Coode 1969). The kernel was found to be reported to contain 12.5% protein and 70% fat (Morton 1985).

Nothing has been reported or published about its medicinal value and uses.

Other Uses

Okari is an occasional timber species but has not been exploited as such because of its higher value as fruit trees. The tree is referred to as red-brown terminalia and is used in furniture construction.

Comments

Tree propagation is by seeds.

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Benincasa hispida cv- gr. Fuzzy Gourd

Scientific Name

***Benincasa hispida* (Thunberg ex Murray) Cogniaux cv- gr. Fuzzy Gourd Group**

Synonyms

Benincasa cerifera Savi var. *chiehqua* (How) C.Y. Wu & S.K. Chen, *Benincasa hispida* (Thun.) Cogn. var. chieh-qua How

Family

Cucurbitaceae

Common/English Names

Festival Gourd, Fuzzy Gourd, Fuzzy Melon, Hairy Cucumber, Hairy Gourd, Hairy Melon, Jointed Gourd

Vernacular Names

Chinese: Jie Gua, Chieh Kua (Festival Gourd), Mao Gua, Mao Kua (Hairy Gourd);
Japanese: Heariimeron;
Malaysia: Mao Kua (Cantonese), Kundor Panjang, Timun Balu (Malay);
Thai: Faeng:
Vietnamese: Bi.

Origin/Distribution

Origin of this variety of *Benincasa hispida* is uncertain but Indo China and India are regarded to be the centres of greatest diversity. Hairy gourd is widely cultivated in China since 500 AD and is extensively cultivated in southeast Asia.

Refer to *Benincasa hispida* (Thunberg ex Murray) Cogniaux cv. group Wax Gourd.

Agroecology

Fuzzy gourd shares the same agroecological requirements as the wax gourd. Refer to *Benincasa hispida* (Thunberg ex Murray) Cogniaux cv. group Wax Gourd for more details.

Edible Plant Parts and Uses

Both the immature and mature but not ripe fruit is harvested for cooking after peeling the skin. The firm flesh is sliced and use in soups, stews, stir-fry on its own or with meat, fish or other vegetables. The gourd is often halved, hollowed out and stuffed with meat (pork or beef), shrimps and mushrooms and then steamed in a pot or fried. A Taiwanese recipe suggests shredding and frying with chilies. The firm flesh of the older mature fruit is also candied with sugar and can be dried for later use. Young shoots, leaves and flowers are occasionally eaten as vegetable as for wax gourd The seeds are prepared as a snack food by frying or roasting.

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Botany

Fuzzy gourd is an annual climber with trifid tendrils. The leaf lamina of fuzzy gourd is deeply lobed with 5–7 lobes, dentate and softly hispid on 5–20 cm long, thick and hispid petiole (Plate 2). The flowers are bright yellow, 6–12 cm across and similar to that described for wax gourd (Plate 1). The fruit is green to dark green with pale green speckles and very much smaller and lighter than the wax gourd. The fruit shape is oblong cylindrical, clavate or dumb-bell-shaped (narrowed in the centre), 15–23 cm long by 5–10 cm across with roundish ends and covered with dense, bristle-like white trichomes on the surface (Plates 3–5). The flesh is white. Its mild

Plate 3 Dumb-bell shaped fuzzy gourd fruits

Plate 1 Large yellow flower of fuzzy gourd

Plate 4 Clavate fuzzy gourd fruits

Plate 2 Lobed, serrated, hispid leaves of fuzzy gourd

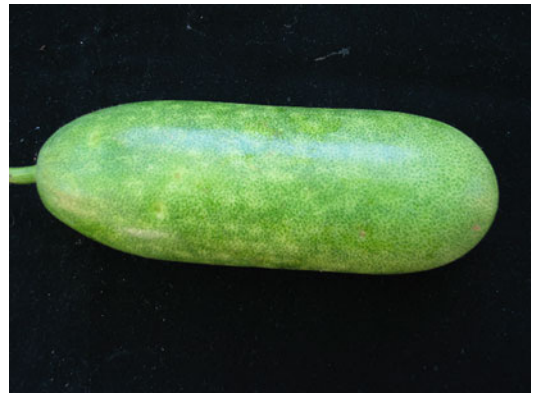

Plate 5 Close-up of oblong-cylindrical, fuzzy gourd fruit

subtle flavour is described as somewhat like a cucumber or summer squash.

Refer to *Benincasa hispida* (Thunberg ex Murray) Cogniaux cv. group Wax Gourd for more details.

Nutritive/Medicinal Properties

Nutrient composition of the edible portion of the hairy melon (*Benincasa hispida* cv. Fuzzy Gourd) fruit per 100 g was reported as: water 93.8 g, energy 45 kJ (11 kcal), protein 0.7 g, fat 0.0 g, carbohydrate 2.0 g, sugars 1.7 g, starch 0.3 g, dietary fibre 1.7 g, Ca 12 mg, Mg 15 mg, Fe 0.3 mg, K 250 mg, Na 2 mg, Zn 0.2 mg; ascorbic acid 69 mg, thiamin 0.07 mg, riboflavin 0.05 mg, niacin 0.20 mg and β-carotene equivalent 20 μg (English and Lewis 1991).

Fuzzy gourd shares similar nutritive and medical attributes as *Benincasa hispida* (Thunberg ex Murray) Cogniaux cv. group Wax Gourd.

Other Uses

Refer to *Benincasa hispida* (Thunberg ex Murray) Cogniaux cv. group Wax Gourd for details.

Comments

According to Hu (2005) six recognised cultivars are grown in China (Cantonese name in bracket): Da Teng (Ta Teng), Bo Luo Zhong (Po Luo Chung), Zi Li Yu (Tzu Li Yu), Hei Pi Qing (Hei P'i Ch'ing), Qi Xing Zai (Ch'i Hsing Tsai), Qi Xing Bo-Luo Zai (Ch'i Hsing Po Luo Tsai).

Refer to *Benincasa hispida* (Thunberg ex Murray) Cogniaux cv. group Wax Gourd for additional references.

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Benincasa hispida cv- gr. Wax Gourd

Scientific Name

***Benincasa hispida* (Thunberg ex Murray) Cogniaux cv- gr. Wax Gourd**

Synonyms

Cucurbita hispida Thunberg ex Murray, *Benincasa cerifera* Savi, *Curcubita pepo-aspera* Blanco

Family

Cucurbitaceae

Common/English Names

Ash Gourd, Wax Gourd, Chinese Preserving Melon, Chinese Water Melon, Gourd Melon, Joined Gourd, Tallow Gourd, Winter Gourd, Winter Melon, White Pumpkin

Vernacular Names

Burmese: Kyauk-Hpayon, Kyauk Pha-Yon Thee;
Czech: Tykev Vvosková;
Chinese: Dong Gua, Tung Kua, Bai Dong Gua, Yin Dong Gua, Bai-Gua, Pai Gua;
Danish: Voksgræskar, Voksagurk;
Dutch: Waskalebas;
Eastonian: Vahakõrvits;
French: Courge À La Cire, Courge Cireuse, Courgette Velue, Pastèque De Chine;
German: Prügelkürbis, Wachskürbis, Wintermelone;
India: Kumora, Komora (Assamese), Chal Kumra, Kumra (Bengali), Bhujailu, Gol-Kaddu, Golkaddu, Kadu, Khola, Kondha, Kudimah, Kumra, Petha, Pethaa, Phuthia, Raksa (Hindu), Boodu Gumbala, Boodukumbalakaayi, Budekumbalakayi, Kaggumbala, Kargumbala, Kooshmaanda (Kannada), Cumbulam, Kumbalam, Kumpalam, Kumpalanna (Malayalam), Kohala (Marathi), Maipawl (Mizoram), Brhatphala, Brihatphala, Ghrinavasa, Gramyakarkati, Karkaru, Karkotika, Kumbhanda, Kunjaphala, Kushmanda, Kushmandaka, Kushmandi, Kushpandaha, Kusmanda, Kusmandaka, Nagapushpaphala, Pitapushpa, Pushpaphala, Puspaphala, Shikhivardhaka, Timisha, Valliphala, Valliphalah (Sanskrit), Alattuppucanikkoti, Alattuppucini, Campalpucini, Camparpucani, Kaliyanap Pucani, Kaliyanappucunai, Kaliyanappucini, Kalyanapucini, Kalyanappushinikkay, Kotai-P-Pucani, Kucumantam, Kulppantakkay, Kulppantam, Kumittikkay, Kumittikkaykkoti, Kummattikkay, Kumpalam, Kunmatakkay, Kusmantam, Makapalikakkoti, Makapalikam, Makakumpi, Maruntitumuriyappanni, Mattupparanki, Mattuppucani, Motacam,

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Nantippucani, Nantippucanikkoti, Nantippucini, Neer Poosanikai, Nirruppucani, Nirruppucini, Paranki, Parankikkay, Pattirapani, Perumpucani, Perumpucanikkay, Perumpucini, Pusanikkai, Pucani, Pucanik Kay, Pushani Kai, Pushini, Tatiyankay, Tatiyankay, Vellaippucanikkay, Vellaippucani, Ven Poosani, Venpucanai, Venpucanai, Venpuncani, Venpucini (Tamil), Karkumbuda (Tulu), Boarda Goomoodoo, Boodida Gummadi, Boodidegummadi, Budida-Gummadi, Budidegummadi, Burdagumudu, Pendli-Gummadi-Kaya, Pendligummadikaya, Pendligummadikaaya (Telugu), Petha (Urdu);
Indonesia: Kundur, Bligo, Kundo (Aceh), Kunrulu (Bugis), Butong (Dayak), Gundur (Gayo), Laha (Irian Jaya), Baligo, Bligo, Bligo Ijo, Bligo Kuning, Bligu Putih, Blonceng, Bligo Semangka (Javanese), Sardak (Lampung), Bhaligho, Kundur (Madurese), Beligu, Kundur (Malay), Kundue (Minangkabau), Undru (Nias), Kudul (Simalur), Baligo, Kundur, Leor, Leyo (Sundanese);
Italian: Zucca Della Cera;
Japanese: Togan, Tougan, Tôga, Togwa, Kamo-Uri;
Khmer: Trâllach;
Korean: Dong A;
Laotian: Mak Ton, Tônx;
Malaysia: Kundor, Kundur (Malay), Celau, Ensengai (Iban);
Nepalese: Kubiindo, Petha;
Pakistan: Petha;
Philippines: Rodal (Bikol), Kandol, Tibiayon (Bisaya), Tabungaw (Iloko), Kondol (Ivatan), Kundul (Kapampangan), Tabugok (Subanum), Kundal (Sulu), Kondol, Tambulok (Tagalog);
Portuguese: Abóbora D'água, Calabaza Branca, Comalenge;
Singapore: Tang Kua (Hokien);
Spanish: Calabaza Blanca, Calabaza China;
Sri Lanka: Puhul (Sinhalese);
Taiwanese: Dangguev;
Thai: Faeng, Fak, Mafak Khom, Mafak Mon, Mafak Mon Khom;
Tibetan: Ku-Sma-Nda-Ka;
Turkish: Mom Kabagi;
Vietanamese: Bí Dao, Bí Bee, Bi Xanh.

Origin/Distribution

Origin of this wax gourd is uncertain but Indo China and India are deemed to be the centres of greatest diversity. Wax gourd is not known in the wild and is usually cultivated. It is extensively cultivated in Southern China and southeast Asia.

Agroecology

The crop is grown from near seal level to 1,000 m elevation but is generally suited to the lowland in the warm tropics and subtropics. It is relatively drought tolerant and can grow in moderately dry regions. The optimum temperature range for growth is 23–28°C.

It prefers a well-drained, friable, light soil with pH 6.0–7.0.

Edible Plant Parts and Uses

The fruit is harvested immature, half-ripe and usually cooked and eaten as vegetables. Wax gourd has a mild to bland flavour and juicy texture and is mainly used in soups, curries and stews, but can also be stuffed with a flavoursome filling and baked. The fleshy pulp is also processed into pickles and sweet candies. The fruit is also boiled with sugar or honey and red dates and canned as a cooling winter melon beverage. The fruit can also be used raw like sliced cucumbers. In India they are used extensively in curries. The firm flesh of half-ripe fruits are used by Indonesian Chinese for the preparation of the popular and much relished *tangkwe* (*tangkuweh* in Sundanese; *tangkuweh* or *tangkuwih* in Javanese) a kind of sweet meat. The flesh is cut into oblong, finger-length sections, soaked in water for 48 h and boiled dried in white sugar. Kolak (Javanese) or *Kotek* (Sundanese) is made from the fruits. The fruit is also comfited in large pieces called *Kluwa* or *sale* (in Javanese) or *lua* (in Madurese). In China and Taiwan, the winter melon is used to make soup in the same way as daikon radishes, and is often combined with pork

or pork/beef bones. In North India and Pakistan, the vegetable is used to prepare a candy called *Petha*. In South Indian cuisine it is used to make curries. Occasionally, it is used to produce a fruit drink which has a very distinctive taste. It is usually sweetened with caramelized sugar, which enhances the taste. In Southeast Asia, the drink is widely marketed as winter melon tea. In China, the winter melon is dried and sweetened and eaten at New Year festivals.

The young tender shoots, tendrils, and leaves of the plant may also be eaten as greens after being boiled, fried or cooked in curries. In Indonesia, the young leaves, flower buds and young fruits are used as *sepan* or in *sayur*. Seeds are consumed after frying or roasting as snack foods.

Plate 1 Ovoid-oblong wax gourd fruit

Botany

Wax gourd is a robust, hispid, monoecious climbing annual growing to several metres long. It has a terete, thick, furrowed and coarsely hairy stem with 2–3fid tendrils. Leaves are distichous, simple, large and borne on 5–20 cm long petioles. The lamina is orbicular-cordate in outline, 10–25 by 10–20 cm with a deeply cordate base and a margin irregularly angled or lobed margin and undulate-crenate, glossy green and densely hairy on both surfaces. Flowers unisexual, large, 6–12 cm across, yellow, solitary in leaf axils, pentamerous, on densely hispid pedicels. Calyx campanulate, corolla rotate, 5–8 cm across, deeply 5 lobed. Male flowers on longer pedicels with 5 stamens four of which in connate pairs, female flowers with densely villose, ovoid ovary, a short style and 3-fid stigma. Fruit a large, stalked berry (pepo), ovoid-oblong, ellipsoid, subglobose or globose, 20–200 cm by 10–21 cm, green to speckled light green, thinly hispid covered with chalky white wax (Plates 1–3). Fruit can weigh from 3 kg up to 30 kg or more. Flesh thick, succulent, white with numerous seeds, flat, ovate elliptic 10–15 mm by 5–7 mm and 1–2 mm thick, distinctly ridged and yellowish brown.

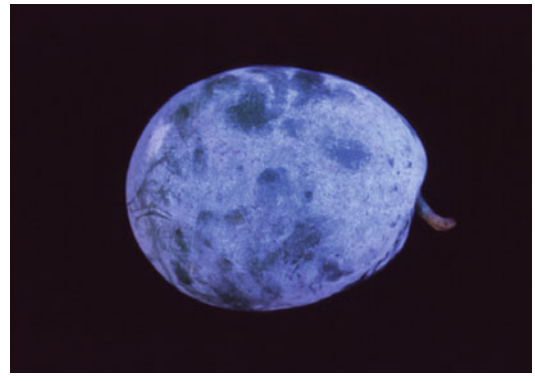

Plate 2 Ovoid wax gourd fruit

Plate 3 Elongate-oblong wax gourd fruit

Nutritive/Medicinal Properties

Nutrient composition of the edible portion of the wax gourd (*Benincasa hispida*) fruit per 100 g was reported as: water 96.1 g, energy 54 kJ (13 kcal), protein 0.4 g, fat 0.2 g, carbohydrate 3.0 g, dietary fibre 2.9 g, Ca 19 mg, Mg 10 mg, P 19 mg, Fe 0.4 mg, P 19 mg, K 6 mg, Na 111 mg, Zn 0.6 mg, Cu 0.023 mg, Mn 0.058 mg, Se 0.2 μg; ascorbic acid 13 mg, thiamin 0.04 mg, riboflavin 0.11 mg, niacin 0.40 mg, vitamin B-6 0.035 mg, folate 5 μg, total saturated fatty acids 0.016 g, 16:0 (palmitic acid) 0.011 g, 18:0 (stearic acid) 0.005 g; total monounsaturated fatty acids 0.037 g, 18:1 undifferentiated (oleic acid) 0.037 g; total polyunsaturated fatty acids 0.087 g, 18:2 undifferentiated (linoleic acid) 0.087 g tryptophan 0.002 g, lysine 0.009 g and methionine 0.003 g (USDA 2010).

The fruit was also found to contain major constituents that includes triterpenoids, flavanoids, glycosides, saccharides, β sitosterin, and uronic acid.

Other Phytochemicals

The major volatile compounds identified in wax gourds were E-2-hexenal, n-hexanal and n-hexyl formate (Wu et al. 1987); and 2,5-dimethylpyrazine, 2,6-dimethylpyrazine, 2,3,5-trimethylpyrazine, 2-methylpyrazine, and 2-ethyl-5-methylpyrazine were the major compounds in the wax gourd beverage. The major odour active compounds of ash gourd (*B. hispida*) was found to be acetoin, octanal and nonanal (Sharma et al. 2010). Acetoin was also identified as the key constituent existing as glycosidic conjugate.

Pectic polysaccharides were obtained from chalkumra (*Benincasa hispida*) fruit by sequential extraction with ammonium oxalate (fraction BOX), dilute acid (fraction BHCl), and cold dilute alkali (fraction BOH) (Mazumder et al. 2004). The highest yield of polysaccharides was obtained with oxalate and HCl. Homogalacturonan accounted for more than half of BOX and 11% of BHCl. Methylation analyses and hydrolysis of BHCl with endo-β-(1→4)-d-galactanase showed the presence of β-(1→4)-d-galactan. The neutral galactan represented more than 76% of BHCl and approximately 40% of BOH. The other polysaccharides were complex galactans in BOH and an acidic arabinan in BOX and BHCl. Three phenolic compounds, astilbin (120 mg), catechin (103 mg), and naringenin (79 mg) were obtained from the separation of 2 g of crude phenolic component extract of the fruit (Du et al. 2005).

A pathogenesis-related (PR) protein, osmotin-like protein (OLP) was purified from the seeds of *Benincasa hispida* (Shih et al. 2001a). Osmotin and OLPs are members of the thaumatin-like, PR-5 family of the PR proteins. The protein was found to have 17 cysteine residues, of which 16 were found in the same positions as those appearing in the sweet-tasting protein thaumatin and several other thaumatin-like proteins. Thaumatin is a low-calorie (virtually calorie-free) protein sweetener and flavour modifier. The substance is often used primarily for its flavour-modifying properties.

Studies over the past three decades have been carried out revealing that the extracts of *Benincasa hispida* displayed antioxidant, antiangiogenic, anticancer, antiulcerogenic, antinociceptive, antipyretic nootropic, antidepressant, anorectic, anxiolytic, antiinflammatory, analgesic, diuretic, antioxidant, antihistamine, antidiarrheal, angiotensin-converting enzyme (ACE) inhibition, renal and gastroprotective activities. However systemic pre-clinical and clinical studies are yet to be carried out.

Antioxidant Activity

The methanolic extract of *Benincasa hispida* seeds exhibited significant free radical scavenging activity in a dose dependent manner when compared with ascorbic acid (Gill et al. 2010). The highest radical scavenging activity of the extract was found to be 79.8% at concentration of 300 μg/ml. The H_2O_2 scavenging effect of the extract was 63.7% at a concentration of 200 μg/ml.

Studies revealed that chronic treatment in Holtzman strain adult albino rats with *Benincasa hispida* pulp extract markedly increased the number of correct choices in radial Y arm maze task (Roy et al. 2007). The extract significantly lowered lipid peroxidation level, significantly elevated superoxide dismutase (SOD), catalase (CAT) and reduced glutathione level in the different parts of the brain such as cerebral cortex (CC), cerebellum (CB), midbrain (MB), caudate nucleus (CN) and pons and medulla (PM) in colchicine induced experimental Alzheimer rat model. The study demonstrated that the antioxidant property of BH property may be beneficial for the management of colchicine induced rat model of Alzheimer's disease.

Antiangiogenic/Anticancer Activity

Studies in Korea reported that seed extracts of *Benincasa hispida* showed anti-angiogenic effect; the extract exhibited potent inhibitory effect in-vivo on basic fibroblast growth factor (BFGF) found in various tumours (Lee et al. 2005). The seed extract decreased BFGF-induced endothelial cell proliferation and tube formation in a dose-dependent fashion. The extract showed no cytotoxicity on human umbilical vein endothelial cells (HUVECs) and normal fibroblast cells. In addition, the seed extract of *Benincasa hispida* exhibited potent inhibitory effect on BFGF-induced angiogenesis in-vivo.

An immuno-potentiator, *Benincasa cerifera* mitogen (BCM) fraction was isolated from seeds (Kumazawa et al. 1985). BCM fraction, was found to be a heteropolymer consisting of uronic acid, neutral sugars, protein, and phosphorus. The proliferation and differentiation of murine B cells were notably activated by BCM fraction. The in-vitro development of peritoneal macrophages into antitumour macrophages was also stimulated by the supplementation of BCM fraction to cultures. BCM fraction augmented the IgM and IgG antibody responses against sheep erythrocytes (SRBC) and the induction of delayed-type footpad reaction against SRBC. The antitumour activity of BCM fraction was noted in terms of prolongation of the survival period of mice bearing Meth A fibrosarcoma.

Wax gourd fruit was found to contain cucurbitacin B (Uchikoba et al. 1998) a triterpenoid constituent of Cucurbitaceae vegetables and a promising phytochemical for cancer prevention. Cucubitacin B was reported to exhibit anticancer and antiinflammatory activities (Jayaprakasam et al. 2003; Liu et al. 2008; Yasuda et al. 2010). Cucurbitacin B potently inhibited cancer cells (Jayaprakasam et al. 2003): colon cancer (HCT-116) by 81.5% at 0.4 μM, breast cancer (MCF-7) by 87% at 0.4 μM, lung cancer (NCI-H460) by 96% at 0.1 μM, central nervous system (CNS) (SF-268) by 92% at 0.05 μM. Cucurbitacin B also displayed antiinflammatory activity, it inhibited COX-2 enzyme by 32% at 100 μg/ml and also inhibited lipid peroxidation by 59% at 100 μg/ml. Cucurbitacin B inhibited cell proliferation and stimulated apoptosis of Hep-2 cells by suppressing STAT3 signal pathway, down-modulating the expression of cyclin B1 and Bcl-2 proteins (Liu et al. 2008). Results of studies suggested that Cucurbitacin B induced G(2) arrest and apoptosis through a STAT3-independent but reactive oxygen species (ROS)-dependent mechanism in human colon cancer SW480 cells (Yasuda et al. 2010).

Antiinflammatory Activities

Studies in Korea showed that aqueous extract of *Benincasa hispida* exhibited antiinflammatory properties (Moon et al. 2009). Aqueous extract of *Benincasa hispida* inhibited high glucose-induced cell adhesion molecules (CAMs) surface and protein expression, resulting in reduced adhesion of U937 monocytes in human umbilical vein endothelial cells (HUVECs) pretreated with the extract. The extract also inhibited mRNA expression level of monocyte chemoattractant protein-1 (MCP-1) and interleukin-8 (IL-8). High glucose-induced ROS production was inhibited by treatment of the extract. It was observed that pretreatment of HUVECs with the extract thwarted NF-kappaB activation via obstruction of phosphorylation and degradation of its inhibitory protein, IkappaB-alpha. The

extract also decreased NF-kB promoter activity. These results suggested that *Benincasa hispida* extract decreased high glucose-induced CAMs activation by inhibiting monocyte adhesion, ROS, and NF-kappaB in HUVECs. Gill et al. (2010) found that the methanolic extract of *Benincasa hispida* seeds showed significant anti inflammatory activity as determined by carrageenan-induced paw edema in rats The extract showed significant reduction (59.7%) in paw volume at the dose of 300 mg/kg when compared with diclofenac.

Analgesic Activity

The methanolic extract of *Benincasa hispida* seeds showed significant analgesic activity as evaluated by tail immersion and tail flick methods in mice (Gill et al. 2010). The extract showed significant decrease in pain at the concentration of 300 mg/kg when compared to morphine.

Antiulcerogenic Activity

Recent studies in India showed that *B. hispida* fruit extracts possessed antiulcerogenic effect (Grover et al. 2001). The oral feeding of different doses of the extract (fresh juice, supernatant and residue fraction of centrifuged juice, alcoholic and petroleum ether extract) significantly decreased the ulcer index produced by various ulcerogens such as aspirin plus restraint, swimming stress, indomethacin plus histamine and serotonin. The antiulcerogenic effect was dose-dependent in the stress induced model of ulcer and not in other models. *B. hispida* probably had a CNS component in prevention of stress induced ulceration. However, antihistaminic, anticholinergic effects and prevention of disturbance in gastric micro-circulation presented possible modes of action. Chronic toxicity studies carried out for 3 months revealed no deleterious effect of fresh juice of *B. hispida* on various hematological and biochemical parameters studied.

Indian researchers showed that rats with ulcers induced by indomethacin had an apparent decrease in ulcer index when treated with fruit extract of *Benincasa hispida* (Shetty et al. 2008). On induction of gastric ulcer, there was significant increase in superoxide dismutase (SOD) in red blood cells and homogenate contents and vitamin C in plasma. There was significant reduction in malondialdehyde with concomitant lowering in SOD and vitamin C concentrations in the treated rats when compared to those not treated with the fruit extract. *Benincasa hispida* was found to contain certain active principles like terpenes, flavanoid C–glycosides and sterols which possessed antioxidant effects and these were postulated to probably inhibit gastric mucosal injury by scavenging the free radicals and suppressing production of SOD and vitamin C in test rats.

Antihistamine Activity

Studies in India found that the methanol extract of *Benincasa hispida* showed excellent protection against the histamine-induced bronchospasm in animal models (Kumar and Ramu 2002). In Japan, the fruits of *Benincasa hispida* was found to display inhibitory activity on the histamine release from rat exudate cells induced by antigen-antibody reaction (Yoshizumi et al. 1998) Among the active triterpenes and sterols, two triterpenes, alnusenol and multiflorenol, were found to have a stabilising effect on mast cells by potently inhibiting the histamine release.

Nootropic and Antiamnesic Activities

In the Y maze test, the methanol extract of *Benincasa hispida* MEBH (0.6–1 g/kg) produced significant reduction in number of entries and increase in percentage of alteration (Kumar and Nirmala 2003). In latency test, the methanol extract at 0.6 and 0.8 g/kg, significantly reduced the latency period. In both models, the methanol extract significantly antagonized the amnesic action of scopolamine. The results showed that the methanol extract exhibited prominent nootropic effect and antiamnesic effect in both models

of memory (spatial working memory and long term memory) Y maze and latency test respectively.

Antidiarrheal Activity

Studies by Mathad et al. (2005) found that rats treated with the methanolic extract of fruit of *Benincasa hispida* exhibited significant inhibitory activity against castor oil induced diarrhoea and inhibited PGE2 (prostaglandin E2) induced enterpooling in rats. It also showed significant decrease in gastro intestinal motility following charcoal meal in rats. The results obtained confirmed the efficacy of the fruit extract as an antidiarrheal agent.

Anorectic Activity

Methanol extract of *Benincasa hispida* was found to significantly reduce the cumulative food intake over a 7 h period in a dose-dependent manner in Swiss albino mice (Kumar and Vimalavathini 2004). The percentage reduction of cumulative food intake at the seventh hour for the methanol extract at doses of 0.2, 0.6 and 1 g/kg was 27%, 38% and 54% respectively. The 4 h gastric emptying was not significantly influenced by the methanol extract when compared to control. The results indicated the possible anorectic activity of *Benincasa hispida,* was most probably mediated through the CNS without affecting gastric emptying. The researchers asserted that further studies are required to ascertain its potential as an antiobesity agent.

Angiotensin-Converting Enzyme (ACE) Inhibition Activity

Studies in Taiwan found *Benincasa hispida* seeds to have a higher capacity on anti-oxidation and inhibition of angiotensin-converting enzyme (ACE) activity than the flesh (Huang et al. 2004). The seed had the lowest Cu^{2+} -induced low-density lipoprotein (LDL) oxidation percentage and inhibition level of ACE activity among all the fruit parts viz. pulp, core, seed, and peel. The higher antioxidant capacity of the seed may result from the higher total phenolics contents and superoxide dismutase activity. The researchers believed that seed extracts of *Benincasa hispida* may offer a good health benefits on lowering risk of cardiovascular diseases and cancers.

Antinociceptive and Antipyretic Activities

The ethanol extract of *B. hispida* seeds at doses of 250 and 500 mg/kg body weight, significantly enhanced the antinociceptive effective in a dose dependent fashion in rats (Qadrie et al. 2009). Similarly, at concentrations of 250 and 500 mg/kg b.w the extract significantly lowered yeast-induced pyrexia in rats. The extract was non-lethal to rats up to the dose of 5,000 mg/kg b.w. These results indicated that the ethanolic extract of *Benincasa hispida* possessed potent antinociceptive and antipyretic effects and thus pharmacologically justifying its folkloric use in the management of fever and pain conditions.

Gastroprotective Activity

Petroleum ether and methanol extracts of *B. hispida* were found to possess significant antiulcer as well as antioxidant property (Rachchh and Jain 2008). Both the extracts of elicited significant reduction in ulcer index in all the models and the results were comparable with that of omeprazole-treated group. Further, significant decrease in vascular permeability was observed. In the cold restraint-stress (CRS)-induced gastric ulcer model, malondialdehyde content was significantly lowered along with elevation in catalase levels as compared to the control group.

Antiobesity Activity

Haidonghua powder (HDHP), made up of *Laminaria japonica* and *Benincasa hispida,* was found to have antiobesity activity (Wang et al.

2000). HDHP (2.5 g/kg) was found to significantly reduce the Lee's index as well as the size of fat cells. HDHP did not affect the serum levels of T3 and T4, insulin and aldosterone, and did not inhibit appetite nor cause diarrhea. HDHP had the effect of anti-obesity, without any effect on the function of thyroid gland and metabolism of water and salt. The mechanism was associated with the reduction of fat cell dimension and the accumulation of fat.

Anti-morphine Addiction

The juice of *Benincasa hispida* showed significant activity against symptoms of morphine withdrawal, such as jumping response and diarrhoea, in mice (Grover et al. 2000). These results suggested that *Benincasa hispida* may prevent the development of morphine addiction and may also suppress symptoms of opioid withdrawal in animals.

Protease Inhibition Activity

A cucumisin-like serine protease was purified from the flesh of *B. hispida* (Uchikoba et al. 1998). The protease was strongly inhibited by diisopropyl fluorophosphate, but not by EDTA and cysteine protease inhibitors. A class III chitinase was purified from the seeds of *Benincasa hispida* (Shih et al. 2001b). The basic chitinase enzyme, was one of at least five chitinases detected in the seed extract of *B. hispida*. Like other class III chitinases, this enzyme also had lysozyme activity. Two squash family serine-protease inhibitors were obtained from *Benicasa hispida* seeds (Atiwetin et al. 2006).

Anxiolytic/Anticompulsive Activity

Methanol extract of *B. hispida* fruit displayed significant antidepressant activity in forced swim test along with anxiolytic property in marble burying test (Rukumani et al. 2003). However, in social interaction test, the methanol extract exhibited anxiogenic activity. In forced swim test, the methanol extract (0.6 and 1 g/kg administered thrice and only once) showed significant reduction in immobility. In marble burying test, the methanol extract (0.2–1 g/kg) in a dose dependent fashion, significantly increased the number of visible marbles. The methanol extract (0.05–1 g/kg) significantly decreased the social interaction time. The results were comparable with the clinically used antidepressants.

The methanolic extract of *Benincasa hispida* fruit exhibited anti-compulsive effect by inhibiting marble-burying behavior in mice which was comparable to that of fluoxetine (Girdhar et al. 2010). The anti-compulsive effect of the extract was further confirmed when sub-effective dose of the extract potentiated the effect of sub-effective dose of fluoxetine. It appeared that the extract acted through its influence on serotonergic system. The involvement of serotonergic system was confirmed by the fact that pretreatment of mice with PCPA (parachlorophenylalanine) partially and significantly attenuated the inhibitory effect of MEBH and completely eliminated the effect of fluoxetine on burying behavior. Thus the significant anti-compulsive effect in marble-burying behavior test in mice may be attributed to enhanced serotonergic function.

Renal Protective Activity

Benincasa cerifera treatment reversed all antioxidant parameters like superoxide dismutase (SOD), reduced glutathione (GSH) and malondialdehyde (MDA) contents as well serum creatinine and blood urea nitrogen (BUN) levels in hyperlipidemic with kidney injury induced by ischemia/reperfusion (I/R) (Bhalodia et al. 2009). These findings implied that reactive oxygen species (ROS) played a crucial role in I/R-induced kidney injury and *Benincasa cerifera* exerted renoprotective activity probably by radical scavenging activity.

Antidiabetic Activity

Results of studies by Lim et al. (2003) suggested the possibility of therapeutic or preventive use of

wax gourd to treat diabetes mellitus. Diabetic rats exhibited lower weight gain compared to the normal rats. The weight gain and feed efficiency ratios in 15 and 20% wax gourd-fed groups were higher than in streptozotocin (STZ)-induced diabetic control group. The plasma glucose levels were significantly lower in all wax gourd groups than in STZ-control group. The plasma insulin levels in diabetic groups were not significantly different compared to the normal group, but the level of 20% Wax gourd group was higher than other diabetic groups. The experimental diabetic groups exhibited the higher levels of muscle glycogen compared to STZ-control group. The lower levels of plasma cholesterol were observed in 20% Wax gourd group throughout the experimental period. The plasma level of triglyceride was increased in STZ-diabetic control and the levels were slightly reduced in the wax gourd groups. Rats of 10% wax gourd group showed lower levels of plasma free fatty acids.

Separate studies reported that rats fed 2.5% wax gourd seed powder showed higher levels of liver glycogen compared with that of the streptozotocin (STZ)- induced diabetic control group (Kim 2004) . The levels of kidney protein were significantly enhanced in the 2.5% and 5.0% wax gourd seed groups. There were no significant difference in cholesterol and liver triglyceride concentrations of the liver and malondialdehyde concentration in the liver, lung, and kidney among all four groups. These results showed that wax gourd seed treatment of 2.5% and 5.0% doses did not exhibit profound anti-lipid peroxidation properties. Lim and Kim (2004) further found that weight gain and feed efficiency ratio in rats were higher in the group fed diets of 5.0% wax gourd seed powder than in streptozotocin (STZ)-induced diabetic-control group. Plasma glucose levels were significantly lowered in the experimental groups. Plasma insulin level did not differ after feeding diets with wax gourd seed in experimental rats. The intake of diets containing 2.5% wax gourd seed powder did not significantly alter plasma cholesterol concentrations compared to STZ-control group. However, it normalized the elevated levels of plasma triglyceride and free fatty acids after 4 weeks. The levels of cholesterol, triglyceride and free fatty acids were higher in rats fed diets of 5.0% than 2.5% wax gourd seed powder. These results suggested that diets containing 2.5% wax gourd seed would be more effective in controlling diabetes mellitus than diets containing 5.0% wax gourd seed. In another study, a significant lowering effects of plasma glucose levels were observed in the chloroform fraction and aqueous fraction of *B. hispida* fruit group compared to streptozotocin (STZ) induced diabetic control group at 14 days (Lim and Lee 2005). Administrations of each of the three fractions decreased plasma triglyceride (TG), free fatty acid (FFA) levels in diabetic rats. Activity of alanine aminotransferase (ALT) in $CHCl_3$ fraction and aqueous fraction groups and aspartate aminotransferase (AST) in aqueous fraction group were significantly lower than STZ-control group. The results showed that the chloroform fraction of the ethanol extract of *Benincasa hispida* could be effective in controlling the STZ-induced diabetic rats.

Separate Korean studies showed that the supplementation of butanol and aqueous fractions of *Benincasa hispida* extract could be beneficial for diabetic complications and damages from the lipid peroxidation (Lim 2007). Hepatic glutathione peroxidase (GSH-px) activity in rats was enhanced in the groups supplemented with chloroform and butanol fractions of *B. hispida*. Glutathione peroxidase activity in the liver cytosol of aqueous fraction groups was significantly lower than that of streptozotocin–induced diabetic control group. The aqueous fraction supplemented group showed marked decrease in the hepatic superoxide dismutase activity. The hepatic cytosol catalase activity was significantly decreased by the supplementation with the butanol fraction.

Anthelmintic Activity

Studies by Bhattacharjee et al. (2010) found that *Benincasa hispida* fresh leaf extracts (crude aqueous, petroleum ether, chloroform and ethanol) significantly exhibited anthelmintic activity when compared with standard (piperazine citrate) group.

Chloroform extract (30.6 and 56.8 minutes) and petroleum ether extract (55.8 and 80.4 minutes) showed shortest time of paralysis and death of *Pheretima posthuma* worms respectively at 50 mg/ml concentration. In contrast, in the control group, no paralysis or death was found in worms during the 24 hours period.

Traditional Medicinal Uses

Benincasa hispida has been used as a food and medicine for thousands of years in the Orient. All parts of the fruit are used medicinally. *Benincasa hispida* is employed as a main ingredient in Kusmanda lehyam in the Ayurvedic system of medicine in India (Mathad et al. 2005). Kusmanda lehyam is used as a rejuvenative agent, in epilepsy and in nervous disorders. It is also recommended in Ayurveda for the management of peptic ulcers. Moreover the fruit, has been used in India for centuries for various ailments such as gastrointestinal problems, dyspepsia, burning sensation, respiratory diseases (cough, asthma), heart diseases, diabetes mellitus, ulcers and urinary diseases. In India and China, they are used as an anthelmintic, antiperiodic, aphrodisiac, for lowering blood sugar, against epilepsy, insanity and other nervous diseases, haemophysis and haemorrhage, and as a diuretic, laxative and bitter tonic. In Sri Lanka, it is used as antidote for vegetable poisons, for asthma, hiccough, insanity, anthelmintic, cholera, cough, delicacies, diabetes and as a diuretic. In Korea, *Benincasa hispida* was used mainly for diabetic compilations and diuresis diseases. In China, it is popular for its dermatologic and cosmetic applications – for facial blemishes, moisturizing and skin softening use, anti-wrinkle and anti-aging skin properties, and preventing sun damage. Wax gourd has been used in traditional Chinese medicine to treat hypertension andinflammation. In China, the dried fruit peel is used for oedema with oliguria, thirst and oliguria due to summer-heat. The fruit is regarded as cooling, cooling, diuretic, laxative and tonic. In Japan, *B. hispida* is a component of most traditional dermatologic formulations because of its skin regenerative property. In the Philippines it is used for tuberculosis and is deemed to be astringent, demulcent and styptic. The seed is used as vermifuge. Oil from seeds is soporific, good for the brain and liver and effective in the treatment of syphilis. Seed ash is a prized remedy for gonorrhea; ash is applied to painful wounds and swellings in India.

Other Uses

Wax gourd is sometimes used as a rootstock for melon (*Cucumis melo*) and other cucurbits as the roots have considerable resistance to soil-borne diseases. The wax from the fruit coatings has been used to make candles.

Comments

Winter melon fruits can be stored for as long as a year without refrigeration.

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Citrullus lanatus

Scientific Name

***Citrullus lanatus* (Thumb.) Matsum. & Nakai**

Synonyms

Citrullus caffer Schrad., *Citrullus lanatus* var. *caffer* (Schrad.) Mansf., *Citrullus vulgaris* Schrad. ex Eckl. & Zeyh., *Colocynthis amarissima* Schrad., *Colocynthis citrullus* (L.) Kuntze, *Cucumis citrullus* (L.) Ser., *Cucumis colocynthis* Thunb., *Cucumis laciniosus* Eckl. ex Schrad., *Cucurbita anguria* Duchesne ex Lam., *Cucurbita caffra* Eckl. & Zeyh., *Cucurbita citrullus* L., *Momordica lanata* Thunb.

Family

Cucurbitaceae

Common/English Names

Common Watermelon, Cultivated Watermelon, Watermelon, Wild Watermelon

Vernacular Names

Arabic: Battikh, Bateekh;
Azerbaijan: Qarpız;
Brazil: Melancia;
Bulgarian: Dinia;
Catalan: Sindria;
Chamorro: Chandia;
Chinese: Si Koa (Bân-Lâm-Gú), Xi Gua, Shi Yong Xi Gua, Choei Koa, Ts'ing Teng Koa, Han Koa, Hia Koa;
Cook Islands: Merēni (Maori);
Croatian: Lubenica;
Cuba: Melón De Agua (Spanish);
Czech: Lubenice Meloun, Meloun Vodní;
Danish: Vandmelon;
Eastonian: Harilik Arbuus;
Esperanto: Akvomelono;
Egypt: Betteakh;
Finnish: Arpuusi, Vesimeloni;
French: Melon D'eau, Pastique;
Gambia: Saura (Manding-Mandinka), Inam (Togo Bassari) Kamie (Kabre), Inabe (Konkomba), Fude (Moore-Nawdam), Kanjinga (Tem);
German: Wassemelone (East Germany), Dessert-Wassermelone, Gewöhnliche Wassermelone, Wasser-Melone, Wassermelone, Wasserzitrulle;
Ghana: Akate, Akyɛkyẽa, Anamuna, (Akan-Fante), Neri (Dagbani) Wátrɛ' (Ga), Atsẽtsẽa (Gbe-Vhe), Àgúshií (Hausa), Inabe (*Konkomba*), Nfatee Nzima (Nzema), Akyẽkyẽa, Anemuna, Efere (Twi), Aŋyaŋye, Dzamatre (Vhe);
Greek: Karpusi, Karpouzia;
Guianas (Guyana, Surinam, French Guiana): Melon D'eau, Pasteque, Patja, Watermeloen, Watermelon;
Guinea: Sara, Sere (Manding-Maninka);

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Hebrew: Avatiach, Avatiach Pashut;
Hungarian: Görögdinnye, Takarmány-Görögdinnye, Takarmánydinnye;
I-Kiribati: Te Meren;
India: Taramuj, Tormuj (Bengali), Indruk, Tarabuucha (Gujarati), Kharbuza, Kharmuja, Tarabuuza, Tarbooz, Tarbuj, Tarbuz, Tarmuj, Tinda (Hindu), Kallangadi Balli (Kannada), Tarbij (Manipuri), Kaduvrindavana, Tarabuuja (Marathi), Tarabuuja (Punjabi), Tarbooz (Urdu);
Indonesia: Watesan (Java), Semangka, Cimangko (Minhasa), Semangka (Sundanese);
Italian: Anguria, Cocomero, Melone D'acqua, Pastecca;
Japanese: Suika, Sui Kwa, Shokuyô Suika, Shokuyou Suika;
Khmer : 'Öö'w Llök;
Korean: Su Bak, Soo Bahk;
Laotian: Môô, Tèèng Môô;
Lithuanian: Tikrasis Arbūzas;
Macedonian: Lubenica;
Malaysia: Tembikai, Mendikai;
Mali: Hadj En-Nas (Arabic), Missi Tsara, Missi: Ox, Tsara (Manding-Bambara), Kànéỳ Molli (Songhai), Fundi (Fruit), Ilif (Plant) Takinkeint, Talejest, Tiledjest (Tamachek);
Mauritania: Fundi (Arabic);
Nepalese: Tarbuja, Tarabuujaa, Tarbujo;
Niger: Kànéỳ (Songhai);
Nigeria: Íkpán (Anaang,) Batteikh Al Hamdal, Batteikh Al Masak (Arabic-Shuwa), Cés (Berom), Ikpogi, Ògì (Edo), Ikon, Íkpán (Efik), Cikirre, Chiklje, Dende, Dene, Denaje (Fulfulde), Mimihi (Gwari), Àgúshií, Bambus, Gúna (Hausa), Ikon, Íkpán (Ibibio), Ègúsí, Élìlì, Nwanru, Ogili-Irele, Ògìlì, Ògìlì-Élìlì, Nkbuluko, Ègúsí, Élìlè, Élìlì (Igbo), Bámbúsθ', Fálí, Gúnà (Kanuri), Epín, Epíngi, Pàràgi (Nupe), Icegher (Tiv), Elebo, Ìkpógrì, (Urhobo), Bàrà, Ègúsí, Ègúsí, Agbè, Egúsí Bora, Egúnsi, Ègúsí, Maga, Ṣ̀ọ́fín (Yoruba);
Niuean: Meleni;
Norwegian: Vannmelon, Vassmelon;
Palauan: Sandiang, Suik;
Papiamento: Patia;
Persian: Raqqi;
Philippines: Sandiya (Bicol), Dagita (Marinduque), Pakwan (Tagalog);
Polish: Arbuz, Arbuz Zwyczajny, Kawon;
Portuguese: Melancia, Melância;
Romanian: Pepene Verde;
Russian: Arbuz, Arbuz Stolovyj;
Sámegiella: Čáhcemelovdna;
Samoan: Meleni, Meleni;
Senegal: Béref, Ségal (Serer), Béref, Hal, Hatar, Xal (Wolof);
Serbian: Lubenitsa;
Sierra Leone: Bɔhrɔ, Cham-Dɛ, Sãhũ-Bombom-Dɛ, Sãŋga-Lɛ (Bulom), Budi (Fula-Pulaar), Legiɛ-Kwi (Gola), Leŋguõ (Kissi), Kɔ-Saa, Saa (Kono), Bara-Egusi, E-Gbara, Egusi (Krio), Sara, Sarɛ (Manding-Mandinka), Sara-Kumba (Maninka), Koja, Pu-Goja (Mende), Sara-Na (Susu-Dyalonke), An-Tent (The Plant), Ma-Tent, Ma-Tent-Ma-Potho (The Fruit), (Temne), Sa, Sara (Vai);
Slovenian: Lubenice;
South Africa: Bitterwaatlemoen, Karkoer, Waatlemoen (Afrikaans), Tsamma, T'sama (Khoisan), Makataan (Tswana);
Spanish: Albudeca, Melón, Sandia;
Swahili: Mtango, Mtikiti;
Swedish: Vattenmelon;
Tahitian: Merēni, Mereni Tahiti;
Thailand: Taeng Chin (Peninsular Thailand), Taeng Moh (Central Thailand), Matao (Northern Thailand);
Tongan: Meleni;
Tongarevan: Melēni, Merēni;
Turkish: Karpuz, Kaun, Kayun;
Tuvaluan: Meleni;
Ukranian: Kabyh, Kavun;
Vietnamese: Dưa Hấu, Dưa Đỏ, Dưa Hấu Ruột Đỏ (Red-Fleshed), Dưa Hấu Ruột Vàng (Yellow-Fleshed);
Venezuela: Patilla;
West Cameroons: Esaka Bawu (Bafok), Ngondo (Kpe), Esaka (Kundu), Esaka (Long), Esaka (Lundu), Osaka (Mbonge), Esaka (Tanga), Ngondo (Wovea);
Yapese: Maeyis.

Origin/Distribution

Citrullus lanatus is indigenous to tropical Africa and subtropical southern Africa, occurring naturally in South Africa, Namibia, Botswana, Zimbabwe, Mozambique, Zambia

and Malawi. It was introduced into Mediterranean areas, the Middle East and West Asia more than 3,000 years ago and easterly to India and subsequently to China around the tenth century and Japan in the sixteenth century. It was introduced to the Americas in early post-Columbian times. It is now widespread in cultivation and frequently naturalized in warmer parts of the world. Tsamma watermelon is the ancestral form of the cultivated dessert watermelon.

Agroecology

In its natural range in the wild, *Citrullus lanatus* prefers deep sands as it has a deep root system, and occurs in grassland or bush land often along in dry watercourses. It is also found naturally in disturbed areas or as a weed in cultivated land. It is a warm temperature crop, flourishing in hot day temperatures and warm nights and is day-length neutral. The Egusi watermelon, grown for its seeds, is cultivated in tropical lowlands up to 1,000 m altitude, the dessert watermelon up to 2,000 m. Both perform better with higher yields in the drier savanna region than in the wet forest zone. *Citrullus lanatus* withstands drought better than most melons. West African seed types require an average annual rainfall of at least 700–1,000 mm and a daytime temperature of 28–35°C. In the Kalahari region, seed melons usually only get 400–650 mm of rain. Excessive rainfall and high humidity promotes excessive vegetative growth and promote disease infection, mainly leaf and fruit rot, with consequent low yields.

Dessert watermelons need about 70–120 days to mature depending on temperature. They prefer full sun but sun-burn can be problematic if foliage growth is not good. They can be grown on a wide range of soil types as long as drainage is good. However, a loose, friable, fertile sandy loam soil containing organic matter with a pH of 6.0–7 is preferred. Compacted clayey layers can be very detrimental to root development and water-logged soils predisposes the crop to ravages from anthracnose disease and fruit rots. Lower soil pH enhances soil-borne disease problems especially those caused by *Fusarium* spp. In areas with high winds, wind breaks should be established.

Edible Plant Parts and Uses

The tsamma watermelon of South Africa and Namibia, is an important water source for humans and animals in the Kalahari desert. The forms of the var. *cordophanus* also provide important water source for the dry regions in East Africa.

The Egusi melon of West Africa which has a bitter flesh is relished for its high protein seeds. After roasting, the seeds are ground into a coarse, whitish, nutritious and pleasantly nutty-tasting meal. In West Africa, the seeds are made into pulp and added as thickener to soups. They are also fermented to produce a sweetener locally called '*ogiri*' or they are roasted, pounded, wrapped in leaves and then boiled to produce another sweetener called *'igbãlo'*. The pulp of roasted and salted seeds is eaten in Sudan and Egypt, where it is called '*tasali*'. In the far northern parts of Sudan seeds of some types are eaten whole, including the seedcoat, after being roasted; these are called '*gorom*'. A highly prized vegetable oil is extracted from watermelon seed. This oil is used for cooking and making soups and also for cosmetic and pharmaceutical purposes. The residue from oil extraction is made into balls that are fried to produce a local snack called '*robo*' in Nigeria. In Asia, especially during festive occasions, the roasted seeds are coloured red and eaten after removal of the seed coats as snacks (Plate 6). The seeds can be roasted to make a

Plate 1 Leaf and watermelon fruit

Plates 2 (**a**–**d**) Different varieties and shapes of water melon

Plate 3 Yellow fleshed seeded water melon

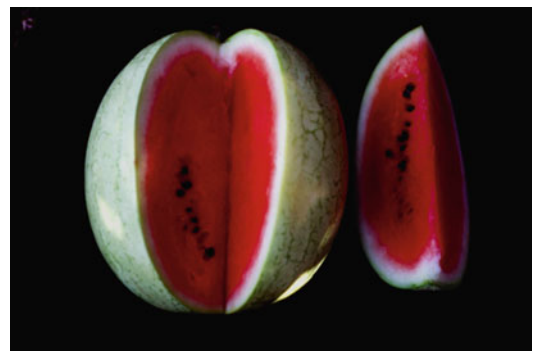

Plate 4 Red fleshed seeded watermelon

substitute for coffee or pulverised to powder for making cakes, bread or added to soups and stews.

Leaves and young fruits are utilised as green vegetables. The unripe fruits are added to soups. Young fruits from which the seeds have been removed are cooked until they are soft. In Zimbabwe the cooked melons are mixed with cooked beans or cowpeas, and powdered seeds of bottle gourd are added. In many African countries, to preserve the fruit flesh, the seeds and rind are removed and slices are dried in the sun. A stiff porridge is made from mature fruits mixed with maize or pearl millet flour. The leaves are occasionally used as a cooked vegetable. In the United States, the rind of some cultivars is made into

Plate 5 Red-fleshed seedles watermelon

Plate 6 Water melon seeds dyed red and eaten as snack

pickle or a sweet preserve. The peels of the fruit are traditionally used for making jam. The fruit is a rich source of pectin and can be added to pectin-low fruits when making jam. In the south of France, the preserving melon or citron is popular for jams. In the orient, the fruit is often converted into "nardek" (watermelon honey). In Russia, the fruit is also salted like cucumbers. The watermelon is very refreshing as a dessert fruit and makes an excellent refreshing, juicy drink. A syrup can also be made from the juice. The juice can also be fermented for alcohol production.

Botany

An annual, monoecious herb with long, hairy, ridged stems scandent or trailing on the ground, with curly, bifid tendrils. Leaves are alternate, simple, 5–20 by 3–19 cm, blade oblong-ovate in outline, 4–25 cm× 3–19 cm, deeply palmately 3–5(–7)-lobed, lobes usually more or less pinnately sinuate-lobulate, margin shallowly sinuate-toothed, long-hairy on the veins, becoming scabrid-punctate (Plate 1). Flowers solitary in leaf axils, unisexual, 2–3.5 cm in diameter, regular, 5-merous, yellow; pedicel 1.5–4 cm long; calyx campanulate; petals united below; male flowers with 3 free stamens alternating with petals; female flowers with inferior, 1-celled, hairy, syncarpous ovary, style 1, stigma 3-lobed. Fruit is a large berry, globose, subglobose, broadly ellipsoid or oblong, to 25 cm diameter or more, weighing 3–25 kg, white, green or yellowish variously mottled or striped (Plates 2a–d), flesh red or pink, sometimes yellow, watery, sweet (Plates 3–5); seeds 20–50, black, flattened, obovate to elliptical, 4–6 mm long, sometimes white-mottled, embedded in the juicy, sweet watery flesh.

Nutritive/Medicinal Properties

The nutrient composition of raw watermelon per 100 g edible portion excluding 48% refuse (rind, seeds, and cutting loss) (USDA 2010) was reported as: water 91.45 g, energy 30 kcal (127 kJ), protein 0.61 g, total lipid (fat) 0.15 g, ash 0.25 g, carbohydrate 7.55 g, total dietary fiber 0.4 g, total sugars 6.20 g, sucrose 1.21 g, glucose 1.58 g, fructose 3.36 g, maltose 0.06 g, Ca 7 mg, Fe 0.24 mg, Mg 10 mg, P 11 mg, K 112 mg, Na 1 mg, Zn 0.10 mg, Cu 0.042 mg, Mn 0.038 mg, F 1.5 µg, Se 0.4 µg, vitamin C 8.1 mg, thiamin 0.033 mg, riboflavin 0.021 mg, niacin 0.178 mg, pantothenic acid 0.221 mg, vitamin B-6 0.045 mg, total folate 3 µg, total choline 4.1 mg, betaine 0.3 mg, vitamin A 569 IU (28 µg RAE), vitamin E (α-tocopherol) 0.05 mg, vitamin K (phylloquinone) 0.1 µg, total saturated fatty acids 0.016 g, 10:0 0.001 g, 12:0 0.001 g, 16:0 (palmitic acid) 0.008 g, 18:0 (stearic acid) 0.006 g; total monounsaturated fatty acids 0.037 g, 18:1 undifferentiated (oleic acid) 0.037 g; total polyunsaturated fatty acids 0.050 g, 18:2 undifferentiated (linoleic acid) 0.050 g; phytosterols 2 mg, amino acids – tryptophan 0.007 g, threonine

0.027 g, isoleucine 0.019 g, leucine 0.018 g, lysine 0.062 g, methionine 0.006 g, cystine 0.002 g, phenylalanine 0.015 g, tyrosine 0.012 g, valine 0.016 g, arginine 0.059 g, histidine 0.006 g, alanine 0.017 g, aspartic acid 0.039 g, glutamic acid 0.063 g, glycine 0.010 g, proline 0.024 g, serine 0.016 g; β-carotene 303 μg, β-crptoxanthin 78 μg, lutein + zeaxanthin 8 μg.

Volatile compounds identified from watermelon fruit included: hexanal, *trans*-2-heptenal, *trans*-2-octenal, nonanal, *trans*-2-nonenal, *trans*,*cis*-2,6-nonadienal, nonan-1-ol, *trans*-2-nonen-1-ol, *cis*-3-nonen-1-ol, *trans*,*cis*-2,6-nonadien-1-ol, *trans*-2-decenal, *trans*-2-undecenal, geranial, β-ionone (Kemp 1975) and 3,6-Nonadien-1-ol (Kemp et al. 1974). Fifty-two compounds were found for the first time as flavour components of watermelon. Among them, the following compounds had not been previously reported as naturally occurring flavour components: 4-oxononanal and 2-hydroxy-, 2-pentyloxy-, 2-hexyloxy-, 2-octyloxy-, 2-nonyloxy-, 2-[(Z)-3-noneyloxy]-, 2-[(Z)-2-nonenyloxy]-, 2-[(Z, Z)-3, 6-nonadienyloxy]-, 2-benzyloxy-, and 2-phenetyloxy-5-pentyltetrahydrofurans (Yajima et al. 1985). Another study reported major volatile components of watermelon fruit as ethyl acetate (23.0%), acetaldehyde (18.0%), tetradecanoic acid (14.1%) and methyl acetate (11.4%) (Pino et al. 2003). One group of volatile compounds with marked characteristic feature of watermelon volatiles was: saturated and unsaturated aliphatic aldehydes and alcohols with skeletons of nine carbon atoms.

Fully ripe seedless triploid watermelons were found to have aldehydes, alcohols, ketones, and one furan (2-pentyl furan, a lipid oxidation product) in their volatile components (Beaulieu and Lea 2006). The most abundant compounds in the five varieties tested were 3-nonen-1-ol/(E,Z)-2,6-nonadienal (16.5–28.2%), (E)-2-nonenal (10.6–22.5%), and (Z)-6-nonenal (2.0–11.3%). Hexanal was most abundant (37.7%) in one variety (Petite Perfection). The most abundant ketone was 6-methyl-5-hepten-2-one (2.7–7.7%). Some sensory attributes reported for these compounds included melon, citrus, cucumber, orange, rose, floral, guava, violet, vegetable, green, grassy, herbaceous, pungent, fatty, sweet, and waxy.

Globulin was found to be the major protein (≥500 g/kg) present in watermelon seed meal, followed by albumin and glutelin (Wani et al. 2011). These proteins were rich in aspartic acid, glutamic acid and serine. Among functional properties, albumin exhibited a much higher dispersibility index (810.3–869.6 g/kg) than globulin (227.8–245.4 g/kg), glutelin (182.1–187.7 g/kg) and prolamin (162.3–177.7 g/kg). Digestibility was in the ranges 760.6–910.0 and 765.5–888.5 g/kg for Mateera and Sugar Baby watermelon protein fractions respectively, while surface hydrophobicity ranged from 126.4 to 173.2 and from 125.8 to 169.3 respectively. The foaming and emulsifying properties of albumin were better than those of the other proteins studied. The good nutritional and functional properties of watermelon seed meal proteins suggested their potential use in food formulations.

The lipid content of *Citrullus lanatus* seeds was found to be 50.23% (Anhwange et al. 2010). The extracted seed oil had an Iodine value of 119.82, saponification value of 189.35, acid value of 5.120, free fatty acid value of 2.56, the peroxide value of 7.51 and the specific gravity and refractive indexes of the oils were found to ranged between 0.91–0.93 and 1.46–1.47 respectively. Watermelon seeds were found to contain urease (Prakash and Bhushan 1998) a proteinaceous enzyme that catalyzes the hydrolysis of urea into carbon dioxide and ammonia.

Antioxidant Activity

Watermelon fruits have been reported to have high antioxidant potential. Watermelon was found to be a rich natural source of lycopene, a carotenoid of great interest because of its antioxidant capacity and potential health benefits. Watermelon cultivars exhibited a range of lycopene concentrations, with seeded and seedless red-fleshed types having 36–78 μg/g lycopene, and orange or yellow watermelons having less than 5 μg/g lycopene (Perkins-Veazie et al. 2003). Under-ripe and over-ripe melons had as much as

20% less lycopene than fully ripe melons, with maturity effects dependent on the variety. Storage of whole or cut melons for 2–10 days lowered lycopene contents by 6–10%. Assays of human plasma after lycopene ingestion indicated that lycopene was as efficiently obtained from watermelon juice as from tomato juice. In subsequent studies they found significant variation in lycopene content, ranging from 33 to 100 mg/kg among 50 commercial cultivars of seeded and seedless red-fleshed watermelons cultivars (Perkins-Veazie et al. 2006). Most of the seeded hybrid cultivars had average lycopene contents. Sixteen of the 33 seedless types had lycopene contents in the high (70–90 mg/kg fresh weight), and very high (>90 mg/kg fresh weight) ranges. All-trans-lycopene was the predominant carotenoid (84–97%) in all watermelon cultivars but the genotypes differed in the relative amounts of cis-lycopene, β-carotene, and phytofluene. Red-fleshed watermelon genotypes differed extensively in carotenoid content and offered opportunities for developing watermelons with specifically enhanced carotenoids. Another recent study reported that carotenoids in the sugar baby variety of watermelon comprised lycopene 37.2 μg/g FW, lutein 2.1 μg/g FW and β-carotene 0.3 μg/g FW (Chandrika et al. 2009). Guava was found to contain more lycopene (45.3 μg/g FW) than watermelon (37.2 μg/g FW), and the in-vitro accessibility of lycopene in guava (73%) was more than that in watermelon (25.8%). Yellow-fleshed watermelons contained many different carotenoids, all in low to trace amounts (Davis et al. 2007). The total carotenoid concentration of yellow-fleshed watermelons ranged from 0 to 7 μg/g fresh weight.

Consumption of watermelon juice was found to increase plasma concentrations of lycopene and β-carotene in humans (Edwards et al. 2003). In a 19-week crossover study, 23 healthy, non-smoking adults (36–69 years) completed three 3-week treatment periods, each with a controlled, weight-maintenance diet. After 3 weeks of treatment, plasma lycopene concentrations for the W-20 (20.1 mg/day lycopene, 2.5 mg/day β-carotene from watermelon juice), W-40 (40.2 mg/day lycopene, 5.0 mg/day β-carotene from watermelon juice), T-20 (18.4 mg/d lycopene, 0.6 mg/d β-carotene from tomato juice) and C-0 (controlled diet, no juice) treatments were 1,078, 1,183, 960 and 2,727 nmol/L, respectively. Plasma concentrations of β-carotene were significantly greater after W-20 (574 nmol/L) and W-40 (694 nmol/L) treatments than after the C-0 treatment (313 nmol/L). Plasma lycopene concentrations did not differ at week 3 after W-20, W-40 and T-20 treatments, indicating that lycopene was bioavailable from both fresh-frozen watermelon juice and canned tomato juice, and that a dose-response effect was not apparent in plasma when the watermelon concentration was doubled.

Methanolic extract of watermelon seeds was also reported to exhibit high antioxidant potential and to have high contents of phenolics and flavonoids (Atrooz 2009). The methanolic extract of watermelon seeds was also exhibited high antioxidant activity in a dose dependent fashion using DPPH and H_2O_2 assays (Gill et al. 2010).

Antiinflammatory and Analgesic Activities

Gill et al. (2010) showed that 200 mg/kg of methanolic extract of watermelon seeds exhibited significant anti-inflammatory and analgesic activity using carrageenan induced rat paw edema and analgesic activity by tail flick and tail immersion methods as compared to diclofenac sodium and morphine respectively.

Antiatherogenic Activity

Watermelon peel extract was found to have antiatherogenic activity. Rats, treated simultaneously with either of the following peel extracts (200 mg/kg of *Mangifera indica* and 100 mg/kg for *Cucumis melo* and *Citrullus vulgaris* for 10 consecutive days) reversed the effects of the atherogenic CCT-diet (supplemented with 4% cholesterol, 1% cholic acid and 0.5% 2-thiouracil) (Parmar and Kar 2008). The CCT diet induced increase in the levels of tissue lipid

peroxidation (in heart, liver and kidney), serum lipids, glucose, creatinine kinase-MB and decrease in the levels of thyroid hormones and insulin indicating their potential to improve the diet induced alterations in serum lipids, thyroid dysfunctions and hyperglycemia/diabetes mellitus. A phytochemical analysis revealed the presence of a high level of polyphenols and ascorbic acid in the test peel extracts suggesting that the beneficial effects could be the result of the rich content of polyphenols and ascorbic acid in the studied peels.

Thyroid Stimulatory Activity

Watermelon peel extract was also found to have thyroid stimulatory activity. Administration of three test peel extracts of *Mangifera indica* (MI), *Citrullus vulgaris* (CV) and *Cucumis melo (*CM) (200 mg/kg of MI and 100 mg/kg both of CV and CM) to Wistar albino male rats for 10 consecutive days significantly elevated both the thyroid hormones T(3) and T(4) with a concomitant reduction in tissue lipid peroxidation (LPO), suggesting their thyroid stimulatory and antiperoxidative role (Parmar and Kar 2008). This thyroid stimulatory nature was also exhibited in propylthiouracil (PTU) induced hypothyroid animals. However, only minor influence was observed in serum lipid profile in which CM reduced the concentrations of total cholesterol and low-density lipoprotein-cholesterol (LDL-C), while CV decreased triglycerides and very low-density lipoprotein-cholesterol (VLDL-C). When the combined effects of either two (MI+CV) or three (MI+CV+CM) peel extracts were evaluated in euthyroid animals, serum thyroid hormones T(3) concentration was increased in response to both combined treatments, while thyroid hormone T(4) level was elevated by the combinations of first two peels only. However, both the categories of combinations increased T(4) levels, but not T(3) in PTU treated hypothyroid animals. Further, a parallel increase in hepatic and renal LPO was observed in these animals, suggesting their unsafe nature in combination. The researchers concluded that the three test peel extracts appeared to be stimulatory to thyroid functions and inhibitory to tissue LPO but only when treated individually.

Watermelon was reported also to be a natural and rich source of the non-essential amino acid, citrulline (Rimando and Perkins-Veazie 2005). Citrulline is used in the nitric oxide system in humans and has potential antioxidant and vasodilatation roles. Citrulline content ranged from 3.9 to 28.5 mg/g dry weight (dwt) and was similar between seeded and seedless watermelon types (16.6 and 20.3 mg/g dwt, respectively). Red flesh watermelons had slightly less citrulline than the yellow or orange flesh watermelons (7.4, 28.5 and 14.2 mg/g dwt, respectively). Rind contained more citrulline than flesh on a dry weight basis (24.7 and 16.7 mg/g respectively) but a lesser on a fresh weight basis (1.3 and 1.9 mg/g, respectively).

L-Arginine Enhancing Activity

Citrulline, was found to be metabolized to arginine, a conditionally essential amino acid for humans (Romero et al. 2006; Collins et al. 2007). Arginine is the nitrogenous substrate used in the synthesis of nitric oxide and plays an essential role in cardiovascular and immune functions. Supplemental administration of L-arginine had been shown to be effective in ameliorating NO production and cardiovascular function in cardiovascular diseases associated with endothelial dysfunction, such as hypertension, heart failure, atherosclerosis, diabetic vascular disease and ischemia-reperfusion injury, but the beneficial actions did not endure with chronic therapy (Romero et al. 2006). Substantial intestinal and hepatic metabolism of L-arginine to ornithine and urea by arginase made oral delivery very ineffective. Additionally, all of these diseased states as well as supplemental L-arginine enhanced arginase expression and activity, thus reducing the effectiveness of L-arginine therapy. In contrast, L-citrulline was not metabolized in the intestine or liver and did not induce tissue arginase, but rather inhibited its activity. L-citrulline entering the kidney, vascular endothelium and other tissues could

be readily converted to L-arginine, thus raising plasma and tissue levels of L-arginine and enhancing NO production.

Supplemental L-citrulline was found to have promise as a therapeutic adjunct in disease states associated with L-arginine deficiencies. Studies showed that dietary L-arginine supplementation reduced fat mass in Zucker diabetic fatty rats (Fu et al. 2005). The body weights of arginine-treated rats were 6%, 10%, and 16% lower at week 4, 7, and 10 after the treatment initiation, respectively, compared with control rats. Arginine supplementation decreased the weight of abdominal (retroperitoneal) and epididymal adipose tissues (45% and 25%, respectively) as well as serum concentrations of glucose (25%), triglycerides (23%), FFA (27%), homocysteine (26%), dimethylarginines (18–21%), and leptin (32%). The arginine treatment enhanced NO production (71–85%), lipolysis (22–24%), and the oxidation of glucose (34–36%) and octanoate (40–43%) in abdominal and epididymal adipose tissues. Results of the microarray analysis indicated that arginine supplementation increased adipose tissue expression of key genes responsible for fatty acid and glucose oxidation: NO synthase-1 (145%), heme oxygenase-3 (789%), AMP-activated protein kinase (123%), and peroxisome proliferator-activated receptor gamma coactivator-1alpha (500%). The scientist concluded that arginine treatment may provide a potentially novel and useful means to enhance NO synthesis and reduce fat mass in obese subjects with type-II diabetes mellitus. Further studies in the Zucker diabetic fatty (ZDF) rats showed that dietary supplementation with watermelon pomace juice or L-arginine increased serum concentrations of arginine; reduced fat accretion; lowered serum concentrations of glucose, free fatty acids, homocysteine, and dimethylarginines; enhanced GTP cyclohydrolase-I activity and tetrahydrobiopterin concentrations in the heart; and ameliorated acetylcholine-induced vascular relaxation (Wu et al. 2007). Compared with the control, dietary supplementation with lycopene or citrus pectin did not affect any measured parameter. These results provided the first evidence for a beneficial effect of watermelon pomace juice as a functional food for increasing arginine availability, reducing serum concentrations of cardiovascular risk factors, improving glycemic control, and ameliorating vascular dysfunction in obese animals with type-II diabetes.

In further, cross-over design studies with 12–23 adults per treatment, fasting plasma arginine concentrations increased 12% after 3 weeks of the lower-dose watermelon treatment (780 g watermelon juice per day for 3 weeks) compared with the baseline; arginine and ornithine concentrations increased 22% and 18%, respectively, after 3 weeks of the higher-dose watermelon treatment (1,560 g of watermelon juice per day) (Collins et al. 2007). Fasting citrulline concentrations did not increase relative to the control but remained stable throughout the study. The increased fasting plasma concentrations of arginine and ornithine and stable concentrations of plasma citrulline in response to watermelon juice consumption indicated that the citrulline from this plant origin was effectively converted into arginine. The results demonstrated that plasma concentration of arginine could be increased through intake of citrulline from watermelon.

Adverse Effects

A 19-month-old girl with developmental delay was found to have moderately elevated plasma citrulline and mildly elevated plasma arginine concentrations caused by excessive consumption of large quantities of watermelon, a fruit containing high free citrulline and arginine concentrations (Mandel et al. 2005). Follow-up ingestion studies of watermelon in six healthy adult volunteers revealed that all developed markedly elevated plasma citrulline (mean maximum 593 μmol/L, range 386–1,069) and moderately elevated plasma arginine (mean maximum 199 μmol/L, range 128–251). The scientist asserted that physicians and laboratory personnel performing metabolic investigations should be aware of watermelon-induced citrullinaemia. Its hallmarks are elevated plasma citrulline, and to a lesser extent arginine, in the absence of orotic or arginosuccinic aciduria or hyperammonemia.

This phenomenon has implications for the management of patients with urea cycle and related disorders.

A trypsin inhibitor consisting of 30 amino acid residues was isolated from seeds of watermelon (Polanowski et al. 1987); the Arg5-Ile6 peptide bond represented the reactive site bond of the trypsin inhibitor (Otlewski et al. 1987). Trypsin inhibitor inhibits the action of trypsin in animal nutrition and thus inhibit digestion.

Insecticidal Activity

Watermelon leaf extract in different solvents exhibited insecticidal activity against the malarial vector, *Anopheles stephensi* (Mullai et al. 2008b). The larval mortality was observed after 24 hours exposure. The LC_{50} values for the extract in benzene, petroleum ether, ethyl acetate and methanol were 18.56, 48.51, 49.57 and 50.32 ppm respectively. The mean percent hatchability of the egg of *Anopheles stephensi* were observed after 48 hours. 100% mortality was exerted at 250 ppm with benzene extract, and the other extracts exerted 100% mortality at 300 ppm. Skin repellent test at 1.0, 2.5 and 5.0 mg/cm^2 concentration gave the mean complete protection time ranged from 119.17 to 387.83 min with the four different extracts tested. The plant extract exhibited insect growth regulatory activity against *Anopheles stephensi* at five different test concentrations ranging from 10 to 150 ppm with different solvents and they exhibit the following EI_{50} values 28.99, 70.02, 106.33 and 84.25 ppm respectively. The crude benzene extract of watermelon leaves was found to be more effective against *Anopheles stephensi* than *Aedes aegypti* (Mullai et al. 2008a). The LC_{50} values were 18.56 and 42.76 ppm respectively. The LC_{50} values for silica gel fractions (bioactive fractions I, II, III and IV) were 11.32, 14.12, 14.53 and 16.02 ppm respectively. The mean per cent hatchability of the egg rafts were observed after 48 h post treatment. The crude extract of benzene exerted 100% mortality at 250 ppm against *A. stephensi* and at 300 ppm against *A. aegypti*. The silica gel fractions I and II afforded 100% mortality at 100 ppm and III and IV exerted the hatchability rate of 4.9% and 5.3% at the same concentration against *A. stephensi*.

Traditional Medicinal Uses

In traditional medicine, watermelon seed is considered demulcent, diuretic, pectoral and tonic. It has been employed for the treatment of the urinary passages and to treat bed wetting. The seed is also a good vermifuge and has a hypotensive action. A fatty oil extracted from the seed, as well as aqueous or alcoholic extracts has been reported to paralyse tapeworms and roundworms. Tar is extracted from the seeds and used for the treatment of scabies and for skin tanning. In Senegal, the fruits are used as a drastic purgative; they are diuretic and used to treat diarrhoea and gonorrhoea in Nigeria. The fruit is also diuretic, being effective in the treatment of dropsy and renal stones. The fruit rind is administered in cases of alcoholic poisoning and diabetes. The root is purgative and in large dose is emetic.

Other Uses

Fodder melon is mainly grown in the United States and South Africa. In the extensive farming systems of semi-arid regions, leaves and fruits of fodder melons are a source of forage and water for livestock. Watermelon seed oil besides being used for cooking, is used for cosmetic purposes and is of interest to the pharmaceutical industry. The seed oil has been used for making soap and for illuminants. The residue from seed oil extraction is made into balls that and also used as cattle feed. Face masks made from the fruit are used as a cosmetic on delicate skins.

Comments

Note: *Citrullus lanatus* (Thumb.) Matsum. & Nakai is sometimes divided into 3 subspecies:
1. *Citrullus lanatus* ssp. *lanatus*

Citrullus lanatus ssp. *lanatus* var. *lanatus* – Tsamma melon, of South Africa and Namibia, used as an important water source for humans and animals in the Kalahari desert.

Citrullus lanatus ssp. *lanatus* var. *citriodes* (Bailey) Mansfiled – the fodder melon of South America and USA,

2. *Citrullus lanatus* ssp. *mucosospermus* Fursa – the Egusi watermelon of West Africa,
3. *Citrullus lanatus* spp. *vulgaris* (Schrad. ex Eckl. & Zeyh.) Fursa

Citrullus lanatus spp. *vulgaris* (Schrader) Fursa var. *cordophanus* (Ter-Avan) Fursa – comprises forms in East Africa, important used as water sources in dry regions,

Citrullus lanatus spp. *vulgaris* (Schrad. ex Eckl. & Zeyh.) Fursa var. *vulgaris* – the most important cultivated watermelon globally.

In Japan, seedless triploid cultivars with high quality fruits (seedless watermelons) have been developed, and is now widely grown in the USA and elsewhere.

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Coccinia grandis

Scientific Name

***Coccinia grandis* (L.) J. Voigt**

Synonyms

Bryonia alceifolia Willd, *Bryonia grandis* L., *Cephalandra indica* (Wight & Arn.) Naudin nom. illeg., *Coccinia cordifolia* sensu auct., non (L.) Cogn., *Coccinia cordifolia* (L.) Cogn. var. *alceifolia* (Willd.) Cogn., *Coccinia cordifolia* (L.) Cogn. var. *wightiana* (M.Roem.) Cogn., *Coccinia grandi*s (L.) Voigt var. *wightiana* (M.Roem.) Greb., *Coccinia indica* Wight & Arnold nom. illeg., *Coccinia loureiriana* M.Roem., *Coccinia wightiana* M.Roem., *Cucumis pavel* Kostel., *Momordica bicolor* Blume, *Momordica monadelpha* Roxb.

Family

Cucurbitaceae

Common/English Names

Ivy Gourd, Kowai fruit, Scarlet-Fruited Gourd, Scarlet Gourd, Small Gourd, Tindora

Vernacular Names

Bangladesh: Kawajhinga, Telakucha;
Chinese: Hong Gua;
Danish: Skariagenagurk;
Ethiopia: Gale (Afaan Oromo);
French: Gourde Écarlate De L´Inde Tindola, Courge Écarlate;
German: Scharlachranke, Tindola;
India: Kunduli (Assamese), Kundri, Telakucha, Telakuch (Bengali), Bimb, Gol, Golan, Golenda, Kaduri, Kandaroi, Kanduri, Kanturi, Kunduru, Shiv Lingi (Hindu), Kaage Thonde, Kaagethonde, Konde Balli, Sihithonde, Theekkuduru, Thonde Balli, Thundike, Tondikay (Kannada), Covel, Kova, Koval (Malayalam), Bimbi, Kondvalli, Thendli, Thondali, Tondili, Tondli, Zidadi (Marathi), Ban-kundri, Kundru (Oriya), Bhrngaraja, Bimbi, Bimbika, Chilihindah, Patalagarudah, Vira (Sanskrit), Acoki, Annalvalli, Aracan, Aracanviroti, Araiyanviroti, Attarittan, Avaiyanal, Avanti, Avaramuli, Ayanamatti, Ayavalli, Cempi, Cenkovai, Ciranapimpi, Ciravi, Civakamuli, Civanarpakal, Civanarpavai, Civanarpavaikkoti, Cutakatti, Ilinkapputol, Kakkam, Katumatuppi, Katutumpi, Korutan, Kotturukanni, Kovai, Kovaikkay, Kovvankay, Koyilakam, Kulirntukolli, Kunkumakkovai, Kutamakaram, Kuvattinurukanni, Makaciravi, Mannumulunki, Marikovai, Matampuratti,

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Matupakku, Matupari, Nallakovai, Naripputu, Narkovai, Periyakovai, Perunkovai, Perunkovaikkoti,Perunkovikakkoti,Perunkovikam, Pimpakam, Pimpam, Pimpi, Pimpikai, Potanacani, Rattakkovai, Rattakkovaikkoti, Talavaykkovai, Tirattikkovai, Tuntakeri, Tuntakori, Tunti, Tuntikeri, Vattakkarimuli, Vattakkovai, Velikkovvai, Vimpakakkoti, Vimpakam, Vimpi, Vimpikai, Velikkovvaikkoti, Vellaippuvi (Tamil), Bimbika, Donda, Donda Kaya, Dondatheege, Kaaidonda, Kaakidonda, Kaki Donda (Telugu);
Indonesia: Bolu Teke, Kapasan, Kemarongan, Papasan, Sarap Alas, Tekli (Java), Aropi Papasan (Sundanese), Papasan, Paspasan, Sarap Alas (Madurese);
Japanese: Yasai Karasu Uri;
Kenya: Nyamutu Kuru (Luo);
Khmer: Slok Baahs;
Laos: Tam Ling, Tam Min;
Malaysia: Pepasan;
Marshall Islands: Kiuri Awia;
Nepalese: Akhu Pami, Golkakri, Gol Kankri, Kundaruu, Kundaru, Van Kirii;
Niger: Magaro;
Pakistan: Kanduri, Kundur;
Pohnpei: Aipikohr;
Somalia: Guud-Fayleey;
Spanish: Pepino Cimarrón;
Swahili: Ruho;
Thai: Tam Lueng, Phak Tam Lueng;
Vietnamese: Bát, Hoa Bát, Rau Bát, Chum Bát.

Origin/Distribution

Ivy gourd occurs wild in northern and eastern Africa, Arabia to tropical south and southeast Asia. It has spread and become naturalised in Tropical northern Australia and Fiji and occasionally adventive in the neotropics.

Agroecology

Ivy gourd is adaptable to wide diversity of habitats ranging from semi-arid areas, dry monsoonal forest, tropical and subtropical rainforest, wooded grasslands, coastal and riparian areas, banks of rivers and rice fields, in disturbed areas, open places, cane fields, roadside and around villages and backyard fences in the tropics and subtropics. It is usually found growing at low altitude but is also found up to 1,000 m as in Uganda and up to 2,350 m elevation in Ethiopia in all types of soil. It is a robust, hardy, sun-loving and aggressive vine and has extensive root system which also makes it is an invasive weed. It climbs over shrubs and trees and smother them, forming a dense sun-blocking canopy.

Edible Plant Parts and Uses

Young fruit and young terminal leafy shoots and leaves are eaten blanched, fried or boiled with rice, noodles or in soups. In Indonesia, leaves and terminal shoots are used for *koloban* for the rice table, also useful in *sayur* and *sambelan*, The fruits are also eaten cooked with rice or sometimes comfited (candied).

Coccinia grandis is a very popular vegetable in Thailand and commonly available in the wet traditional markets. Its cultivation in home gardens has been encouraged by the Thai government due to its being a good source of several micronutrients, including vitamins A and C. The young tender leafy shoot tips in lengths of 40–50 cm long are harvested, bundled, packed in plastic bags or in bamboo baskets with banana leaves underneath for maintaining humidity, and shipped to wholesale markets from where they are distributed to retail markets in small bundles. Young leafy terminal tips are blanched for dipping in chilli paste or used in stir-fries. They are also added to soup dishes like porcine blood curd soup, ivy gourd and minced pork soup or mixed vegetable soup and noodles. The young green leaves are boiled and mashed before adding to porridge for young children. In Thailand, the young fruits are fermented and used widely in soups and curries with rice or fried. The young green fruit are also pickled and eaten by dipping in chili paste. The ripe fruits can be eaten raw or comfited. The flesh can be processed into fermented or dehydrated chips. In Vietnam the fruits, leaves and leafy shoots are boiled or cooked in soups.

Ivy gourd is an important tropical vegetable cultivated in India, the fruit is commonly used in Indian cuisine. It is eaten as a curry, by deep-frying it; stuffing it with *masala* and sautéing it. It is also used in *sambaar*, a vegetable- and lentil-based soup. Studies by Kulkarni and Vijayanand (2010) showed that dehydrated ivy gourd slices remained acceptable during storage of 4 and 6 months in low density polyethylene (LDPE) and metallized polyester polyethylene (MPP) pouches respectively, at room temperature.

In East Africa, ripe, red fruit are eaten raw, or they are peeled and cut into pieces and prepared as a stew with onions and tomatoes and other vegetables such as egg plant, bottle gourd, ridge gourd, okra and pulses. Meat is added when available. The dish may be served with bread, sorghum or any other starchy food. Immature green fruits are prepared in soups and curries and widely used in this way in Ethiopia and India. The leaves are also eaten as a vegetable by the Mursi tribe in Ethiopia. The seeds are chewed in Ethiopia and Kenya.

Botany

Dioecious perennial climbing or trailing herbaceous vine with tuberous root system. Stems green, ribbed when young, glabrous, with simple, axillary tendrils. Leaves alternate, simple, broadly ovate, 5-lobed, 5–9 × 4–9 cm, acute and mucronate at the apex, cordate at the base; surfaces glabrous or scaly, margins sinuate; petiole 1–5 cm long (Plates 1 and 2). Inflorescence usually of solitary, or paired axillary dioecious flowers rarely 3–4. Calyx of 5 subulate, recurved lobes 2–5 mm long on the hypanthium. Corolla campanulate, white, 3–4.5 cm long, deeply divided into 5 ovate lobes (Plate 3). Stamens 3, present as staminodes in female flowers. Long style and trifid stigma and inferior ovary in female flower. Fruit a smooth,

Plate 1 Leaf and immature fruit

Plate 2 Leaves and leafy shoots sold as vegetables in a local market

Plate 3 White flower and fruits

Plate 4 Ripe and immature fruits

ovoid to ellipsoid berry, 3–7 cm by 1–3.5 cm, green with longitudinal stripes when young turning bright red when ripe (Plates 1, 3 and 4). Seeds flat, 7 mm long.

Nutritive/Medicinal Properties

Per 100 g edible portion, the fruit was found to contain: water 93.5 g, energy 75 kJ (18 kcal), protein 1.2 g, fat 0.1 g, carbohydrate 3.1 g, fibre 1.6 g, Ca 40 mg, P 30 mg, Fe 1.4 mg, thiamin 0.07 mg, riboflavin 0.08 mg, niacin 0.7 mg and ascorbic acid 1.4 mg (Rubatzky and Yamaguchi 1997). Compared to *Ipomoea aquatic*, *Amaranthus*, chayote and pumpkin leafy shoots, ivy gourd leafy shoots were found to have the highest β-carotene content 4,036 μg/100 g edible portion (Wasantwisut and Viriyapanich 2003). Ivy gourd is also rich in protein, fibre and is modest in calcium. The proximate nutrient composition of the leaves and stems per 100 g edible portion were reported as: moisture 91 g, energy 32 kcal, protein 3.6 g, fat 0.2 g, carbohydrate 3.9 g, fibre 2.7 g, ash 1.4 g, vitamin A RE 673 μg, vitamin A RAE 336 μg, β carotene 4,036 μg, thiamin 0.11 mg, vitamin C 13 mg, calcium 57 mg, iron 1.4 mg and zinc 0.5 mg (Puwastein et al. 1999).

The nutritional content of *Coccinia grandis* leafy shoots and leaves was found comparable or richer than many of the common vegetables such as celery, lettuce and asparagus in terms of mineral elements, protein, amino acids and vitamins (Xu et al. 2003). Among the vegetables compared namely *Apium graveolens, Asparagus officinalis, Brasenia schreberi, Glycine max, Ipomoea aquatica, Kalimeris indica* and *Lactuca sativa* var. *longifolia*, *C. grandis* was found to be the highest in potassium, iron, zinc and selenium contents. *C. grandis* leaves had the highest thiamin, riboflavin and niacin contents. Taking the egg protein as standard protein and WHO/FAO reference model of essential amino acid (EAA) as an appraisal criterion, the protein of *C. grandis* reached up to 2.1% (fresh protein). Its gross protein was rich in all types of amino acids that accounted for 93.8%. EAA was 42% of the total amino acid. The first limiting amino acids were sulfur-containing amino acids, methionine and cysteine. The close degree of the protein in *C. grandis* was 0.8070 compared with that of the egg protein, and its score of ratio coefficient of amino acid was 71.946. The protein quality of *C. grandis* was far superior to that of the 7 vegetables (Xu et al. 2003).

Numerous scientific studies have validated the plant's hypoglycaemic, anti-diabetic, antidyslipidemic, antimicrobial and hepatoprotective activities as well as anti-hyperuricaemia and antitussive attributes and supported its traditional medicinal uses for diabetes, lowering blood cholesterol, gout and other complaints.

Antioxidant Activity

All the fractions of the hydromethanolic extract of the leaves of *Coccinia grandis* showed effective H-donor activity, reducing power, free radical scavenging activity, metal chelating ability and inhibition of β-carotene bleaching (Umamaheswari and Chatterjee 2008). None of the fractions exerted an obvious pro-oxidant activity. The antioxidant property was found to be concentration dependent. The free radical scavenging and antioxidant activities may be attributed to the presence of phenolic and flavonoid compounds present in the fractions. The results indicated the leaves of *C. grandis* to be a potential source of natural antioxidant.

Recent studies showed that various fractions of hydromethanol extract of the leaves of *Coccinia grandis* exhibited significant antioxidant activity in ethanol-treated rats with oxidative stress (Umamaheswari and Chatterjee 2009).

Administration of ethanol to rats led to a significant increase in the activities of serum transaminases, alkaline phosphatase, uric acid and the levels of lipids, malondialdehyde and lipid hydroperoxides. Meanwhile, there was a significant a reduction in the activities of enzymatic and non-enzymatic antioxidants in the brain. Simultaneous administration of the leaf fractions (petroleum-ether, chloroform, ethylacetate and residual) prevented the enzymatic leakage and the rise in uric acid and lipid levels. All the fractions (except the residual fraction) prevented the peroxidative damage caused by ethanol, which was evidenced from the improved antioxidant potential. Further, histopathological examination of the brain tissue revealed that the fractions offered significant protection against ethanol toxicity. Among the fractions tested, the chloroform fraction exhibited appreciable antioxidant property, which was almost comparable with the standard Vitamin E.

Antidyslipidemic Activity

Ethanol extract of *Coccinia grandis* exhibited significant triglyceride (TG) and cholesterol-lowering effects in dyslipidemic hamster model (Singh et al. 2007). The active component C(60)-polyprenol in the extract significantly lowered serum triglyceride by 42%, total cholesterol (TC) 25% and glycerol 12%, accompanied HDL-C/TC ratio 26% in high-fat diet (HFD)-fed dyslipidemic hamsters at the dose of 50 mg/kg body weight. Results were comparable to standard drug fenofibrate at the dose of 108 mg/kg. Based on these investigations, it was concluded that the compound polyprenol isolated from leaves of *C. grandis* possessed marked antidyslipidemic activity.

Single dose treatment of alloxan-induced diabetic rat with extracts of *Coccinia cordifolia* (300 mg/kg), *Catharanthus roseus* (150 mg/kg of body weight) significantly reduced blood glucose by 47.4% and 37.1% on 7th day and by 59.7% and 48.5% on 14th day respectively (Akhtar et al. 2007). A significant reduction in serum total cholesterol of 31.7% and 43.3% and serum triglycerides of 45.5% and 39.4% was noted on the 14th day with a single dose of the extracts of *C. cordifolia* (300 mg/kg) and *C. roseus* (150 mg/kg of body weight), respectively. Their hypoglycemic and hypolipidemic activities were comparable to glibenclamide (0.05 mg/kg) and metformin HCl (100 mg/kg). Conversely, *C. cordifolia* extract at the dose of 150 mg/kg did not show any significant effect and *C. roseus* extract at the dose of 300 mg/kg killed all the rats in 2–5 days. *C. cordifolia* was found to be better than *C. roseus* in decreasing blood glucose and serum triglycerides but had weaker activity for lowering serum cholesterol on long-term treatment basis in alloxan-induced diabetic rats.

Hypoglycaemic, Antidiabetic Activity

Dried extracts of *Coccinia indica* leaves (500 mg/kg body weight) administered to diabetic patients for 6 weeks restored the activities of enzyme lipoprotein lipase (LPL) that was reduced and glucose-6-phosphatase and lactate dehydrogenase, which were raised in untreated diabetics (Kamble et al. 1998). Oral administration of 500 mg/kg of *C. indica* leaves showed significant hypoglycemia in alloxanized diabetic dogs and increased glucose tolerance in normal and diabetic dogs. Oral administration of 200 mg/kg of an aqueous ethanol extract of the *Coccinia* leaf and fruits for 45 days to diabetic animals demonstrated a significant reduction in blood glucose, glycosylated haemoglobin, lipids and fatty acids, viz., palmitic, stearic, and oleic acid and elevation in total haemoglobin, linolenic and arachidonic acid and plasma insulin, suggesting that the administration of *Coccinia* plant parts to diabetic animals normalized blood glucose (Venkateswaran and Pari 2002). In other papers they reported that oral administration of *Coccinia indica* leaf extract (CLEt) (200 mg/kg body weight) to streptozotocin (STZ)-diabetic rats for 45 days resulted in a significant reduction in plasma thiobarbituric acid reactive substances, hydroperoxides, vitamin E and ceruloplasmin (Venkateswaran and Pari 2003a, b). The extract also caused a significant rise in plasma vitamin C and lowered glutathione, superoxide dismutase, catalase, glutathione peroxidase and glutathione-S-transferase in liver and kidney of streptozotocin diabetic rats distinctly indicating the antioxidant property of

the leaf extract. The effect of the leaf extract at 200 mg/kg body weight was more effective than glibenclamide, a reference drug. In another study, administration of the leaf extract for 45 days to STZ diabetic rats significantly lowered the accumulation and cross-linking of aortic collagen (Venkateswaran et al. 2003). In diabetic rats, the collagen content, as well as the degree of cross-linking, was increased, as evidenced by increased shrinkage temperature and decreased pepsin solubility. The effects of *C. indica* (collagen content 23.87 mg/100 mg tissue, extent of cross-linking 0.893 mg hydroxyproline/100 mg tissue) were commensurate with that of glibenclamide (collagen content 26.18 mg/100 mg tissue, extent of cross-linking 0.787 mg hydroxyproline/100 mg tissue), a reference drug. A mixture of 300 mg of water extract of dried powdered roots of *Abroma* and leaves of *C. indica* in equal proportions to streptozotocin induced diabetic rats caused a significant reduction in fasting blood sugar and ameliorated glucose tolerance and lipid profile after 8 weeks (Eshrat 2003).

Several studies demonstrated that ivy gourd leaf extract rectified the elevated enzymes glucose-6-phosphatase, lactic dehydrogenase in glycolytic pathway and restored the lipoprotein lipase activity in lypolytic pathway with the control of hyperglycemia in diabetes (Hossain et al. 1992; Shibib et al. 1993). The leaf extract decreased blood glucose by diminishing its synthesis, through reduction of the key gluconeogenic enzymes glucose-6-phosphatase and fructose-1,6-bisphosphatase and by enhancing glucose oxidation by the shunt pathway through activation of its principal enzyme G6PDH. Studies showed that blood sugar was lowered by 23% and 27% in the normal fed and streptozotocin-diabetic rats respectively compared with controls which were given distilled water. Hepatic glucose-6-phosphatase and fructose-1,6-bisphosphatase activities were reduced by 32% and 30% respectively in the streptozotocin-diabetic rats, compared with 19% and 20% reduction in the normal fed controls, whereas both the red-cell and hepatic G6PDH activities were found to be augmented by feeding the extract in the streptozotocin-diabetic and in the normal fed controls. Concomitant with the reduction of glucose-6-phosphatase, urea cycle enzyme arginase was also lowered 21% and 12% in the liver of 48 h-starved and normal-fed animals respectively. Unlike glucose-6-phosphatase, starvation induced levels of gluconeogenic enzymes alanine aminotransferase and aspartate aminotransferase were unaffected by *Coccinia* extract. Purintrapiban et al. (2006) reported that the water extract of *C. indica* stem exhibited a dose-dependent induction of 2-deoxyglucose (2-DG) uptake in rat L8 myotubes. Maximal uptake was observed with approximately threefold rise in 2-DG transport in 16 h treatment compared with the control. Effect of water extract was stronger than that of 1 mm metformin. The effects of insulin and water extract were additive. Water extract -induced glucose uptake was significantly hindered by cycloheximide and partially reversed by SB203580. GLUT1 protein was markedly raised in response to the water extract. Redistribution of GLUT4 to the plasma membrane was demonstrated. Triterpenoids and carbohydrates were detected in the water extract. They concluded that new GLUT1 protein synthesis was necessary for the water extract stimulated glucose transport while p38-MAPK-dependent activation of transporter intrinsic activity partly contributed to the water extract action. These results supported the traditional use of *C. indica* for the prevention and treatment of diabetes.

A composite extract consisting of *Musa paradisiaca* and *C. grandis* exhibited a prophylactic therapeutic effect against streptozotocin (STZ)-induced diabetes through β-cell regeneration capacity (Mallick et al. 2009). Indices of protein metabolic disorders were varied from control in STZ-induced diabetes, which were protected significantly after the treatment of the composite extract. This protection was more prominent when the extract-pretreated albino rats were subjected to diabetes induction by STZ.

In a double-blind, placebo-controlled, randomized trial involving 60 incident type 2 diabetic subjects (aged 35–60 years), administration of *Coccinia* plant extract resulted in a significant decrease in the fasting, postprandial blood glucose and haemoglobin A1C of the experimental group compared with that of the placebo group (Kuriyan

et al. 2008). The fasting and postprandial blood glucose levels of the experimental group at day 90 significantly abated, by 16% and 18%, respectively. There were no significant alterations observed in the serum lipid levels. The study indicated that the extract had a potential hypoglycemic action in patients with mild diabetes.

Chronic administration of *Coccinia indica* fruit extracts (200 mg/kg) for 14 days lowered the blood glucose content of the diabetic induced animals as compared to diabetic control group (Gunjan et al. 2010). The effect was comparable to that of standard antidiabetic drug, Glibenclamide. Another recent study showed that the ethanolic extract of *C. indica* leaves possessed significant hypoglycaemic, hypolipidemic and antioxidant effects in Sprague-Dawley strain of albino rats (Eliza and Usha 2010). There was a significant lowering in blood glucose, serum cholesterol, triglyceride and lipid peroxides contents and elevation of reduced glutathione and liver glycogen in *C. indica* treated group when compared with the diabetic control. No toxic effects were revealed from the toxicity studies. Administration of ethanol extract of aerial plant parts of *C. indica* to streptozotocin induced diabetic rats for 14 days was also found to cause significant antihyperglycemic and hypolipidemic effects (Balaraman et al. 2010). The extract was also found to be significantly effective on restoration of altered biochemical parameters (plasma glucose, cholesterol, triglycerides, LDL, HDL, SGOT, SGPT and ALP) and decreased body weight in treated animals.

Hepatoprotective Activity

Alcoholic extract of the fruits of *C. grandis* conferred protective effect against CCl4-induced hepato-toxicity in experimental rats (Vadivu et al. 2008) The alcoholic extract of *Coccina grandis* fruit at a dose level of 250 mg/kg significantly decreased the activities of serum enzymes (SGOT, SGPT, and ALP) and bilirubin in experimental rats which were comparable to that of silymarin. The ethanolic extract of *C. grandis* leaves was found to possess significant hepatoprotective activity (Sunilson et al. 2009). The ethanol cleaf extract at an oral dose of 200 mg/kg exhibited a significant prophylactic effect as shown by decreasing serum levels of glutamic oxaloacetic transaminase, glutamic pyruvic transaminase, alkaline phosphatase, total bilirubin and total cholesterol and increasing levels of total protein and albumin levels as compared to silymarin, the positive control. These biochemical observations were supported by histopathological examination of liver sections. The activity was postulated to be due to the presence of flavonoid compounds. The extracts showed no signs of acute toxicity up to a dose level of 2,000 mg/kg.

Coccinia grandis leaf extract was found to have liver protective and antioxidant effect in male albino rats (Sivaraja et al. 2010). Aqueous extracts of *C. grandis* had higher superoxide radical scavenging activity and at 250 mg/kg body wt., showed significant hepatoprotective activity when compared with that of ethanol induced control groups. The liver marker were significantly increased in ethanol induced animals after administration of plant extract of *C. grandis* (250 mg/kg body wt., for 45 days); the elevated levels of liver marker enzymes were significantly reduced when compared to the levels in control groups. The antioxidant enzymes were significantly decreased in ethanol treated groups. Administration of plant extract reverted significantly the decreased levels. Results showed that *C. grandis* leaf extract could protect the liver against ethanol induced oxidative damage by possibly reducing the rate of lipid peroxidation and increasing the antioxidant defence mechanism in rats.

Antihyperuricaemia Activity

Coccinia grandis was also found to have antihyperuricaemia activity (Umamaheswari et al. 2007). The methanolic plant extract exhibited xanthine oxidase inhibitory activity producing inhibition greater than 50% at IC_{50} values below 100 µg/ml. The extract also showed a significant decrease in the serum urate level (3.90 mg/daily) when compared to hyperuricaemic control (11.42 mg/daily) mice. This effect was almost similar to the serum urate level of allopurinol (3.89 mg/daily), the reference standard.

Antitussive Activity

The results of studies showed significant reduction of cough number obtained in the presence of both concentrations of methanol extract of *C. grandis* fruit and the prototype antitussive agent, codeine phosphate (Pattanayak and Sunita 2009). Also, the methanol extract exhibited significant antitussive effect at 100, 200 and 400 mg/kg, per os by suppressing cough by 20.57%, 33.73% and 56.71% within 90 minutes of performing the experiment.

Antimicrobial Activity

Methanol extract of *Coccinia grandis* leaves exhibited major activity against *Staphylococcus aureus, Escherichia coli, Shigella dysenteriae, Shigella soneii and Pseudomonas aeruginosa*; but was not active against *Shigella flexneri* and *Shigella boydii* (Dewanjee et al. 2007). Against fungi, the extract was found effective only at higher concentrations. *Candida albicans* showed highest sensitivity whilst *Penicillium* spp. were resistant. Farrukh et al. (2008) also showed that leaves and stems of *C. grandis* had antibacterial activity. Water extract of *C. grandis* leaves and ethanolic extract of stem displayed significant activity against *Shigella boydii* and *Pseudomonas aeruginosa* respectively. Water extract of leaves showed moderate activity against *Salmonella typhi, Klebsiella pneumoniae* and *Pseudomonas aeruginosa*, whereas hexane extract of leaves were moderately active against all Gram positive and negative bacteria except *Proteus mirabilis* which showed no activity. Water fraction of *Coccinia grandis* stem showed activity against *Shigella boydii* only whereas hexane extract was moderately active against *Streptococcus pyogenes, Salmonella typhi, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa* and *Shigella boydii*. Ethyl acetate fraction of stem also showed moderate activities against all bacteria except *Staphylococcus aureus* and *Proteus mirabilis.* The ethanol extract showed good activity against all organisms except *Klebsiella pneumoniae* and *Proteus mirabilis.*

In another study, the crude extracts of *C. indica* fruit exhibited moderate to significant antibacterial activity against all tested bacteria (*Staphylococcus aureus, Bacillus cereus, Pseudomonas putida, Salmonella paratyphi A, Salmonella paratyphi B, Klebsiella pneumonia)* with inhibition zone ranging from 1 to 19 mm and was comparable to the standard (Shaheen et al. 2009). Petroleum ether extract was the most active and showed considerable antibacterial activity against all tested Gram positive and Gram negative bacteria producing maximum inhibition against *S. aureus*. Other tested extracts also inhibited the growth of a number of test organisms but to a lesser extent and were mainly active against the Gram-positive *Staphylococcus aureus*. The study also revealed that methanol extract was active against *Bacillus cereus* and *Pseudomonas putida*. None of the extracts showed significant antibacterial activity against *Salmonella paratyphi A* and *B*. Least activity was shown by chloroform extract against all the tested bacteria.

Antimutagenic Activity

C. grandis was one of 15 Thai vegetables reported to possess antimutagens inhibiting the mutagenicity of both direct-acting mutagens such as AFB1 (aflatoxin B1) (Kusamran et al. 1998).

Traditional Medicinal Uses

The whole plant is used medicinally in India and Indonesia. Ivy gourd is ethnomedicinally used as antipyretic, anti inflammatory, wound healing, purgative, antiemetic, antiulcer, anticonvulsant, astringent poultice and treatment of diabetes mellitus, bronchial inflammation, asthma, coughs, respiratory mucosae, gout and skin diseases since ancient times (Burkill 1966; Singh et al. 2007; Vadivu et al. 2008; Pattanayak and Sunita 2009; Shaheen et al. 2009). The fruits, stems and leaves have been employed to reduce high blood pressure and to treat abscesses.

The leaves when mixed with gingelly oil (sesame oil) is used to treat ring worm, psoriasis and

itch; when mixed with ghee to cure sore, skin diseases, cutaneous eruptions of small pox; to cause cooling effect to eyes; to heal big ulcers, small lesions of scabies, anuria and to alleviate body heat. The leaves are also employed for treating jaundice, bronchitis, skin eruptions, burns, rheumatism, syphilis and gonorrhoea. Juice of the leaves, stem and roots serve as a cure for diabetes, intermittent glycosuria, sore-tongues, earaches, enlarged glands and skin diseases such as pityriasis and also treats urinary tract infection, related troubles. The dried root bark has cathartic properties. Root tubers are used to alleviate pain in joints, diabetes, skin lesions, apthous ulcers, The green fruit is chewed to cure sores on tongue and the dried fruit used to remove eczema. *Coccinia* powder is used treating gastro – intestinal disturbances, liver weakness, dysentery, vomiting and worm infestation, purifies blood, curb infection in the body, effective against chronic cough and cold and gives good results for bronchitis and asthma. In the Moluccas, a stem infusion is given for vertigo, the roots similarly used for high fever, the leaves for skin complaints and an infusion drunk, ashes of the roots are also used. In Niger, the roots are used to treat intestinal ailments. In Ethiopia, the fresh or dried roots are crushed, boiled and used for stabbing pain and kidney infections. In Somalia, the fresh cotton wad dab in a boiled preparation of crushed, fresh or dried leaves is used to treat snake poison in the eyes.

Other Uses

Ivy gourd is often grown as a fence or hedge.

Comments

In Hawaii and some Pacific islands, ivy gourd has become an aggressive and invasive weed.

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Cucumis melo L. (Cantalupensis Group) 'Charentais'

Scientific Name

***Cucumis melo* (Cantalupensis Group) 'Charentais'**

Synonyms

For Cucumis melo, Cantalupensis Group

Cucumis melo L. subsp. melo var. cantalupensis Naudin, Cucumis melo L. var. cantaloupensis Naudin, Cucumis melo cantaloupensis Naudin.

Family

Cucurbitaceae

Common/English Names

Cantaloup, Cantaloupe, Cantalope, European Cantaloupe, True cantaloupe

Vernacular Names

For Cucumis melo L. (Cantalupensis Group)

Arabic: Qâwûn Kantalûbî.
Danish: Kantalupmelon.
Dutch: Kanteloep, Kantaloep, Wratmeloen.
Finnish: Cantaloupe-Meloni.
French: Cantaloup, Melon Cantaloup, Melon Charentais.
German: Kantalupe, Kantalupmelone, Warzenmelone.
Italian: Melone Cantalupo.
Japanese: Kyantaroopu, Kantaruupu.
Portuguese: Melão-Cantalupo.
Spanish: Melón Cantalupo.
Swedish: Cantaloupe.
Turkish: Kantalup Kavunu, Dilimli Kavun, Kabuklu Kavun.

For Cucumis melo L. (Cantalupensis Group) 'Charentais'

French: Cantaloup Charentais, Melon Cantaloup Des Charentes, Melon Charentais.

Origin/Distribution

The true cantaloupe was named after the commune Cantalupo in Sabina, in the Sabine Hills near Tivoli, Italy, a summer residence of the Pope. This includes the European "cantaloupe" with skin that is rough and warty, not netted.

Charentais is a type of true cantaloupe from Europe (what Americans call cantaloupes are actually muskmelons.) The Charantais cantalope originated from the region of France of the same name.

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Agroecology

Cantaloupes and Muskmelons are warm climate crops and are cold and frost sensitive. The crop is grown in the open in summer or heated glasshouses in winter in the temperate areas. Cantaloupes grow best in sandy, well-aerated, well-watered soil that is free of encroaching weeds.

Edible Plant Parts and Uses

Cantaloupe is normally eaten as a fresh fruit, as a salad, fresh juice drink, or as a dessert with ice-cream or custard. Melon pieces wrapped in prosciutto are a familiar modern antipasto.

Botany

The plant description is as described for muskmelons. Charentais cantaloupe melons are globose to subglobose, typically 15–25 cm across, orange-fleshed fruit with light green striped, thin skin that becomes creamy or creamy-yellow when mature (Plate 1).

Plate 1 Large sub-globose greenish white and yellow-skinned Charentais fruits with vertical, pale green furrows and green speckles

Nutritive/Medicinal Properties

The nutritive value of charantais melon would be similar to that described for *C. melo* (Reticulatus Group).

Twenty-eight volatiles (11 esters, 8 sulfur compounds, 6 alcohols, and 3 carbonyl compounds) were isolated from 15 Charentais cantaloupe melons (*Cucumis melo* var. *cantalupensis*) (Aubert and Bourger 2004). Most of the esters such as ethyl 2-methylbutyrate, ethyl butyrate, ethyl hexanoate, hexyl acetate, and butyl acetate and sulfur compounds such as ethyl 2-(methylthio)acetate, 2-methylthioethanol, ethyl 3-(methylthio)propanoate, 3-(methylthio)propyl acetate, and 3-(methylthio) propanol with low odour values were 2–30-fold lower in long shelf life cultivars than in the others.

Compared to other melon types, Cantaloupe Charentais melons were found to be highly aromatic with a major contribution to the aroma being made by aliphatic and branched esters (Flores et al. 2002). Alcohol acyltransferases (AAT) were found to play a significant role in the biosynthesis of ester aroma volatiles in fruit (Lucchetta et al. 2007). Three ripening-specific recombinant AATs of cantaloupe Charentais melon fruit (Cm-AAT1, Cm-AAT3, and Cm-AAT4) were found capable of synthesizing thioether esters with Cm-AAT1 being by far the most active.

Other Uses

Like all cantaloupes, the rejected cantaloupes are used as cattle feed to help them from dehydrating in the dry climate.

Comments

Cantaloupes are usually established from seeds.

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Cucumis melo (Conomon Group)

Scientific Name

***Cucumis melo* L (Conomon Group)**

Synonyms

Cucumis chinensis Pangalo nom. illeg., *Cucumis conomon* Thunb., *Cucumis melo agrestis* Conomon Group, *Cucumis melo conomon* Munger & Robinson, *Cucumis melo* convar. *conomon* (Thunberg) Grebenscikov, *Cucumis melo* subsp. *chinensis* (Pangalo) Filov, *Cucumis melo* subsp. *conomon* (Thunb.) Greb., nom. inval., *Cucumis melo* L. subsp. *melo* var. *conomon* (Thunb.) Makino, *Cucumis melo* var. *acidulus* Naud., *Cucumis melo* L. var. *conomon* (Thunb.) Makino, *Cucumis melo* var. *indicus* Malin. nom. illeg., *Cucumis melo* L. var. *saccharinus* Naud., *Cucumis melo* var. *utilissimus* (Roxb.) Duthie & Fuller, *Cucumis utilissimus* Roxb., *Melo chinensis* Pangalo, *Melo conomon* (Thunb.) Pangalo, *Melo monoclinus* Pangalo.

Family

Cucurbitaceae

Common/English Names

Chinese White Cucumber, Chekiang Melon (Hong Kong), Chinese Marrow, Chinese Melon, Long Melon, Oriental Melon, Oriental Pickling Melon, Pickling Melon, Snake Cucumber, Sweet Melon, Thai Slicing Melon

Vernacular Names

Chinese: Cai Gua, Yue Gua;
French: Melon Sucrin, Melon Sucré;
German: Gemüse-Melone, Zuckermelone;
Indonesian: Ketimun Krai, Mentimun Krai, Timun Krai, Krai, Kari Bali, Boteng Suri, Timun Suri (Javanese), Timun Bhalounghak (Young), Krae (Ripe) (Madurese) Bonteng Karai, Boteng Puan (Sundanese);
Japanese: Katsuria-Uri, Uri, Shiro Uri;
Korean: Wolgwa;
Russian: Dynja Ovoščenaja;
Spanish: Melón Manzana, Pepino Limón;
Thai: Taeng-Thai, Taeng-Lai;
Vietnamese: Dưa Gang, Dưa Gang Trái Tròn, Dưa Gang Trái Dài.

Origin/Distribution

The oriental, pickling melon (*C. melo* ssp. *melo* var. *conomon*) is considered to be the most ancient form of melon domesticated in China (Jeffrey 1980; Walter 1989). It is also held that it had originated from wild melon (var. *agrestis*) in China (Walters 1989). Oriental melon is cultivated in Asia – India, China, Japan, Korea and southeast Asia.

Molecular polymorphism studies suggested that *Cucumis melo* vars. *makuwa* and *conomon*

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are derived from small seed type melon in east India (Kato et al. 2002). Vars. *makuwa* and *conomon* are supposed to have originated in India, the secondary center of genetic diversity of cultivated melon, and were introduced into China from the west via the Silk Road. (Kitamura 1950).

Agroecology

There is a wide array of cool temperate and warm tropical varieties of cultivars of oriental pickling melon. Generally, the crop is frost intolerant, abhors a very wet climate and is found from near seal level to 1,300 m elevation. It is not suited for areas with heavy rain of more than 1,500 mm per year unless grown in protected glasshouses It is grows in full sun in the fields, farms, home gardens and glasshouses. It performs best in well-aerated, well-drained fertile, water retentive, loamy soils rich in organic matter, with a pH range of 5.5–6.8. It is intolerant of heavy clays and waterlogged conditions. It is quite drought tolerant but needs adequate water for good growth and development. It can grow sprawling on the ground or be trained up trellises.

Edible Plant Parts and Uses

Both immature and mature fruit is eaten raw or cooked, pickled or made into sweets and juice. Katsura-uri Japanese pickling melon (*Cucumis melo* var. *conomon*) or Katsura-uri is an heirloom vegetable in Kyoto, Japan (Nakamura et al. 2008a, b). It is harvest half-ripe and used primarily in traditional Japanese cuisine. The fully ripened fruit of Katsura-uri has rarely been used in Japanese eating habits, because half-ripe fruit is utilized for making pickles, but the fully ripened fruit is no longer valuable for pickles due to the flesh being too soft. Nakamura et al. (2008a, b) reported that fully ripe Katsura-uri has potential for use in non-pickling products as it has the unique properties of not being sweet and the possession of a strong melon-like odour and has demonstrated health benefits.

Plate 1 'Bonteng Suri' or 'Timun Suri' – yellowish-white, oblong, oval fruits with white-flesh from Java, Indonesia

In southeast Asia, both immature and ripe fruits can be made into pickles, *acar*, chutney and sweets (candies, *dodol*). Ripe fruit is relished as a refreshing drink when blended and mixed with sugar or honey and ice as is popularly done with the Timun Suri cultivar (Plate 1) during the Ramadhan fasting month in Indonesia. In Indonesia, fruits of timun Krai cultivar (Plates 2 a, b) is used raw or often steamed in a special Surabaya dish called rujuk Cingur (a special mixed fruit salad with savory, spicy peanut sauce). Young fruits are eaten raw as lalab or serve as sayur in Indonesia. The fruit can be finely diced and used as a seasoning in salads and soups. The fruits are also used in curries and stews. In Thailand, mature fruit is eaten fresh; young fruit is occasionally harvested and eaten as vegetable like cucumber either raw or cooked in sour curry; ripe fruit i.e. consumed as Thai traditional dessert. The seed is edible raw or cooked and yields a rich nutty flavoured oil.

Botany

The plant is a trailing, prostrate, or climbing, much-branched, annual, monoecious, herb with angular, hirsute stem having a diameter of 5.5–8.5 mm. Tendrils simple, unbranched. Leaves are alternate, simple, suborbicular to ovate, shallowly 5–7 lobed, finely dentate margin and

Plate 2 (**a** and **b**) 'Timun Krai' or 'Boteng Karai' – green striped, white-fleshed fruits from Java, Indonesia

Plate 3 Orangey-yellow, oval fruits with irregular cream streaks at both ends from Sarawak, Malaysia

Plate 5 Yellow, greenish-yellow, smooth, oblong fruits from Sabah, Malaysia

Plate 4 Yellowish-white, ellipsoid fruits from Sabah, Malaysia

deeply cordate base, dark green, 7–18 cm long by 7–15 cm wide, 8–15 cm across, both surfaces covered with villous hairs. Flowers andromonoecious, yellowish on 5–3 cm long penduncle. Male flowers fasciculated 2–4 flowered, 26–44 mm across, calyx campanulate, sepals subulate, corolla campanulate, 5-parted, yellow, stamens 3. Perfect flowers solitary with a short sericeous (short, adpressed hairs) ovary inferior, 3–5 carpels. Fruit, polymorphous, ellipsoid, oval-oblong, pyriform, globose, elongate pepo 11–30 cm long, smooth, glabrescent, colour variable white, yellow, golden-yellow, yellowish-white, yellowish with white longitudinal stripes, green, green with dark green longitudinal stripes (Plates 1–8), edible insipid to mildly sweet flesh, white, orange, yellow or pink and numerous white, elliptic, small (<8 mm seeds), flattened seeds.

Plate 6 White, smooth, narrow oblong fruits with white flesh from Sabah, Malaysia

Plate 7 Yellowish-brown fruits from Selangor, Malaysia

Plate 8 Brownish-yellow fruits from Papua New Guinea

Nutritive/Medicinal Properties

The sucrose content of Huangjingua (*Cucumis melo* var. *makuwa* Makino) was found to increase with fruit maturity but the sucrose content remained unchanged in Yuegua (*Cucumis melo* var. *conomon* Makino) (Zhang and Li 2005). In Huangjingua, both sucrose and total sugar gradients were observed, rising from mesocarp adjacent to pedicel, middle part of mesocarp, and up to mesocarp adjacent to the umbilicus. In terms of sweetness index, fructose was found to be the major contributor to sugar accumulation in both varieties. Also, Huangjingua could be comparatively considered as a high-sucrose accumulator and Yuegua a minor-sucrose accumulator.

3-methylthiopropionic acid ethyl ester, an odour producing compound, isolated from fully ripened Katsura-uri Japanese pickling melon fruit (*Cucumis melo* var. *conomon*) was found to have antimutagenic and anticarcinogenic activities (Nakamura et al. 2008a, b). It was found to be an antimutagen in *Escherichia coli* mutagenicity assay. It also demonstrated in-vivo animal cancer prevention, and induced differentiation, a chemotherapeutic strategy, in an in-vitro human colon-cancer cell system. Katsura oriental pickling melon showed higher bio-antimutagenicity and yield in the n-hexane, chloroform and ethyl acetate fractions than other common and traditional vegetables tested (Nakamura et al. 1998). In more recent studies, Nakamura et al. (2010) identified six fragrant ingredients in fully-ripened Katsura-uri (Japanese pickling melon, *Cucumis melo* var. *conomon*). Four of them were sulfur-containing compounds [methylthioacetic acid ethyl ester (MTAE), acetic acid 2-methylthio ethyl ester (AMTE), 3-methylthiopropionic acid ethyl ester (MTPE), and acetic acid 3-methylthio propyl ester (AMTP)]; and the others were benzyl acetate and eugenol. MTAE and AMTP were found to possess antimutagenic activity as determined by their ability to inhibit the UV-induced mutation in repair-proficient *E. coli* B/r WP2. MTAE and MTPE (esters with thiocarbonic acid and alkyl alcohol) induced the differentiation of human colon cancer cells (RCM-1

cells), but AMTE and AMTP (esters with carbonic acid and thioalkyl alcohol) did not. AMTE, MTPE, AMTP, and eugenol had higher oxygen radical absorbing capacity than the antioxidative vitamin C. The quantity of MTPE, AMTP and eugenol increased 49-fold, >1,175-fold and 11-fold, respectively, in the fully-ripened fruit as compared to the half-ripened fruit.

Three trypsin inhibitors (CMCTI-I, II, and III) were isolated from oriental pickling melon (*Cucumis melo* var. *conomon* Makino) seeds (Nishino et al. 1992). All three inhibitors could inhibit lysyl endopeptidase and trypsin at the enzyme-inhibitor ratio of 1:1.

In folkloric ethnomedicine, the fruit has been used as a cooling cleanser or moisturiser for the skin and also used for burns, scald and abrasions. The fruit is also stomachic. The seed is digestive, antitussive, febrifuge and anthelmintic. When used as a vermifuge, the powdered seeds are made into an emulsion and consumed. The root is emetic and diuretic and the flowers are also emetic and expectorant.

Other Uses

Melons like cantaloupes can be used as animal feed.

Comments

C. melo is a very diverse species of the genus *Cucumis* (Kirkbride 1993; Jeffrey 1980). They both divided *C. melo* into two subspecies *melo* and *agrestis*. Munger and Robinson 1991 divided *C. melo* into six varieties. Irrespective of their importance and genetic diversity, classification of East and South Asian *C. melo* melons is not consistent, and all types of cultivated melon were classified as var. *conomon* by Munger and Robinson (1991). However, they are divided into two varieties, var. *makuwa* (dessert type) and var. *conomon* (pickling type), in Japan and China, they are cultivated as different crops which are called as 'makuwa' and 'shirouri' in Japan and 'Tian Gua' and 'Cai Gua' in China, respectively. Makino (1928) and Kitamura (1950) divided var. *makuwa* into eight different forms. Based on the length of ovary hair, Pitrat et al. (2000) divided *C. melo* into two ssp. *agrestis* and *melo*, and vars. *conomon*, *makuwa*, *chinensis*, *momordica* and *acidulus* were grouped under ssp. *agrestis*. According to Stepansky et al. (1999) var. *conomon* is closely related to African and Asian vars. *agrestis*, *momordica* and *chito*, rather than to vars. *flexuosus* and *inodorus*.

Rahayu and Hartana (2002) investigated variations on morphology, anatomy, and isozyme banding patterns of *Cucumis sativus* and *Cucumis melo* by employing 18 populations of cultivars from 17 regions in Java. On the basis of those features, cultivars of *Cucumis* populations in Java were grouped into 9 different cultivars. Three of them were timun wuku, timun saloyo, and timun jepang, which belonged to *C. sativus*. The remaining cultivars, namely krai rundu, timun suri, krai kapasan, bhalungkak, blewah, and melon, belonged to *C. melo*. The grouping based on morphological and anatomical characters showed that timun saloyo was closely related to timun jepang compared to timun wuku. Timun suri was closely related to bhalungkak, while blewah was closely related to melon compared to other cultivars.

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Cucumis melo (Inodorus Group)

Scientific Name

***Cucumis melo* L. (Inodorus Group)**

Synonyms

For Cucumis melo L. (Inodorus Group)

Cucumis eumelo subsp. *zard* Pangalo, nom. inval., *Cucumis melo inodorus* Munger & Robinson, *Cucumis melo melo* Zard Group, *Cucumis melo* convar. *zard* (Pangalo) Grebenšč., *Cucumis melo* L. subsp. *melo* var. *inodorus* H. Jacq., *Cucumis melo* var. *autumnalis* Filov, nom. invalid., *Cucumis melo* var. *inodorus* H. Jacq., *Cucumis melo* var. *hibernus* Filov, nom. invalid., *Cucumis melo* var. *maltensis* Ser., *Cucumis persicus* (Sag.) M.J. Roem., *Melo zard* Pangalo.

For Cucumis melo L. (Inodorus Group) 'Honey Dew'

Cucumis melo L. (Inodorus Group) 'Rosée de Miel'

Family

Cucurbitaceae

Common/English Names

American Melon, Fragrant Melon, Oriental Sweet Melon, Winter Melon.

Major Types: Canary (USA), Casaba (USA), Crenshaw (USA), Christmas (USA), Honeydew (USA), Bai Lan Gua (China)

Vernacular Names

For Cucumis melo L. (Inodorous Group)

Arabic: Shahed;
Chinese: Yang Xiang Gua. (Yang Hsiang Kua), Lü Bai Rou Yang Xiang Gua, Song Tian Gua;
French: Melon, Melon D'hiver, Melon D'amérique, Melon Sucrin, Melon Sucré.
German: Melone, Zuckermelone;
Japanese: Shiro Uri, Suiito Meron, Wintaa Melon;
Malay: Tembikai Susu;
Portuguese: Melão;
Spanish: Melón.

For Cucumis melo L. (Inodorus Group) 'Canary'

English: Canary Melon (USA), Spanish Melon;
French: Melon Espagnol, Melon Canari;
Vietnamese: Dưa Hoàng Yến.

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For Cucumis melo L. (Inodorus Group) 'Crenshaw'

English: Crenshaw Melon (USA);
French: Melon Crenshaw;

Cucumis melo L. (Inodorus Group) 'Honey Dew'

Chinese: Mi Gua, Bai Lan Gua, Hualaishi;
English: Honeydew Melon (USA), Honey Dew Melon;
French: Melon D'hiver, 'Rosée De Miel';
Japanese: Hanedeyuu Meron;
Malay: Tembikai Susu;
Philippines: Honeydew;
Vietnamese: Dưa Mật, Dưa Tây Xanh, Dưa Tây, Dưa Xanh.

Origin/Distribution

Melons (*Cucumis melo*) are believed to have originated in Africa where wild landraces are found, however the exact distribution of these wild melons are unclear because of frequent occurrence of plant escapes from cultivation. Melons have been domesticated in eastern Mediterranean, Middle east and West Asia for more than 4,000 years ago and afford probably the best melons in the world. Important centres of genetic diversity of cultivated melon have been developed in Iran, Uzbekistan, Afghanistan, China and India. For the whole inodorus group, Pitrat et al. (2000) reported the origin to be in Turkey and the Middle East.

Agroecology

Melons of the Inodorous group are warm-season crops that grow best at mean air temperatures between 22°C and 28°C. In temperate zones, they require 110 frost-free days to reach harvest and are commonly ready for harvest in late summer, autumn, or early winter. They grow best in full sun or diffused sun. Melons can be grown on a wide range of soil types provided drainage is good. The best soils are deep fertile sands. Melons can be grown on heavier soils if well drained in which case raised beds may be beneficial. Light soils warm more quickly and suit early cropping, whereas heavier soils will be more suitable for mid-season crops. Windbreaks are essential, particularly for early crops to protect against windblown sand, to reduce wind damage to plants and fruit, to increase temperatures around plants and to increase activity of bees. Cover crops are also beneficial for they improve both drainage and soil structure. Cover crops should be ploughed in at least 4 weeks before sowing.

Edible Plant Parts and Uses

All melons of the Inodorous group are popularly and widely eaten when ripe as fresh dessert fruit. They are eaten fresh, made into refreshing drink, fruit salad with and without vinaigrette, melon sherbert, ice cream, or smoothie. Honeydew is popularly used with prosciutto wrapped honeydew melon balls. Melons can be cut into halves, quarters, wedges, cubes, or scooped into balls with a melon baller. Most melons will benefit from a squeeze of lemon or lime juice to enhance the flavour and served at room temperature. Immature melons are also cooked or pickled. In Turkmenistan, honeydew melons are processed to a dried traditional product known as '*kavun kaki*' (Berdiyev et al. 2009). The seeds are dried, roasted and eaten.

Botany

Annual, trailing, prostrate or rarely climbing herb. Stem angular and hirsute, sometimes becoming circular and glabrous. Leaves sub-orbicular to reniform, shallowly 5-7-lobed, lobes obtuse, both surfaces covered with soft villous hairs; size variable, 8–15 cm long and broad, smaller in wild forms. Flowers usually andromonoecious; male flowers fascicled, perfect or female flowers solitary. Male flowers with villous, campanulate

calyx of 5 subulate lobes, 5 lobed sub-campanulate yellow corolla, 3 free stamens. Bisexual flowers are similar with pubescent globose, ovoid or cylindrical ovary, with short, simple style and 3–5 obtuse stigmas. Fruit polymorphous, round, oval to oblong ellipsoid or football-shaped, (8)-15– 30 cm long, 1.5–3.6 kg weight. Seeds ovoid to ellipsoid, creamy white to brown.

The various melon types in this group can be differentiated primarily by the fruit morphological and physiological traits.

Honeydew is an American name for the French variety 'White Antibes,' which was grown for many years in southern France and Algeria for foreign shipment. Honeydew melons are smooth, round to slightly oval, 15–22 cm across, with white, pale greenish white, creamy-white or yellow skin and usually pale green or green sweet flesh and uniquely flavoured (Plates 1–5). New varieties may have orange or pink tinged flesh.

Canary melon is a large, round to slightly oval, bright-yellow melon with a pale green to white inner flesh (Plates 6–9). The name comes from its bright yellow color, which resembles that of the canary. The outer skin is softer than that of honeydew and the cantaloupe. This melon has a distinctively sweet flavour that is slightly tangier than a honeydew melon. This melon is often marketed as the Juan Canary melon.

Casaba is reported to have originated from Asia Minor. Round and similar in size to a cantaloupe, it has distinctive longitudinal wrinkles and ripens to bright yellow. The flesh is usually thick, and either white, pale greenish, yellow, or orange. Although generally sweet-flavoured, its flesh is not as sweet as a honeydew.

Plate 1 Smooth, lemon-yellow-skinned, pale green fleshed honeydew melon

Plate 2 Smooth, orange-yellow honeydew melon with greenish flesh

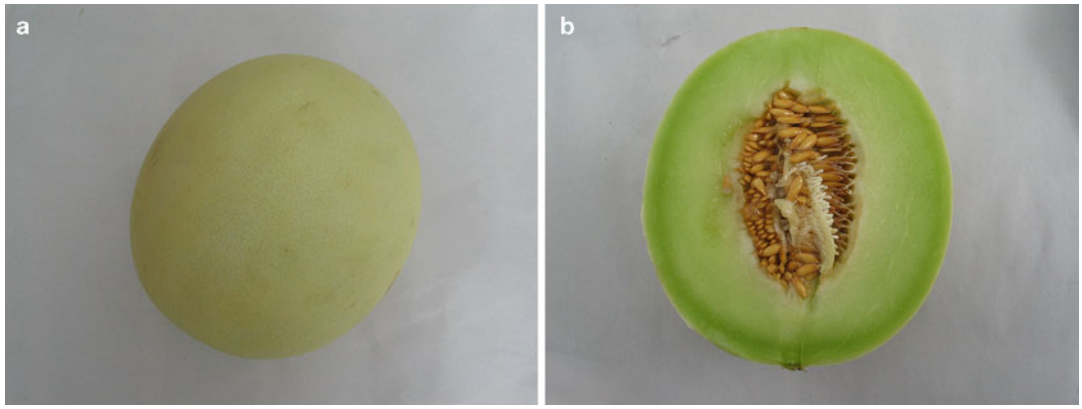

Plate 3 (**a** and **b**) Smooth, white-skinned, green fleshed honeydew melon

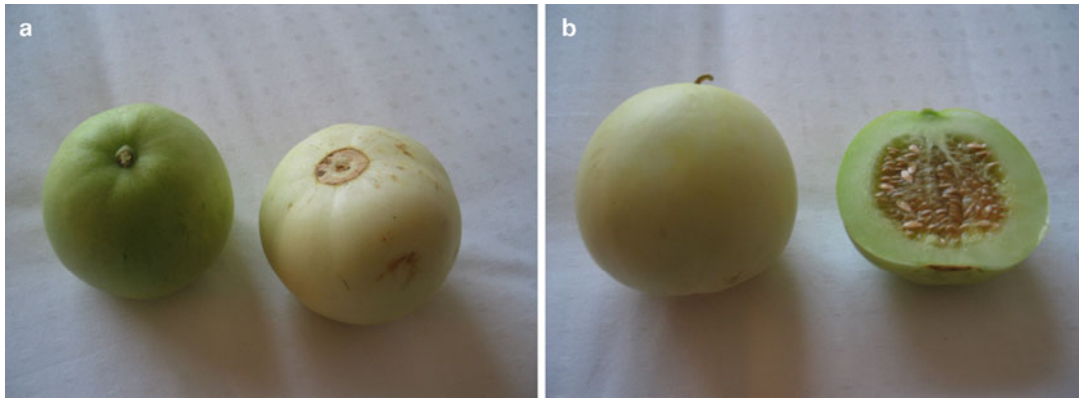

Plate 4 (**a** and **b)** Smooth, white or pale greened skinned apple-sized honeydew Indonesian cultivar dubbed "epal" with green flesh and large central seed core

Plate 5 Smooth and creamy-white-skinned, greenish-white flesh variant of bailan honeydew melon in Xian, China

Plate 7 Close-up of globose yellow canary fruit and reniform to suborbicular, shallowly-lobed leaves

Plate 6 Bright yellow, oval Canary melon on the vine

Plate 8 Smooth, bright yellow Canary melon with greenish-white flesh

Crenshaw melons are a hybrid between the casaba and Persian melon with a yellowish skin and salmon collared flesh Crenshaw melons

Plate 9 A smooth, orangey blotched, miniature sized (8–10 cm across) honeydew melon with greenish-white flesh in Sarawak

are oblong with a tapering ends, resembling a football. Some Crenshaw melons have been known to grow as large as watermelons. They have a greenish slightly ribbed skin that ripens to greenish-yellow or a bright yellow. Ripe Crenshaw melons emit a musky fragrance. The sweet inner flesh is usually a pinkish orange, salmon-coloured, but may also be yellow or even ivory and with a large seeded central.

Christmas melons, also known as 'Santa Claus' or 'Piel de Sapo' usually peaked in December. They are large, oblongish with a tapered ends, resembling a football, about 30 cm long, fairly smooth-skinned, and its thick rind is coloured with blotches or mottles of green or black and yellow, or with longitudinal green stripes and have yellow-orange flesh or pale green flesh. A Christmas melon's flavour is said to be reminiscent of a very sweet honeydew melon.

Bailan Melon is most famous among all melon varieties in Lanzhou, the capital of Gansu province in China. Qingbaishi countryside in Lanzhou enjoys a great reputation for its high yield of Bailan melon. Bailan is a type of honeydew melon, globose to subglobose, white-skinned with sweet white or pale green flesh (Plate 5). It was believed to have originated from honeydew seeds donated to the locals by Henry Wallace, Vice president of the United States, visiting in the 1940s. Thus, in China the melon is sometimes called the *Wallace* (in pinyin Chinese *Hualaishi).*

Nutritive/Medicinal Properties

Nutrient Composition

Food composition of raw honeydew melon fruit per 100 g edible portion (refuse 54–49% rind, 5% cavity components), was reported as: moisture 89.82 g, energy 150 kJ, (36 kcal), protein 0.54 g, fat 0.14 g, ash 0.41 g, carbohydrate 9.09 g, total dietary fibre 0.8 g, total sugars 8.12 g, sucrose 2.48 g, glucose 2.68 g, fructose 2.96 g; K 228 mg, Ca 6 mg, Mg 10 mg, Fe 0.17 mg, P 11 mg, Na 18 mg, Zn 0.09 mg, Cu 0.024 mg, Mn 0.027 mg, Se 0.7 μg; vitamin C 18.0 mg, thiamin 0.038 mg, riboflavin 0.012 mg, niacin 0.418 mg, pantothenic acid 0.155 mg, vitamin B-6 0.088 mg, total folate 19 μg, vitamin A 3 μg RAE, vitamin A 50 IU, vitamin K (phylloquinone) 2.9 μg, α-tocopherol 0.02 mg, γ-tocopherol 0.03 mg, choline 7.6 mg, betaine 0.1 mg, β-carotene 30 μg, lutein + zeaxanthin 27 μg; total saturated fatty acids 0.038 g, 12:0 (lauric acid) 0.002 g, 14:0 (myristic acid) 0.002 g, 16:0 (palmitic acid) 0.032 g, 18:0 (stearic acid) 0.003 g; total monounsaturated fatty acids 0.003 g, 18:1 undifferentiated (oleic acid) 0.003 g; total polyunsaturated fatty acids 0.059 g, 18:2 undifferentiated (linoleic acid) 0.026 g, 18:3 undifferentiated (linolenic acid) 0.033 g; tryptophan 0.005 g, threonine 0.013 g, isoleucine 0.013 g, leucine 0.016 g, lysine 0.018 g, methionine 0.005 g, cystine 0.005 g, phenylalanine 0.015 g, tyrosine 0.010 g, valine 0.018 g, arginine 0.014 g, histidine 0.005 g, alanine 0.044 g, aspartic acid 0.088 g, glutamic acid 0.153 g, glycine 0.016 g, proline 0.012 g and serine 0.023 g (USDA 2010).

Food composition of raw casaba melon fruit per 100 g edible portion (refuse 40–29% rind, 11% cavity components), was reported as: moisture 91.85 g, energy 118 kJ, (28 kcal), protein 1.11 g, fat 0.10 g, ash 0.36 g, carbohydrate 6.58 g, total dietary fibre 0.9 g, total sugars 5.69 g; K 182 mg, Ca 11 mg, Mg 11 mg, Fe 0.34 mg, P 5 mg, Na 9 mg, Zn 0.07 mg, Cu 0.060 mg, Mn 0.035 mg, Se 0.4 μg; vitamin C 21.8 mg, thiamin 0.015 mg, riboflavin 0.031 mg, niacin 0.232 mg, pantothenic acid 0.084 mg, vitamin

B-6 0.163 mg, total folate 8 μg, choline 7.6 mg, vitamin K (phylloquinone) 2.9 μg, α-tocopherol 0.05 mg, choline 7.6 mg, lutein + zeaxanthin 26 μg; total saturated fatty acids 0.025 g, 12:0 (lauric acid) 0.001 g, 14:0 (myristic acid) 0.001 g, 16:0 (palmitic acid) 0.021 g, 18:0 (stearic acid) 0.002 g; total monounsaturated fatty acids 0.002 g, 18:1 undifferentiated (oleic acid) 0.002 g; total polyunsaturated fatty acids 0.039 g, 18:2 undifferentiated (linoleic acid) 0.017 g and 18:3 undifferentiated (linolenic acid) 0.022 g (USDA 2010).

In a study of sensory and analytical comparison of orange-fleshed honeydew to cantaloupe and green-fleshed honeydew, Saftner et al. (2008) found that the β-carotene concentration of orange flesh cantaloupe 'Cruiser', orange fleshed honeydew 'Orange Dew' and the three orange honeydew breeding lines was the same (range 14–17 mg/kg). The β-carotene content of orange fleshed honeydews 'Temptation' and 'Honey Gold' (8 mg/kg) was intermediate between those of cantaloupe (16 mg/ kg) and green honeydew (1 mg/ kg).

A catabolite of β-carotene is Vitamin A, which is > 80 times more abundant in orange netted melons such as cantaloupe than in green honeydews (Robertson and Decker-Walters 1999). The ascorbic acid concentration of all of the melon genotypes evaluated was the same and ranged between 140 and 198 mg/kg. The ascorbic acid concentration of all of the melon genotypes was the same and varied between 140 and 198 mg/kg. There were distinct qualitative and quantitative differences in aromatic volatiles among melon genotypes with concentrations of many volatiles, particularly the more abundant esters, being generally higher in cantaloupe than in honeydews. Juice extracts from fresh-cut 'Temptation' generally had aromatic volatile concentrations intermediate between those of cantaloupe and green honeydew. However, 'Temptation' and the other orange honeydew genotypes were distinctive from cantaloupe and the green honeydew in having relatively high contents of nonenyl and nonadienyl acetates having honeydew-like or uncharacterized aromas.

Other Phytochemicals (Fruit)

Due to the low odour thresholds of unsaturated C9 alcohols and their acetates, they were considered to be major contributors to honeydew melon aroma (Buttery et al. 1982). Sulfur-containing compounds, with low odour thresholds and were believed to play an important role in the overall aroma profile of melon fruit, especially cantaloupe (Wyllie and Leach 1992), were not detected in this study. Except for the C9 acetates and alcohols, most of the volatiles identified were fairly common in fruits and were not specifically confined to melons. The acetate ester concentrations and the total volatile concentration were higher in 'Temptation' than in the other orange honeydews, but all orange honeydew genotypes had higher acetate ester and total volatile concentrations than the green honeydew. These results suggested that cantaloupe had the strongest aroma, followed by 'Temptation', other orange honeydew genotypes and green honeydew.

Major aroma compounds in green fleshed honeydew melon were found to be: (z)-6-noneyl acetate, (Z,Z)-3,6-nonadienyl acetate, (z)-3-noneyl acetate, 3-methyl-2-butenyl acetate, and ethyl (methylthio)acetate (Buttery et al. 1982). (z)-6-noneyl acetate was found to be an important contributor to the total aroma. Aromatic volatiles in green flesh honeydew in terms of retention index detector response in picoamperes (pA) were found as follows (Saftner et coll. 2008): ethyl acetate 36.8; (*Z*,*Z*,6)-3-nonadienyl acetate 14.7; isoamyl acetate and 2-methylbutyl acetate 13.0; nonal 9.1; ethyl butyrate 8.9; ethyl 2-methylbutyrate 8.4; hexyl acetate 5.9; (*E*)-2-nonenal 5.5; benzyl acetate 5.4; amyl acetate 4.4; octyl acetate 4.0; phenylethyl acetate 3.8; ethyl hexanoate 3.4; ethyl valerate 3.3; (Z)-3-hexenyl acetate 3.0; (*Z*)-6-nonenyl acetate 2.9; nonyl acetate 1.9; ethyl octanoate 1.8; (*Z*)-3-nonenyl acetate 1.2; ethyl decanoate 0.9; butyl acetate 0.5; heptyl acetate 0.4; methyl hexanoate 0.4; isobutyl acetate 0.4; and (*Z*)-6-nonen-1-ol <0.3.

Aromatic volatiles in orange flesh honeydew 'Temptation' in terms of retention index detector response in picoamperes (pA) were found as follows (Saftner et coll. 2008): ethyl acetate

169.5; methyl butyrate 17.2; ethyl isobutyrate 21.5; isobutyl acetate 82.6; ethyl butyrate 21.5; butyl acetate 48.3; ethyl 2-methylbutyrate 126.2; isoamyl acetate and 2-methylbutyl acetate 269.9; ethyl valerate 32.4; amyl acetate 12.5; methyl hexanoate 6.1; isobutyl butyrate 1.4; benzaldehyde 1.5; ethyl hexanoate 24.5; (*Z*)-3-hexenyl acetate 82.0; hexyl acetate 136.9; isobutyl isobutyrate 1.2; 1-octanol <0.3; nonanal 11.6; heptyl acetate 4.1; (*Z*)-3-nonen-1-ol 2.7; (*E*)-2-nonenal 6.9; benzyl acetate 60.5; (*Z*)-6-Nonen-1-ol 1.4; ethyl benzoate <0.3; ethyl octanoate 8.4; octyl acetate 11.1; phenylethyl acetate 7.3; nonyl acetate 15.0; (*Z*)-3-nonenyl acetate 53.6; (*Z*)-6-nonenyl acetate 42.6; (*Z*,*Z*,6)-3-nonadienyl acetate 25.4; and ethyl decanoate 3.2; geranyl acetone 12.5.

Forty-two volatiles were identified in the aroma component of honeydew melon (Perry et al. 2009). (E,Z)-2,6-nonadienyl acetate was identified for the first time in melon. Aroma extract dilution analysis (AEDA) of the extract revealed that (E,Z)-2,6-nonadienal was the most impactful compound of honeydew melon. AEDA results also showed that (Z,Z)-3,6-nonadien-1-ol and phenylethyl alcohol imparted fresh and sweet-floral characters, respectively, to the honeydew aroma.

A serine protease, protease D was isolated from the sarcocarp (flesh) of honeydew melon fruit (*Cucumis melo* L. var. *inodorus* Naud) (Uchikoba et al. 1993). The enzyme was strongly inhibited by diisopropyl fluorophosphate but was not inhibited by metal-chelating reagents or cysteine protease inhibitors. The enzymatic properties of honeydew melon protease D were similar to those of cucumisin, except for its stability at high temperature, wide pH range and against detergents.

Phytochemicals (Seeds)

Seeds of *Cucumis melo* var. *inodorus* were found to contain phenolic glycosides that included (E)-4-hydroxycinnamyl alcohol 4-O-(2′-O-β-d-apiofuranosyl)(1″ → 2′)-β-d-glucopyranoside; benzyl O-β-d-glucopyranoside; 3,29-O-dibenzoylmultiflor-8-en-3α,7β,29-triol and 3-O-p-amino-benzoyl-29-O-benzoylmultiflor-8-en-3α,7β,29-triol (De Marino et al. 2009). The multiflorane triterpene esters were identified as new melon constituents.

Cucumis melo var. *inodorus* seeds were found to contain 4.5% moisture, 25.0% crude fat, 25.0% crude protein, 23.3% crude fibre, 2.4% ash and 19.8% carbohydrate (Abdul Manaf et al. 2008). The freshly extracted honeydew melon seed oil was found to have an iodine value of 153.4 g I_2/100 g oil, saponification value of 210.2 mg KOH/g oil, 0.9% unsaponifiable matter and 2.5% free fatty acid. The oil had a color index of 1.6Y + 0.4R, and had 10 fatty acids, of which 86.1% were unsaturated. Linoleic acid (L) predominated with 69.0% followed by oleic acid (O) (16.8%) and palmitic acid (P) (8.4%). LLL (24.9%), OLL (21.5%), PLL (15.9%) and POL (12.4%) were the major triacylglycerols present. The melting and crystallization temperatures were −5.12°C and −59.01°C, respectively. Electronic nose analysis showed the presence of more volatile compounds compared to refined sunflower oil, an oil rich also in linoleic acid.

Antioxidant Activity

Non-netted orange-fleshed honey dew fruit (*Cucumis melo* L. Inodorus group) cultivars ‘Orange Delight’ and ‘Orange Dew’, were generally superior to ‘Honey Gold’, ‘Temptation’ and a breeding line as they consistently demonstrated some of the highest levels of total ascorbic acid, β-carotene, and potassium (Lester and Hodges 2008). ‘Orange Delight’ and ‘Orange Dew’ were also among the cultivars with the highest activities of ascorbate peroxidase , catalase and superoxide dismutase. These two cultivars also exhibited the least increase in malondialdehyde (MDA) (i.e. lipid peroxidation) during storage, suggesting antioxidant levels limited oxidative-related senescence compared to the other genotypes.

Studies revealed the orange-fleshed non-netted honeydew *(Cucumis melo* L.) a cross between orange-fleshed cantaloupe and non-netted, green-fleshed honeydew to be a rich source of

many human health-related nutrients (Lester 2008). The concentrations of soluble solids, sucrose, total sugars, β-carotene, and 5-methyltetrahydrofolic acid increased in an inward direction from the sub-peel (hypodermal) mesocarp tissues toward the seed cavity. The activities of antioxidant enzymes, ascorbate peroxidase, catalase, and superoxide dismutase also increased in an inward direction. The concentrations of calcium, iron, magnesium, manganese, and sodium all decreased in the inward direction. When expressed on a dry weight basis, the concentrations of ascorbic acid, boron, copper, fructose, glucose, phosphorus, potassium, and zinc were higher in the subpeel region compared to the inner mesocarp tissues, but the reverse was true when data were expressed on a fresh weight basis. These data revealed considerable variation in sugars, minerals, and phytonutrients across the mesocarp regions and that expressing the data on a fresh or dry weight basis could alter interpretations of the nutritional significance and health benefits of the fruit. Specific and total superoxide dismutase (SOD) activities were found to vary significantly among the genotypes of muskmelons (*Cucumis melo* L.) (Lester and Hodges 2008). Netted (cantaloupe) genotypes generally had the lowest SOD activities compared to the green- and orange-fleshed honey dew types. Casaba type fruit had average SOD activities that were approximately 1.6-fold greater than those of honey dew types, and approximately nine-fold greater than those of cantaloupe types. These data indicated the existence of useful genetic diversity among commercial melon varieties and in exotic genotypes that could be used to develop *C. melo* as a functional food with enhanced antioxidant superoxide dismutase content.

Other Uses

Rejected melons are used as cattle feed to keep them from dehydration during the dry periods.

Comments

All melons are established from seeds.

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Cucumis melo (Makuwa Group)

Scientific Name

***Cucumis melo* L. (Makuwa Group)**

Synonyms

Cucumis melo L. Group Conomon var. *makuwa*, *Cucumis melo* L. var. *makuwa* Makino, *Cucumis melo* L. var. *makuwa* (Kitamura ex Makino), *Cucumis melo* ssp. agrestis var. *makuwa*.

Family

Cucurbitaceae

Common/English Names

Japanese Cantaloupe, Oriental Melon, Oriental Pickling Melon

Vernacular Names

Chinese: Huangjingua, Tian Gua;
French: Cantaloup Du Japon;
Japanese: Makuwa, Makuwa Uri;
Korean: Chamoe;
Vietnamese: Dua Gan.

Origin/Distribution

Molecular polymorphism studies suggested that *Cucumis melo* vars. *makuwa* and *conomon* are derived from small seed type melon in east India (Kato et al. 2002). Vars. *makuwa* and *conomon* are believed to have originated in India, the secondary center of genetic diversity of cultivated melon, and were introduced into China from the west via the Silk Road. (Kitamura 1950). It was also thought that the varieties had originated from wild melon (var. *agrestis*) in China (Walters 1989). Makuwa is now domesticated in northern China, Korea and Japan.

Agroecology

This melon is a cool sub-temperate crop. Its agro-ecological requirements are similar to that described for squashes and pumpkins in *Cucurbita pepo*, growing best in areas with day temperatures between 24°C and 29°C and night temperatures between 16°C and 24°C. The plant is quite drought tolerant but requires sufficient water for optimum growth and yield. It requires a rich, well-drained, moisture retentive, friable soil and a very sunny position.

Edible Plant Parts and Uses

The fruits are eaten fresh or pickled; in Korea fruits are made into pickles called *chamoe jangajji*. The white flesh is very juicy, sweet to

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mildly sweet and tastes like a cross between a regular honeydew and a cucumber.

Botany

The plant is a trailing, prostrate, branched, annual herb with angular, hirsute stem having a diameter of 7 mm. Leaves are alternate, simple, broadly reniform to sub-orbicular shallowly 5–7 lobed, lobes obtuse with finely dentate margin and deeply cordate base, dark green, 8–15 cm across, both surfaces covered with villous hairs. Flowers andromonoecious. yellow on 5–3 cm long peduncle. Male flowers fasciculated, 24–25 mm across, calyx campanulate, sepals subulate, corolla campanulate, 5-parted, yellow, stamens 3. Perfect flowers solitary with a short sericeous (short, adpressed hairs) ovary. Fruit, ellipsoid to oval-oblong, smooth, yellow to orangey yellow with cream-coloured impressed longitudinal stripes (Plates 1–3), 10 cm long with white flesh and numerous white, oblong, small, flattened seeds.

Plate 1 Ripe *Cucumis melo* var. *makuwa* fruits

Plate 2 Close-up of side view of fruit

Plate 3 Close-up of stylar end of fruit

Nutritive/Medicinal Properties

The sucrose content of Huangjingua (*Cucumis melo* var. *makuwa* Makino) was found to increase with fruit maturity but the sucrose content remained unchanged in Yuegua (*Cucumis melo* var. *conomon* Makino) (Zhang and Li 2005). In Huangjingua, both sucrose and total sugar gradients were observed, rising from mesocarp adjacent to pedicel, middle part of mesocarp, and up to mesocarp adjacent to the umbilicus. In terms of sweetness index, fructose was found to be the major contributor to sugar accumulation in both varieties. Also, Huangjingua could be comparatively considered as a high-sucrose accumulator and Yuegua a minor-sucrose accumulator.

The total phenolic concentration, antioxidant, xanthine oxidase and α-glucosidase activities of the fruit of *Cucumis melo* var. *makuwa* were found to be higher in the peel than in other fruit parts (flesh and placenta) (Shin et al. 2008). The total phenolic concentration was highest in the peel 151.64 μg/g (water extract) and 224.77 μg/g (ethanol extract). The total flavonoid content in the water and ethanol extracts in the peel was high 45.53 μg/g and 67.16 μg/g, respectively. Peel extracts displayed higher DPPH scavenging activity in both water and ethanol extracts – 25.0% (water extract) and 83.3%

(ethanol extract) at 1% concentration. In the ABTS (2,2′-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid)) assay the water extracts had values of 79.2% for peel, 57.6% for flesh and 74.0% for placenta at 1% concentration. For the ethanol extracts, ABTS values were 99.9% for peel, 52.1% for flesh and 41.2% for placenta at 1% concentration. Further, xanthine oxidase inhibitory activity and α-Glucosidase inhibition activity of both extracts of the peel appeared to be higher than those of the placenta and flesh. The data showed that the antioxidant and α-Glucosidase inhibition activity of peel extracts were higher than those of placenta and flesh. Also, the antimicrobial effect of ethanol extract from different fruit parts was shown only on *Streptococcus agalactiae*, a beta-hemolytic Gram-positive streptococci.

Two steroids Δ(7)-stigmasterol-(3β) acetate and α-spinasterol acetate were identified from the leaves and stem of *Cucumis melo* var. *makuw*a (Terauchi et al. 1970).

The calyces of the fruit are used as emetics in traditional medicine.

Other Uses

The fruits would be similarly used for cattle feeds as for other melons.

Comments

C. melo is a diverse species of the genus *Cucumis* (Kirkbride 1993; Jeffrey 1980) and its taxonomy is still confusing. Jeffrey 1980; Kirkbride 1993 divided *Cucumis melo* into 2 subspecies *melo* and *agrestis*. According to the quadrinomial classification based on length of ovary hair (Pitrat et al. 2000), the scientific name for oriental melon is *Cucumis melo* ssp. *agrestis* var. *makuwa*. According to the trinomial classification of Munger and Robinson (1991), the scientific name is *Cucumis melo* var *cononom*. Makino (1928) and Kitamura (1950) divided var. *makuwa* into eight different forms. Tanaka et al. (2007) adopted *C. melo* L. Group conomon var. *makuwa*.

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Cucumis melo (Reticulatus Group)

Scientific Name

***Cucumis melo* L. (Reticulatus Group)**

Synonyms

Cucumis cantalupensis Haberle ex M.J. Roem., nom. illeg., *Cucumis cantalupo* (Ser.) Haberle ex Rchb., *Cucumis eumelo* var. *cantalupa* Pangalo, *Cucumis melo cantalupensis* Munger & Robinson, *Cucumis melo* convar. *cantalupa* (Pangalo) Grebenšč., *Cucumis melo* J. Schultze-Motel convar. *melo*, *Cucumis melo* Cantaloupe Group, *Cucumis melo* L. var. *cantalupensis* Naudin nom. illeg., *Cucumis melo* var. *cantalupa* Sag. ex Filov, nom. invalid., *Cucumis melo* var. *cantalupo* Ser., *Cucumis melo* Var.-Gr. *cantalupensis* Alef., *Cucumis melo* var. *reticulatus* Ser., *Melo cantalupa* Pangalo.

Family

Cucurbitaceae

Common/English Names

American Cantaloupe, Cantaloupe, False Cantaloupe, Muskmelon, Netted Melon, Nutmeg Melon, Persian Melon, Rock Melon

Vernacular Names

For Muskmelon/ Rockmelon

Arabic: Qâwûn;
Chinese: Wang Jiao Tian Gua, Wang Wen Tian Gua, Xiang Gua, Ying Pi Tian Gua, Zui Gua;
Danish: Netmelon;
Dutch: Knobbelmeloen, Netmeloen, Muskaatmeloen;
Finnish: Verkkomeloni;
French: Melon Brodé, Melon De Cavaillon, Melon Maraîcher;
German: Netzmelone, Rippen-Melone, Zuckermelone;
India: Kharbuza (Hindu);
Indonesia: Blewah, Blewek, Bluwak, Bluwek, Garbis. Krai Bali, Semangka Landa (*Javanese*); Bhalungka, Bhalungkak, Samangka Balandha, Semangka Balandha (Madurese);
Italian: Melone Retato, Melone Reticolato, Melone Moscato;
Japanese: Masuku Meron;
Malaysia: Tembikai Wangi;
Philippines: Atimon, Katimon (Bisaya), Itimon (Iloko), Inkug (Sulu), Melon (Tagalog);
Portuguese: Melão-De-Casca-De-Carvalho, Melão Reticulado;
Russian: Kantalupka;
South Africa: Spanspek, Sweet Melon;
Spanish: Melón Bordado;
Swedish: Nätmelon;

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Thai: Taeng Thai;
Turkish: Kavun Fidani;
Vietnamese: Dua Tây Vang.

For Cantaloupe

Arabic : Qâwûn Kantalûbî;
Danish: Kantalupmelon;
Dutch: Kantaloep, Kanteloep, Wratmeloen;
Finnish: Cantaloupe-Meloni;
French: Cantaloup, Melon Cantaloupe, Melon Cantoup, Melon Cantaloup Brodé, Melon Cantaloup, Melon Charentais;
German: Kantalupe, Kantalupmelone, Warzenmelone;
Italian: Melone Cantalupo;
Japanese: Kantaruupu, Kyantaroopu;
Portuguese: Melão-Cantalupo, Melão Cantaloupe;
Spanish: Melón Cantalupo, Melón Cantaloupe;
Swedish: Cantaloupe;
Turkish: Kantalup Kavunu, Dilimli Kavun, Kabuklu Kavun;
Vietnamese: Dua Cantaloupe.

Origin/Distribution

Muskmelons or cantaloupes originated in India and Africa. They were first cultivated by the Egyptians and later the Greeks and Romans. Cantaloupe was introduced to North America by Christopher Columbus. Today, the major producers of the cantaloupe or muskmelon are the United States, Turkey, Iran, and many Central American countries.

Agroecology

Muskmelons or cantaloupes are warm climate crops. They are cold and frost sensitive. The crop is grown in the open in summer or heated glasshouses in winter in the temperate areas. They grow well on a wide range of soil types. Medium-textured soils (loams) will generally produce higher yields and better quality melons. In all cases the soil must exhibit good internal and surface drainage with an optimum pH of 5.8–6.2. Fruits in contact with moist soil develop cosmetic blemishes and rots from moulds.

Edible Plant Parts and Uses

The fruits are eaten fresh as dessert fruit in fruit salads or with ice cream or custard. Ripe melon pieces wrapped in prosciutto are a familiar antipasto. Fruits are consumed also in refreshing drinks with water or milk. Mature fruits are also canned or used for syrup or jam; dehydrated slices (lightly processed) for short-term or moderate storage can be reconstituted; and the pressed juice can be canned. Immature fruits are also used fresh in salads, as pickled vegetables or cooked in soup, stew, curry, stir-fries. Melon seeds are a dietary source of unsaturated vegetable oil and protein, and may be lightly roasted and eaten like nuts.

Botany

Annual, trailing, much-branched, scabrid climber with scabrid or hirsute quinquangular stems with simple, unbranched tendrils. Leaves distichous, long petioled, suborbicular or reinform, shallowly 3–7 lobed, cordate base, finely dentate at the margin tomentose and green on both surfaces (Plate 1). Flowers usually andromononoecious; male flowers fascicled, perfect or female flowers solitary. Male flowers with campanulate clayx of 5 subulate lobes, 5 lobed sub-campanulate yellow corolla, 3 free stamens with short glabrous filaments and oblong, twisted anthers. Bisexual flowers are similar with pubescent globose, ovoid or cylindrical ovary, with short, simple style and 3–5 obtuse stigmas. Fruit polymorphous, usually globose, subglobose or ellipsoid, hairy or glabrous, often scabrous with tubercles or reticulate, netted ridges (Plates 1–3) with sweet, succulent orange or pinkish, fragrant, musky flesh containing numerous ovate-oblong, flattened, white or ivory seeds, 1–1.2 cm by 0.5–0.7 cm.

Plate 1 Fruit and leaves of rockmelon

Plate 2 Close-up of the netted rind of rock melon

Plate 3 Fruit of cantaloupe with vertical green striped and netted skin and orange flesh

Nutritive/Medicinal Properties

Food composition of raw cantaloupe fruit per 100 g edible portion (refuse 49–39% rinds, 9% cavity components, 1% cutting loss), was reported as: moisture 90.15 g, energy 141 kJ, (34 kcal), protein 0.84 g, fat 0.19 g, ash 0.65 g, carbohydrate 8.16 g, total dietary fibre 0.9 g, total sugars 7.86 g, sucrose 4.35 g, glucose 1.54 g, fructose 1.87 g, maltose 0.04 g, galactose 0.06 g, starch 0.03 g; K 267 mg, Ca 9 mg, Mg 12 mg, Fe 0.21 mg, P 15 mg, Na 16 mg, Zn 0.18 mg, Cu 0.041 mg, Mn 0.041 mg, F 1.0 μg, Se 0.4 μg; vitamin C 36.7 mg, thiamin 0.041 mg, riboflavin 0.019 mg, niacin 0.734 mg, pantothenic acid 0.105 mg, vitamin B-6 0.072 mg, total folate 21 μg, vitamin A 169 μg RAE, vitamin A 3,382 IU, vitamin K (phylloquinone) 2.5 μg, α-tocopherol 0.05 mg, γ-tocopherol 0.11 mg, choline 7.6 mg, betaine 0.1 mg, β-carotene 2,020 μg, α-carotene 16 μg, β-cryptoxanthin 1 μg, lutein + zeaxanthin 26 μg; total saturated fatty acids 0.051 g, 12:0 (lauric acid) 0.001 g, 14:0 (myristic acid) 0.001 g, 16:0 (palmitic acid) 0.043 g, 18:0 (stearic acid) 0.0025 g; total monounsaturated fatty acids 0.003 g, 18:1 undifferentiated (oleic acid) 0.003 g; total polyunsaturated fatty acids 0.081 g, 18:2 undifferentiated (linoleic acid) 0.035 g, 18:3 undifferentiated (linolenic acid) 0.046 g; phytosterols 10 mg, tryptophan 0.002 g, threonine 0.017 g, isoleucine 0.021 g, leucine 0.029 g, lysine 0.030 g, methionine 0.012 g, cystine 0.002 g, phenylalanine 0.023 g, tyrosine 0.014 g, valine 0.033 g, arginine 0.029 g, histidine 0.015 g, alanine 0.095 g, aspartic acid 0.136 g, glutamic acid 0.209 g, glycine 0.026 g, proline 0.019 g and serine 0.042 g (USDA 2010).

Cantaloupes are an excellent source of both vitamin A, β-carotenes and vitamin C. It is also a good source of vitamins B6, niacin, thiamine, potassium. Cantaloupes are also high in dietary fibre as well as folate, a nutrient needed for growth and the development of haemoglobin.

Volatile compounds isolated from muskmelon fruit included n-hexanol, 1-octen-3-ol, cis-3-nonen-1-ol, n-butyl acetate, isobutyl acetate, 2-methylbutyl acetate, n-hexyl acetate, ethyl n-butyrate, ethyl 2-methylbutyrate, benzyl acetate, β-phenethyl acetate, and γ-phenylpropyl acetate (Kemp et al. 1973). The prevalence of six thioether esters, methyl (methylthio)acetate, ethyl (methylthio)acetate, 2-(methylthio)ethyl acetate, methyl 3-(methylthio)propanoate, ethyl

3-(methylthio)propanoate, and 3-(methylthio) propyl acetate, were deemed to be of importance to the aroma profiles of *Cucumis melo* fruit (Wylie and Leach 1992). Twenty sulfur volatiles, including S-methyl esters of ethanethioic, butanethioic and pentanethioic acids, and dimethyltrisulfide were identified in muskmelon (*Cucumis melo* cv. Makdimon) (Wyllie et al. 1994). From aroma extraction dilution analysis (AEDA) seven key compounds were identified, four of which contained sulfur; S-methyl thiobutanoate, 3-(methlythio)-propyl acetate, 3-(methylthio)propanal and possibly dimethyltetrasulfide. Of these seven key sensory responses only two were described as fruity/floral (ethyl 2-methylpropanoate and 3-(methylthio)propyl acetate), the other five components being responsible for the earthy, stale musk aroma of this melon. However, comparison of odour units suggested a higher weighting than the AEDA results for the common fruity ester notes from methyl and ethyl 2-methylbutanoate and 2-methylbutyl acetate. Preliminary tests indicated that blending the flesh of this melon prior to steam distillation extraction activated lipoxygenase and hydrolase activity and modified the aroma profile appreciably.

Muskmelon fruit stored frozen prior to steam distillation-extraction yielded an essence which, contained considerably larger amounts of trans-2-nonenal, n-nonanol, cis-3-nonen-1-ol, cis-6-nonen-1-ol, and the methyl and ethyl esters of linoleic and linolenic acids (Kemp et al. 1973). Marked decreases in the relative amounts of benzyl acetate, β-phenethyl acetate, and γ-phenylpropyl acetate resulted from freezing. All 21 compounds examined were present in the essence prepared from fresh, refrigerated, and frozen fruit. A total of 53 components were quantified in the essence and 38 in the fresh fruit of *Cucumis melo* cv. Athena (muskmelon) (Jordán et al. 2001). In addition, four new components were described as contributors to the aromatic profile of muskmelon including 2-methyl-3-buten-2-ol, 2,3-butanediol, methyl 3-phenylpropionate, and ethyl 3-phenylpropionate (found only in the puree of the fruit). The olfactometric analysis revealed the presence of 25 components with aromatic activity. Esters, alcohols, and one sulfur component [ethyl 3-(methylthio)propionate] appeared to be the most important contributors to the essence aroma.

Increased fruity and sweet taste attributes in cantaloupe (*Cucumis melo* L. var. *reticulatus*, Naudin, cv. 'Sol Real') were negatively correlated with percentage concentrations of acetates, aromatic acetates, and total aromatic compounds, and positively correlated with concentrations of percentage non-acetate esters (Beaulieu and Lancaster 2007). Ethyl hexanoate was strongly positively correlated with fruity and sweet taste. Cucurbit, water-like, hardness, cohesiveness, and denseness were positively correlated with percentage acetates, aromatic acetates, and total aromatic compounds, and negatively correlated with percentage non-acetate esters. Several non-acetate esters such as ethyl 2-methyl propanoate, ethyl butanoate, ethyl 2-methyl butanoate, and ethyl hexanoate were negatively (often strongly) correlated with cucurbit. Hardness was positively and strongly correlated with aromatic acetates and all aromatic (benzyl) compounds. Firmer and denser cubes contained more acetates and fewer non-acetate esters. The apparently negative or undesirable attributes cucurbit and water-like were associated with higher acetates and aromatic compounds.

Aromatic volatiles in orange flesh cantaloupe (Saftner et al. 2008) were quantified in terms of retention index detector response in picoamperes (pA): ethyl acetate 99.0; methyl butyrate 16.4; ethyl isobutyrate 13.6; isobutyl acetate 88.7; methyl 2-methylbutyrate 0.4; ethyl butyrate 159.6; butyl acetate 69.7; ethyl 2-methylbutyrate 159.8; isoamyl acetate and 2-methylbutyl acetate 296.8; ethyl valerate 25.0; amyl acetate 1.2; methyl hexanoate 12.3; isobutyl butyrate 0.9; benzaldehyde 1.2; ethyl hexanoate 297.4; (*Z*)-3-hexenyl acetate 145.2; hexyl acetate 252.6; isobutyl isobutyrate 2.9; 1-octanol 1.2; ethyl (*E*)-4-heptenoate 1.5; ethyl heptanoate <0.3; nonanal 26.8; heptyl acetate 15.5; (*Z*)-3-nonen-1-ol nd; (*E*)-2-nonenal 2.7; Benzyl acetate 57.6; (*Z*)-6-nonen-1-ol <0.3; ethyl benzoate 4.4; ethyl octanoate 9.7; octyl acetate 15.4; phenylethyl acetate 3.6; nonyl acetate 1.8; (*Z*)-3-nonenyl acetate 2.4; (*Z*)-6-nonenyl acetate 2.5; (*Z*,*Z*,6)-3-nonadienyl acetate 2.6; ethyl decanoate

8.2; geranyl acetone 3.1; and α-farnesene <0.3. All of the aromatic volatiles identified by Saftner et al. (2008) had been previously reported in melons (Beaulieu and Lea 2006; Buttery et al. 1982). Distinct qualitative and quantitative differences were found in aromatic volatiles among melon genotypes (Wyllie et al. 1994) with concentrations of many volatiles, particularly the more abundant esters, being generally higher in cantaloupe than in honeydews (Wyllie and Leach 1992; Yabumoto et al. 1978).

Climateric varieties of *Cucumis melo* were found to contain volatile sesquiterpenes mainly in the rind (Portnoy et al. 2008). The orange-fleshed 'Dulce' had α-farnesene as the main, while the green-fleshed 'Noy Yizre'el' had δ-cadinene, γ-cadinene and α-copaene. Sesquiterpene synthase activities, mainly restricted to rinds of mature fruits, were shown to generate different sesquiterpenes in each variety according to the compositions found in rinds.

Seeds from a *C. melo* reticulatus hybrid 'ChunLi' was found to contain high percentages of lipids (35.36%) and proteins (29.90%) (Hu and Ao 2007). Hexane-extracted oil had acid, peroxide, iodine and saponification values of 1.51, 3.95, 89.5 and 226.73, respectively. Gas chromatographic analysis of the oil revealed the presence of 25 fatty acids varying from C4 to C24 with the exception of C5, C7, C11 and C19. The concentrations of individual fatty acids varied from trace quantities to about 54.8%. Linoleic, oleic, palmitic and stearic acids were the major fatty acids contributing to 53.9%, 12.1%, 23.9% and 5.7%, respectively, of the total fatty acids which had a relatively high percentage (67.5%) of unsaturated fatty acids. Seed proteins were rich in arginine, aspartic and glutamic acids while limiting in methionine and lysine.

The methanolic seed extract of *Cucumis melo* L. var. *reticulatus* (Cucurbitaceae) afforded three new chromone derivatives: 5,7-dihydroxy-2-[2-(4-hydroxyphenyl)ethyl] chromone 3, 5,7-dihydroxy-2-[2-(3,4-dihydroxyphenyl)ethyl] chromone 4, and 7-glucosyloxy-5-hydroxy-2-[2-(4-hydroxyphenyl)ethyl]chromone 6, together with three known compounds; β-amyrin 1, β-sitosterol 2, and β-sitosterol-3-O-β-glucopyranoside 5 (Ibrahim 2010). The n-hexane and methanolic extracts were evaluated for their antimicrobial activity, as well as cytotoxic activity using the brine shrimp bioassay.

Some pharmacological properties of the plant are elaborated below.

Antioxidant Activity

Ismail et al. (2010) determined the phenolic content and antioxidant activity of methanol extracts from different parts of cantaloupe (leaf, stem, skin, seed and flesh). The flesh extract afforded the highest yield (89.6%) whilst the lowest yield was obtained from the seed (13.7%). The leaf extract showed the highest total phenolic content (26.4 mg GAE/g extract) and total flavonoid content (69.7 μg RE/g extract) along with best antioxidant activity through all antioxidant assays. Further, the stem extract also exhibited good antioxidant activity. The results suggested that methanol extracts of cantaloupe leaf and stem may serve as a potential source of natural antioxidant for food and nutraceutical applications.

Studies revealed that orange-fleshed non-netted honeydew *(Cucumis melo* L.) a cross between orange-fleshed cantaloupe and non-netted, green-fleshed honeydew could be a rich source of many human health-related nutrients (Lester 2008). The concentrations of soluble solids, sucrose, total sugars, β-carotene, and 5-methyltetrahydrofolic acid increased in an inward direction from the subpeel (hypodermal) mesocarp tissues toward the seed cavity. The activities of antioxidant enzymes, ascorbate peroxidase, catalase, and superoxide dismutase also increased in an inward direction. The concentrations of calcium, iron, magnesium, manganese, and sodium all decreased in the inward direction. When expressed on a dry weight basis, the concentrations of ascorbic acid, boron, copper, fructose, glucose, phosphorus, potassium, and zinc were higher in the subpeel region compared to the inner mesocarp tissues, but the reverse was true when data were expressed on a fresh weight basis. These data revealed that there was consider-

able variation in sugars, minerals, and phytonutrients across the mesocarp regions and that expressing the data on a fresh or dry weight basis could alter interpretations of the nutritional significance and health benefits of fruit.

Specific and total superoxide dismutase (SOD) activities were found to vary significantly among the genotypes of muskmelons (*Cucumis melo* L.) (Lester et al. 2009). Netted (cantaloupe) genotypes generally had the lowest SOD activities compared to the green- and orange-fleshed honey dew types. Casaba type fruit had average SOD activities that were approximately 1.6-fold greater than those of honey dew types, and approximately 9.0-fold greater than those of cantaloupe types. These data indicated the existence of useful genetic diversity among commercial melon varieties and in exotic genotypes that could be used to develop *C. melo* as a functional food with enhanced SOD content.

Using a swine model, a SOD-rich melon (*Cucumis melo*) pulp concentrate (MPC) provided at the dose of 50 IU/kg of food for up to 12 days was effective in reducing the level of stress proteins along the gastrointestinal tract of pigs after weaning (Lallès et al. 2011). Plasma SOD increased with MPC dose at day 14. Mucosal weights in the proximal and mid small intestine were lower at day 14, caecum tissue weight was significantly greater, and sucrase-specific activity in mid and distal small intestine mucosa was significantly lower in the MPC2 group than in the control group. MPC supplementation essentially decreased significantly stress proteins in the stomach (all), the mid small intestine (heat-shock protein-27, neuronal nitric oxide synthase) and the colon (heat-shock protein-70, neuronal nitric oxide synthase).

Antidiabetic Activity

Oxidative stress is implicated as an important factor that causes diabetic nephropathy (progressive kidney disease). Studies by Naito et al. (2005) found that oxykine, a cantaloupe extract, rich in vegetal superoxide dismutase covered by polymeric films of wheat matrix gliadin, reduced the diabetes-induced oxidative stress and kidney cell damage. Treatment with oxykine prevented the advance and acceleration of diabetic nephropathy for rodent model of type 2 diabetes. Oxykine reduced the diabetes-induced oxidative stress and renal mesangial cell injury. Albeit the need for further studies, oxykine may be a safe and cheap approach for the prevention of diabetic nephropathy.

Antiinflammatory Activity

Cantaloupe melon (*Cucumis melo*) CME extract, high in superoxide dismutase activity inhibited in a concentration-dependent manner the production of superoxide anion with a maximal effect at 100 μg/ml (Vouldoukis et al. 2004b). This inhibitory effect of CME appeared to be closely linked to the superoxide dismutase (SOD) activity because it was drastically decreased after heat inactivation of the SOD activity (HI-CME). In addition, the CME inhibited the production of peroxynitrite. CME also stimulated the IgG1IC-induced production of interleukin IL-10 instead of TNF-alpha. These data demonstrated that, in addition to its antioxidant properties, the anti-inflammatory properties of the CME extract were largely related to its capacity to stimulate the production of IL-10 by peritoneal macrophages. It was also demonstrated that animals supplemented with the CME/wheat gliadin combination during 28 days were protected against the pro-inflammatory properties of interferon IFN-gamma while the other products were ineffective. The data demonstrated that when the SOD activity was sustained during the digestive process by its combination with wheat gliadin it was possible to elicit in-vivo the pharmacological effects of this antioxidant enzyme. Vouldoukis et al. (2004a) also demonstrated that supplementation with gliadin-combined standardized melon, SOD extract (Glisodin) promoted the cellular antioxidant status and protected against oxidative stress-induced cell death. Animals supplemented with Glisodin showed a significant rise in circulated antioxidant enzymes activities, correlated with an increased resistance of red blood cells to

oxidative stress-induced hemolysis. Hepatocytes isolated from animals supplemented with Glisodin manifested a delayed depolarization response and an enhanced resistance to oxidative stress-induced apoptosis.

Antiplatelet Aggregation Activity

Adenosine isolated from an aqueous melon (*Cucumis melo*) extract was shown to inhibit human platelet aggregation induced by epinephrine, ADP (adenosine diphosphate), collagen, thrombin, sodium arachidonate, prostaglandin endoperoxide analogue U-46619 and PAF-acether (Altman et al. 1985). It demonstrated potential to be used in patients with heart disease as a blood-thinning agent, and also as a relief from angina. Studies in patients with stable angina pectoris, found that infusion of adenosine provoked signs and symptoms of myocardial ischaemia in patients with ischaemic heart disease with only a slight elevation in cardiac work compared to exercise (Straat et al. 1991). Studies by Sadigh et al. (2009) showed that low-dose adenosine infusion reduced the ischemic burden and improved left ventricular regional systolic function in the ischemic walls of patients with exercise-induced myocardial ischemia, confirming adenosine to be a potential preconditioning agent in humans. Ischemic preconditioning protects the heart through brief episodes of ischemia and renders the myocardium resistant to subsequent ischemic insults.

Anticancer Activity

Twenty-one cucurbitane-type triterpenoids, including nine new compounds (1–9) and 12 known compounds were isolated from the stems of *Cucumis melo* (Chen et al. 2009) Two known compounds, cucurbitacin B and cucurbitacin A, displayed significant cytotoxic activity against the proliferation of human lung adenocarcinoma epithelial cell line A549/ATCC and hepatocellular carcinoma BEL7402 cells in-vitro. Of the new compounds, only compound 7 was mildly cytotoxic. The inhibitory effects of all compounds on the Jak-Stat3 signaling pathway were evaluated, but only cucurbitacin B showed significant inhibitory activity of phosphotyrosine STAT3.

Dyslipidemia, Hypothyroidism Activity

In one study, out of four different doses (50–300 mg/kg), 200 mg/kg of *Mangifera indica* (MI) peel and 100 mg/kg of *Cucumis melo* (CM) peel and *Citrullus vulgaris* (CV) peel extracts inhibited lipid peroxidation maximally in liver (Parmar and Kar 2008). In the second study, rats treated simultaneously with either of the peel extracts (200 mg/kg of *Mangifera indica* and 100 mg/kg for *Cucumis melo* and *Citrullus vulgaris*) for 10 consecutive days reverted the atherogenic CCT diet-induced elevation in the levels of tissue lipid peroxidation, serum lipids, glucose, creatinine kinase-MB and decrease in the levels of thyroid hormones and insulin indicating their potential to ameliorate the diet induced alterations in serum lipids, thyroid dysfunctions and hyperglycemia / diabetes mellitus. The CCT atherogenic diet was supplemented with 4% cholesterol, 1% cholic acid and 0.5% 2-thiouracil. A phytochemical analysis indicated the presence of a high amount of polyphenols and ascorbic acid in the test peel extracts suggesting that the beneficial effects could be the result of the rich content of polyphenols and ascorbic acid in the test peels. In a subsequent study, the three test peel extracts appeared to be stimulatory to thyroid functions and inhibitory to tissue lipid peroxidation but only when treated individually (Parmar and Kar 2009). Administration of three test peel extracts significantly increased both the thyroid hormones (T(3) and T(4)) with a concomitant reduction in tissue lipid peroxidation, suggesting their thyroid stimulatory and anti-peroxidative role. This thyroid stimulatory nature was also exhibited in propylthiouracil-induced hypothyroid animals. However, only minor influence was observed in serum lipid profile in which *Citrus melo* peel lowered the concentrations of total cholesterol and low-density lipoprotein-cholesterol (LDL-C), while *Citrullus vulgaris* peel decreased

triglycerides and very low-density lipoprotein-cholesterol (VLDL-C). When the combined effects of either two (MI + CV) or three (MI + CV + CM) peel extracts were evaluated in euthyroid animals, serum T(3) concentration was increased in response to MI + CV and MI + CV + CM treatments, while T(4) level was elevated by the combinations of first two peels only. Both the categories of combinations increased T(4) levels, but not T(3) in propyl-thiouracil-induced hypothyroid animals. In addition a concomitant rise in hepatic and renal lipid peroxidation was observed in these animals, suggesting their unsafe nature in combination.

Food Allergen

Cucumisin (Cuc m 1) a subtilisin-like endopeptidase and several N-terminal cucumisin fragments were identified as the major allergens of melon (*Cucumis melo*) (Cuesta-Herranz et al. 2003). The ubiquitous distribution of this protein family (cucumisin-like proteases) in many plant species and its high structural similarity suggested its potential role as a new panallergen in plant foods.

Traditional Medicinal Uses

The root is reported to be n emetic and the peduncle has been used medicinally for general anasarca and digestion by the Chinese and to arrest vomiting in Indo-China. The fruit pulp or the juice forms a nutritive, demulcent, diuretic, and cooling drink. It is beneficial as a lotion for chronic and acute eczema as well as for removing tan and freckles, and internally, in cases of dyspepsia. The seeds yield sweet, edible oil, which is nutritive and diuretic, being useful in painful discharge and suppression of urine.

The seed kernels have been prescribed for cancer of the stomach and for purulent difficulties of the digestive tract generally. They are also used in menorrhagia, after the oil has been extracted.

Other Uses

All melon fruits can be used as cattle feed to help in dehydration during the dry periods.

Comments

Muskmelons are propagated from seeds.

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Cucumis melo L. (Reticulatus Group) 'Hami melon'

Scientific Name

***Cucumis melo* L. (Reticulatus Group) 'Hami'**

Synonyms

Cucumis melo L. (Reticulatus Group) 'Hamigua', *Cucumis melo* var. *reticulatus* Syringe

Family

Cucurbitaceae

Common/English Names

Cantaloupe, Chinese Hami Melon, Chinese Winter Melon, Hami Melon, Persian Melon

Vernacular Names

Chinese: Ha Mi Gua, Ha Mi Kua;
French: Melon Hami De Chine;
Japanese: Hami Uri;
Malay: Tembikai Hami;
Vietnamese: Dua Vàng Hami.

Origin/Distribution

Hami melon originated from Hami, Xinjiang, China. It is the most important melon crop grown in the north-western provinces of China. More than 100 cultivars and hybrids of Hami melon have been reported in China.

Agroecology

Like muskmelon, Hami melon is a warm season crop. Its native habitat is characterised by a semi-arid continental climate of middle temperate zone, with low mean annual rainfall of <500 mm, long days, large difference in day-night temperatures, shorter spring and autumn and longer winter and summer, frost-free period of 179 days and 2,821 h of sunshine annually. It thrives in areas with fertile soil and where irrigation is available.

Edible Plant Parts and Uses

Ripe Hami melons are eaten fresh or made into refreshing drinks. Immature melons are also cooked or pickled. The seeds are dried, roasted and eaten.

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Plate 1 Ellipsoid-oval, green speckled skinned hami melon

Plate 3 Yellow, green blotched, netted hami melon

Plate 2 Salmon-coloured flesh and ivory coloured seeds

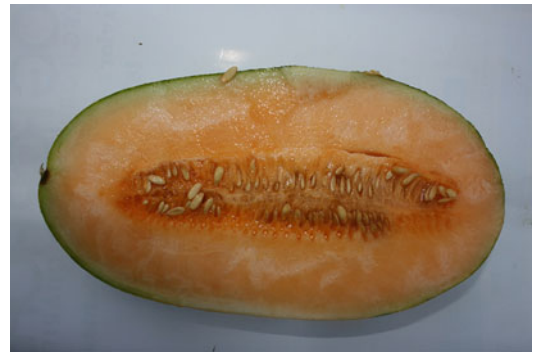

Plate 4 Orange, juicy flesh with ivory-coloured seeds

Botany

A strong, annual, herbaceous climber or trailing on the ground, hispid throughout with striate – sulcate stems and simple tendrils. Leaves suborbicular or reniform, 8–12 cm by 4–8 cm wide, shallowly lobed, lobes obtuse. Flowers usually andromononoecious; male flowers fascicled, perfect or female flowers solitary. Flowers as described for *C. melo* Reticulatus Group. Fruits large, oval to ellipsoid, with a green or yellow speckled thick rind or with dark green vertical patches and bands, smooth or partially and superficially netted (Plates 1 and 3) and orange, salmon or pinkish-orange, musky-flavoured, sweet, juicy, crispy flesh. Seeds are numerous, creamy-white or ivory (Plates 2 and 4).

Nutritive/Medicinal Properties

The nutritive value would be similar to that as described for *C. melo* Reticulatus Group (USDA 2010).

Forty-two volatile components were identified in Hami melon (*Cucumis melo* L. var. Winchosen) flesh (Moshonas et al. 1993). Twenty-four components were newly reported in *Cucumis melo*, including a series of four diacetate esters. Non-volatile components quantified in Hami melon flesh included fructose, glucose, sucrose and ascorbic acid.

Ma et al. (2007) reported that freezing process and frozen storage could not significantly reduce either micro-organisms counts or the enzymatic activities of polyphenoloxidase (PPO), peroxidase (POD) and lipoxidase (LOX) in hami melon.

Liquid nitrogen ultra-rapid freezing maintained most aromatic components of hami melon as compared with slow freezing. The mechanism of aromatic change in frozen hami melon was mainly attributed to concentration changes in esters because of enzymolysis or synthetic reactions of esters catalysed by lipoxidases. Increasing concentration of linoleic acid and linolenic acid in frozen melon cells stimulated the biochemical reaction of unsaturated fatty acids in lipoxidase system, accelerating the enzymolysis of the double bonds in the ninth and tenth carbon of linoleic acid and linolenic acid. Thus, with protraction in frozen storage duration much more unsaturated alcohols and aldehydes with 6 and 9 carbons were produced, the green notes of frozen storage melon became much more intense, and the ester fragrance became weaker. Earlier studies revealed that high thermal treatment was deleterious to hami melon juice (Ma 2004, cited by Chen et al. 2010). It was reported that the total esters decreased 20%, and 6-carbon, 9-carbon alcohol and aldehyde contents decreased significantly after thermal treatment. Concurrently, new aroma compounds, such as dimethyl disulfide (0.56%), dimethyltrisulfide (0.09%), 2-methylpiperazine (0.04%) and N-ethylmethylthiamine (0.21%) were produced. The flavour of high temperature-treated melon juice had a cooked off-odour and no green flavour.

The dense phase carbon dioxide (DP-CO_2) treatment of hami-melon juice had significant effects on inactivation of microorganism and enzyme (Chen et al. 2010). It was found that higher pressure caused more inactivation of microbial total count and enzyme activity. The least residual activity of polyphenol oxidase (PPO), peroxidase (POD), and lipoxygenase (LOX) was 25.26%, 38.46% and 0.02% at 35MP, respectively. The restoration of PPO, POD and LOX residual activity after DP-CO_2 processing was also noted, and was pressure level-dependent. The aroma compounds were less affected after being treated with DP-CO_2, 45 volatile compounds were detected by SPME/GC/MS. After 4 weeks storage at 4°C, there was no change in ester composition/concentration (ethyl acetate, ethyl propanoate, ethyl butyrate, butyl acetate and ethyl-2-methyl butyrate) after DP-CO_2 treatment. There were slight, insignificant changes in alcohols and aldehydes concentrations, such as (Z)-nonel-3-ol, (E,Z)-2,6-nonadien, (Z)-nonel-6-ol, and nonanol, hexanal, (Z)-6-nonenal, nonanal, and 2-nonenal. The flavour of DP-CO_2-treated melon juice was similar to fresh melon juice, which had a green flavour. The data proved that DP-CO_2 processing afforded a promising non-thermal alternative pasteurization to preserving the nutrient and unique flavour of fresh-squeezed hami melon juice.

Other Uses

As with all melons they can be used as cattle feed.

Comments

Some authors consider Hami melon to belong to the *C. melo* Indorous Group, while numerous scientists in China placed it under the *C. melo* Reticulatus group.

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Cucumis metuliferus

Scientific Name

***Cucumis metuliferus* E. Mey. ex Naudin**

Synonyms

Cucumis metulifer Naudin, *Cucumis tinneanus* Kotschy & Peyr.

Family

Cucurbitaceae

Common/English Names

African Cucumber, African Horned Cucumber, African Horned Melon, Bitter Wild Cucumber, Hedged Gourd, Horned Cucumber, Horned Melon, Horny Cucumber, Jelly Melon, Kiwano, Spiny Cucumber

Vernacular Names

Afrikaans: Rooikomkommer, Rooi-Agurkie, Wilde-Komkommer;
Benin: Agbôwounon, Gbowunon (Fon), Agbowunon (Goun);
Botswana: Magabala, Mokapana (Tswana), Mogau;
Danish: Afrika Agurk;
Democratic Republic of Congo: Nku, Mutete, Mugaika, Mukaka, Uhufafa (Bantu), Kunguliranalima (Shi);
Dutch: Zuiltjesdragende Komkommer;
East Africa: Tangon;
Eastonian: Ogamelon;
Finnish: Kivakurkku, Kiwano;
French: Concombre À Corne, Concombre Africain, Concombre Cornu, Kiwano, Melon À Corne, Melon Porte-Corne, Métulon, Metulo;
German: Horn-Gurke, Hommelone, Hornmelone, Kiwabo, Kiwano, Geleemelone, Kiwake, Morgensterngurke;
Israel: Melano®;
Italian: Kiwano;
Japanese: Kiwano;
Malawi: Bitter Wild Cucumber;
Mozambique: Mutete, Mugaika, Mushonga, Mugaka (Shona, Southern Mozambique);
Niger: Nku, Mutete, Mugaika, Mukaka, Uhufafa (Bantu), Golo'n Zâki (Hausa), Oemanam Anag Eshan (Tamacheck), Gorgno Tiambou (Zarma);
Portuguese: Kiwano, Kumbundu, Maxije, Pepino Africano Umbundu;
Slovenia: Afriška Kumara, Kivano;
Somalia: Patir;
South Africa: Bitter Wild Cucumber (English), Rooi-Agurkie, Rooikomkommer (Afrikaans), Mukake (Venda), Uhufafa (Zulu), Mokapana, Magabala (Tswana);

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Spanish: Kiwano;
Swedish: Kiwano, Afrikansk Gurka;
Zambia: Mugagachiga;
Zimbabwe: Mushonga, Mugaka, Mutete, Mugaika, Mugaka (Shona, Southern); Ihalabujana Mu, Gumudza'mbga (Northern), Gaka, Gakachika.

Origin/Distribution

Kiwano's natural distribution is found in the tropical and subtropical sub-Saharan regions of Africa, stretching from Senegal to Somalia and South Africa. It has also been recorded in Yemen. The crop is commercially grown as an export crop in Kenya, New Zealand, France and Israel. It has become naturalized in Australia, and is reported as adventive in Croatia.

Agroecology

It occurs naturally in semi-evergreen forest, woodland, wooded grassland and grassland. It is also found on abandoned cultivated land, often riverine, in riverbeds or flood plains, on fringes of gullies 200–1,100 m above sea level but nearer the equator the upper limit may reach 1,800 m. Kiwano thrives in full sun and will grow on most soil types including rocky slopes but does best on well-drained, sandy loam, alluvial soils rich in organic matter. The plant perform well in humid areas and can grow in areas with as low as 350–550 mm annual rainfall and in dry areas with irrigation. Flowering and fruiting can be influenced by day-length. Flower induction appears to require short days; days longer than 14 h curb flowering. In contrast, short days can lead to parthenocarpic fruits. Optimum temperature range is between 20°C and 30°C although the lower limit is near 0°C and the upper limit is near 40°C. However, it appears that temperatures above 30°C affects flowering. In addition, germination is greatly inhibited at temperatures above 35°C or below 8°C. Low cool temperature suppresses growth and the plant is frost sensitive.

Edible Plant Parts and Uses

Kiwano fruit can be eaten raw, baked, juiced, pickled, dried and preserved. The fruit is juicy, quite bitter and bland but with sugar the flavour can be enhanced. It can be eaten as a fruit snack, fruit salad as in Zimbabwe, and the pulp can be eaten with ice cream or processed into sorbet. In Botswana, whole ripe fruit are baked in the coals of fires. They are also peeled, split open, sun-dried on both sides, and stored as ready-made preserves. Immature fruit can be pickled like gherkins. The seeds and leaves are edible. Immature fruits are often peeled and eaten raw with the seeds, and relished like cucumber. The seeds can be ground into flour. The leaves contain useful nutrients and are picked when young, boiled, and eaten like spinach.

Botany

An annual with climbing or sprawling, prostrate setose stems arising from a semi-woody root. Leaf-lamina is variable in size 3.5×3.5 cm –12×13.5 cm, dark green, sub-pentagonal to cordate, hispid-setulose especially on veins beneath, margins sinuate-denticulate rather shallowly 3–5-lobed, shortly acuminate apex, with deep broad basal sinus on strongly setulose petiole. Leaf petiole up to 110 mm long, strongly patent-setulose. Slender, curling, unbranched tendrils arise from the axils. Flowers are unisexual, monoecious, male and female flowers on the same plant. Male flowers solitary or 2–10 in usually sessile fascicles, pedicellate, with lobed receptacle tube and yellow petals. Female flowers are solitary, pedicellate, sometimes co-axillary with male, with ellipsoid ovary covered with large soft spines, perianth is similar to that of the male flower. Fruit is large, 6–12 cm long, ellipsoid, ornamented with stout, conical, blunt, fleshy spines, dark green mottled paler grey-green or yellow (Plates 1–2.), becoming orangey-red when ripe. Fruit flesh is translucent green, mucilaginous with numerous smooth, ellipsoid, flattened, 6–9 mm long, white, edible seeds (Plate 2).

Plate 1 Ripe kiwano fruit

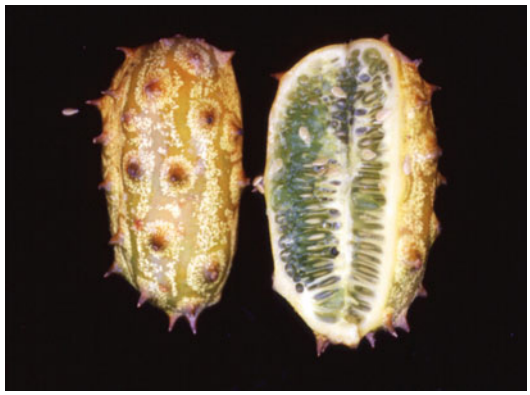

Plate 2 Flesh and seeds in sliced kiwano fruit

Nutritive/Medicinal Properties

Kiwano fruit was reported to be more nutritious than cucumbers, having notably higher values for most nutrient components. One analysis reported the fruit to be about 90%, and containing (on a dry-weight basis) about 10% protein, 6% fat, and 45% carbohydrate, with only about a third to a half the vitamin C of fresh oranges (Arnold et al. 1984). Kiwano fruit was found to be low in total antioxidant with a mean of 0.16 mMol/100 g fresh weight versus pomegranate with a high value of 11.33 mMol/100 and cucumber with a lower value of 0.05 mMol/100 g as determined by the FRAP (Ferric-reducing ability of plasma) assay (Halvorsen et al. 2002). The low free radical scavenging activity of kiwano was also confirmed by studies conducted in Botswana (Motlhanka 2008).

Kiwano leaves were found to contain per 100 g edible portion: energy 43 kcal, moisture 87%, protein 4 g, fat 0.7 g, fibre 2.42 g, ash 2.73 g, carbohydrate 5.55 g, Ca 2,974 mg, P 434 mg, Na 317 mg, Mn 4 mg, Cu, 1 mg, Zn 11 mg, Mg 1,022 mg and Fe 20 mg (Odhava et al. 2007).

Scientific studies revealed that kiwano fruit (powdered) had an effect on enzymes and haematological parameters in albino rats (Wannang et al. 2007). 1,000 mg/kg produced significant elevation in red blood cells, platelets, haemoglobin and packed cell volume (PCV) values, and an insignificant decrease in clotting and bleeding time. Biochemical parameters evaluation disclosed that 500–1,000 mg/kg of the powdered fruit produced a dose-dependent significant increase in the contents of serum alkaline phosphatase (ALP), aspartate aminotransferase (AST), alanine aminotransferase (ALT), blood urea nitrogen and total protein. This in turn increased the oxygen carrying capacity hence, increasing tissue oxygenation.

In folkloric medicine in Africa, kiwano seeds are ground into fine flour, then made into an emulsion with water and ingested as vermifuge to expel the tapeworms or other parasites from the body. In Benin, the fruit is peeled and wallowed in alcohol of palm or juice of lemon for local application. In the Okavango delta, Botswana, the Shona tribe use a decoction of the root for relief of pain after childbirth. It is also believed that the boiled root is a very good gonorrhoea remedy. Also some segments of the society in Botswana believe it is good for diabetic patients.

Other Uses

Kiwano is used as a rootstock for disease resistance for cucumber, *Cucumis sativus*.

Comments

Kiwano is readily propagated by seeds.

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Cucumis sativus

Scientific Name

***Cucumis sativus* L., var. sativus**

Synonyms

Cucumis esculentus Salisb., *Cucumis hardwickii* Royle, *Cucumis muricatus Willd., Cucumis rumphii* Hassk., *Cucumis sativus* fo. *albus* Hiroë, *Cucumis sativus* fo. *albus* Pangalo, *Cucumis sativus* fo. *australis* Kitam., *Cucumis sativus* fo. *borealis* Kitam., *Cucumis sativus* fo. *brunnescens* Gabaev, *Cucumis sativus* fo. *pallescens* Gabaev, *Cucumis sativus* fo. *tuberculatus* Hiroë, *Cucumis sativus* fo. *typicus* Gabaev, *Cucumis sativus* fo. *viridis* Gabaev, *Cucumis sativus* grex *viridis* (Ser.) Alef., *Cucumis sativus* subsp. *agrestis* Gabaev, *Cucumis sativus* subsp. *chinensis* Filov, *Cucumis sativus* subsp. *europaeo-americanus* Filov, *Cucumis sativus* subsp. *indo-japonicus* Filov, *Cucumis sativus* subsp. *gracilior* Gabaev, *Cucumis sativus* subsp. *himalaicus* Filov, *Cucumis sativus* subsp. *occidentali-asiaticus* Filov, *Cucumis sativus* subsp. *rigidus* Gabaev, *Cucumis sativus unranked antasiaticus* Gabaev, *Cucumis sativus unranked curtus* Alef., *Cucumis sativus unranked donii* Alef., *Cucumis sativus unranked excellens* Alef., *Cucumis sativus unranked flexuosus* Alef., *Cucumis sativus unranked gracilior* Gabaev, *Cucumis sativus unranked hardwickii* (Royle) Alef., *Cucumis sativus unranked hollandicus* Alef., *Cucumis sativus unranked longus* Harz, *Cucumis sativus unranked opheocarpus* Harz, *Cucumis sativus unranked orasiaticus* Gabaev, *Cucumis sativus unranked pallidus* Alef., *Cucumis sativus unranked praecox* Alef., *Cucumis sativus unranked rossicus* Alef., *Cucumis sativus unranked serotinus* Alef., *Cucumis sativus unranked setosus* Alef., *Cucumis sativus unranked sikkimiae* Harz, *Cucumis sativus unranked smilli* Forssk., *Cucumis sativus unranked turcicus* Alef., *Cucumis sativus unranked vulgaris* Alef., *Cucumis sativus* var. *albus* Ser., *Cucumis sativus* var. *anatolicus* Gabaev, *Cucumis sativus* var. *anglicus* L.H. Bailey, *Cucumis sativus* var. *arakis* Forssk., *Cucumis sativus* var. *battich-djebbal* Forssk., *Cucumis sativus* var. *brullos* Forssk., *Cucumis sativus* var. *chatte* Forssk., *Cucumis sativus* var. *chiar* Forssk., *Cucumis sativus* var. *cilicicus* Gabaev, *Cucumis sativus* var. *ennemis* Forssk., *Cucumis sativus* var. *europaeus* Gabaev, *Cucumis sativus* var. *fakus* Forssk., *Cucumis sativus* var. *falcatus* Gabaev, *Cucumis sativus* var. *fastigiatus* Ser., *Cucumis sativus* var. *flavus* Ser., *Cucumis sativus* var. *grossularioides* Tkachenko, *Cucumis sativus* var. *hardwickii* (Royle) Gabaev, *Cucumis sativus* var. *indo-europeus* Gabaev, *Cucumis sativus* var. *irano-turanicus* Gabaev, *Cucumis sativus* var. *izmir* Gabaev, *Cucumis sativus* var. *pallidus* Gabaev, *Cucumis sativus* var. *schemmam* Forssk., *Cucumis sativus* var. *sikkimensis* Hook. f., *Cucumis sativus* var. *squamosus* Gabaev, *Cucumis sativus* var. *testudaceus* Gabaev, *Cucumis sativus* var. *tuberculatus* Gabaev, *Cucumis sativus* var. *variegatus* Ser., *Cucumis*

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sativus var. *viridis* Ser., *Cucumis sativus* var. *vulgatus* Gabaev, *Cucumis sativus* var. *xishuangbannanesis* Qi Chunzhang & Yuan Zhenzhen, *Cucumis setosus* Cogn., *Cucumis sphaerocarpus* Gabaev, *Cucumis vilmorinii* Sprenger.

Family

Cucurbitaceae

Common/English Names

Chinese cucumber, Cucumber, Gherkin

Vernacular Names

Arabic: Khiyar, Qisa;
Bangladesh: Khira, Sasha;
Brazil: Pepino;
Burmese: Thakhwa;
Chinese: Huang Gua, Huang Kwa, Wong Gwa, Qing Gua, Tseng Kwa;
Czech: Okurka Setá;
Danish: Agurk, Almindelig Agurk;
Dutch: Agurk, Komkommer;
Eastonian: Harilik Kurk;
Fijian: Kiukaba;
Finnish: Kurkku;
French: Concombre, Concombre Blanc, Concombre Blanc Long, Concombre Commun, Concombre Maraîcher, Concombre Vert Long, Cornichon;
German: Gurke, Freiland-Gurke, Gorke, Gümmerle, Joreke, Jurche, Krazewez, Murgen, Salat-Gurke, Urmurke;
Ghana: Kokómbà (Ga);
Guinea-Bissau: Betbinho (Balanta), Pepino (Crioulo);
Hungarian: Uborka;
India: Tiyah (Assamese), Khira (Bengali), Kakri, Kankri, Kheera, Khira, Tihu (Hindu), Maghe Kaayi, Moge Kaayi, Mullu Southe, Mullusavte, Santekayi, Sautekayi, Southe Kaayi, Thaseya Kaayi, (Kannada), Kakkari, Mullanvellari, Mullen-Belleri, Vellari (Malayalam), Thabi (Manipuri), Kaakdi, Kakdi, Kheera, Khira, Tavase, Thavase, Tavsini (Marathi), Fanghma (Mizoram), Fanghma, Kakodi (Oriya), Bahuphala, Kandalu, Kantakilata, Kantakiphala, Kantalu, Karkaru, Karkatee, Koshaphala, Pitapushpa, Sakusa, Sudhavasa, Sukasa, Sushitala, Swetakarkataka, Tiktakarkatika, Trapukarkati, Trapusa, Trapusah, Trapusha, Trapusi, Tundilaphala (Sanskrit), Am, Anilvarikkotunkay, Anilvariyan, Araikkiraikkay, Arpapiramanakam, Civataki, Civatakikkoti, Civatati, Cukacakam, Cukacakkoti, Cukacam, Cukacanam, Cukkam, Iram, Kacakam, Kakkari, Kakkarikkay, Karkati, Kakrikai, Karuvacam, Kattirikuntan, Kutalakkoti, Kutalam, Kutam, Kutari, Mayaka, Miruntu, Mullan Vellari, Mullanvellari, Mul-Vellari, Mulluvellari, Mulvellarikkay, Nattuvellari, Nirvellari, Pantalkattiri, Patolikai, Pipingkay, Pippinkay, Pottiri, Pottiricceti, Tirapucam, Tirikatam, Tocakkay, Uruvar, Uruvarkoti, Uruvaram, Urvarukam, Uruvarpayan, Urvarappan, Urvarappankoti, Usnakapakari, Varukam, Vellaippukikakkoti, Vellaippukikam, Vellari, Vellari-K-Kay, Vellarikkai, Vellarikai, Vellari-Ppu, Vellarikkay, Vellarikkoti, Virali, Vittukakkoti, Vittukam (Tamil), Dosa Kaya, Dosekaaya, Dosekaya, Dozakaya, Ujakaayipa (Telugu), Khira, Kiyar, Khiyar, Tukhm-I-Khiyaria, Maghz-I-Tukhm-I-Khiyarin, Maghz-I-Khiyarin, Maghz Tukhm-I-Khiyarin, Tukhm Khiyarin Nim Koafta, Maghz Tukhm Khilyarin, Maghz Tukhm Khiyarin, Maghz-I-Tukhm-I-Khiyarin, Tukhm Khiyarin, Tukhm Khiyarin Nim Kofta (Urdu);
Indonesia: Katimun, Timun (Java), Betiak, Betik, Lepang (Kalimantan), Antemon, Boyuk, Temon (Madurese), Ketimun (Malay), Ancimun, Ansimun, Cimen, Daka, Dimu, Kadingir, Karere, Kariri, Koto Kimuni, Laiseu, Melike, Timu, (Sumatra), Bojo, Suai (Sulawesi), Bonteng (Sundanese);
Italian: Cetriolo;
Japanese: Kyu Uri, Moro Kyu;
Khmer: Trâsâk;
Korean: Oh Ee;
Laos: Mak, Teng, Tččng;

Malaysia: Rampu, Timun (Iban), Simun (Kelabit); Dobba, Timun, Timun China (Malay), Entimum (Sakai);
Mali: Faggus (Arabic);
Nepalese: Asare Kankro, Airelu Kankro, Kakro, Khira;
Nigeria: Ngùrlí (Kanuri);
Pakistan: Khira;
Persian: Kiyar, Tukhm-E-Khiyar;
Philippines: Kalabaga (Bisaya), Kasimun (Bontok), Pipino (Iloko), Madas, Maras (Sulu), Pepino, Pipino (Tagalog);
Polish: Ogórek;
Portuguese: Pepino;
Rotuman: Kukama;
Sierra Leone: Kipɔsi (Gola), Kumba (Kissi), Kɔkumba (Kono), Kɔkumba (Krio), Kɔkumba (Limba), Kipɔsi, Kɔkumba (Mende), Ma-Kɔkumba, Ma-Kɔnkɛ̀bos (Temne), Kipɔsi (Vai);
Slovak: Kumara, Kumara Navadna;
Slovenian: Uhorka Siata;
Spanish: Alpicoz, Cohombro, *Cucumis sativus*, Pepino;
Sri Lanka: Pipinya, Pipingha, Pipingkai (Sinhala);
Swahili: Tango;
Swedish: Gurka;
Thai: Taeng Kwaa, Taeng Om (Chiangmai), Taeng Raan (Northern Thailand);
Tibetan: Ga Go Na;
Vietnamese: Dua Chot, Dua Leo.

Origin/Distribution

Cucumis sativus is believed to have originated in Asia as wild cucumbers exist in India and a closely related species is found in eastern Himalayan (Sebastian et al. 2010). Evidence indicates that it has been cultivated in western Asia for more than 3,000 years. From India it spread to Greece and Italy, where the Romans were especially fond of the crop, and later into China. Cucumber is now cultivated commercially in farms, green houses and in home gardens throughout the world especially in the tropics and sub-tropics.

Agroecology

Cucumber is thermophilic, it requires a warm, mild climate. In cool, temperate countries it is grown in greenhouses; only during hot summers can it be grown outside. The optimum temperature for growth is about 30°C and the optimum night temperature 18–21°C; the minimum temperature for good plant development is 15°C. The plant is killed by frost, growth is halted at 10°C. Pickling cultivars are usually more adapted to low temperatures. Cucumber is heliophilous and thrives best in full sun. High light intensity is needed for optimum yields. Sensitivity to day-length differs according to cultivar; short day-lengths usually promote vegetative growth and female flower production. Cucumber needs adequate amount of water but it abhors water-logging. Low relative humidity results in high plant evaporation due to the large leaf area, and sufficient irrigation is then very critical. High relative humidity promotes the occurrence of downy mildew. The soil should be fertile, well-aerated, well-drained, friable, with a pH of 6.0–7.0. Soils that are sandy, silty, or clayey-loamy should be enriched by tilling in a cover crop or animal manure. Heavy soils or poorly drained soils are not suitable for the production of cucumbers. Cucumbers can be grown on trellises in greenhouses hydroponically in troughs or tubes wherein the plants are anchored in gravel, sand or soilless mixes.

Edible Plant Parts and Uses

Cucumbers are grown to be eaten fresh (called *slicers*) and those intended for pickling (called *picklers*). Young fruits of special small-fruited cultivars called ‘gherkin’ are best used pickled in vinegar. Cucumber fruits can also be salted. In Egypt cucumbers are pickled by soaking in brine to produce *torshi khiar* and in Korea *Oi sobagi kimchi* and *oiji* (pickle) are made. The fresh, immature fruit are eaten in salads. Fruits are sliced or cut into small pieces eaten as such or served with vinegar or a salad dressing on its own

or mixed with other vegetables. Thinly sliced cucumber mixed with vinegar, sugar, salt, peer and calmansi is a popular side-dish in the Philippines. Cubes of sliced peeled cumber mixed with vinegar, pounded chillies, pounded dried shrimps and sugar is a popular Nyonya side dish in Malaysia. Cucumber is also sliced or cut into pieces and used in soups, stews, curries or stir fries with beef, chicken, pork or fish or made into chutney or achar. In East Africa, cucumber is relished in a dish called 'kachumbari', a kind of African coleslaw. In Asia, the older, ripe and larger fruits are used in soups and stews. The young tender leafy shoots are consumed as greens. The kernels of the seeds are extracted and used in confectionary. The seeds yield an edible oil used in salad dressing and French cooking.

Botany

Cucumber is an annual monoecious herb with trailing or climbing, 4–5 angled stems up to 5 m long, sparsely branching with simple tendrils up to 30 cm long. The plant is covered with scabridulous hairs and the root system is extensive and superficial. Leaves are alternate, simple and borne on petiole 5–20 cm long. Lamina is triangular-ovate in outline, 7–20 cm × 7–15 cm, palmately 3–7-lobed, deeply cordate at base, acute at apex, toothed, hispidulous or scabridulous on both surfaces (Plate 1). Flowers are unisexual, regular, pentamerous; sepals narrowly triangular, 0.5–1 cm long; corolla widely campanulate, lobes up to 2 cm long, yellow. Staminate flowers occur in 3–7-flowered fascicles, with pedicel 0.5–2 cm long, stamens 3. Pistillate flowers are solitary, with pedicel short and thick up to 0.5 cm long, lengthening in fruit up to 5 cm, ovary inferior, ellipsoid, muricate, 2–5 cm long, prickly hairy or warty, stigma 3-lobed. Fruit is a pendulous, globose to cylindrical berry up to over 30 cm long, often slightly curved, sparsely tuberculated or warty when young becoming smooth and glabrous, skin usually green, but in some cultivars white, yellow or brown, flesh pale green, many-seeded (Plates 1–4). Seeds ovate-oblong, 8–10 mm × 3–5 mm, compressed, white, smooth.

Nutritive/Medicinal Properties

Food composition of raw cucumber fruit per 100 g edible portion (refuse 27% parings, ends and bruised spots) was reported as: moisture 96.73 g, energy 12 kJ, (52 kcal), protein 0.59 g, fat 0.16 g, ash 0.36 g, carbohydrate 2.16 g, total dietary fibre 0.7 g, total sugars 1.38 g, glucose 0.63 g, fructose 0.75 g, starch 0.08 g; K 136 mg, Ca 14 mg, Mg 12 mg, Fe 0.22 mg, P 21 mg, Na 2 mg, Zn 0.17 mg, Cu 0.071 mg, Mn 0.073 mg, F 1.3 μg, Se 0.1 μg; vitamin C 3.2 mg, thiamin 0.031 mg, riboflavin 0.025 mg, niacin 0.037 mg, pantothenic acid 0.240 mg, vitamin B-6 0.051 mg, total folate 14 μg, vitamin A 4 μg RAE, vitamin A 72 IU, γ-tocopherol 0.02 mg, vitamin K (phylloquinone) 72 μg, α-tocopherol 0.03 mg, choline 5.7 mg, betaine 0.1 mg, β-carotene 31 μg, α-carotene 8 μg, β-cryptoxanthin 18 μg, lutein + zeaxanthin 16 μg; total saturated fatty acids 0.013 g, 14:0 (myristic acid) 0.002 g, 16:0 (palmitic acid) 0.010 g, 18:0 (stearic acid) 0.002 g; total monounsaturated fatty acids 0.002 g, 18:1 undifferentiated (oleic acid) 0.002 g; total polyunsaturated fatty acids 0.0034 g, 18:2 undifferentiated (linoleic acid) 0.002, 18:3 undifferentiated (linolenic acid) 0.002 g; tryptophan 0.007 g, threonine 0.012 g, isoleucine 0.012 g, leucine 0.025 g, lysine 0.025 g, methionine 0.012 g, cystine 0.007 g, phenylalanine 0.031 g, tyrosine 0.002 g, valine 0.012 g, arginine 0.031 g, histidine 0.002 g,

Plate 1 Cumber fruit and leaves

Plate 2 (**a**–**d**) Different cucumber varieties

Plate 3 White cucumber variety

alanine 0.031 g, aspartic acid 0.037 g, glutamic acid 0.204 g, glycine 0.025 g, proline 0.012 g and serine 0.025 g (USDA 2010).

Dry seeds of *C. sativus* were found to contain albumins, globulins and glyoxysomal enzymes: malate synthase, isocitrate lyase, citrate synthase, malate dehydrogenase, catalase and crotonase (Köller et al. 1979).

Abou-Zaid et al. (2001) identified five acylated flavone C-glycosides from *Cucumis sativus* leaves: isovitexin 2″-O-(6‴-(E)-p-coumaroyl)glucoside; isovitexin 2″-O-(6‴-(E)-p-coumaroyl) glucoside-4′-O-glucoside; isovitexin 2″-O-(6‴-(E)-feruloyl)glucoside-4′-O-glucoside;isoscoparin 2″-O-(6‴-(E)-p-coumaroyl)glucoside; isoscoparin 2″-O-(6‴-(E)-feruloyl)glucoside-4′-O-glucoside and five known flavone-glycosides isovitexin, saponarin, saponarin 4′-O-glucoside, vicenin-2, apigenin 7-O-(6″-O-p-coumaroylglucoside), isovitexin 2″-O-(6‴-(E)-feruloyl) glucoside and isoscoparin 2″-O-(6‴-(E)-feruloyl)glucoside. Also, from the leaves of *Cucumis sativus* the following C-glycosides were isolated and identified: isovitexin 2″-O-glucoside, isovitexin, isoorientin, 4′-X-O-diglucosides of isovitexin and swertiajaponin (Krauze-Baranowska and Cisowski 2001) and from the flowers kaempferol 3-O-rhamnoside and 3-O-glycosides of kaempferol, quercetin, isoramnetin were identified. McNally et al.

Plate 4 (**a**–**b**) Different gherkin varieties

(2003) identified from cucumber leaf tissues two new major C-glycosyl flavonoids: vitexin-6-(4-hydroxy-1-ethylbenzene) (cucumerin A) and isovitexin-8-(4-hydroxy-1-ethylbenzene) (cucumerin B), and the known C-glycosyl flavonoids apigenin-8-C-β-d-glucopyranoside (vitexin), apigenin-6-C-β-d-glucopyranoside (isovitexin), luteolin-8-C-β-d-glucopyranoside (orientin), and luteolin-6-C-β-d-glucopyranoside (isoorientin), as well as 4-hydroxycinnamic acid (p-coumaric acid) and its methyl ester (p-came). Separate studies indicated that isoorientin exhibited significant hepatoprotective effect at 15 mg/kg b.w. dose (Orhan et al. 2003), and caused concentration dependent inhibition of the amplitude and the frequency of the phasic contractions of rats and guinea-pig uterus (Afifi et al. 1999) and isovitexin had antioxidant properties (Pedras et al. 2003).

Twenty-one volatile components were identified in three Greek cucumber cultivars (Sotiroudis et al. 2010). The major components from each sample were found to be: sample A, Z-6-nonenol (61.54%), E-2-nonenal (6.98%), sample B, E,Z-2,6-nonadienal (47.08%), E-2-nonenal (17.39%), Z-3-nonenol (14.79%), 3-nonenal (7.32%), sample C, pentadecanal (43.47%), 9,12,15-octadecatrienal (14.52%) and 9,17-octadecadienal (12.33%).

Cucumer plant was found to contain phenolic compounds: p-coumaric, caffeic, and ferulic acids and p-coumaric acid methyl ester (Daayf et al. 2000). Cucumber juice is often recommended as a source of silica to improve the complexion and health of the skin, plus cucumber's high water content makes it naturally hydrating – a must for glowing skin. *Cucumis sativus* is a species known to accumulate high levels of silicon (Si) in the tops including the fruits (Liang et al. 2005). Cucumbers are also used topically for various types of skin problems, including swelling under the eyes and sunburn. Two compounds in cucumbers, ascorbic acid and caffeic acid, prevent water retention, which may explain why cucumbers applied topically are often helpful for swollen eyes, burns and dermatitis.

Cucumber contains many other phytochemicals that exhibit various pharmacological activities.

Antioxidant Activity

C. sativus fruit aqueous extract showed maximum antioxidant and analgesic effect at 500 μg/ml and 500 mg/kg, respectively (Kumar et al. 2010). The free radical scavenging was compared with ascorbic acid, BHA (Butylated hydroxyl anisole) whereas, the analgesic effect was compared with Diclofenac sodium (50 mg/kg). The presence of flavonoids and tannins in the extract suggested that these compounds may be responsible for free radical scavenging and analgesic effects. Besides the identification of 21 volatile compounds in cucumber, the in-vitro antioxidant (DPPH [1,1-diphenyl-2-picrylhydrazyl] assay) and antimicrobial activity of the extracts and/or volatiles from all studied samples of 3 Greek cucum-

ber cultivars against six bacteria and three fungi were demonstrated (Sotiroudis et al. 2010). Isovitexin (apigenin-6-C-β-d-glucopyranoside) isolated from cucumber leaves was reported to have antioxidant activity (Pedras et al. 2003).

Of three Cucurbitaceous species investigated, *Cucumis sativus* was found to be the most active antioxidant, followed by *Citrullus colocynthis* while *Momordica charantia* had the least antioxidant activity (Ibrahim et al. 2010). Quantitative analysis of total phenolic compounds using Folin-Ciocalteu reagent revealed the presence of 50.87 mg GAE/g, 56.58 mg GAE/g, and 42.36 mg GAE/g, in *C. colocynthis, C. sativus* and *M. charantia*, respectively. HPLC analysis of phenolic content revealed the presence of chlorogenic acid 16.3 mg per 100 g dry sample and 27.7 mg per 100 g dry samples in *C. colocynthis* and *C. sativus* respectively and gallic acid (26.7 mg per 100 g dry sample) as the major phenolic acid in *M. charantia*.

Anticancer Activity

Cucurbitacins were originally isolated as the bitter principles of the Cucurbitaceae (Enslin and Rehm 1958). Besides cytotoxicity and anti-cancer activity, cucurbitacins also exhibited further wide ranging in-vitro or even in-vivo pharmacological effects, such as purgative, anti-inflammatory, and anti-fertility activities (Chen et al. 2005). Cucurbitacin C is found only in *C. sativus* (Enslin and Rehm 1958).

Cucurbitacin I, a cell-permeable, bitter triterpenoid compound from *Cucumis sativus* displayed anti-proliferative and antitumour properties both in-vitro and in-vivo (Blaskovich et al. 2003). It acted as a potent and highly selective inhibitor of Janus kinase/signal transducer and activator of transcription 3 (JAK/STAT3) signaling pathway. It suppressed STAT3 (signal transducer and activator of transcription 3) tyrosine phosphorylation in v-Src-transformed NIH 3 T3 cells and human lung adenocarcinoma A549 cells (IC_{50}= 500 μM), resulting in inhibition of STAT3 DNA-binding and STAT3-mediated gene transcription. It was shown to inhibit the growth of STAT3-transformed tumours in nude mice. Studies by Lui et al. (2009) showed that cucurbitacin I may be a potent chemopreventive agent for nasopharyngeal carcinoma with anti-invasion and anoikis-sensitizing activities. Brief exposure of nasopharyngeal carcinoma cells to cucurbitacin I was adequate to significantly decrease the in-vitro clonogenicity and in-vivo tumorigenicity of nasopharyngeal carcinoma cells. Cucurbitacin I also reduced the invasiveness of invasive nasopharyngeal carcinoma cell lines with elevated STAT3 activation. In addition, the data demonstrated for the first time that cucurbitacin I harboured potent anoikis-sensitization activity (i.e. sensitizing cancer cells to detachment-induced cell death) against human cancer.

Antimicrobial Activity

Three antimicrobial sphingolipids isolated from the chloroform fraction of the crude methanol extract of cucumber stems were identified as (2S,3S,4R,10E)-2-[(2′R)-2-hydroxytetracosanoylamino]-1,3,4-octadecanetriol-10-ene (1), 1-O-β-D-glucopyranosyl(2S,3S,4R,10E)-2-[(2′R)-2-hydroxy-tetracosanoylamino]-1,3,4-octadecanetriol-10-ene (2) and soya-cerebroside I (3) (Tang et al. 2010). They showed antifungal and antibacterial activity on four fungal phytopthogens (*Pythium aphanidermatum*, *Botryosphaeria dothidea*, *Fusarium oxysporum* f.sp. *cucumerinum* and *Botrytis cinerea*) and three bacterial species (*Xanthomonas vesicatoria, Pseudomonas lachrymans* and *Bacillus subtilis*). Among them, compound 1, a relatively low polarity aglycone, exhibited stronger antimicrobial activity than its corresponding glycoside 2.

Hypolipidemic Activity

The oral administration of the pectin extracted from the fruit of *Cucumis sativus* at a dose of 5 g/kg body weight/day displayed significant hypolipidemic action in normal as well as cholesterol-fed experimental animals (Sudheesh and

Vijayalakshmi 1999). Concentrations of cholesterol, triglycerides, phospholipids and free fatty acids were found to be significantly reduced in the serum and tissues of experimental animals. Activity of HMG CoA reductase was found to be enhanced. Pectin administration decreased the activities of glucose-6-phosphate dehydrogenase and malate dehydrogenase while it enhanced the activities of lipoprotein lipase and plasma LCAT (lecithin cholesterol acyltransferase). Concentrations of bile acids (hepatic and faecal) and faecal neutral sterols showed significant increases in the pectin-administered groups.

Hypoglycemic Activity

A plant extract of *C. sativus* exhibited anti-hyperglycemic effect in rabbits; it caused significant glycemic decrease (Roman-Ramos et al. 1995; Hernandez-Galicia et al. 2002). α-galactosidase activity was demonstrated in cucumber seedlings (Stano et al. 2001). α-galactosidase is a glycoside hydrolase enzyme that hydrolyses the terminal α-galactosyl moieties from glycolipids and glycoproteins. α-galactosidase also helps to prevent flatulence.

Skin-whitening and Antiwrinkle Activity

Methanol extracts of cucumber leaves and stems inhibited melanin production in melanoma B16 cells (Kai et al. 2008). These extracts did not affect the activity of mushroom tyrosinase or crude enzyme lysate from B16 cells. However, the extracts decreased tyrosinase expression at the protein level. These results suggested that the depigmenting activity of extracts from *C. sativus* leaves and stems involved the expression of tyrosinase. Of eight compounds isolated from the leaves, lutein and (+)-(1 R,2S,5 R,6S)-2,6-di-(4'-hydroxyphenyl)-3,7-dioxabicyclo [3.3.0]octane were found to suppress melanogenesis with IC_{50} = 170.7 μM and IC_{50} = 270.8 μM respectively. In addition, lutein markedly down-regulated the tyrosinase expression levels, the latter compound only weakly reduced tyrosinase expression. This suggested lutein to be an active component in the leaves of *C. sativus* and to be a potentially useful skin-whitening agent. Besides volatile compounds, it was found that cucumber contained a high concentration of L-(+) lactic acid which, as a member of α-hydroxy acids (AHAs) with established use in cosmetology, could explain the traditional use of cucumber in skin treatment (Sotiroudis et al. 2010).

The lyophilized juice of *Cucumis sativus* fruit showed DPPH-free radical and superoxide radical scavenging activity, with IC_{50} at a concentration of 14.73 and 35.29 μg/ml, respectively (Nema et al. 2011). The cucumber juice also exhibited potent anti-hyaluronidase and anti-elastase activity with IC_{50} of 20.98 μg/ml and 6.14 μg/ml, respectively. Content of ascorbic acid was found to be 3.5% w/w indicating its rich source of ascorbic acid and rationalizing the use of *C. sativus* as potential anti-wrinkle agent in cosmetic products

Antiulcerogenic Activity

The methanolic extract of *Cucumis sativum* seeds showed maximum antioxidant potential (Gill et al. 2009). The ulcerative index inhibition in rats in Pyloric Ligation (PL) and Water Immersion Stress (WIS) models was found to be 52.5% and 62.7%, respectively at higher dose. The cucumber seed exhibited maximum reduction of gastric acid volume, free and total acidity such as 41%, 48% and 29% at 300 mg/kg concentration, respectively. The results suggested that methanolic extract of *Cucumis sativum* L. seeds possessed significant antiulcer potential which could be due to its antioxidant activity.

Antiatherogenic Activity

Studies in Cameroon reported that *Cucumeropsis mannii* and *Cucumis sativus* oils were comparable to corn oil and palm oil in preventing atherosclerosis, indicating that they could be potential good edible oils for treating cardiovascular illnesses (Achu et al. 2008). There was no signifi-

cant difference in weight gain in all the groups amounting to 128.65% (palm oil), 132.75% (*Cucumeropsi mannii*), 140.8% (*C. sativus*) and 153.45% (corn oil). The weights of the livers varied from 4.22 (palm oil) to 5.17 g (corn oil), ratio of weights of liver to that of rat, ranged from 0.029 to 0.034 and percentage weight gain from 128.65% (palm oil) to 153.45% (corn oil). There was no significant difference in the values. For the atherogenic parameters measured, the triglyceride level ranged from 73 (palm oil) to 79.4 (*C. sativus* oil) with no significant difference. Total cholesterol levels ranged from 49.6 (corn oil) to 64.2 mg/dl (*C. sativus* oil) with significantly lower values in the corn oil group but similar values in the rest of the groups. HDL ranged from 18.94 (*Cucumeropsis mannii* oil) to 32.8 (palm oil) which was significantly high, LDL from 6.2 (palm oil) to 25.06 mg/dl (*C. mannii* oil) and atherogenic ratio (AR) from 0.2 (palm oil) to 1.61 (*Cucumeropsis mannii*) which was significantly high. The levels of these atherogenic parameters were far below the borderline level for oils to cause atherosclerosis.

Anthelminthic Activity

The ethanolic extracts of the seeds of *Cucumis sativus*, exhibited potent activity against tapeworms which was comparable to the effect of piperazine citrate (Elisha et al. 1987).

Trypsin Inhibitors

Cucumber seeds were found to contain trypsin inhibitors: CSTI-IIb *Cucumis sativus* (cucumber) trypsin inhibitors IIb; CSTI-IV, *Cucumis sativus* (cucumber) trypsin inhibitors IV (Wieczorek et al. 1986).

Traditional Medicinal Uses

The fruit is demulcent, depurative, diuretic, emollient, purgative and resolvent. The fresh fruit is used internally for the treatment of blemished skin, heat rash etc., whilst it is used externally as a poultice for burns, sores, scalds, wounds and also as a cosmetic for softening, moisturising and whitening the skin. Ripe raw cucumber fruits are said to cure sprue, and in Indo-China cooked immature fruits are given to children to treat dysentery. The seed is cooling, diuretic, tonic and anthelmintic. Seeds are used as taeniacide. The leaf juice isemetic, it is used to treat dyspepsia in children. Leaves along with cumin seeds are administered in throat affections. A decoction of the root is diuretic.

Other Uses

Crushed cucumbers contain the following compounds: (E, Z)-2,6-nonadien-l-al, (E)-2-nonen-1-al, (E)-2-hexen-l-al, 1-nonanal, and 1-nonanol, out of which compounds (E, Z)-2,6-nonadien-l-al and (E)-2-nonen-l-al were found to repel 98% of American cockroaches, *Periplaneta americana*, when present at concentrations of 50 ppm in a test chamber (Scriven and Meloan 1984).

Comments

Commercially, cucumbers are propagated by seeds.

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Cucurbita ficifolia

Scientific Name

***Cucurbita ficifolia* Bouché**

Synonyms

Cucurbita melanosperma Gasp., *Pepo ficifolia* (Bouché) Britton.

Family

Cucurbitaceae

Common/English Names

Angel's Hair, Asian Pumpkin, Black-Seeded Gourd, Chilacayote, Chiverre, Fig-Leaf Gourd, Fig-Leaved Gourd, Malabar Gourd, Malabar Squash, Pie Melon, Shark Fin Melon, Siam Pumpkin, Thai Marrow, Thin Vermicelli Pumpkin

Vernacular Names

Argentina: Cayote, Lacayote;
Bolivia: Lacayote;
Chile: Alcayota;
Columbia: Vitoria;
Costa Rica: Calabaza Cabellos De Angel, Chiberre, Chiverre, Chiverri;
Czech: Tykev Fíkolistá;
Danish: Figenbladgræskar;
Eastonian: Viigilehine Kõrvits;
Ecuador: Zambo;
French: Courge À Confiture, Courge À Choucroute De Cheveux D'ange, Courge De Siam, Courge À Graines Noires, Courge À Feuilles De Figuier, Melon De Malabar, Potiron Cheveux D'ange;
German: Feigenblattkürbis;
Guatemala: Chilacoyotl (Nahuatl);
Honduras: Calabaza Cabellos De Angel, Chiberre, Chiverri;
Hungarian: Istengyalulta Tök, Laskatök, Téli Tök;
Italian: Zucca Del Siam, Zucca Del Malabar;
Japanese: Kurodane Kabocha;
Kenya: Kahurura;
Mexico: Chilacoyotl (Nahuatl), Chilacayote, Tzilacayote;
Panama: Chilacayote;
Peru: Lacayote;
Polish: Dynia Figolistna;
Portugal: Abóbora-Chila, Chila, Gila;
Russian: Tykva Figolistnaja;
Slovaščina: Figovolistna Buča, Smokvolistna Buča;
Spanish: Alcayota, Cabello De Angel, Calabaza De Cabello De Angel, Cayote, Cidra, Chilacayota, Chilacayote, Chiverre, Sambo, Silacayote, Zapallo;
Tanzania: Boga La Kimasai (Swahili).

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Origin/Distribution

The centre of origin and domestication of *Cucurbita ficifolia* is still uncertain. Some views have suggested Central America or southern Mexico as places of origin, while others suggested South America, and more specifically the Andes. Biosystematic studies have been unable to support the Mexican origin suggested by the distribution of common names derived from Nahuatl throughout America. Archaeological vestiges point to a South American origin, since the oldest remains are Peruvian, but biosystematics have not been able to confirm this hypothesis either. It is cultivated in the high valleys of the Andes from Mexico to Chile and also widely cultivated on a small scale elsewhere, even in SE Asia in the cool elevations. The gourd is cultivated in the highlands of Ethiopia, Kenya and Tanzania and is occasionally grown in Angola. In Asia it is grown in India, Japan, Korea and China and in the highlands of the Philippines.

Agroecology

Being a cool climate crop, *C. ficifolia* is grown is grown at altitudes above 1,000 m, in the mountains of Latin America from 1,000–3,000 m and in the cool highlands elsewhere in the tropics. It is more cold resistant than any other *Cucurbita* species, but night frost is detrimental to the plant. It requires a short photoperiod for flowering but daylight neutral cultivars have been developed. In temperate areas it is grown in the summer, starting flowering with decreasing day length. Fig leaf gourd thrives on fertile, well-drained soils with a pH range of 6.5–7.5.

Edible Plant Parts and Uses

The fruit, seeds, flowers, leaves and young tender shoots are eaten. The fruit has been reported to be more nutritious than other cucurbits. The tender immature fruits are used like cucumber and summer squash and cooked as a vegetable or used in soups. In Asia the pulp strands are used to make soup, quite similar to shark fin soup, hence the name "shark fin melon". The flesh of mature fruits is impregnated with sugar for preparation of a candy confection, mature fruits are fermented for an alcoholic beverage. In Spain the mature fruit is processed into jam while in Chile, marmalade is process from the fruit. In Costa Rica, it is customary to make *empanadas* stuffed with sugared "*chiverre*" filling at Easter time. In Spain, Portugal and Hungary the sweet, mature fruit are used to make dessert sweet speciality (angels' hair).

The seed is delicious when roasted and eaten as snacks like peanuts and can also be eaten raw. The roasted, dehusked seeds are also used as a garnish for potatoes and meats. The seeds are used along with honey to make *palanquetas*, a dessert in Chiapas, Mexico. An edible oil is obtained from the seed.

The flowers, leaves and young shoots are used as greens. The male flowers and buds are used in salads, stews and soup. In East Africa mainly the leaves are eaten. In Kenya and in Tanzania, the leaves are prepared in a mixture with maize, pulses, green bananas or Irish potato. In some parts in Mexico, the runner tips (shoots) and the flowers are eaten cooked as vegetables.

Botany

C. ficifolia is a monoecious, short-lived, perennial climbing or trailing vine with a spiny, 5-angled or rounded stem that roots at the nodes and with long, branched tendrils. Leaves are simple, alternate circular-ovate to reniform in outline, sinuate to lobe with serrate or entire margin, 18–25 cm across. Flowers are solitary, axillary, yellow to pale orange, unisexual, regular, pentamerous, up to 7.5 cm across, calyx and corolla campanulate with short tube; male flowers with short, thick and columnar androecium of 3 stamens, filaments with >1 mm long trichomes; female flowers on short, ridged pedicels with inferior, multilocular ovary, a thickened style with three-lobate stigmas. The fruit is a pepo, globose to ovoid-elliptical, oblong, up to 35

Plate 1 Sub-globose fruit with white stripes towards the apex and white and green irregularly patterned blotches, and white- fleshed

Plate 2 Oblong fruits with white and green irregularly patterned blotches.

across, hard, smooth, white to green with white stripes towards the apex and white and green irregularly patterned blotches, or minutely spotted white and green, hard and smooth rind with a white, sweet and fibrous flesh (Plates 1 and 2). Seeds are numerous, ovate-elliptical, flattened, 15–25×7–12 mm, and a dark brown to black or creamy white colour.

Nutritive/Medicinal Properties

Exact data on the composition of *Cucurbita ficifolia* had not been published, but would probably be similar to that of other cucurbits. The nutrient composition of the mature fruit was reported in the following range (per 100 g edible portion): moisture 85–91 g, protein 0.8–2 g, fat 0.1–0.5 g, carbohydrates 3.3–11 g, vitamin A 340–7,800 IU, thiamine 0.07–0.14 mg, riboflavin 0.01–0.05 mg, niacin 0.5–1.2 mg, vitamin C 6–21 mg, Ca 14–48 mg, Fe 7 mg, Mg 16–34 mg, P 21–38 mg (Roxas 1994). The composition of immature fruits was found comparable to that of *Cucurbita pepo* (summer squash).

The composition of pumpkin (*Cucurbita* spp.) leaves per 100 g edible portion (Grubben 2004) was reported as: water 89 g, energy 105 kJ (25 kcal), protein 4.0 g, fat 0.2 g, carbohydrate 2 g, fibre 2.4 g, Ca 475 mg, P 135 mg, Fe 0.8 mg, β-carotene 1.0 mg, thiamin 0.08 mg, riboflavin 0.06 mg, niacin 0.3 mg and ascorbic acid 80 mg.

The most important nutritional value is found in the seeds which afford considerable protein and oil. The lipid fraction of C2 Chilean variety of *Cucurbita ficifolia* showed a saturated fatty acid/monounsaturated fatty acid/polyunsaturated fatty acid relation of (1:1,8:3,5), similar to that of the edible oils marketed in the country (Erazo et al. 1992). The C1 variety showed a relation of (1:1.2:1) close to recommended ratio (1:1:1). In the unsaponifiable fraction of the seeds of both varieties, the hydrocarbons were the main component, with three sterols being present in low levels. The residual meal of the C2 variety showed a higher content of total proteins, similar to that of soybean.

Cucurbita ficifolia seed oil extracted with supercritical carbon dioxide (SC-CO2) was found to contain mainly ω 6-linoleic acid (about 60%), followed by palmitic acid (about 15%) and oleic acid (about 14%) (Bernardo-Gil and Lopes 2004). In terms of free fatty acids contents no significant differences between the oils extracted by n-hexane and SC-CO2 methods were found. The oil extracted by SC-CO2 was clearer than that extracted by n-hexane, showing some refining. The acidity index was 5.5 for the n-hexane extracted oil.

Antidiabetic/Hypoglycaemic Activity

Numerous papers had been published on the antidiabetic/hypoglycaemic activity of fruit extracts

of *Cucurbita ficifolia* in animal models (mice, rabbits) as well as in clinical tests with diabetic patients.

Administration of *C. ficifolia* extract produced a significant decrease in blood glucose levels, from 12.07 (217.2 mg/daily) to 9.42 mM (169.6 mg/daily) 3 h after and to 8.37 mM (150.8 mg/daily) 5 h after the extract administration in Type 2 diabetic patients (Acosta-Patino et al. 2001). The hypoglycemic action *of Cucurbita ficifolia* concurred with its effects previously observed in laboratory animals.

Freeze-dried juice of *Cucurbita ficifolia* administered by intraperitoneal route showed an acute hypoglycemic effect in alloxan-diabetic mice (Alarcon-Aguilar et al. 2002). In addition, daily oral administration of this preparation showed a highly significant reduction of glycemia after 14 days of treatment. Freeze-dried juice caused acute toxicity when administered intraperitoneally, and also when it was administered daily by the oral route.

In separate studies, oral administration of *Cucurbita ficifolia* fruit extract (300 and 600 mg/kg body weight, day) for 30 days resulted in a significant reduction in blood glucose, glycosylated haemoglobin, and an elevation in plasma insulin and total haemoglobin in streptozotocin-induced diabetic rats (Xia and Wang 2006a). The effect was compared with 150 mg/kg body weight tolbutamide.

Xia and Wang (2006b) found that *C. ficifolia* contained fairly high levels of D-CI, a component of an insulin mediator, thus, *C. ficifolia* may be a natural source of D-CI for reducing blood glucose concentrations in diabetics. Oral administration of *C. ficifolia* fruit extract containing 10 or 20 mg D-CI/kg body weight for 30 days resulted in significantly decreased levels of blood glucose, and elevated levels of hepatic glycogen, total haemoglobin and plasma insulin. There was also a significant improvement in blood glucose tolerance in the diabetic rats treated with *C. ficifolia* fruit extract. The effects were compared with 20 mg/kg body weight chemically synthesized D-CI. Findings from this study demonstrated that *C. ficifolia* fruit extract was an effective source of D-CI for its hypoglycaemic effects in rats, and therefore may be useful in the treatment of diabetes.

Xia and Wang (2007) in further studies showed that feeding with *C. ficifolia* fruit extract caused reduction in STZ-induced hyperglycaemia while increase plasma insulin level in STZ diabetic rats, and appreciably reduced STZ-induced lipid peroxidation in rat pancreas. Further there was a significant increase in the number of β cells in *C. ficifolia*-treated animals when compared with untreated diabetics, however, their number was still less than that obtained for normal rats, indicating the mode of protection of *C. ficifolia* fruit extract on pancreatic β cells. The present study thus confirmed a hypoglycaemic effect of *C. ficifolia* fruit extract and suggested that oral feeding of *C. ficifolia* fruit extract may have a role in the renewal or recovery of partially destroyed β cells in STZ diabetic rats. Their results provided some documentation to define the role and mode of action of *C. ficifolia* fruit extract in its potential and promising use in treating diabetes.

In recent studies, Xia and Wang (2009) reported that long term feeding treatment of streptozotocin (STZ)-induced Type 1 diabetic rats for 30 days showed a significant reduction in blood glucose, triglyceride, low density lipoprotein and a significant elevation in high density lipoprotein level. A significant effect on oral glucose tolerance was also observed. Chronic administration showed an improvement in the oral glucose tolerance curve. These results suggested that *C. ficifolia* fruit extract exhibited hypoglycemic as well as hypolipidemic effects in the STZ-induced diabetic rats.

Proteolytic Enzyme Activity

A protease, about 60 kDa was purified from the pulp of *Cucurbita ficifolia* (Curotto et al. 1989) and from the seeds, a 77 kDa serine protease was purified (Dryjański et al. 1990a, b). The serine protease hydrolysed many different peptide bonds in B-chain of insulin and was able to cleave four bonds in endogenous serine proteinase inhibitor (CMTI). The proteinase was more selective towards the native squash seed trypsin inhibitor

(CMTI I). The inhibitor even devoid of the N-terminal arginine residue was still active against trypsin. Research in Chile (Illanes et al. 1985) showed that some proteolytic enzymes (alkaline proteases) from the pulp of *C. ficifolia* fruit could be used to treat waste water from the industrial processing of foods derived from fish. This discovery is of great interest because of the reduction in costs that these industries could achieve by using enzymes which would replace those imported at present. These proteases are also useful in the food industry for the production of corn and legume protein hydrolyzates.

Traditional Medicinal Uses

Like several other cucurbits, fig-leaf gourd consumption by diabetic patients has a hypoglycaemic effect, making it an appropriate medicine against diabetes mellitus. The seed complete with the husk is ground into a flour that is made into an emulsion with water and taken as a vermifuge. A purgative should be taken afterwards to expel tapeworms or other parasites.

Other Uses

Fig-leaf gourd is used in temperate countries as a rootstock for greenhouse cucumber (western Europe, Korea, China, Japan) and for melon and watermelon (Korea, China, Japan). It gives the grafted crop increased cold tolerance and high resistance to soil-borne pathogens and increases the resistance to *Pythium* and powdery mildew. In Europe, fig-leaf gourd is also cultivated as an ornamental because of its decorative white-spotted dark green fruits. The vine and fruit are used for fodder.

Comments

The plant is propagated from seeds.

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Cucurbita maxima

Scientific Name

***Cucurbita maxima* Duchesne ex Lam.**

Synonyms

Cucurbita maxima Duchesne subsp. *maxima*, *Cucurbita potiro* Pers., *Pepo macrocarpus* Rich. ex Spach, *Pepo maximus* (Duch. ex Lam.) Peterm., *Pepo potiro* (Pers.) Sag.

Family

Cucurbitaceae

Common/English Names

Autumn Squash, Banana Squash, Buttercup Squash, Giant Pumpkin, Hubbard Squash, Japanese Squash, Sweet-Fleshed Pumpkin, Sweet-Fleshed Squash, Turban Squash, Winter Gourd, Winter Pumpkin, Winter Squash

Vernacular Names

Afrikaans: Ayote, Lacayote, Calabaza, Moscada, Moschuskurbis, Abocra-Rasteira Pampoen;
Arabic: Qara' Sudani;
Argentina: Zapallo;
Bangladesh: Bilati;
Bulgarian: Kestenka;
Chinese: Nam Kwa, Fan Kwa, Bei Gua, Fan Nan Gua, Sun Gua, Yang Gua, Yin Du Nan Gua, Yu Gua;
Czech: Dýně Obrovská, Tykev Velkoplodá;
Danish: Centnergrćskar;
Dutch: Pompoen, Ronde Pompoen, Reuzenpompoen, Reuzenkalebas;
Eastonian: Suureviljaline Kőrvits;
Egypt: Nqara Sudani, Qar'islambuli, Qar'malti, Qar'maghrabi, Karr Estmboly (Arabic);
Finnish: Jättiläiskurpitsa;
French: Potiron, Patisson, Citrouille, Potiron, Giraumon, Courge-Giraumon, Courge D'hiver, Grosse Courge, Courge-Potiron;
Germany: Risen-Kürbis, Risenkürbis, Riesenkuerbis Turbankürbis;
Ghana: Efere, Efre (Akan-Asante), Kaere, Kilbindo (Dagbani), Efir (Fante), Sakribonte (Ga), Kàwúrènchú (Guang-Gonja), Dedschaelbɔne (Konkomba), Efrɛ (Tiwi);
Guinea: Budi (Fula-Pulaar), Guié (Manding-Maninka);
Hebrew: Delaat Gedola;
Hungarian: Óriástök, Sonkatök, Sütotök;
India: Kadduu, Sitaphal, Vilayati Kaddu (Hindu);
Indonesia: Waluh, Labu, Labu Merah;
Italian: Cocozza, Giramonte, Zucca, Zucca Gigante;
Japanese: Kabocha, Kuri Kabocha, Seiyou Kabocha;
Khmer: Lo-Peu;
Laos: Fak Kham, Fak Thoong;

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Liberia: Bili Gah (Mano);
Malaysia: Labu, Labu Manis, Labu Merah, Labu Parang;
Mali: Akesaïm, Takasaïm (Tamachek);
Mexico: Calabaza Tamalayota;
Nepalese: Kadu, Kashi Phal, Pharsi, Sitaa Phal;
Nigeria: Arä, Garä (Arabic); Murr (Arabic-Shuwa); Bátìrí, Goojii, Ebé (Berom), Yáaŋgú (Dera), Éyèn (Edo), Mfrì Ǹdìsè, Mfrì, Ndìsè, N˙Nàŋ˚Í (Efik), Feraare, Fol'yere (Fula-Fulfulde), Knuba, Knugba (Gwari), Knugba, Goojíí, Kàbaíwaà, Kàbeéwaà, Kúbeèwaá, Kankana, Lakit (Huasa), Balayal, Goòjií, Kabus, Kabushi (Huasa West), Ǹdìsi (Ibibio), Ányụ̄, Ukora, ụ̀gbòguụ̀lụ̀, ụ̀gbòghọ̀rò (Igbo), Kàfétò (Kanuri), Èbě (Nupe), Àgbàdù (Tiv), Ètò-Úrhòbò, Koko-Eyen (Urhobo), Apala, Élégédé (Yoruba);
Norwegian: Kjempegraskar;
Pakistan: Halva Kaddu, Mitha Kaddu (Urdu);
Papiamento: Pampuna;
Papua New Guinea: Pamkin;
Paraguay: Dutué;
Philippines: Kumbasa (Bontok), Kalabasa (Cebu), Karabasa (Iloko), Kabasi (Sulu) Kalabasa, Kalabasang-Bilog, Kalabasang-Pula (Tagalog);
Polish: Dynia Duza, Dynia Olbrzymia;
Portuguese: Abóbora-Menina, Abóbora-Moranga, Girimú, Moganga Girimú, Moganga;
Russian: Ispolinskaja Tykva, Tykva Gigantskaja, Tykva Krupnoplodnaja;
Senegal: Budi (Fula-Pulaar), Ié (Manding-Bambara), Guié (Manika), A Dyeng (Serter), Bag, Banga, Dombos, Nade, Yomba (Wolof);
Serbian: Bondeva Pecenka;
Sierra Leone: Njalin (Kissi); Towa (Mende), Akali (Temne);
Slovaščina: Buča Velikank, Orjaška Buča;
Slovencina: Tekvica Obrovská;
Spanish: Ayotera, Cala Bacera, Calabaza, Calabaza Amarilla, Calabaza De Castilla, Calabaza De Cidra, Calabaza Grande, Calabaza Gigante, Calabaza Tonanera, Calabaza Redonda, Quinoa, Quinua, Zapallo;
Swedish: Jättepumpa, Pumpa, Vintersquash;
Thai: Fak Thong, Namtao Farang;
The Gambia: Laket (Wolof);
Togo: Kaere, Katekatego (Bassari), Kodshŏdo (Tem);
Uganda: Kicwika, konokono (Acholi), Okondo (Alur & Jonam), Buziriziri, Kimisebebe (Bugisu), Kedi (Kakwa), Ensujju, Essunsa (Luganda), Enjubi, Ejubi (Madi), Ebishusha, Kasogo, Obututu (Rukiga), Ebishusha, Obututu (Runyankore), Emyongo (Runyoro), Emyongo (Rutooro), Ensujju, Imunyuru (Teso);
Vietnamese: Bi Do, Bi Ngo;
West Cameroons: Dibok (Bafok), Abok (Koosi), Diboke (Kpe), Dibuke (Kundu), Dibok (Long), Dibuke (Lundu), Dibuke (Mbonge), Diboke (Tanga) Diboke (Wovea).

Origin/Distribution

C. maxima is a native of temperate South America – Chile, Argentina, Bolivia and Uruguay. *Cucurbita maxima* is the only species which originated in South America.

Agroecology

C. maxima and *C. pepo* have long been cultivated in temperate regions and is cultivated in the highlands above 1,000 m in the tropics. Optimum temperature is a monthly mean temperature of 18–27°C. Like most cucurbits, *C. maxima* thrives on a wide variety of well drained soils, high in organic matter with a pH from 5.5 to 6.8. The crop is tolerant of low temperature but will not tolerate frost and water-logging. Both photoperiod and temperature determine the ratio of male to female flowers – long days and high temperatures favouring male sex expression.

Edible Plant Parts and Uses

Flowers, fruit, and long tendril shoots and leaves are relished as vegetable. The tender young shoots and leaves are cooked as vegetables and used as a potherb or added to soups and stews. Squash and pumpkin blossoms (with stamens removed) are edible raw or cooked are commonly sold in local markets in southeast Asia (Plate 6). They are often dipped in batter and fried. The fruit is delicious

Plate 1 *Cucurbita maxima* Kabocha variety with rounded fruit stalk not enlarged at the apex

when baked, or peeled, cut into pieces and cooked until soft or used in stews and pies and also jams. The fruit is largely used by Indians in their curries. The mature fruit is it is made into a popular porridge in Zimbabwe. The flesh can be dried, ground into a powder and used with cereals in making bread and cakes. Seeds (Plate 7) are eaten raw, dried or roasted and serves as snack food. In some African countries like Cameroon and Nigeria the seeds are commonly roasted and salted, or ground into a thick paste that is mixed with vegetables in cooking. The seed can also be ground into a powder and used with cereals in making breads. The seed is rich in oil, which has a very pleasant nutty flavour and used for cooking.

Plate 2 *Cucurbita maxima* an orange-coloured variety with rounded fruit stalk not enlarged at the apex

Plate 3 *Cucurbita maxima* pale, pale bluish, furrowed variety with rounded fruit stalk not enlarged at the apex

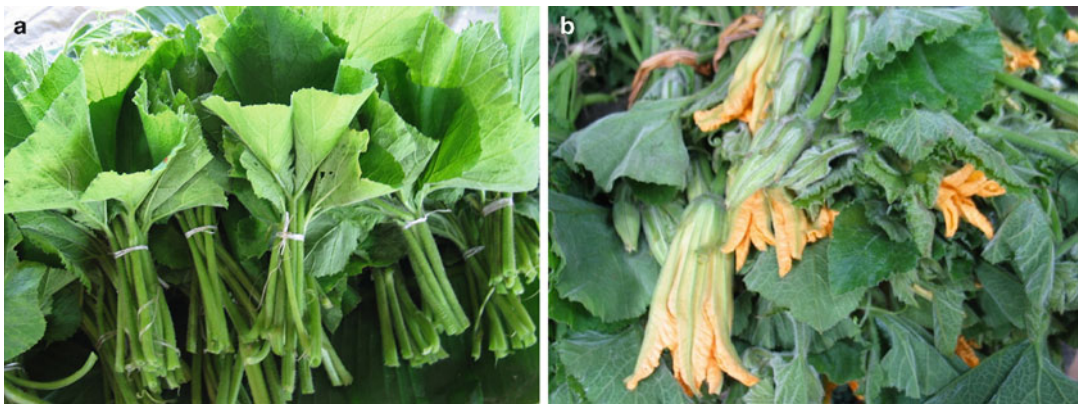

Plate 4 (**a)** Leaves and (**b)** flowers of *C. maxima* being sold as vegetables

Plate 5 Large, orangey-yellow flower and unlobed leaves of *C. maxima*

Plate 6 *C. maxima* pumpkin flowers on sale in a local market

Plate 7 Obovoid, rough-surfaced, white seeds of *C. maxima*

Botany

Monoecious, annual, trailing herb or climbing by lateral, 2–5-branched tendrils, strongly branched; stems rounded and soft, long running, softly pubescent, often rooting at nodes. It has an extensive but shallow root system with a branched tap root. Leaves are alternate, simple, exstipulate; petiole 5–20 cm long; lamina usually reniform, not lobed, deeply cordate at base, margins finely toothed, softly hairy, occasionally with white blotches, 3-veined from the base (Plates 4). Flowers are solitary, axillary, unisexual, regular, pentamerous, large, 10–20 cm across, lemon yellow to orange-yellow (Plates 4b, 5 and 6); sepals free, subulate to linear; corolla campanulate, with widely spreading lobes that curved outwards. Staminate flowers long-pedicellate with three free stamens. Pistillate flowers are shortly pedicellate, with an inferior, ellipsoid, 1-celled ovary with a thick style and 3–5 bilobed stigmas. Fruit a large, globose to ovoid or obovoid berry, weighing up to 50 kg, with a moderately hard rind with wide range of colours and yellow-orange flesh with many seeds (Plates 1–3). The fruit stalk is soft, cylindrical, corky, not ridged and not flared at the point of attachment. Seeds are obovoid, flattened, 1.5–2.5 cm × 1–1.5 cm, white to pale brown, with smooth or somewhat rough surface (Plate 7).

Nutritive/Medicinal Properties

Refer to notes under *Cucurbita moschata* for nutrient composition of *Cucurbita* spp. fruits, seeds, flowers and leaves analysed by the USDA (2010).

The proximate composition of pumpkin fruit per 100 g edible portion (minus the rind and seeds 37%) was reported as: water 95.0 g, energy 55 kJ (13 kcal), protein 0.7 g, fat 0.2 g, carbohydrate 2.2 g, fibre 1.0 g, Ca 29 mg, P 19 mg, Fe 0.4 mg, β-carotene 450 μg, thiamin 0.16 mg, riboflavin trace, niacin 0.1 mg, folate 10 μg, ascorbic acid 14 mg (Holland et al. 1991). The composition of pumpkin leaves per 100 g was reported as: water

89.2 g, energy 113 kJ (27 kcal), protein 4.0 g, fat 0.2 g, carbohydrate 4.4 g, fibre 2.4 g, Ca 477 mg, P 136 mg, Fe 0.8 mg, β-carotene 3,600 μg, thiamin 0.06 mg, riboflavin 0.32 mg, ascorbic acid 80 mg. The composition of pumpkin seeds (without shell) per 100 g was reported as: water 5.5 g, energy 2,331 kJ (555 kcal), protein 23.4 g, fat 46.2 g, carbohydrate 21.5 g, fibre 2.2 g, Ca 57 mg, P 900 mg, Fe 2.8 mg, thiamin 0.15 mg, niacin 1.4 mg (Leung et al. 1968). Pumpkin seeds also contained considerable amounts of vitamin E.

In *C. maxima* variety "Jerimum Caboclo", 11 carotenoids were found with lutein, and β-carotene as the major pigments accounting for about 60% and 27%, respectively, of an average total carotenoid content of 78.4 μg/g (Arima and Rodríguez-Amaya 1990). The principal carotenoids in *C. maxima* were confirmed to be lutein and β-carotenene (Azevedo-Meleiro and Rodriguez-Amaya 2007).

The concentration and distribution of carotenoids in *C. maxima* fruit were found to vary with cultivars with red and orange coloured varieties being valuable sources of carotenoids. The following carotwnoids were found in the fruit: α-carotene, β-carotene, violaxanthin, neoxanthin, all-trans-lutein, zeaxanthin, lutheoxanthin and the isomers 9-cis-β-carotene and 13-cis-β-carotene (Kreck et al. 2006). The total carotenoid content (expressed as dry weight) of the pumpkin peel varied with variety, with 12 mg/kg for "Butternut" up to 1,751 mg/kg for "Rouge", whereas total carotenoid contents in the pulp differed from 17 mg/kg for "Baby Bear" to 683 mg/kg for "Rouge". The variety, "Hokkaido" showed high total carotenoid contents in pulp (218 mg/kg) and peel (1,048 mg/kg), whereas for, "Butternut" low concentrations in pulp (44 mg/kg) and peel (12 mg/kg) were detected. The following carotenoid profile was described for pumpkin *C. maxima* var. Marita by Muntein and Rotar (2010): the major provitamin A in the fruits' mesocarp was identified as β, β – carotene (15.36 μg/g dry weight); minor provitamins A were the hydrocarbons β, ε-carotene and 15, 15'- Z – β, β- carotene, and the xanthophylls 5,6–epoxy-β-carotene, α-cryptoxanthin and B-cryptoxanthin, all with concentrations less than 1.00 μg/g dry weight. The fruit epicarp showed a similar provitamin A pattern, with lower amounts of β, β – carotene (9.47 μg/g dry weight), while from the minor provitamins A, 5,6–epoxy- β-carotene was absent.

Pumpkin fruit is very rich vitamin A and carotenes, while the young leaves are rich in β-carotene, Ca and P. Pumpkin seeds represent also a useful source of many nutrients essential to humans. Pumpkin seeds were found to contain 58.8% protein and 29.8% fat (Glew et al. 2006). However, the lysine score of the protein was only 65% relative to the FAO/WHO protein standard. Pumpkin seed contained useful amounts of linoleic (92 μg/g dry weight) and the following elements (on a μg per g dry weight basis): potassium (5,790), magnesium (5,690), manganese (49.3), zinc (113), selenium (1.29), copper (15.4), chromium (2.84), and molybdenum (0.81), but low amounts of calcium and iron.

All cucurbits including *C. maxima* were found to contain oxygenated triterpene glycosides called cucurbitacins (Miró 1995); the main cucurbitacin in *C. maxima* was found to be cucurbitacin B (Rehm and Wessels 1957). These compounds were present in all plant parts in different concentrations. If concentrated in the edible parts, they can cause a bitter taste.

Among the following: cold-pressed onion, parsley, cardamom, mullein, roasted pumpkin, and milk thistle seed oils, roasted pumpkin seed oil was found to contain the highest content of total carotenoids 71 μmol/kg, zeaxanthin 28.5 mg/kg, β-carotene, 6.0 mg/kg, cryptoxanthin 4.9 mg/kg, and lutein 0.3 mg/kg oil (Parry et al. 2006). Ojiako and Igwe (2007) reported the seed flour of *C. maxima* to contain alkaloids, steroids, pentose, and reducing sugars. The seeds were found to have 24.3% carbohydrates, 16.8% protein and 51.49% fats, and the defatted seed flour contain 39 pm potassium, 11.50 ppm sodium, 15 ppm calcium, 0.048 ppm zinc and 0.032 ppm iron.

Thirty-one major components were indentified in the floral volatiles from two cultivars of *Cucurbita maxima* (squash) (Anderson 1987). The components comprised of low molecular weight aliphatic alcohols and aldehydes, monoterpenoids,

sesquiterpenoids, indole, and aromatic alcohols, aldehydes, and methyl ethers.

Various aerial parts of *C. maxima* plant have been reported to possess different pharmacological activities.

Antioxidant Activity

Total polyphenolic 12 mg/gm (gallic acid equivalent), flavonoid 3.8 mg/gm (rutin equivalent) and flavonol 0.8 mg/gm (rutin equivalent) were determined in the methanolic extract of *C. maxima* pericarp (Attarde et al. 2010). IC_{50} value for DPPH method of the petroleum ether, chloroform and methanol extracts were found to be 393 μg/ml, 355 μg/ml and 155 μg/ml respectively. The IC_{50} value for nitric oxide scavenging activity were 280 μg/ml, 303 μg/ml and 211 μg/ml and for hydrogen peroxide scavenging activity 545 μg/ml, 273 μg/ml and 619 μg/ml respectively. The methanol fruit extract showed higher antioxidant activity as compared to the petroleum ether or chloroform fruit extract.

Antigenotoxic Activity

The antigenotoxic constituent from the chloroform extract of squash (*C. maxima*) flower was identified as spinasterol or 24α-ethyl-5α-cholesta-7, trans-22-dien-3β-ol (Villasenor et al. 1996). It decreased the mutagenicity of tetracycline by 64.7% at a concentration of 100 mg/kg mouse.

Antimicrobial Activity

Villasenor et al. (1995) found that the undiluted ethanol extracts of squash (*Cucurbita maxima)* fruits exhibited complete inhibition against *Bacillus subtilis* and only partial inhibition against *Escherichia coli*. The extracts of squash flowers and leaves showed either minimal or an absence of antimicrobial activity against both organisms.

Other Pharmacological Activities

In the pharmacological screening of the crude extracts of squash fruits and leaves, there was a reduction in motor activity, ataxia, temporary palpebral ptosis, hyperaemia, micturition and abdominal gripping in the test mice (Villasenor et al. 1995). The ethyl acetate extract of squash flowers elicited a reduction in respiratory rate, analgesia, paralysis of the hind-legs, persistent skin folds, hyperaemia, diarrhoea, and exophthalamos.

Anthelmintic Activity

Recent research confirmed the anthelmintic attribute of the *C. maxima* seed extract against canine tape worms (Díaz Obregón et al. 2004). The MIC of 23 g of pumpkin seed in 100 ml. of distilled water could produce an anthelmintic effect. This concentration was equivalent to about 73 pumpkin seeds. The aqueous seed extract at a concentration of >23 g caused alterations in helminthic motility, exhibited protheolithic effect, and caused destruction of gravid proglottids and the tegument of mature proglottids.

Antiplasmodial Activity

The crude ethanolic extract of dry *C. maxima* seeds exhibited strong anti-malarial activity (Amorim et al. 1991). Following oral administration of the extract (250 and 500 mg/kg), parasitemia levels in *Plasmodium berghei*-infected mice was reduced by 50%. Treatment of normal animals with 500 mg/kg of the extract 3 days before intravenous injection of *P. berghei* also elicited a significant 30% decrease in parasitemic levels. No effect was noted when the animals were treated with the extract only on the day of inoculation.

Larvicidal Activity

Leaf extract of *C. maxima* exhibited larvicidal and ovicidal activity against *Culex quinquefas-*

ciatus mosquito (Mullai and Jebanesan 2007). The LC_{50} values for the following extracts, benzene, ethyl acetate, petroleum ether and methanol were 123.02, 75.91, 117.73 and 171.64 ppm respectively. The mean percent hatchability of the egg rafts were observed after 48 hours treatment. 100% mortality was observed at 600 ppm of *C. maxima*. *C. maxima* extract exerted complete protection time of 78–215 minutes.

Trypsin Inhibitor Activity

Seed and vascular exudates of *Cucurbita maxima* were found to contain a group of highly conserved serine proteinase inhibitors collectively called Pumpkin Fruit Trypsin Inhibitors (PFTIs) that prevented proteolytic activity of trypsin or chymotrypsin (Dannenhoffer et al. 2001). Earlier studies reported the isolated of a strong inhibitor of human Hageman factor fragment (HFf, beta-factor XIIa) and bovine trypsin was isolated from pumpkin (*Cucurbita maxima*) seed extracts (Hojima et al. 1982). Pumpkin seed Hageman factor inhibitor (PHFI)was unusual in its lack of inhibition of several other serine proteinases tested – human plasma, human urinary, and porcine pancreatic kallikreins, human α-thrombin, and bovine α-chymotrypsin. Human plasmin and bovine factor Xa were only mildly inhibited. PHFI also inhibited the HFf-dependent activation of plasma prekallikrein and clotting of plasma. PHFI presented a pI of 8.3, and had 29 amino acid residues, amino-terminal arginine, carboxyl-terminal glycine, 3 cystine residues, undetectable sulfhydryl groups and carbohydrate, and arginine at the reactive site. PHFI appeared to be the smallest protein inhibitor of trypsin known.

Squash (*Cucurbita maxima*) seeds also yielded trypsin inhibitor III (Nowak et al. 1981) The inhibitor was found to consist of 28 amino acids cross-linked by two disulfide bridges. Arginine in position 5 was shown to be present at the reactive site of the inhibitor. Wilusz et al. (1983) reported the isolation of two trypsin isoinhibitors, ITD I and ITD III, from squash seeds (*Cucurbita maxima*). Both isoinhibitors were found to contain 29 amino-acid residues, including 6 half cystine residues. They differed only by one amino acid. Lysine in position 9 of ITD III was substituted by glutamic acid in ITD I. Arginine in position 5 was present at the reactive site of both isoinhibitors.

Wieczorek et al. (1986) isolated the following trypsin inhibitors from *C. maxima* seeds: CMTI-I, *Cucurbita maxima* (squash) trypsin inhibitors I, CMTI-III, *Cucurbita maxima* (squash) trypsin inhibitors III, CMTI-IV, and *Cucurbita maxima* (squash) trypsin inhibitors IV. Three analogues of *Cucurbita maxima* trypsin inhibitor III (CMTI-III) containing the Val residue in the reactive site (position 5) displayed an elastase inhibitory activity (Rozycki et al. 1994).

A protein inhibitor (CMTI-V; Mr 7106) of trypsin and activated Hageman factor (Factor XIIa), a serine protease involved in blood coagulation, was isolated for the first time from pumpkin (*Cucurbita maxima*) seeds by Krishnamoorthi et al. (1990). The protein was found to have 68 amino acid residues and one disulfide bridge and showed a high degree of sequence homology to the Potato I inhibitor family. *Cucurbita maxima* trypsin inhibitor-V (CMTI-) was also found to be a specific inhibitor of human blood coagulation factor β-factor XIIa (Wen et al. 1995). The K44R showed at least a five-fold increase in inhibitory activity toward human β-factor XIIa, while there was no change toward bovine trypsin. The specificity of CMTI-V could be changed from trypsin to chymotrypsin inhibition by mutation of the P1 residue to either leucine or methionine (K44L or K44M). In comparison to the intact form, the hydrolysed CMTI-V* manifested distinct reduced inhibitory properties and binding affinities toward trypsin and human blood coagulation factor XIIa (Cai et al. 1995).

Toxicity Studies

Toxicity evaluation studies showed that the average lethal dose (LD_{50}) of the hydroalcohol extract from seeds of *C. maxima* was higher than 5,000 mg/kg and subacute treatment showed increases in body weight (Cruz et al. 2006). The

levels of serum alkaline phosphatase, alanine aminotransferase (ALT), and aspartate aminotransferase (AST) and the hematological parameters did not show any alterations. The results suggested that the hydroalcoholic extract from *C. maxima* seeds, at a concentration of 5,000 mg/kg, exhibited a considerable safety margin, being devoid of acute toxicity. This was also confirmed in another study. Administration of the extract prepared from dried seeds of *Cucurbita maxima* to rats and pigs following a single dose or 4 weeks of daily oral administration produced no alterations in serum glucose, urea, creatinine, total protein, uric acid, glutamic oxaloacetate transaminase, glutamic pyruvate transaminase, lactate dehydrogenase or blood counts. Urine analysis (urea, uric acid, creatinine, total protein, Na and K), as well as histopathological investigation, showed no abnormalities (Queiroz-Neto et al. 1994). Collectively, these results indicated that the seeds of *C. maxima* as used in Brazilian folk medicine were not toxic for rats and swine.

Traditional Medicinal Uses

Pumpkin has been featured in various systems of traditional medicine for several ailments (antidiabetic, antihypertensive, antitumour, immunomodulation, antibacterial, antihypercholesterolemia, intestinal antiparasitia, anti-inflammation and antalgic) (Bown 1995; Burkill 1985; Chiej 1984; Chopra et al. 1986; Rahman et al. 2008). The fruit is diuretic, tonic, and allays thirst; fruit pulp is often used to treat inflammations and boils. The dried pulp is a remedy for haemoptysis and hemorrhages from the pulmonary organs, being given in the form of a confection. The fruit pulp is used as a soothing poultice on burns, inflammations and boils. In India, the fruit pulp is used as poultice for carbuncles, boils and ulcers. For venomous insect bites, the fruit stalk in contact with the ripe gourd is cut, dried, and made into a paste and applied to venomous insect bites, especially centipedes. The paste is also used for ear-ache. The seeds are anthelmintic and used as vermifuge, diuretic and tonic. The seeds pulped or in emulsion, are employed as vermifuge and are eaten fresh to expel worms from the stomach. As a diuretic they are given in gonorrhoea and urinary diseases. The oil from the seed has been used as a nerve tonic. In North America, great healing qualities for skin problems such as sores and ulcers are attributed to pumpkin seed oil and the Indians traditionally use the seeds to treat intestinal infections and kidney problems and to expel tapeworms; the flowers are used topically to soothe minor injuries. In southern Europe the seeds are also used as an anthelmintic. In Brazil, pumpkin seeds of *Cucurbita maxima* are frequently used for stomach pain, as an anti-inflammatory and antipyretic, and for the treatment of worms. (Cruz et al. 2006).

Other Uses

The big, yellow-orange fruits of certain varieties are used for decoration. The dried fruit rinds can be used for making bowls. A nourishing facemask can be made from the flesh that is effective for dry skins. The seed contains 34–54% of semi-drying oil and has been used for lighting. Matured fruits are also used as live-stock feed.

Ascorbate oxidase was satisfactory extracted from *Cucurbita maxima* by continuous process in perforated rotating disc contactor using aqueous two-phase systems (Porto et al. 2010). The system showed satisfactory results (partition coefficient, 3.35; separation efficiency, 54.98%; and purification factor, 1.46) and proved suitable for the pre-purification of ascorbate oxidase in continuous process. Ascorbate oxidase is the enzyme used to determine the content of ascorbic acid in the pharmaceutical and food industries and clinical analyses.

Comments

It can be difficult to differentiate *Cucurbita maxima* plants or fruits from the related *Cucurbita moschata* and *Cucurbita pepo* as the plant habit is similar and the fruit shape and size are variable. The following features of the fruit stalk, stem and leaves can assist:

Cucurbita maxima possesses a soft, rounded fruit stalk not enlarged at the apex; soft, rounded stems and soft textured and usually unlobed leaves.

Cucurbita moschata has a hard, smoothly angled fruit stalk widened at the apex; hard, smoothly grooved stems and soft textured, moderately lobed leaves.

Cucurbita pepo has an angular fruit stalk sometimes slightly widened at the apex; hard, angular, grooved, prickly stems and palmately lobed, often deeply cut and prickly, coarse leaves.

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Cucurbita moschata

Scientific Name

***Cucurbita moschata* Duchesne**

Synonyms

Cucurbita hippopera Ser., *Cucurbita macrocarpa* Gaspar., *Cucurbita melopepo* Lour., *Cucurbita moschata* (Duchesne ex Lam.) Duchesne ex Poiret, *Cucurbita pepo moschata* Duch. ex Lam., *Cucurbita pepo* L. var. *moschata* Duchesne, *Cucurbita pepo* var. *meloniformis* (Carriere) Makino, *Cucurbita pepo* var. *toonas* Makino, *Cucurbita spathularis* Schrad., *Gymnopetalum calyculatum* Miq., *Pepo eximius* Sag., *Pepo indicus* Burm., *Pepo moschatus* (Duch. ex Lam.) Sag.

Family

Cucurbitaceae

Common/English Names

Butternut Squash, Cheese Pumpkin, Golden Cushaw, Japanese Pumpkin, Melon Squash, Musky Gourd, Musky Pumpkin, Musky Squash, Musky Winter Squash, Seminole Pumpkin, Tropical Pumpkin, Winter Crookneck Squash, Winter Marrow, Winter Pumpkin, Winter Squash, Winter Straightneck Squash

Vernacular Names

Afrikaans: Pampoen;
Arabic: Qar' Miskî, Qar'miski, Qara' Sudani;
Argentina: Calabaza;
Bangladesh: Mitiskumra;
Bolivia: Joko;
Brazil: Abóbora;
Chinese: Fan Gua, Fan Kua, Fan Gua TengFan Nan Gua, Jin Dong Gua, Nan Gua, Nan Kua, Nan Gua Zi, Zhong Guo;
Colombia: Tamalayota;
Costa Rica: Ayote, Calabaza De Chipre, Calabaza Moscada;
Czech: Tykev Pižmová;
Danish: Centnergræskar, Kroghals, Krumhalsgrćskar, Moskusgrćskar;
Dutch: Pompoen, Reuzenkalebas;
Ecuador: Zapallo;
Eastonian: Muskuskőrvits;
Egypt: Karr Misky;
French: Citrouille, Courge De Chypre, Courge Muscarde, Courge Musquée, Giraumon Courge Muscarde, Courge Musquée, Giraumon, Patisson;
German: Bisam-Kürbis, Bisamkürbis, Mantelsackkürbis, Moschus-Kürbis, Moschuskuerbis, Speisekürbis;
Greek: Kolokynthi I Moschomos;
Guatemala: Ayote, Calabaza De Chipre, Calabaza Moscada;
Hebrew: Delaat, Delaat Hagina;
Hungarian: Pézsmatök;

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India: Kadimah, Lal Kumra, Miithaa Kadduu, Mitha Kumra, Sitaphal, Vilayati Kaddu (Hindu), Sura Kai (Tamil);
Indonesia: Waluh, Waloh (Javanese), Labuh (Madurese), Labu (Malay), Waluh (Sundanese);
Italian: Zucca Moscata, Zucca Moscada, Zucca Muschiata, Zucca Torta;
Japanese: Kabocha, Kabotcha, Nihon Kabotcha;
Khmer: Lo-Peu;
Korean: Hipak;
Laos: Fak Kham, Fak Thoong, Mak Eu;
Malaysia: Tatak Labu (Kelabit), Entekai Besai, Entakai Kemayau, Entekai Panjai (Iban), Labu, Labu Parang, Labu Mérah, Labu Ambon, Labu Manis, Labu Parang, Labu Kestéla, Waluh (Malay);
Mexico: Calabaza De Castilla, Tamalayota;
Morocco: Courge Bédouine;
Nahuatl: Tamalayotl;
Nigeria: Elegede (Yoruba);
Norwegian: Muskatgraskar;
Panama: Auyama;
Papua New Guinea: Pamkin;
Peru: Lacayote, Zapallo;
Philippines: Kalabasa (Tagalog);
Polish: Dynia Pizmowa;
Portuguese: Abóbora Almiscarada. Abóbora Da Guiné, Abóbora Moscata, Abóbora Preta, Abóbora-Rasteira;
Russian: Tykva Krupnoplodnaja, Tykva Muskatnaia;
Singapore: Labu Lemak, Labu Tukai;
Slovenia: Muškatna Buča;
Spanish: Ayote, Calabaza Almisclada, Calabaza Almiscarada, Calabaza Amelonada, Calabaza Moscada, Calabaza Moscada, Calabaza Pellejo, Chicamita;
Swedish: Bisampumpa;
Switzerland: Courge Muscade;
Thai: Fak Thong, Namtao Farang;
Uganda: Kicwika, Konokono (Acholi), Okondo (Alur & Jonam), Buziriziri, Kimisebebe (Bugisu), Kedi (Kakwa),Ensujju, Essunsa (Luganda), Enjubi, Ejubi (Madi), Ebishusha, Kasogo, Obututu (Rukiga), Ensujju, Imunyuru (Teso), Ebishusha, Obututu (Runyankore), Emyongo (Runyoro), Emyongo (Rutooro);
Venezuela: Auyama;
Vietnam: Bi Do, Bi Ngo.

Origin/Distribution

Pumpkin is not known wild; probably originated from Southern Mexico-Central America. It is cultivated throughout the world, and is the most commonly cultivated *Cucurbita* species in lowland tropical areas of Asia, Africa and the Americas.

Agroecology

Pumpkin is a warm season crop adaptable to areas with monthly mean temperature of 18–27°C. Cultivated in the tropics from the lowlands to 1,500 m elevation. It is least tolerant of low temperatures. Like most cucurbits, it can be planted on a wide variety of well drained soils, high in organic matter. The optimum soil pH should be 5.5–6.8. They are drought tolerant and intolerant of waterlogging. Both photoperiod and temperature determine the ratio of male to female flowers – long days and high temperatures favouring male sex expression.

Edible Plant Parts and Uses

Cucurbita moschata is the most widely grown and consumed pumpkin in tropical Asia and the south Pacific. Flowers, fruit, and long tendril shoots and leaves are relished as vegetable. The tender young shoots and leaves are cooked as vegetables and used as a potherb or added to soups and stews. One common dish is *pasolo* fish made with pumpkin leaves, cooked fish, coconut and onions. Pumpkin blossoms (with stamens removed) are edible raw or cooked. In the Pacific, in one recipe pumpkin flowers are fried with fish, onion and tomato. The blossoms are also dipped in batter and fried. The fruit is delicious when baked, or peeled, cut into pieces and cooked until soft or used in stews, pies, jams and custards. The fruit is used also in curries. In the Pacific, a pumpkin drink is prepared with coconut milk. The flesh can be dried, ground into a powder and used with cereals in making bread and cakes. Pumpkin flesh when cooked and

mashed is excellent food for babies. Another common dessert in the pacific is savoury bananas with pumpkin. Seeds are eaten raw, dried or roasted and serve as snack food. The seed can also be ground into a powder and used with cereals in making breads. The seed is rich in oil, which can be used for cooking.

Pumpkin seed products can be used for bread fortification (El-Soukkary 2001).

Botany

Cucurbita moschata is a monoecious, scandent or climbing, annual herb. It is lightly and densely pubescent, with short and long uniseriate trichomes and slightly angular stems and 3–5 branched tendrils and an extensive, shallow branched tap root system. Leaves are alternate, simple, long petiolate (30 cm or longer), broadly ovate-cordate to suborbicular, 20–25 × 25–30 cm, have white blotches, shallowly lobate with three to five ovate or triangular lobules, obtuse apex that is briefly apiculate, serrate-denticulate margins (Plates 11a, b). Flowers are pentamerous, solitary, axillary, large and bright yellow to orangey-yellow. The male flowers have long (16–18 cm) pedicels and a very short calyx, broadly campanulate to pateriform and foliaceous. The female flowers have thick shorter pedicels of 3–8 cm, and a globose, ovoid, oblate, cylindrical, piriform, conical, turbinate ovary

Plate 1 (**a**) and (**b**) Pumpkin cultivars with large, oblate, ovoid fruits with thick, angled peduncle flared at the apex and moderately lobed leaves

Plate 2 (**a**) and (**b**) Pumpkin cultivars with large, elongate, ellipsoid and oblong fruits with thick, angled peduncle flared at the apex

Plate 3 (**a**) and (**b**). Pumpkin cultivars with large, different shapes and coloured fruits with thick, angled peduncle flared at the apex

Plate 4 (**a**) and (**b**). Pumpkin cultivars with large, oblong and cylindrical, elongate fruits with thick, angled peduncle flared at the apex

with a thickened style and three lobate stigmas. The fruit varies greatly in size and shape (generally following the form of the ovary): smooth or with rounded ribs, rarely verrucose or granulose, with a rind that is both thickened and durable and soft and smooth, and of a very variable colour – light green to uniform dark green or with cream spots, light to dark, or completely white (Plates 1–10). *C. moschata* have a five-ridged peduncle that flares at fruit attachment point (Plates 1–10). The flesh is light or bright orange (Plate 6, 10) to greenish, ranges

Plate 5 Orangey-yellow flesh and creamy-white seeds

Plate 6 Dark greenish blue pumpkin with orange flesh

Plate 7 Close up of pumkin fruit with numerous obovoid yellowish-white seeds

Plate 8 Bin of butternut squash on sale in the market

Plate 9 Close-up of butternut squash

Plate 10 Flesh and seeds of butternut squash

Plates 11 (**a**) and (**b**). Leafy shoots and moderately lobed, pumpkin leaves on sale in a local market

from light to very sweet, is soft and generally not fibrous. It has numerous seeds which are ovate/elliptical, flattened, measuring 8–21 × 5–11 mm with a yellowish-white surface (Plate 6, 10).

Nutritive/Medicinal Properties

Analyses carried out in the United States reported raw, pumpkin fruit, *Cucurbita* spp. (minus 30% seeds, rind and stalk) to have the following proximate composition (per 100 g edible portion): water 91.60 g, energy 26 kcal (109 kJ), protein 1.00 g, total lipid 0.10 g, ash 0.80 g, carbohydrates 6.56 g, total dietary fibre 0.5 g, total sugars 1.36 g, Ca 21 mg, Fe 0.80 mg, Mg 12 mg, P 44 mg, K 340 mg, Na 1 mg, Zn 0.32 mg, Cu 0.127 mg, Mn 0.125 mg, Se 0.3 µg, vitamin C 9 mg, thiamine 0.050 mg, riboflavin 0.110 mg, niacin 0.60 mg, pantothenic acid 0.298 mg, vitamin B-6 0.061 mg, total folate 16 µg, choline 8.2 mg, vitamin A 7384 IU, vitamin E (α-tocopherol) 1.06 mg, vitamin K (phylloquinone) 1.1 µg, total saturated fatty acids 0.052 g, 12:0 (lauric acid) 0.001 g, 15:0 (pentadecanoic acid) 0.006 g, 16:0 (palmitic acid) 0.037 g, 18:0 (stearic acid) 0.003 g; total monounsaturated fatty acids 0.013 g, 16:1 undifferentiated (palmitoleic acid) 0.006 g, 18:1 (oleic acid) 0.006 g; total polyunsaturated fatty acids 0.005 g, 18:2 undifferentiated (linoleic acid) 0.002 g, 18:3 undifferentiated (linolenic acid) 0.003 g; phytosterols 12 mg, tryptophan 0.012 g, threonine 0.029 g, isoleucine 0.031 g, leucine 0.046 g, lysine 0.054 g, methionine 0.011 g, cystine 0.003 g, phenylalanine 0.032 g, tyrosine 0.042 g, valine 0.035 g, arginine 0.054 g, histidine 0.016 g, alanine 0.028 g, aspartic acid 0.102 g, glutamic acid 0.184 g, glycine 0.027 g, proline 0.026 g, serine 0.044 g, β-carotene 3,100 µg, α-carotene 515 µg, β-cryptoxanthin 2,145 µg, lutein+ zeaxanthin 1,500 µg (USDA 2010).

Raw, pumpkin flower, *Cucurbita* spp. (minus 65% pistil and calyx) was reported to have the following proximate composition (per 100 g edible portion): water 95.15 g, energy 15 kcal (63 kJ), protein 1.03 g, total lipid 0.07 g, ash 0.48 g, carbohydrates 3.28, Ca 39 mg, Fe 0.70 mg, Mg 24 mg, P 49 mg, K 173 mg, Na 5 mg, Se 0.7 µg, vitamin C 28 mg, thiamine 0.042 mg, riboflavin 0.075 mg, niacin 0.690 mg, total folate 59 µg, vitamin A 1947 IU, total saturated fatty acids 0.036 g, 12:0 (lauric acid) 0.001 g, 14:0 (myristic acid) 0.005 g, 16:0 (palmitic acid) 0.026 g, 18:0 (stearic acid) 0.002 g; total monounsaturated fatty acids 0.009 g, 16:1 undifferentiated (palmitoleic acid) 0.005 g, 18:1 undifferentiated (oleic acid) 0.004 g; total polyunsaturated fatty acids 0.004 g, 18:2 undifferentiated (linoleic acid) 0.002 g and 18:3 undifferentiated (linolenic acid) 0.002 g (USDA 2010).

Analyses carried out in the United States reported that raw, pumpkin leaves, *Cucurbita* spp. (minus 59% stem and tough leaves) had the following proximate composition (per 100 g edible portion): water 92.88 g, energy 19 kcal (79 kJ), protein 3.15 g, total lipid 0.40 g, ash

1.24 g, carbohydrates 2.33 g, Ca 39 mg, Fe 2.22 mg, Mg 38 mg, P 104 mg, K 436 mg, Na 11 mg, Zn 0.20 mg, Cu 0.133 mg, Mn 0.355 mg, Se 0.9 μg, vitamin C 11 mg, thiamine 0.094 mg, riboflavin 0.128 mg, niacin 0.920 mg, pantothenic acid 0.042 mg, vitamin B-6 0.207 mg, total folate 36 μg, vitamin A 1942 IU, total saturated fatty acids 0.207 g, 12:0 (lauric acid) 0.004 g, 14:0 (myristic acid) 0.026 g, 16:0 (palmitic acid) 0.146 g, 18:0 (stearic acid) 0.011 g; total monounsaturated fatty acids 0.052 g, 16:1 undifferentiated 0.026 g, 18:1 undifferentiated 0.025 g; total polyunsaturated fatty acids 0.022 g, 18:2 undifferentiated (linoleic acid) 0.010 g, 18:3 undifferentiated (linolenic acid) 0.012 g; tryptophan 0.041 g, threonine 0.156 g, isoleucine 0.156 g, leucine 0.318 g, lysine 0.200 g, methionine 0.054 g, cystine 0.032 g, phenylalanine 0.171 g, tyrosine 0.156 g, valine 0.181 g, arginine 0.217 g and histidine 0.050 g (USDA 2010).

Dried pumpkin and squash seed kernels called pepitas, *Cucurbita* spp. (minus 26% hulls) were reported to have the following proximate composition (per 100 g edible portion): water 5.23 g, energy 559 kcal (2,339 kJ), protein 30.23 g, total lipid 49.05 g, ash 4.88 g, carbohydrates 10.71 g, total dietary fibre 6 g, total sugars 1.40 g, sucrose 1.13 g, glucose 0.13 g, fructose 0.15 g, starch 1.47 g; Ca 46 mg, Fe 8.82 mg, Mg 592 mg, P 1,233 mg, K 809 mg, Na 7 mg, Zn 7.81 mg, Cu 1.343 mg, Mn 4.543 mg, Se 9.4 μg, vitamin C 1.9 mg, thiamine 0.273 mg, riboflavin 0.153 mg, niacin 4.987 mg, pantothenic acid 0.750 mg, vitamin B-6 0.143 mg, total folate 58 μg, choline 63 mg, vitamin A 16 IU, β-tocopherol 0.03 mg, γ-tocopherol 35.10 mg, δ-tocopherol 0.44 mg, vitamin K (phylloquinone) 7.3 μg, total saturated fatty acids 8.659 g, 6:0 0 (caproic acid).001 g, 10:0 (capric acid) 0.003 g, 12:0 (lauric acid) 0.006 g, 14:0 (myristic acid) 0.059 g, 15:0 (pentadecanoic acid) 0.008 g, 16:0 (palmitic acid) 5.364 g, 17:0 (margaric acid) 0.037 g, 18:0 (stearic acid) 2.869 g, 20:0 (arachidic acid) 0.212 g, 22:0 (behenic acid) 0.057 g, 24:0 (lignoceric acid) 0.044 g; total monounsaturated fatty acids 16.242 g, 16:1 undifferentiated (palmitoleic acid) 0.048 g, 16:1 c 0.048 g, 18:1 undifferentiated (oleic acid) 16.133 g, 18:1 c 16:108 g, 18:1 t 0.005 g, 20:1 (gadoleic acid) 0.056 g, 22:1 undifferentiated (erucic acid) 0.001 g, 22:1 t 0.001 g, 24:1c 0.005 g; total polyunsaturated fatty acids 20.976 g, 18:2 undifferentiated (linoleic acid) 20.170 g, 18:2 n-6,c,c 20.667 g, 18:2 CLAS 0.004 g, 18:2 t not further defined 0.039 g, 18:3 undifferentiated (linolenic acid) 0.120 g, 18:3 n-3, c,c,c (ALA) (α-linolenic acid) 0.120 g, 20:2 n-6 c,c 0.004 g, 20:4 undifferentiated (arachidonic acid) 0.131 g, 22:4 0.006 g, total trans fatty acids 0,064 g, total mononenoic fatty acids 0.026 g; tryptophan 0.576 g, threonine 0.998 g, isoleucine 1.281 g, leucine 2.419 g, lysine 1.236 g, methionine 0.603 g, cystine 0.332 g, phenylalanine 1.733 g, tyrosine 1.093 g, valine 1.579 g, arginine 5.353 g, histidine 0.780 g, alanine 1.485 g, aspartic acid 2.960 g, glutamic acid 6.188 g, glycine 1.843 g, proline 1.316 g, serine 1.673 g, β-carotene 9 μg, α-carotene 1 μg, β-cryptoxanthin 1 μg, lutein + zeaxanthin 74 μg. (USDA 2010).

As evidenced from above, pumpkin fruit is an excellent rich source of vitamin A and carotenes: β-carotene, α-carotene, β-cryptoxanthin and luetin and zeaxanthin. They also contain all the essential minerals, amino acid, folate, vitamin E and vitamin K and is low in fatty acids and calories. Pumpkin flower is also a rich source of vitamin A. Pumpkin leaves are excellent source of vitamin A, good source of vitamin C, folate, Ca, Fe, P, K and protein.

The main carotenoids in Argentinian butter squash were identified as β-carotene (β,β-carotene), α-carotene (β,ε-carotene), and lutein (β,ε-carotene-3,3′-diol) and the minor carotenoids, as phytofluene (7,8,11,12,7′,8′-hexahydro-ψ,ψ-carotene), ζ-carotene (7,8,7′,8′-tetrahydro-ψ,ψ-carotene), neurosporene (7,8-dihydro-ψ,ψ-carotene), violaxanthin (5,6,5′,6′- diepoxy-5,6,5′,6′-tetrahydro-β,β-carotene-3,3′-diol) and neoxanthin (5,6-epoxy-6,7-didehydro-5,6,5′,6′-tetrahydro-β,β- carotene-3,5,3′-triol) (González, et al. 2001). In some samples, 5,6,5′,6′-β-carotene diepoxide, (5,6,5′,6′-diepoxy-5,6,5′,6′-tetrahydro-β,β-carotene) and flavoxanthin (5,8-epoxy-5,8-dihydro-β,ε-carotene-3,3′-diol) were detected. The presence of cis-isomers of β,β-carotene was also detected by HPLC. The

vitamin A value obtained was 432 μg RE/100 g fresh sample, indicating this vegetable to be an important source of provitamin A. The principal carotenoids in *Cucurbita moschata* were β-carotene and α-carotene, whereas lutein and β-carotene dominated in *C. maxima* and violaxanthin, β-carotene and lutein in *C. pepo* (Azevedo-Meleiro and Rodriguez-Amaya 2007). Hydroxylation appeared to be a control point in carotenoid biosynthesis. Two new glyceroglycolipids, 1-O-(9Z,12Z,15Z-octadecatrienoyl)-3-O-[β-D-galactopyranosyl-(1→6)-O-β-D-galactopyranosyl-(1→6)-O-β-D-galactopyranosyl] glycerol and 1-O-(9Z,12Z-octadecadienoyl)-3-O-[β-D-galactopyranosyl-(1→6)- O-β-D-galactopyranosyl-(1→6)-O-β-D-galactopyranosyl] glycerol were characterised from the fruit of *C. moschata* (Jiang and Du 2009). Six compounds were isolated from *C. moschata* and identified as β-sitosterol, cis-15-vaccenic acid, stearic acid, cis-15-vaccenic acid methyl ester, soya-cerebroside I and sucrose (Wang et al. 2010).

Studies in Brazil detected 19 carotenoids in *Cucurbita moschata* variety "Baianinha" (Arima and Rodríguez-Amaya 1990). β-carotene was the principal carotenoid, accounting for 74% of an average total carotenoid content of 317.8 μg/g. The abundance of β-carotene in the *C. moschata* variety "Baianinha" makes this squash one of the richest sources of provitamin A. The average vitamin A value was 43,175 IU (International Units) per 100 g or 4,317 RE (retinol equivalents) per 100 g. Its vitamin A value was >11 times that of *C. maxima* variety "Jerimum Caboclo" and five-fold that of *C. moschata* cultivar "Menina Verde", the squash found previously to contain highest provitamin A among the *Cucurbita* vegetables most commercialized in São Paulo in South-eastern Brazil.

Acid hydrolysis of butternut (*Cucurbita moschata*) afforded fraction enriched in soluble dietary fibre and yield obtained was between 21 and 28 g/100 g for pH 1.5 and for pH 2.0 (Fissore et al. 2010). Yield increase was directly correlated with the decrease of pH and the increase of reaction time. Products endowed in low methoxyl pectins were obtained in all cases. At the lowest pH assayed, pectins were essentially constituted by homogalacturonan. Neutral sugars were constituted mainly by arabinose, galactose, rhamnose, and glucose in different proportions for each fraction. Generally, butternut fractions exhibited high glucose contents.

Pumpkin seeds are most nutritious – excellent source of vitamin A, all the essential minerals, protein and fair sources of Vitamin B1(Thiamine) and niacin. Pumpkin seeds were found to contain several major groups of active constituents: essential fatty acids, amino acids, minerals, phytosterols (e.g. β-sitosterol) and vitamins – vitamin B-6, vitamin K, pantothenic acid, γ-tocopherol, vitamin B1(thiamine) and niacin; folate, choline (USDA 2010). Glew et al. (2006) reported that on a dry weight basis, pumpkin seed contained 58.8% protein and 29.8% fat. However, the lysine score of the protein was only 65% relative to the FAO/WHO protein standard. The pumpkin seed contained useful amounts of linoleic (92 μg/g dry weight) and the following elements (on a μg per g dry weight basis): potassium (5,790), magnesium (5,690), manganese (49.3), zinc (113), selenium (1.29), copper (15.4), chromium (2.84), and molybdenum (0.81), but low amounts of calcium and iron. Other major constituents included mucilaginous carbohydrates (Yang et al. 2007), phenolic glycosides (Li et al. 2009a, b). The phenolic glycosides from the seed included:(2-hydroxy)phenylcarbinyl5-O-benzoyl-β-d-apiofuranosyl(1→2)-β-d-glucopyranoside; 4-β-d-(glucopyranosyl hydroxymethyl)phenyl 5-O-benzoyl-β-d-apiofuranosyl(1→2)-β-d-glucopyranoside, phenylcarbinyl 5-O-(4-hydroxy) benzoyl-β-D-apiofuranosyl (1→2)-β-D-glucopyranoside; like 1-O-benzyl[5-O-benzoyl-β-D-apiofuranosyl(1→2)]-β-D-glucopyranoside; cucurbitoside C and cucurbitoside A. Koike et al. (2005) isolated five phenolic glycosides, cucurbitosides A-E (1–5), were isolated from the seeds of *Cucurbita moschata*. Their structures were elucidated as 2-(4-hydroxy)phenylethanol 4-O-(5-O-benzoyl)-β-D-apiofuranosyl(1→2)-β-D-glucopyranoside (1), 2-(4-hydroxyphenyl) ethanol 4-O-[5-O-(4-hydroxy)benzoyl]-β-D-apiofuranosyl(1→2)-β-D-glucopyranoside (2), 4-hydroxybenzyl alcohol 4-O-(5-O-benzoyl)-β-D-apiofuranosyl(1→2)-β-D-glucopyranoside

(3), 4-hydroxybenzyl alcohol 4-O-[5-O-(4-hydroxy)benzoyl]-β-D-apiofuranosyl (1→2)-β-D-glucopyranoside (4) and 4-hydroxyphenyl 5-O-benzoyl-β-D-apiofuranosyl(1→2)-β-D-glucopyranoside (5) respectively.

The sterol fraction of *C. moschata* seed oil was found to consist of δ 5 and δ 7 sterols (Rodriguez et al. 1996). The main components were identified as 24S-ethyl 5 α-cholesta-7,22E-dien-3 β-ol (α-spinasterol); 24S-ethyl 5 α-cholesta-7,22E,25-trien-3β-ol(25-dehydrochondrillasterol);24S-ethyl 5 α-cholesta-7,25-dien-3 β-ol; 24R-ethyl-cholesta-7-en-3 β-ol (δ 7-stigmastenol) and 24-ethyl-cholesta-7,24(28)-dien-3β-ol(δ7,24(28)-stigmastadienol).

Whole pumpkin seed meal was found to have a high calorie content of 568 cal/100 g, (Salgado and Takashima 1992). Raw pumpkin seed meal had a protein value of 37.6% and the delipidized meal 68.8%. The PER (protein efficiency ratio) values for raw seed meal and delipidized meal were 2.26 and 1.65, respectively. The delipidized pumpkin seed meal was limiting in threonine (66.8%). Studies in Egypt indicated that pumpkin seed products could be added to wheat flour up to a 17% protein level for raw, roasted and autoclaved pumpkin meal, 19% level for germinated, fermented and pumpkin protein concentrate and 21% level for pumpkin protein isolate without a detrimental effect on dough or loaf quality (El-Soukkary 2001). However, the addition of pumpkin seed proteins resulted in increasing protein, lysine and mineral levels compared to the control. While lysine and tryptophan were the first and second limiting amino acids in the control bread, tryptophan and lysine were the first and second limiting amino acids for raw, roasted, autoclaved, germinated and fermented pumpkin meal; valine and lysine and valine and total sulfur amino acids were the first and second limiting amino acids for pumpkin protein concentrate and isolate, respectively. Adding pumpkin seed proteins improved in-vitro protein digestibility.

Studies in Egypt reported that pumpkin seed kernel flour had higher values of chemical score, essential amino acid index, and in-vitro protein digestibility than paprika and watermelon seed flours (El-Adawy and Taha 2001). For both watermelon and pumpkin seed kernel flours, the first limiting amino acid was lysine, but for paprika seed flour it was leucine. Protein solubility index, water and fat absorption capacities, emulsification properties, and foam stability were superior in watermelon and pumpkin seed kernel flours and moderate in paprika seed flour. All flour samples contained considerable amounts of P, K, Mg, Mn, and Ca. Anti-nutritional compounds such as stachyose, raffinose, verbascose, trypsin inhibitor, phytic acid, and tannins were found in all flours. Flour samples could be potentially added to food systems such as bakery products and ground meat formulations not only as a nutrient supplement but also as a functional agent in these formulations (El-Adawy and Taha 2001). Paprika seed and seed kernels of pumpkin and watermelon were rich in oil and protein. Oil samples had high amounts of unsaturated fatty acids with linoleic and oleic acids as the primary acids. All oil samples fractionated into seven classes including triglycerides as a major lipid class.

A new unsaturated hydroxy fatty acid, 13-hydroxy-9,11,15-octadecatrienoic acid was isolated from the leaves of *Cucurbita moschata* (Bang et al. 2002).

Antioxidant Activity

The pumpkin polysaccharide was demonstrated to effectively inhibit the H_2O_2-induced decrease of cell viability, lactate dehydrogenase leakage, and malondialdehyde formation (Yang et al. 2007). It also reduced the H_2O_2-induced decline of superoxide dismutase activity and glutathione depletion in cultured mouse peritoneal macrophages, indicating that pumpkin polysaccharide possessed significant cytoprotective effect and antioxidative activity. The pumpkin polysaccharide was found to have the following monosaccharide components: glucose (21.7%) and glucuronic acid (18.9%) as the major constituents followed by galactose (11.5%), arabinose (9.8%), xylose (4.4%), and rhamnose (2.8%).

Anti-prostate Activity

Pumpkin seed oil alone or combined with phytosterol-F was found to thwart the testosterone/prazosin-induced (T-P) increases in prostatic weight-to-body weight ratio and protein synthesis (Tsai et al. 2006). Also, phytosterol-F had some additive effect on the total protein synthesis within the ventral prostate. T-P rats had a significantly higher prostatic weight-to-body weight ratio and higher protein levels for both the ventral prostate and dorsolateral prostate. The curbicin preparation obtained from pumpkin seeds was used in combination with saw palmetto in two randomised double-blind trials to effectively decrease symptoms of benign prostatic hyperplasia (BPH) (Carbin and Eliasson 1989; Carbin et al. 1990). Urinary flow, micturition time, residual urine, frequency of micturition and a subjective assessment of the effect of treatment were all significantly improved in the treatment group. No adverse side effects were observed. Researchers in Germany (Schiebel-Schlosser and Friederich 1998), evaluated the effectiveness of pumpkin seed oil alone for BPH, the results of the large multicenter trial yielded favourable results in reducing BPH symptoms.

Animal studies showed that the oil preparation of pumpkin seeds could markedly reduce bladder pressure, increase bladder compliance and decrease the urethral pressure (Zhang et al. 1994). The n-butyl alcohol and ether seed extracts elicited no such effect. Separate studies showed that pumpkin seed oil could inhibit testosterone-induced hyperplasia of the prostate in rats and therefore may be beneficial in the management of benign prostatic hyperplasia (Gossell-Williams et al. 2006). Testosterone significantly increased prostate size ratio, and this enhanced increase was inhibited in rats fed with pumpkin seed oil at 2.0 mg/100 g of body weight. The protective effect of pumpkin seed oil was significant at the higher dose. Neither testosterone nor pumpkin seed oil had any significant effect on the weight gain of the rats.

Ribosome Inactivating Proteins and Associated Activities

Two ribsome inactivating proteins, designated α -moschin and β-moschin were obtained from brown pumpkin (*Cucurbita moschata*) seeds (Ng et al. 2002). α-moschin closely resembled the fruit-fly programmed-cell death gene product. The protein designated β-moschin shared striking similarity to prepro 2S albumin in N-terminal sequence. α- and β-moschins inhibited translation in the rabbit reticulocyte lysate system with an IC_{50} of 17 and 300 μM, respectively. Xia et al. (2003) purified a ribosome-inactivating protein designated moschatin from the mature seeds of pumpkin (*Cucurbita moschata*). Moschatin was found to be a type 1 RIP and rRNA N-glycosidase with a pI of 9.4 and molecular weight of approximately 29 kD. It potently obstructed the protein synthesis in the rabbit reticulocyte lysate with a IC_{50} of 0.26 nM. Using the anti-human melanoma McAb Ng76, a novel immunotoxin Moschatin-Ng76 was prepared successfully. It efficiently inhibited the growth of targeted melanoma cells M21 with a IC_{50} of 0.04 nM, 1,500 times lower than that of free moschatin. The results implied that moschatin could be used as a new potential anticancer agent.

A novel antifungal peptide, designated cucurmoschin with a molecular mass of 8 kDa was isolated from the seeds of the black pumpkin (Wang and Ng 2003) Cucurmoschin inhibited mycelial growth in the fungi *Botrytis cinerea*, *Fusarium oxysporum* and *Mycosphaerella oxysporum*. It inhibited translation in a cell-free rabbit reticulocyte lysate system with an IC_{50} of 1.2 μM. The N-terminal sequence of cucurmoschin was rich in arginine, glutamate and glycine residues. From the extract of *Cucurbita moschata* (pumpkin), an active glycoprotein of 30,665 Da with properties of a RIP was purified and isolated (Barbieri et al. 2006). It inhibited protein synthesis by a rabbit reticulocyte lysate with 0.035 nM (1.08 μg/ml) and by HeLa, HT29 and JM cells with IC_{50} in the 100 nM range. It deadenylated hsDNA and other

polynucleotidic substrates, and depurinated yeast rRNA at a concentration of 0.1 ng/ml. All these were comparable to those of other RIPs. The *C. moschata* RIP gave a weak cross-reaction only with an antiserum against dianthin 32, but not with antisera against other RIPs, and exhibited superoxide dismutase, antifungal and antibacterial activities.

Bladder Stone Alleviation

Studies in Thailand demonstrated that supplementation of pumpkin seeds as snacks could help to reduce the risk of bladder stone disease in children and adolescents (Suphakarn et al. 1987; Suphiphat et al. 1993). The results demonstrated that the longer the supplementation period of pumpkin seeds, the better were the effects. Pumpkin seeds lowered calcium-oxalate crystal occurrence (oxalcrystalluria) and calcium level but increased phosphorus, pyrophosphate, glycosaminoglycans, and potassium values in urine as compared with orthophosphate supplementation. Pumpkin seeds provided high phosphorus levels, improve the nutrient levels and increased the level of inhibitors of crystal formation or aggregation which would subsequently reduce the risk of bladder stone disease.

Antiobesity Activity

A water-soluble extract, named PG105, prepared from stem parts of *Cucurbita moschata*, was found to contain potent anti-obesity activities in a high fat diet-induced obesity mouse model (Choi et al. 2008). In this animal model, increases in body weight and fat storage were suppressed by 8-week oral administration of PG105 at 500 mg/kg, while the overall amount of food intake was not changed. Further, PG105 protected the development of fatty liver and enhanced the hepatic β-oxidation activity. Results from blood analysis showed that the levels of triglyceride, cholesterol and leptin were significantly lowered by PG105 administration, while that of adiponectin was enhanced. In the liver of PG105-treated mice, the mRNA level of lipogenic genes such as SREBP-1c and SCD-1 was reduced, while that of lipolytic genes such as PPARalpha, ACO-1, CPT-1, and UCP-2 were modestly increased. The data suggested that PG105 may have great potential as a novel anti-obesity agent in that both inhibition of lipid synthesis and acceleration of fatty acid breakdown were induced by this reagent.

Antidiabetic Activity

Two new tetrasaccharide glyceroglycolipids (QGMG-3 and QGMG-2) were isolated from the fruit of *Cucurbita moschata* (Jiang and Du 2011). The two compounds significantly reduced blood glucose level of the streptozotocin- induced diabetic mouse and high-fat diet-induced diabetic mouse.

Antihypercholesterolemic Activity

Administration of pumpkin seed oil together with the antihypercholesterolemic drug, simvastatin, to high cholesterol-fed rabbits, for 3 weeks caused a significant reduction of the aortic contractile response to norepinephrine and normalized the most adverse effects observed during hypercholesterolemia (al-Zuhair et al. 1997). These effects were elucidated by the potentiating effects of simvastatin with antioxidants and essential fatty acids in pumpkin seed. In contrast, serum activities of aminotransferases and creatine phosphokinase were enhanced with simvastatin treatment but not with the combination therapy in hypercholesterolemic rabbits. *C. moschata* extract at 100 μg/ml was found to be similar to 0.4 μg/ml pravastatin in inhibiting HMG-CoA reductase and possibly reduced cholesterol biosynthesis (Duangjai et al. 2010).

Antiparasitic/Anthelminthic Activities

Curcurbitin, a constituent in pumpkin seeds was found to exhibit anti-parasitic activity in-vitro (Rybaltovskii 1966) Human trials conducted in China had shown pumpkin seeds to be beneficial for people with acute schistosomiasis, a severe parasitic, snail-transmitted disease occurring primarily in Asia and Africa (Chou and Ming 1960). Preliminary human research conducted in China and Russia showed that pumpkin seeds may also help resolve tapeworm infestations (Chung and Ko 1976. Plotnikov et al. 1972), A mixture of areca nuts and pumpkin seeds was found efficacious against *Taenia saginata* infection (Chung and Ko 1976); and cucurbin, a preparation from pumpkin seeds was found to be effective in cestodiasis caused by cestoda tapeworms (Plotnikov et al. 1972).

Hypotensive Activity

Studies in Egypt showed that treatment of spontaneously hypertensive rats with the calcium antagonist felodipine or angiotensin-converting enzyme inhibitor (ACE-inhibitor), captopril alone or combined with pumpkin-seed oil elicited improvement in the measured free radical scavengers in the heart and kidney (Zuhair et al. 2000). Also, pretreatment of spontaneously hypertensive rats with pumpkin seed oil for 4 weeks prior to intra-venous administration of felodipine or captopril produced a significant beneficial hypotensive action. The studies concluded that simultaneous administration of felodipine or captopril with natural antioxidants could yield a beneficial therapeutic effect and retard the progression of hypertension.

Antiarthritic Activity

Administration of pumpkin seed oil to arthritic rats was found to improve the levels of glutathione, plasma total proteins, albumin and lipid peroxide and liver glucose-6-phosphate dehydrogenase and Serum N-acetyl-β-D-glucosaminidase activities affected during arthritis, especially at the chronic phase (Fahim et al. 1995). Also, a dramatic inhibition of paw oedema was observed.

Antidepressant Effect

Pumpkin seeds were suggested to be beneficial in overcoming depression attributable to its L-tryptophan, however further investigation is warranted before it can be considered for this purpose (Eagles 1990).

Proteolytic Activity

The proteolytic enzyme extracted from 3-day germinated pumpkin (*C. moschata*) seeds displayed potent activity only against pumpkin seed globulin, mild activity against the globulins of squash and cucumber and casein, and no activity against the other protein substrates (Spencer and Spencer 1974). Activity against pumpkin globulin peaked at pH 7.4. When assayed by an increase in ninhydrin-positive products, the enzyme extract from pumpkin seeds also demonstrated strong activity against pumpkin globulin and weak activity against casein.

Traditional Medicinal Uses

Pumpkin seed is used as vermifuge. It is eaten fresh or roasted for the relief of abdominal cramps and distension due to intestinal worms. Normally seeds are ground into fine flour, then made into an emulsion with water and consumed. It is then necessary to take a purge in order to expel the tapeworms or other parasites from the body. Native Americans have used pumpkin seeds for the treatment of intestinal infections and this eventually led the United States Pharmacopoeia to list pumpkin seeds as an official medicine for parasite elimination from 1863 to 1936. Pumpkin seeds have also been used to treat a variety of kidney problems by the natives. The flowers were used topically to soothe minor injuries. The boiled root is used as a galactogue.

Other Uses

The fruits and plants are also used for livestock feed. The fantastic shape and coloration of fruits considered attractive for horticultural purpose as ornamental plants.

Studies showed that *C. moschata* seed extracts (aqueous, methanolic and dichloromethane) exhibited anthelmintic activity against the parasitic nematode of small ruminants *Haemonchus contortus* (Marie-Magdeleine et al. 2009). All three extracts were inhibitory (>90%) on larval development and the dichloromethane and methanolic extracts inhibited (>59%) adult nematode motility.

Comments

It can be difficult to differentiate *Cucurbita maxima* plants or fruits from the related *Cucurbita moschata* and *Cucurbita pepo* as the plant habit is similar and the fruit shape and size are variable. The following features of the fruit stalk, stem and leaves can assist:

Cucurbita maxima possesses a soft, rounded fruit stalk not enlarged at the apex; soft, rounded stems and soft textured and usually unlobed leaves.

Cucurbita moschata has a hard, smoothly angled fruit stalk widened at the apex; hard, smoothly grooved stems and soft textured, moderately lobed leaves.

Cucurbita pepo has an angular fruit stalk sometimes slightly widened at the apex; hard, angular, grooved, prickly stems and palmately lobed, often deeply cut and prickly, coarse leaves.

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Cucurbita pepo

Scientific Nam

***Cucurbita pepo* L.**

Synonyms

Cucumis pepo (L.) Dumort, *Cucurbita esculenta* S.F. Gray, *Cucurbita fastuosa* Salisb., *Cucurbita mammeata* Molina, *Cucurbita maxima* var. *courgero* Ser., *Cucurbita maxima oblonga courgero* (Ser.) Ser., *Cucurbita melopepo* L., *Cucurbita oblonga* (Duch. ex Lam.) Link, *Cucurbita ovifera* L., *Cucurbita pepo polymorpha* Duch. ex Lam., *Cucurbita subverrucosa* Willd., *Cucurbita venosa* Descourt., *Cucurbita verrucosa* L., *Pepo citrullus* Sag. *Pepo melopepo* (L.) Moench, *Pepo vulgaris* Moench, *Pepo verrucosus* (L.) Moench.

Family

Cucurbitaceae

Common/English Names

(1) General For All – Edible Summer Squash, Summer Squash,
(2) Pumpkins – Autumn Pumpkin, Jack O'lantern Pumpkin, Pumpkin, Summer Pumpkin,
(3) Zuchhini, Courgette, Vegetable Marrow Zucchini, Zuchinni Squash
(4) Cocozelle,
(5) Crookneck, Crookneck Squashes
(6) Yellow Summer Squash, Straightneck Squash,
(7) Acorn, Acorn Squash,
(8) Gem Squash,
(9) Button Squash, Cibleme (Cajun French), Custard Marrow, Custard Squash, Granny Squash, Pattpan, Petit Pan, Scallop Squash, Scallopini, Sunburst Squash, White Squash,
(10) Vegetable Marrow,
(11) Spaghetti Marrow, Spaghetti Melon, Spaghetti Squash, Vegetable Spaghetti (See separate chapter)

Vernacular Names

Arabic: Kosah, Qar' Baladî, Qar'kosah;
Argentina: Zapallo De Angola
Bangladesh: Safed Kadu;
Brazil: Abóbora, Aboboreira;
Chinese: Fan Gua, Mei Zhou Nan Gua, Nan Gua, Xi Hu Gua, Xi Hu Lu;
Czech: Dýně Obecná, Tykev Turek;
Danish: Mandelgræskar, Græskar, Pepogræskar;
Dutch: Courgette, Kalebas, Pompoen, Sierpompoen;
Eastonian: Harilik Kõrvits;
Egypt: Karr Kosa;

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Finnish: Kesäkurpitsa, Koristekurpitsa, Kurpitsa, Spaghettikurpitsa, Zucchini;
French: Cibleme (Cajun), Citrouille, Courge, Courge Commune, Courge Pépo, Courgette, Courgette Pépon, Pâtisson, Pépon;
German: Gartenkürbis, Gemüsekürbis, Gewöhnlicher Kürbis, Herkules-Keule, Kuerbis, Kürbis, Markkürbis;
Greek: Kolokythi;
Guatemala: Hüicoy;
Hebrew: Delaat Hasade, Kishu;
Hungarian: Étkezési Tök, Közönséges Tök, Ri Tök, Spárga Tök, Takármany Útök, Tök, Úritök;
India: Lanka, Safed Kaddu (Bengali), Chappan Kaddu, Kumrha, Safed Kaddu (Hindu), Bude-Kumbala-Kayi, Bileegumbala, Boodugumbala (Kannada), Mairen (Manipuri), Bhopli, Kohala (Marathi), Kumpalam, Kumpalanna (Malayalam), Karkaru, Kurkaru, Kurlaru, Kushmanda (Sanskrit), Parangi (Tamil), Budadegummadi, Budide-Gummadi (Telugu);
Indonesia: Labu, Labu Merah, Waluh;
Italian: Cocuzza, Zucca, Zucca Da Mangiare, Zucchini, Zucchino, Zucchetta, Zucchette;
Japanese: Pepo Kabotcha, Ponkin;
Khmer: Lo-Peu;
Laos: Fak Kham, Fak Thoong;
Malaysia: Labu Kuning, Labu Manis;
Mexico: Calabaza;
Nepalese: Pharsi;
Norwegian: Courgette, Gresskar, Mandelgraskar, Squash, Zucchini;
Papua New Guinea: Pamkin;
Pakistan: Ghia Kaddu (Urdu);
Philippines: Kalabsa;
Polish: Dynia, Dynia Ozdobna, Dynia Pospolita, Dynia Zwyczajna;
Portuguese: Abobrinha, Aboborinha, Abóbora Porqueira;
Russian: Kabačok, Patison, Tverdokoraja Tykva, Tykva, Tykva Obyknovennaia;
Slavašcina: Buča Navadna, Bučka, Cukini, Navadna Buča;
Slovencina: Tekvica Obyčajná;
Spanish: Calabaza Común, Calabaza De San Juan;
Swahili: Mboga;
Swedish: Matpumpa, Prydnadspumpa, Pumpa, Sommarsquash, Vintersquash;
Thailand: Fak Thong Nam Tao (Central), Ma Fak Niao (Northern);
Vietnamese: Bi Do, Bi Ngo;
Venezuela: Calabaza.

Origin/Distribution

Cucurbita pepo is recognised to have originated in Mexico where it was domesticated at least 5,000 years ago and spread over northern Mexico to the southwestern U.S. It is believed that it was domesticated on separate occasions in Mexico and the United States as data from archaeological research and molecular studies suggest that two lineages of domesticated taxa exist in *Cucurbita pepo*. It was introduced into Europe with other *Cucurbita* species during the sixteenth century. Zucchini, a popular variety of *C. pepo* has its origin in Europe, a result of spontaneous mutation called sport. It is believed that this occurred in the late nineteenth century in Italy.

Agroecology

Cucurbita pepo is a sub-temperate species but can be grown in the tropics in the cool highlands. It thrives best in areas with day temperatures between 24°C and 29°C and night temperatures between 16°C and 24°C. *C. pepo* behaves as a day neutral plant but photoperiod has an impact on flowering and sex expression. The male flowers are promoted when there are long hot days. Long days and warm temperatures seem to favour the staminate flowering phase and delay the pistillate phase and fruit development. The plant is quite drought tolerant but requires sufficient water for good growth and yield.

C. pepo can be grown on a wide variety of soils. It prefers a well drained, fertile, and light to medium textured soil that has high organic matter content. The optimum soil pH should be 5.5–7.5. The plant is sensitive to saline soils.

Edible Plant Parts and Uses

The fruit, flowers, young leaves, young shoot tips and seeds of *C. pepo* are edible. The immature fruits, called courgette, zucchini or summer squash, are the important types of *Cucurbita pepo* relished. They are eaten as a vegetable, steamed, boiled, grill, fried, baked, barbequed or hollowed and stuffed. Mature fruits, called winter squash or pumpkin and acorns are used peeled and cooked like the fruits of *Cucurbita maxima* for instance in pumpkin pie. In West Africa the fruits are used in soups and with couscous. Gem squashes, small globular fruits popular in southern Africa, are cooked whole or cut in half and their flesh is scooped out and eaten. 'Vegetable spaghetti' cultivars are a speciality; when cooked the flesh of mature fruits resolves into thin strands which look like spaghetti. In 2005, courgette was voted one of Britain's top ten favourite culinary vegetable. In El Salvador, *calabaza* is a common ingredient in pupusas, usually with cheese as *calabaza y queso*. In France the courgette is a key ingredient in Ratatouille, a stew of summer vegetables in olive oil.

Zucchini are usually eaten cooked in various cuisines. It can be prepared using a variety of cooking techniques, including steamed, boiled, grilled, stuffed and baked, barbecued, fried, or incorporated in other recipes such as *souffles*. It also can be baked into bread. In Mexico, zucchini is often used for a salad, *sopa de flor de calabaza*, and it is quite popular in a variation of the traditional *quesadillas*. In Italy, zucchini are served in a variety of ways, especially breaded and pan-fried. In Turkey, zucchini is the main ingredient in the popular dish *mücve*r, or "zucchini pancakes", made from shredded zucchini, flour and eggs, lightly fried in olive oil and eaten with yogurt. In Libya, after being hollowed out, zucchini is stuffed with minced meat and rice plus herbs and spices and steamed. Zucchini is also used to make various kinds of stew. In Greece, zucchini is usually fried or boiled with other vegetables. It is served as a hors d'œuvre, or during fasting seasons as a main dish. In Bulgaria, zucchini are fried and then served with a dip, made from yoghourt, garlic and dill. Another very popular dish is oven-baked zucchini – sliced or grated – covered with a mixture of eggs, yoghourt, flour and dill. Zucchini can also be eaten raw, sliced or shredded in a cold salad, as well as hot and barely cooked in hot salads, as in Thai or Vietnamese recipes.

Both male and female flowers are edible. Firm and fresh blossoms that are only slightly open and with intact pedicels or pedicels removed are harvested for cooking. Before cooking the pistils are removed from female flowers, and stamens removed from male flowers. There are a variety of recipes in which the flowers may be are used as deep fried as fritters or tempura (after dipping in a light tempura batter), stuffed, sautéed, baked, or used in soups. In Mexico, the flower (known as *Flor de Calabaza*) is preferred over the vegetable, and is often cooked in soups or used as a filling for quesadillas. Some restaurants in Rome specialize in deep-frying the flowers, known as *fiori di zucca*. In several parts of Greece the flowers are stuffed with white cheese, usually feta or *Mizithra* cheese, or with a mixture of rice and herbs. Then they are deep-fried, or, less often, baked in the oven with tomato sauce. The flowers are also used to dress a meal or garnish the cooked fruit.

Cucurbita pepo seeds are edible in the same way as those of other cucurbits, either raw or roasted and consumed as snacks. Pumpkin (*Cucurbita pepo*) seed oil is a common salad oil which is produced in the southern parts of Austria, Slovenia and Hungary. Due to its green colour it is not used for cooking but in India the seed oil is used for cooking. Pumpkin seed powder is used in China and the United States as an ingredient of salad dressings and in baked products. The young tender leaves and shoot tips are used as potherb e.g. in south-western Nigeria, but in general the leaves of *Cucurbita moschata* are preferred, being less coarse.

Botany

A vigorous annual, monoecious, trailing vine or semi-bushy herb. Roots are shallow and extensively branched with a well developed taproot.

Stems are hard and angular, usually five-angled, short to semi-erect and pubescent-scabrous. Tendrils have two to six branchlets, or are simple and little developed tendrils in the semi-shrubby types. Leaves alternate, simple, prickly with spiculate bristles, large, broadly triangular without or usually with deep acute lobes 20–30 × 20–35 cm, with or without white blotches and with denticulate to serrate-denticulate margins (Plates 1, 3, 5, 6). Flowers are bright yellow, pentamerous, solitary and borne in leaf axils. Male flowers have long peduncle 7–20 cm, a campanulate calyx of 9–12 mm, linear sepals; a tubular/campanulate corolla, 5–10 cm long, which is divided into five lobes for up to one-third or more of its length; and three stamens. Female

Plate 1 *Cucubita pepo* (scallop) fruit and entire leaves

Plate 2 Yellow scalloped patty pan squash

Plate 3 *Cucubita pepo* (zucchini) with entire leaves

Plate 4 Green and yellow zucchini fruits

Plate 5 *Cucubita pepo* (zucchini) with deeply lobed leaves

Plate 6 Dark, green, plain clavate, zucchini fruits

Plate 7 *Cucubita pepo* flower and simple, entire leaves

Plate 8 *Cucubita pepo* young fruit

Plate 9 *Cucubita pepo* white squash

Plate 10 *Cucubita pepo* dark-green plain zucchini

flowers have sturdy, sulcate, shorter peduncle of 2–5 cm; the ovary is globose, oblate, ovoid, cylindrical, smooth, ribbed or verrucose and multilocular; and the calyx is very small. Fruit stalk is angular (5–8 ridged) and grooved but not flared at the point of attachment. Fruit – a pepo and variable shape and size: oblate, with scalloped edges (pattypan or button squash), oblate and longitudinal furrowed (acorn squash), fusiform, clavate, elongate with rounded ends, short torpedo–shaped; smooth to heavily ribbed, often verrucose and, with a rigid skin varying in colour from white, pale to dark green, to yellow, plain to minutely speckled with cream or green contrasting with yellow, orange or two-coloured (Plates 1–15). The flesh is cream to yellowish or pale orange with numerous flattened, obovoid to broadly elliptic, white to pale brown seeds.

Nutritive/Medicinal Properties

Analyses carried out in the United States reported that raw, zucchini, summer squash fruit with skin, *Cucurbita* spp. (minus 5% ends) had the following proximate composition (per 100 g edible portion) (USDA 2010): water 94.64 g, energy 16 kcal (69 kJ), protein 1.21 g, total lipid 0.18 g, ash 0.62 g, carbohydrates 3.35 g, total dietary fibre 1.1 g, total sugars 1.73 g, Ca 15 mg, Fe 0.35 mg, Mg 17 mg, P 38 mg, K 262 mg, Na 10 mg, Zn 0.29 mg, Cu 0.051 mg, Mn 0.175 mg, Se 0.2 μg, vitamin C 17 mg, thiamine 0.048 mg, riboflavin 0.142 mg, niacin 0.487 mg, pantothenic acid 0.155 mg, vitamin B-6 0.218 mg, total folate 29 μg, choline 9.5 mg, vitamin A 200 IU, vitamin E (α-tocopherol) 0.12 mg, vitamin K (phylloquinone) 4.3 μg, total saturated fatty acids 0.037 g, total monounsaturated fatty acids 0.014 g, total polyunsaturated fatty acids 0.076 g, tryptophan 0.010 g, threonine 0.029 g, isoleucine 0.044 g, leucine 0.071 g, lysine 0.067 g, methionine 0.018 g, cystine 0.012 g, phe-

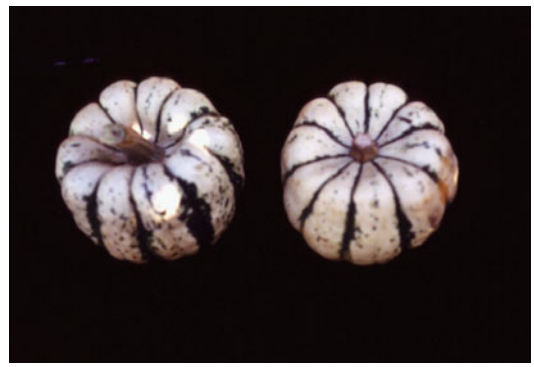

Plate 13 *Cucubita pepo* acorn squash

Plate 11 *Cucubita pepo* pale green white speckled, torpedo-shaped zucchini

Plate 14 *Cucurbita pepo*, summer pumpkin with hairy, prickly stem and slightly lobed leaves

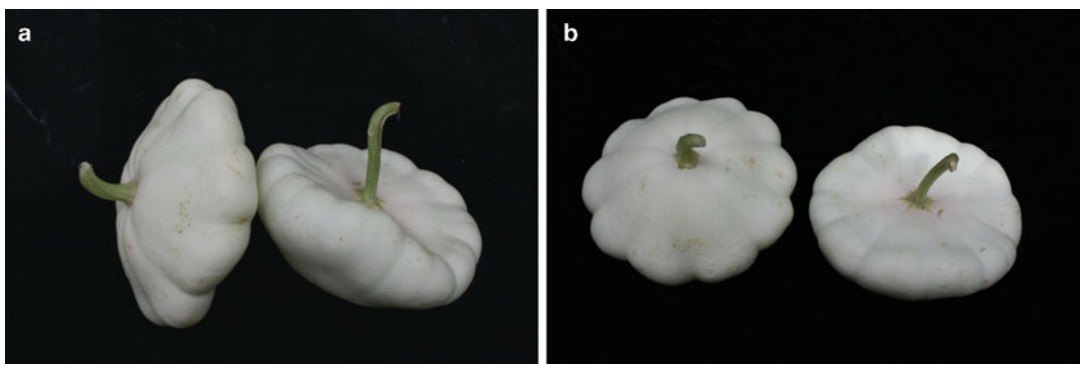

Plate 12 (**a**) and (**b**) *Cucurbita pepo* white scalloped patty pan

Plate 15 *Cucurbita pepo*, summer pumpkin with angular fruit stalk slightly widened at the apex

nylalanine 0.043 g, tyrosine 0.032 g, valine 0.054 g, arg inine 0.051 g, histidine 0.026 g, alanine 0.063 g, aspartic acid 0.147 g, glutamic acid 0.129 g, glycine 0.046 g, proline 0.037 g, serine 0.049 g, β- carotene 120 µg, lutein + zeaxanthin 2,125 µg. *C. pepo* fruit was found to have lutein and β-carotene as the principal carotenoids (Azevedo-Meleiro and Rodriguez-Amaya 2007).

Fruits of *Cucurbita pepo*, especially ornamental forms, may contain bitter compounds; cucurbitacins B, D, E, G and I and the glycoside of cucurbitacin E had been recorded (Wang et al. 2007). The fruit was also found to contain bioactive cucurbitane glycosides: cucurbitacin L (2-O-β-D-glucopyranoside), cucurbitacin K (2-O-β-D-glucopyranoside) and hexanorcucurbitane glycosides: 2,16-dihydroxy-22,23,24,25,26,27-hexanorcucurbit-5-en-11,20-dione 2-O-β-D-glucopyranoside and 16-hydroxy-22,23,24,25,26,27-hexanorcucurbit-5-en-11,20-dione 3-O-αa-L-rhamnopyranosyl-(1→2)-β-D-glucopyranoside. Other cucurbitacins recorded from fruits are discussed below. A lectin isolated from the fruit exudates of *C. pepo* was found not to be a glycoprotein; it consisted of a single polypeptide chain of about 20,000 mol. wt (Allen 1979). It was found to be a major protein (18% of the total) of the phloem exudate with a specificity for β-1,4-linked N-acetylglucosamine oligosaccharides. It was postulated that it may have an anti-parasitic activity. Chromatographic purification of the pumpkin (*Cucurbita pepo*) fruit rind and flesh extracts afforded triglyceride fatty acid mixture, tetrahydrothiophene, linoleic acid, calotropoleanly ester, cholesterol and 13(18)-oleanen-3-ol (Badr et al. 2010). Dodecane and tetradecane was detected in the extract's unpolar fraction.

Eight phenolic glycosides: cucurbitosides F-M (1–8), were isolated from the seeds of *Cucurbita pepo* (Li et al. 2005). Their structures were elucidated as 4-(2-hydroxyethyl)phenyl 5-O-(2-S-2-methylbutyryl)-β-d-apiofuranosyl(l→2)-β-d-glucopyranoside (1), 4-(2-hydroxyethyl)phenyl5-O-(3-methylbutyryl)-β-d-apiofuranosyl(l→)-β-d-glucopyranoside (2), 4-(2-hydroxyethyl)phenyl 5-O-nicotinyl-β-d-apiofuranosyl(l→2)-β-d-glucopyranoside (3), 4-(2-hydroxyethyl)phenyl 5-O-(4-aminobenzoyl)-β-d-apiofuranosyl(lα2)-β-d-glucopyranoside (4), 4-(2-hydroxyethyl) -2-methoxyphenyl 5-O-(2-S-2-methylbutyryl)-β-d-apiofuranosyl(l→2)-β-d-glucopyranoside (5), 4-(hydroxymethyl) phenyl 5-O-(2-S-2-methylbutyryl)-β-d-apiofuranosyl(l→2)-β-d-glucopyranoside (6), 4-(hydroxymethyl)phenyl 5-O-nicotinyl-β-d-apiofuranosyl(l→2)-β-d-glucopyranoside (7), and 4-(hydroxymethyl) phenyl 5-O-(4-aminobenzoyl)-β-d-apiofuranosyl(l→2)-β-d-glucopyranoside (8).

Protein values in 8 seed lines of *C. pepo* were found to be significantly different among seed types and varied from 37.1% to 44.4% (Idouraine et al. 1996). Oil content was high in all seeds and ranged from 34.5% to 43.6%. Carbohydrates varied significantly among seeds. Ash values ranged between 5.1% and 6.3%. Energy levels varied from 549 to 598 kcal/100 g. Amino acid patterns were identical among the seed lines. Cysteine and methionine contents were low. Fatty acid composition varied significantly among the seeds of selected lines. Oleic acid was significantly the most dominant (46.6–60.4%) followed by linoleic (9.6–27.9%) and palmitic acid (12.8–15.8%). With the exception of magnesium and manganese, all other endogenous mineral contents varied significantly among seed samples. Potassium, magnesium, and calcium were the most predominant.

Pumpkin (*Cucurbita pepo*) seeds were found to be rich in oil (about 35%), protein (38%), α-tocopherols (3 mg/100 g) and carbohydrate content (about 37%) (Younis et al. 2000) The

four dominant fatty acids found were: palmitic C16:0 (13.3%), stearic C18:0 (8.0%), oleic C18:1 (29.0%) and linoleic C18:2 (47.0%). The oil contained an appreciable quantity of unsaturated fatty acids (78.0%) and was enriched with linoleic acid (47.0%). Main carotenoids in the pressed seed meal of pumpkin (*Cucurbita pepo*) oil were found to be lutein, β-carotene (Matus et al. 1993). Also present in small amounts were violaxanthin, luteoxanthin, auroxanthin epimers, lutein epoxide, flavoxanthin, chrysanthemaxanthin, 9(9′)-cis-lutein, 13(13′)-cis-lutein, 15-cis-lutein (central-cis)-lutein, α-cryptoxanthin, β-cryptoxanthin and α-carotene.

Pumpkin (*Cucurbita pepo*) seed oil is a common salad oil which is produced in the southern parts of Austria, Slovenia and Hungary (Murkovic et al. 1996a, b). It was found to have a high content of free fatty acids and very high level of vitamin E, especially γ-tocopherol. Due to its dark green colour, the oil was not used for cooking. The γ-tocopherol content, which is about 5–10 times as much as that of α-tocopherol varied considerably, 41–620 mg/kg dry pumpkin seeds (Murkovic et al. 1996a, b). β- and δ-tocopherol were found at low levels. The oil content of the pumpkin seed was about 50%. The four dominant fatty acids were palmitic, stearic, oleic and linoleic acids. These four fatty acids comprised 98% of the total amount of fatty acids, others being found at levels <0.5%.

The crude protein content of defatted *Cucurbita pepo* seed flour (DCPF) was found to be as high as 57.50% with a highly valuable nutritive profile, rich in essential amino acids and minerals (Atuonwu and Akobundu 2010). DCPF was highly digestible (77.91%) and had a protein efficiency ratio (PER) of 1.80. The anti-nutrients were below acceptable limits. The physico-chemical and sensory evaluation of cookies disclosed that up to 10% substitution of wheat flour with DCPF produced acceptable cookies similar to the control (100% wheat flour).

Two new flavonol glycosides: rhamnazin 3-rutinoside and isorhamnetin 3-rutinoside-4′-rhamnoside were isolated from the male flowers of *Cucurbita pepo* (Itokawa et al. 1981). Three oxidosqualene cyclase (OSC) cDNAs (CPX, CPQ, CPR) were cloned from seedlings of *Cucurbita pepo* by homology based PCR method (Shibuya et al. 2004). CPQ and CPX were found to encode cucurbitadienol synthase and cycloartenol synthase. Cucurbitadienol synthase, the first committed enzyme for cucurbitacin biosynthesis, is a distinct enzyme from cycloartenol synthase for phytosterol biosynthesis.

The edible fruit, seeds and flowers also contain bioactive phyto-nutrients that impart many pharmacological properties.

Antioxidant Activity

The pumpkin *Cucurbita pepo* seed protein isolate exhibited in-vitro antioxidative activity (Nkosi et al. 2006b). The isolate exhibited about 80% radical scavenging activity, approximately 64% chelating activity of on Fe^{2+} ions and an inhibition of approximately 10% of xanthine oxidase. Administration of the protein isolate to rats was effective in alleviating the detrimental effects associated with protein malnutrition and acetaminophen intoxication. After 5 days on the low-protein diet the activity levels of the enzymes alanine transaminase and aspartate transaminase were significantly higher than their counterparts on a normal balanced diet. The administration of protein isolate after acetaminophen intoxication resulted in significantly reduced activity levels. It was concluded that the protein isolate had promising antioxidant properties.

Total antioxidant capacities, 2,2-diphenyl-1-picrylhydrazyl (DPPH), hydroxyl (HO) scavenging activities, and total phenolic value of *C. pepo* female and male flowers were higher in ethylacetate/water extract than in other extracts (Tarhan et al. 2007). Further, all determined antioxidant capacities of female flowers were significantly higher than male flowers.

Anticancer Activity

Four bioactive cucurbitacins: 23, 24-dihydrocucurbitacin F; 23, 24-dihydrocucurbitacin D; cucurbitacin B cucurbitacin B and cucurbitacin

E 2 were isolated *C. pepo* cv Dayangua fruit (Feng et al. 2007). Cucurbitacin E was identified as a sterol with potent growth inhibitory activity in-vitro against prostate carcinoma explants (IC_{50} of 7–50 nM in 2- to 6-day exposures) (Duncan et al. 1996). In a follow up study, cucurbitacin E and a series of cucurbitacin analogues exerted antiproliferative activity by causing marked disruption of the F- actin cytoskeleton. The distribution of vimentin was also altered in cells exposed to cucurbitacin E. The results suggested cucurbitacins to be potent disruptors of cytoskeletal integrity. Prostate carcinoma cells appeared notably sensitive to growth inhibition by cucurbitacin E. Besides cytotoxicity and anti-cancer activity, cucurbitacins also exhibited further wide ranging in-vitro or even in-vivo pharmacological functions, such as purgative, antiinflammatory, and anti-fertility activities (Guha and Sen 1975).

Fruits were also found to contain cucurbitaglycosides cucurbitane triterpenoids with a purine unit, cucurbitaglycoside A and cucurbitaglycoside B which showed cytotoxic activity against the human epithelial carcinoma cell line HeLa with IC_{50} of 17.2 and 28.4 μg/ml, respectively (Wang et al. 2008).

Studies by Premzl et al. (2001) concluded that both cysteine and aspartic proteinase activities were needed for invasion by ras-transformed human breast epithelial cells (MCF-10A neo T) in-vitro. A squash aspartic proteinase (SQAPI)-like inhibitor, isolated from squash *Cucurbita pepo*, showed significant inhibition (65.7%) of the tumour invasion.

In a comparative study on the anti-cancerous effects of hydro-alcoholic extracts of *Cucubita pepo* and *Solanum nigrum,* the IC_{50} of *S. nigrum* extract was significantly lower than that of the *C. pepo* extract on all four cell lines: Chinese hamster ovarian cells (CHO), rat fibroblast, and cancer HepG2 and CT26 cell lines (Shokrzadeh et al. 2010). The IC_{50} of hydro-alcoholic extract of *C. pepo* on the four cell lines increased in the following rank sequence of cells: CHO < fibroblast < CT26 < HepG2. Also, the highest and lowest cytotoxicity of the *C. pepo* extract was related to HepG2 (IC_{50} = 132.6 3 μg/ml) and fibroblast (IC_{50} = 293.2 μg/ml) cell lines.

Hepatoprotective Activity

Administration of pumpkin (*C. pepo*) seed protein isolate was found effective in alleviating the detrimental effects associated with protein malnutrition in rats (Nkosi et al. 2005). After 5 days on the low-protein diet the activity levels of all four enzymes: lactate dehydrogenase (LD), alanine transaminase (ALT), aspartate transaminase (AST) and alkaline phosphatase (ALP) in the liver were significantly higher than rats on a normal balanced diet. Carbon tetrachloride intoxication resulted in significant increases in the activity levels of all four enzymes investigated. The administration of pumpkin seed protein isolate after carbon tetrachloride intoxication significantly lowered activity levels of all four enzymes. The researchers further reported that after 5 days on the low-protein diet the activity levels of all the enzymes as well as antioxidant levels were significantly lower than rats on a normal balanced diet (Nkosi et al. 2006ab). However, a low-protein diet resulted in significantly enhanced levels of lipid peroxidation. Carbon tetrachloride-intoxicated rats responded in a similar way to their counterparts on a low-protein diet. The administration of pumpkin seed protein isolate after carbon tetrachloride intoxication resulted in significantly elevated levels of all the variables investigated, with the exception of the lipid peroxidation levels which were significantly reduced. From the results it was concluded that pumpkin seed protein isolate administration was effective in alleviating the detrimental effects associated with protein malnutrition and carbon tetrachloride intoxication. It was suggested that pumpkin seed protein isolate had components that exhibited antiperoxidative properties.

Benign Prostatic Hyperplasia Inhibition

In a randomised, double-blind study, involving 53 patients over a 3-month period, the preparation Curbicin, obtained from pumpkin (*Cucurbita pepo*) seeds and dwarf palm plant (*Sabal serrulata*), was found to alleviate symptoms caused by

prostatic hyperplasia (Carbin et al. 1990). Urinary flow, micturition time, residual urine, frequency of micturition and a subjective assessment of the effect of treatment were all significantly ameliorated in the treatment group. No undesirable side effects were observed. Gossell-Willimas et al. (2006) reported that testosterone significantly increased prostate size ratio, and this induced increase was inhibited in rats fed with pumpkin (*C. pepo*) seed oil at 2.0 mg/100 g of body weight in a 20-day study. The protective effect of pumpkin seed oil was significant at the higher pumpkin seed oil concentration. They concluded that pumpkin seed oil could inhibit testosterone-induced hyperplasia of the prostate and therefore may be beneficial in the management of benign prostatic hyperplasia.

Tsai et al. (2006) reported that the ventral prostate glands of rats treated with testosterone/prazosin (T-P) became hyperplastic compared with rats in the control or vehicle treated (pumpkin seed oil alone or in combination with phytosterol-F). Compared with the control or vehicle group, T-P rats had a significantly higher prostatic weight-to-body weight ratio for the ventral prostate, but not for the dorsolateral prostate. The T-P rats had significantly higher protein levels within both lobes. When compared with the T-P-alone rats, the T-P rats treated with pumpkin seed oil alone or pumpkin seed oil combined with phytosterol-F exhibited a significantly lower weight ratio for the ventral prostate and significantly lower protein levels within both lobes. Further, phytosterol-F had some additive effect on the total protein synthesis within the ventral prostate. They concluded that pumpkin seed oil alone or combined with phytosterol-F could thwart the T-P-induced increases in prostatic weight-to-body weight ratio and protein synthesis.

Studies showed that citral significantly increased prostate weight in rats but, pumpkin seeds significantly inhibited enlarged prostate especially at high seed dose (10%) level (Abdel-Rhaman 2006). Results indicated that pumpkin seeds could alleviate the signs of benign prostatic hyperplasia (BPH) such as decrease of protein binding prostate contents, weight of ventral prostate size, improved histology of testis that may be beneficial in the management of mild stage of benign prostatic hyperplasia. Benign prostatic hyperplasia (BPH) is a common disease in elderly men. Although it is a non-malignant disease, it can have a significant impact on the quality of life of elderly men.

Antiulcerogenic Activity

C. pepo was reported to have gastroduodenal protective and anti-ulcerogenic properties (Sarkar and Buha 2008). A significant reduction in alkaline phosphatase activity and mucosal thickness and elevation in ulcer index was noted in aspirin treated stomach and duodenum of albino rats. However, pre-treatment with *C. pepo* fruit pulp extract for 14 consecutive days elevated alkaline phosphate activity and mucosal thickness accompanied by a decrease in ulcer index.

Antihypercholesterolemic Activity

Studies showed that animals fed a high concentration of dehydrated pumpkin (*C. pepo*) in their diet for 8 weeks had reduced levels of plasma and hepatic cholesterol but manifested relevant lesions in the liver (Silveira et al. 1996). The researchers stated that further studies were necessary to evaluate the right proportion of pumpkin to reduce cholesterolemia without undesirable effects.

Antidiabetic Activity

Of the ethanolic extracts of *Cucurbita pepo, Cucumis sativus* and *Praecitrullus fistulosus* peels, *Cucurbita pepo* peel was found to be the most effective in ameliorating diabetes mellitus (Dixit and Kar 2010). All the three peel extracts nearly reversed most of the undesirable changes induced by alloxan suggesting their possible role in ameliorating diabetes mellitus and related alterations in serum lipids and antioxidative enzymes.

However, *Cucurbita pepo* peel was found to be the most efficacious. Total polyphenols, flavonoids and ascorbic acid contents of the test peels appeared to be associated with the observed antidiabetic and antioxidative potentials.

Antitussive Activity

Several water-soluble pectic polysaccharides isolated from the pumpkin (*C. pepo*) fruit were found to have antitussive activity (Nosáľová et al. 2011). Oral administration of pumpkin pectic polysaccharides inhibited the number of coughs induced by citric acid in guinea pigs to varying extent. The cough depressant efficacy of most of the tested polysaccharides was comparable and even higher than that of codeine. The antitussive activity of the pectic polysaccharides was postulated to be related to their molecular and structural properties, whereby a synergistic action between the polysaccharide and non-carbohydrate components on the biological response was suggested.

Immunoregulatory Activity

Seeds of *C. pepo* were reported to contain compounds with immunoregulatory potential (Winkler et al. 2005). Extracts of pumpkin seeds suppressed mitogen-induced neopterin production and tryptophan degradation in a concentration-dependent fashion in stimulated peripheral blood mononuclear cells in-vitro. The data demonstrated the capacity of pumpkin extracts to modulate immunobiochemical pathways induced by interferon γ.

Ribosome-Inactivating Protein/DNA Inhibition Activity

The flesh of *Cucurbita pepo* fruit contained a type-1 ribosome-inactivating protein (RIP), designated pepocin (Yoshinari et al. 1996). Pepocin was found to have a molecular mass of 26 kDa and a pI of about 9.9. It possessed no glycosidic linkages. The protein inhibited protein synthesis in a rabbit-reticulocyte lysate with an IC_{50} of 15.4 pM, and depurinated 28S rRNA in the ribosomes of the lysate in a manner similar to that of ricin A-chain and other RIPs. The enzyme was also active on wheat-germ ribosomes and on *Escherichia coli* ribosomes.

Immunoglobulin, a 32 kDa anti-endonuclease from *Cucurbita pepo* var *patissonina* was found to inhibit DNA synthesis (Rzepecki and Szopa 1995). Low concentrations of IgGs (about 50 μg IgG per 1×10^6 cell nuclei) temporary inhibited DNA synthesis. This inhibition involved only the synthesis of DNA bound to the nuclear matrix.

Larvicidal Activity

There was a report of studies conducted in the forties that reported acetone extracts of pumpkin seeds killed mosquito larvae (Hartzell and Wilcoxon 1941).

Trypsin/Serine Protease Inhibition Activity

Three trypsin inhibitor fractions were found in white bush fruits (*Cucurbita pepo* var. *patissonina*) (Pham et al. 1995a). One of them, CPPTI-fIII, differed in its amino-acid composition, molecular mass, amino-acid residue at position P1 of the reactive site and inhibition spectrum when compared to the inhibitors of white bush dormant seeds, CPPTI-I and CPPTI-II (Pham et al. 1995b). Tyrpsin inhibitors are anti-nutrients, they reduce the availability of the essential enzyme trypsin and inhibit digestion.

C. pepo seeds were found to have 3 trypsin inhibitors – *Cucurbita pepo* var *Giromontia* (zucchini) trypsin inhibitor I; CPTI-II, *Cucurbita pepo* (summer squash) trypsin inhibitors II; CPTI-III, *Cucurbita pepo* (summer squash) trypsin inhibitors III (Wieczorek et al. 1986). Three trypsin inhibitors (Otlewski et al. 1984) and a serine proteinase inhibitor (CPTI-II) were isolated from summer squash (*Cucurbita pepo*) seeds (Otlewski and Wilusz 1985).

Traditional Medicinal Uses

The seed is becoming popular for its medicinal properties including the prevention of kidney stones. In Africa, the pulp is used as a poultice to treat burns and inflammations and as a cooling compress to treat headache and neuralgia; it has also been applied to tumours and corns. Seeds are eaten as an anthelmintic. In Mauritius, an infusion of the seeds is used internally to treat hypertension and prostate complaints, and externally to treat erysipelas. Pumpkin (*Cucurbita pepo*) seeds are used locally in Eritrea to treat tapeworm. (Younis et al. 2000).

Other Uses

In many western countries special cultivars are grown for the nicely shaped and coloured ornamental inedible fruits *('coloquintes')*. *C. pepo* (pumpkins) are sometimes grown for animal feed. In India, the seed oil is also used for lighting. The fruit pulp has been used to dehair and soften hides in tanning.

Comments

Cucurbita pepo is a highly polymorphic species. Accordingly, the cultivar groups can be arranged under two subspecies, following Robinson and Decker 1997.

The cultivars can be grouped into eight morphotypes in two subspecies, ssp. *pepo* and ssp. *ovifera*. The latter group comprise the ornamental cultivars.

Cucurbita pepo, which has been divided into two taxa, subsp. *pepo* and subsp. *ovifera* var. *ovifera* (L.) Harz. Several cultivar classifications have been proposed, but none has been widely accepted. Eight groups of edible cultivars of *C. pepo subsp. pepo* have been proposed:

- Pumpkin (*C. pepo* L. var. *pepo* L. Bailey) includes prostrate cultivars which produce spherical, oval or oblate fruit that is rounded or flat at the ends. The fruit of this group is grown to be eaten when ripe and sometimes is used as fodder (Plates 13 and 14).
- Scallop (*C. pepo* L. var. *clypeata* Alefield) has a semi-shrubby habit, the fruit ranges from flat to almost discoidal, with undulations or equatorial margins, and it is eaten before maturity.
- Acorn (*C. pepo* L. var. *turbinata* Paris) is both a shrubby and creeping plant with fruit which is obovoid or conical, pointed at the apex and longitudinally costate-grooved. The rind is soft, hence the fruit can be eaten in the ripe state.
- Crookneck (*C. pepo* L. var. *torticollia* Alefield) is a shrubby type, with yellow, golden or white fruit which is claviform and curved at the distal or apical end and generally has a verrucose rind. It is eaten unripe since the rind and the flesh harden when ripe.
- Straightneck (*C. pepo* L. var. *recticollis* Pari) is a shrubby plant with yellow or golden fruit and a verrucose rind similar to that of var. *torticollia*.
- Vegetable marrow (*C. pepo* L. var. *fastigata* Paris) has creeper characteristics as a semi-shrub and has short cylindrical fruit that is slightly broader at the apex, with a smooth rind which hardens and thickens on ripening and which varies in colour from cream to dark green.
- Cocozzelle (*C. pepo* L. var. *longa* Paris) has cylindrical, long fruit that is slender and slightly bulbous at the apex; it is eaten in the unripe state and one of the most common names is Cocozzelle.
- Zucchini (*C. pepo* L. var. *cylindrica* Paris) is the most common group of cultivars at present. Its plants are generally semi-shrubby and its cylindrical fruit does not broaden or else broadens only slightly. It is eaten as a vegetable in the unripe state.

It can be difficult to differentiate *Cucurbita maxima* plants or fruits from the related *Cucurbita moschata* and *Cucurbita pepo* as the plant habit is similar and the fruit shape and size are variable. The following features of the fruit stalk, stem and leaves can assist:

Cucurbita maxima possesses a soft, rounded fruit stalk not enlarged at the apex; soft, rounded stems and soft textured and usually unlobed leaves.

Cucurbita moschata has a hard, smoothly angled fruit stalk widened at the apex; hard, smoothly grooved stems and soft textured, moderately lobed leaves.

Cucurbita pepo has an angular fruit stalk sometimes slightly widened at the apex; hard, angular, grooved, prickly stems and palmately lobed, often deeply cut and prickly, coarse leaves.

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Cucurbita pepo 'Vegetable Spaghetti'

Scientific Name

***Cucurbita pepo* L. 'Vegetable Spaghetti'**

Synonyms

Cucurbita pepo L. subsp. *pepo* (Vegetable Spaghetti Group)

Family

Cucurbitaceae

Common/English Names

Gold String Melon, Fish Fin Melon, Noodle Squash, Shark-Fin Melon, Spaghetti Marrow, Spaghetti Melon, Spaghetti Squash, Vegetable Spaghetti

Vernacular Names

Chinese: Yú Chì Guā;
Dutch: Spaghettikalebas, Spaghettipompoen;
Eastonian: Spagetikõrvits;
French: Courge Spaghetti, Spaghetti Végétal;
German: Spaghettikürbis;
Italian: Zucca Spaghetti;
Japanese: Kinshi Uri;
Portuguese: Abóbora Spaghetti;
Spanish: Zapallo Spaghetti;
Swedish: Spagettipumpa.

Origin/Distribution

The exact origin of vegetable spaghetti is not known, but is believed to be from the Americas. It is now cultivated throughout the world.

Agroecology

This squash is a cool climate crop but is frost tender. It can be grown on a wide range of soils but does best on well-drained, slightly acidic soil with a pH of 5.5–7.0, in full sun.

Edible Plant Parts and Uses

When raw the flesh is firm and solid but on cooking the flesh disintegrates into ribbons or spaghetti-like strands that also resemble strands of cooked shark fin. Spaghetti squash can be baked, boiled, steamed or micro-waved. It can be served with or without a sauce as a substitute for pasta or made into a vegetarian shark-fin soup, casserole or eaten as cold salad. The seeds can be roasted like pumpkin seeds. The flowers are also edible when cooked like zucchini flowers.

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Botany

A vigorous annual, monoecious, trailing vine or semi-bushy herb. Roots are shallow and extensively branched with a well developed taproot. Stems are hard and angular, usually five-angled, short to semi-erect and pubescent-scabrous light green. Tendrils have two to six branchlets, or are simple and little developed tendrils in the semi-shrubby types. Leaves alternate, simple, large, broadly triangular usually with deep acute lobes 20–30×20–35 cm, with denticulate to serrate-denticulate margins. Flowers are bright yellow, pentamerous, solitary and borne in leaf axils. Male flowers have long, light green peduncle 7–20 cm, a campanulate calyx of 9–12 mm, linear sepals; a tubular corolla, 5–10 cm long, which is divided into five lobes for up to one-third or more of its length; and three stamens. Female flowers have sturdy, sulcate, shorter peduncle of 2–5 cm; the ovary is ovoid, cylindrical, smooth, and the calyx is very small. Fruit oblong cylindrical pepo, light green turning to ivory to yellow or yellow with white or greenish streaks when mature (Plates 1–3), containing many white ovoid, flattened seeds (Plates 3 and 4). Flesh is yellow, orange or white (Plates 3–5).

Plate 2 Top view showing attachment of the peduncle

Plate 3 LS view of fruit showing the orange-coloured flesh

Plate 1 Side view of fruit

Plate 4 Close-up of white seeds

Plate 5 White-fleshed fruit

Nutritive/Medicinal Properties

Nutrient value of raw spaghetti winter squash per 100 g edible portion (exclude refuse of 29% rind and seeds) (USDA 2010) is reported as: water 91.60 g, energy 31 kcal (130 kJ), protein 0.64 g, total lipid 0.57 g, ash 0.28 g, carbohydrate 6.91 g, Ca 23 mg, Fe 0.31 g, Mg 12 mg, P 12 mg, K 108 mg, Na 17 mg, Zn 0.19 mg, Cu 0.037 mg, Mn 0.125 mg, Se 0.3 μg, vitamin C 2.1 mg, thiamin 0.037 mg, riboflavin 0.018 μg, niacin 0.950 mg, pantothenic acid 0.360 mg, vitamin B-6 0.101 mg, total folate 12 μg, vitamin A RAE 3 μg, vitamin A 50 IU, total saturated fatty acids 0.117 g, 12:0 (lauric) 0.002 g, 14:0 (myristic) 0.002 g, 16:0 (palmitic) 0.101 g, 18:0 (stearic) 0.011 g; total monounsaturated fatty acids 0.042 g, 16:1 undifferentiated (palraitaleic) 0.002 g, 18:1 undifferentiated (oleic) 0.039 g; total polyunsaturated fatty acids 0.239 g, 18:2 undifferentiated (linolenic) 0.090 g, 18:3 undifferentiated (linolenic) 0.149 g; tryptophan (linoleic) 0.009 g, threonine 0.018 g, isoleucine 0.024 g, leucine 0.034 g, lysine 0.022 g, methionine 0.007 g, cystine 0.005 g, phenylalanine 0.024 g, tyrosine 0.020 g, valine 0.026 g, arginine 0.033 g, histidine 0.011 g, alanine 0.025 g, aspartic acid 0.064 g, glutamic acid 0.105 g, glycine 0.022 g, proline 0.021 g and serine 0.024 g.

Spaghetti squash contains many nutrients, including folic acid, potassium, vitamin A, and β-carotene. It is also low in calories.

For its medicinal attributes refer to notes for *Cucurbita pepo*.

Other Uses

Like all squashes, it can be used for animal feed.

Comments

Spaghetti squash is a winter squash under the vegetable marrow group included under *Cucurbita pepo* L. subsp. *pepo*.

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Lagenaria siceraria

Scientific Name

***Lagenaria siceraria* (Molina) Standl.**

Synonyms

Cucurbita hispida sensu Thunb.(sensu stricto), non Thunb., *Cucurbita idolatrica* Willd., *Cucurbita lagenaria* L. nom. illeg., *Cucurbita leucantha* Duchesne., *Cucurbita leucantha* Lam. nom illeg., *Cucurbita siceraria* Molina, *Lagenaria idolatrica* (Willd.) Ser., *Lagenaria lagenaria* (L.) Cockerell nom. inval., *Lagenaria leucantha* Rusby, *Lagenaria microcarpa* Naud., *Lagenaria siceraria* convar. *clavatina* Grebenšč. nom. invalid., *Lagenaria siceraria* convar. *cugurda* Grebenšč. nom. inval., *Lagenaria siceraria* Grebenšč. convar. *siceraria* nom. invalid., *Lagenaria siceraria* var. *depressa* (Ser.) Hara, *Lagenaria siceraria* var. *hispida* Hara, *Lagenaria siceraria* var. *microcarpa* (Naud.) Hara, *Lagenaria. vulgaris* Seringe, *Pepo lagenarius* Moench.

Family

Cucurbitaceae

Common/English Names

Birdhouse Gourd, Bottle Gourd, Calabash Gourd, Hard-Shelled Gourd, Dolphin Gourd, Long Squash, Trumpet Gourd, White-Flowered Gourd

Vernacular Names

Algeria: Qar'a Tawil; Dubb'a; Qar'a Dubba, Qar'a Duruf; Qar'a Aslawiya (Arabic), Takhsait, Ouowi, Laqttine, Tafe- Qeloujla (Berber), Calebasse; Calebasse D'urope, Bouteille, Congourde, Gourde (Local French);
Angola: Mbinda (Umbundu), Dinango, Mbinda (Kimbundu);
Arabic: Garra, Qar'a, Dubb'a;
Benin: Étré (Adja), Wambika (Berba), Kpakata, Igba (Dassa), Tchiko (Dendi), Ka (Fon), Calebassier (French), Ka, Oka (Goun), Ko-Yégué (Gourma), Étré (Mina), Wanni (Natimba), Ika (Pédah), Oka (Sahoué), Dioni (Somba), Djorokoroka (Yom), Gô, Igba (Yoruba);
Bolivia: Mate, Porongo;
Brazil: Abóbora-D'água, Cabaça, Cabaceiro, Porongo (Portuguese);
Brazzaville: Lendouma (Akwa), Calebasse (French);
Central African Republic: Kaoya (Sango);
Chinese: Bian Pu, Hu Gua, Hu Lu, Hu Lu Gua, Hu Zi, Hu Tzu, Luo Gua, Mo Gua, Po Gwa, Pul Qua, Wu Lo Kwa;
Czech: Divenice Lahvovitá, Kalabasa;
Dahomey: Kpê-On (Busa);
Danish: Flaskegræskar, Flaskegraeskar, Kalabas;
Democratic Republic Of Congo: Lendouma (Akwa), Murhandagule (Shi), Lufun-La-Mbiin (Yanzi);
Dutch: Fleskalebas, Flessepompoen;
Eastonian: Harilik Pudelkõrvits;

T.K. Lim, *Edible Medicinal And Non-Medicinal Plants: Volume 2, Fruits*,
DOI 10.1007/978-94-007-1764-0_44, © Springer Science+Business Media B.V. 2012

Egypt: Qar'a Tawil; Dubb'a; Qar'a Dubba, Qar'a Duruf; Qar'a Aslawiya (Arabic), Takhsait, Ouowi, Laqttine, Tafe- Qeloujla (Berber);
Ethiopia: Qil (Agew-Awi), Buke (Afaan Oromo), Botto (Gedeoffa), Kkil;
Fiji: Vago;
Finnish: Pullokurpitsa;
French: Calebasse (Fruit), Calebassier, Calebassier Grimpant (Plant), Cougourde, Courge, Courge Massue, Courge Pelerine, Courge Siphon, Gourde, Gourde Bouteille, Gourde Massue (Ornamental Club Gourd). Gourde Trompette (Trumpet Gourd) Gourde De Pèlerins (Traveller's Gourd);
German: Flaschenkürbis, Flaschen-Kürbis, Gewöhnlicher Flaschenkürbis, Kalebassenkürbis, Trompetenkürbis;
Ghana: Akpe, Kpatu, Daka, Sasagné, TστστʃO (Adnagme-Krobo), Adidi-Pakyie, Bɛntowa (Akan-Asante), Garle, Kjirge, Tschocho, Tumbe (Dagbani), Adenkum-Mfoaa, Adidi Apakyi, Apakyi, Apakyiwa, Bɛntua, Σ-Danka, Dwereba, Ngotoa, Nsutoa (Fante), Akpaki, Bén'toa, Kyene, TʃEne (Ga), Adaŋga, Adangagoe, Akpẽ, Akpaku, Akugoe, Dugoe, Ekplẽ, Go, Sasa Goe, Tigoe, Tigwe, Trɛ, Trɛkpe, Trɛkptrɛkpa (Gbe-Vhe), Sunga (Grusi), Chɛfòl, Dèŋkèŋ, Kàtùrbí, Kàwífẽ (Guang-Gonja), Gole, Wamde (Moore), Adenkum, Adidi Apakyi, Apakyi, Apakyiwa, Apebentutu, Bentoa, Kora, Krokuma, Mfoaa, Nkaŋ-Kruwa, Nsɔase, Nsutoa, Sã-Kora Sã-Kor (Twi), Adanga, Akatse Goe, Akogo, Akpɛ, Akwɛ, Dizebome, Tigwe, Tsigui (Vhe);
***Guinea*:** Horde (Fula-Pulaar), Bolin-Bara, Fé Lemba, Fé Lémé Nkuru, Kulu Félé (Manding-Maninka);
Guinea-Bissau: Fôóti (Balanta), Eparrá, Omparsa (Bidyogo), Cabaça (Crioulo), Core, Fahándu, Lami-Córè, Ordè (Fular-Pulaar), Mirandjô–Lô (Manding-Mandinka), Pucúo (Mandyak), Udungue (Mankanya), Ecanda (Pepel);
Hebrew: Qara;
Hunagrian: Lopotök;
India: Sorakaya, Anapakaya, Anamgapkaya, Burrakaya And Tumri (Telangana, Andra Pradesh), Lao, Lau (Assamese), Ladu, Lau, Laus, Lokitumbi (Bengali), Dhudi, Dudi, Tumada, Tumbadi (Gujarati), Al Tumba, Altumba, Dudhi, Dudi, Dodi, Kaddis, Kaddu, Kadvilauki, Ghia, Ghiya, Lauki, Laukii, Lokhi, Titalauki, Tumba, Tumri (Hindu), Easagori Balli, Eesugaayi, Eesugaayi Balli, Eesugumbala, Elachiballi, Gaayi Balli, Haalu Gumbala, Halugumbala, Isugumbala, Kadusore, Kahisore, Khaisore, Sore Balli, Sorekai, Tumbi (Kannada), Bela-Schora, Caca-Palam, Caipa-Schora, Choraikka,Chorakka, Churan, Cura, Kaippan Cura, Kaippancura, Kattucura, Peccura, Pechura, Piccura, Sorekai, Sorekayi, Tumburini, Tumburu (Malayalam), Khongdrum, Khongdum (Manipuri), Bhopla, Charanga, Dudhi, Doodhbhoplaa, Doodhya, Kadubhopla, Phopla (Marathi), Lau (Oriya), Dani, Dudhi, Tumbi (Punjabi), Alabu, Alaabu, Iksvaku, Iksvakuh, Katukalambuni, Katutumbi, Lamba, Pindaphala, Tiktaalaabu, Tiktalabu, Tumbi, Tumbi Ishavaaku, Tumbini (Sanskrit), Akakkoti, Alakam, Anakam, Cenkotakakkoti, Cenkotakam, Ciratumpi, Curai, Curai Vittu, Curaicamulam, Curaikkoti, Kariccurai, Karuncanam, Korkoti, Kumatti, Kutampil, Kuyampikkati, Munakkam, Natankay, Nattuccurai, Nattuccuraikkoti, Netuncurai, Netuncuraikkoti, Nittakkavitakkay, Nittakkavitam, Purkoti, Shorakkai, Sorakkai, Surai, Suraikai,Surakkai, Tumpal, Tumpalai, Tumpam, Utiriminti, Utirimintikkay (Tamil), Aanapa-Kai, Alaabuvu, Anapachettu, Anapakaaya, Anugakaaya, Beerakaya, Gubbakaaya, Kundaanuga, Nlaanuga, Sora Kaya, Sorakkaya, Sorakaaya (Telugu), Kaddu-E-Daraz, Maghz Tukhme Kaddu, Maghz Kaddu-I-Shirin, Maghz-I-Tukhm-I-Kaddu, Maghz Tukhm Kaddu Shirin, Maghz Kaddu, Ab Kaddu Sabz, Maghz Kaddu Nim Kofta, Kaddu-I-Taza Tarasha Hua, Moghz Tukhm Kaddu, Maghz Tukhm Kaddu, Maghz Tukhm Kaddu-I-Shirin (Urdu);
Indonesia: Kukuk (Java), Labu Botol, Labu Air, Labu Putih;
Italian: Cucuzzi, Zucca Bottiglia, Zucca Da Nuoto, Zucca Da Tabacco, Zucca Da Vino;
Japanese: Hyoutan, Maru-Yougao,Yuugao;
Khmer: Khlôôk;
Laotian: Mak Nam, Mak Nam Tao, Namz Taux;
Liberia: Gah (Mano);
Libya: Qar'a Tawil; Dubb'a; Qar'a Dubba, Qar'a Duruf; Qar'a Aslawiya (Arabic), Takhsait,

Ouowi, Laqttine, Tafe- Qeloujla (Berber), Calebasse; Calebasse D'urope, Bouteille, Congourde, Gourde (Local French):
Madagascar: Voambahy, Voatavominta;
Malaysia: Labu, Labu Air Berleher, Labu Air Putih, Labu Jantung, Labi Kendi, Tukal (Besisi), Sinu (Sakai), Tokal (Semang), Tukal (Pangan);
Mali: Gabá, Gabá Íí, Kɛ̀mɛ (Dogon), Fie, File (Manding-Bambara);
Mexico: Bule, Acocotli, Lek;
Morocco: Grac Slawiya; Qar'a Tawil; Dubb'a; Qar'a Dubba, Qar'a Duruf; Qar'a Aslawiya (Arabic), Takhsait, Ouowi, Laqttine, Tafe-Qeloujla (Berber), Qer'aa, Qer'aa Beida, Qer'aa Gardousi, Qer'aa Medwen, Qer'aa El-Leben (Rabat Drug Market), Calebasse D'urope, Bouteille, Congourde, Gourde (Local French), Grac Slawiya (Tatouane Province);
Niger: Gáasí, Tàndà Tàndà (Songhai);
Nigeria: Aéekó, Òt (Abu), Urok (Agwagwune), Ekori (Akpet), Aboh (Akpet-Ehom), Ìkìm, Ìkpʮ (Anaang), Bukhsa Langa, Gumbul, Gumbul Alme (Arabic-Shuwa), U-Bene (Atte), Ice (Ayu), Fund, Kurtu (Bade-Ngizim), Otoh (Ba'ban), Сч̀, Gòfùs, Kácʮoŋ, Kwɛ̀t, Létè, Syìí (Berom), Diba (Bokyi), Gewi, Kula, Liggide (Bole), Mkpini (Busa), Ajingvwo (Chawai), Laura, Ne-Jáárό (Chawai-Kurama), ụ̀bàbá (Degema), Gθ́là, Gila, Gwákθ́rák, Líßè (Dera), Àbụ̀ró, Bàbà (East, Kalbari), Mgbana (Ebira), ẹ̀kpérè, Uko ẹ̀kpéré, Okpan (Edo), Àyàrá, Ékíkóp, Ekpat, Ìkó, Ìkó, Òkpóη (Efik), ạ̀gbị̀nạ̀ (Engenni), Egbele (Epie), U-Kwlobu (Evant), ßiilоonde, ßirdude, Dawđeer, Dumbaare, Eegirde, Faandu Dawa, Faandu Dawara, Faandu Hecceru, Faandu Heccuuru, Faandu Layru, Faandu Urdi, Fawrưđe, Fenndirđe, Futeere, Gonogono, Goraru, Gulum Butu, Gummbal, Gummbal Nalle, Gurmusal, Janndorde, Jantuuru, Jollooru, Junguru, Kuccere, Litaare, Loonde, Mabakachi, Masaki, Mođaare, Namarde, Putteputre, Sanndorđe, Tummbude, Tunduwol, Yonkirde, Yoogirde (Fula-Fulfulde), Kurupta (Ga'anda), Wara (Gure Kahugu), Kucha (Gwanto), Bvokun, Bwebehi, Esshi, Gurra, Gwabwi, Obwe (Gwari), Agofata, Akwato, Borin Danki, Bututu, Búúta, Ďan Jallo, Ďan Kwakwangi, Ďan Udma, Dasa, D'an Jallo, Dúmaá, Duma, Dúmán Gaùraákaa, Gago, Gako, Godo, Gooráá, Gumbali, Guraka, Gyanď ama, Jallo, Kabewa, Ka-Fi-Ďa-Wuya, Kan Doki, Kan Kare, Karuguna, Kata, Kúlùbuútuù, Kundumasa, Kurtun Lalle, Kurtutu, Kurtúú Kwachare, Kwarya Hawainya, Kwoton Tadawa, Leßan Uwar Miji, Lúúdayíí, Másákíí, Moď a, Murgwi, Rudu, San Doki, Shantu, Zunguru, Zuru (Huasa), Bayammi, Ďan Kwakwangi, Jemo, Karuguna, Kululu, Kumbo, Zomodo, Zumudi (West Huasa), Ďɛ́ŋdà, Kußana (Hwana), Hep (Hyam), Ukoko (Ibie), Mwetsa (Icen), E-Tséndégé (Icheve), Σbàtu, Ógò (Idoma), Abwe, Ágbè, Agbo, Ágbụ̀gbà, Akbẹ̀lẹ, Akpẹ̀lẹ, Ebele, Èbèlè, Mbùbò, Mgbò̩lò̩, Ńkúkú, Ñtìkpó, ọba, Ọ́bà, Òbò, Okbili, Okutu, Ò̩nụ̀nụ̀, Oyo, Ugba, ụ̀gbā, Ugbugba, Ùkó (Igbo), Mbùbù, Ọ́bà (Igbo, Awka), Ágbè, Mkpá, Ọ́bà, Ógbūgbá, Úgbā (Igbo, Onishita), Èbèlè, Mgbam (Igbo, Owerri), Àgbò̩rò̩, Ọ́bèlè (Ijo-Ikwere), Ugbá (Isekiri), Àgbá, Ìgògò, Pị̀ghàn, ụ̀gbá, ụ̀gbàgbá, Ùgbàlá, Ùgbégbé (Izon), La (Janjo), Gila (Jara), Akũri, Aku, Kusa, Kwi, Buna (Jukun), Kashiom (Kaje), Ŋgap (Kaka), Kergba (Kanufi-Kaninkhon), Gùwá, Jeni, Jiwi, Kumo, Ngùwú (Kanuri), Đàyí, Jewi, Kare (Karekare), Igwa (Karshi), Kurum (Katab), Ékób (Khana), Nyásó, U-Kpán, Ù-Tikà (Kpan), Gwaraki (Longuda), Tongi (Ndora), Gŏbo, Shókó (Ngamo), Bàbò, Bingi, Evo, Gbàla, Kókpa, Kondò, Kpasà, Vàtà Aflat, Zunguru (Nupe), Ògbòkót (Obolo), ọbọ-Ukwa (Ogori-Magongo), Ugo, Oko (Okpamheri), Apele (Okpe), Ù-Gà (Oring), I-Jendir (Otank), Ribo (Piti), Nba (Shall), Fiê Fiê Küe (Shanga), Bungda (Tera), Bungdi, Dì˚Rbí (Tera-Pidlimndi), Aluku, Iceghe, Ijondogh, Ikpete, Ikpokpo, Iyongu, Kapu, Kwèsé, Mkem, Tsogh, Icogh (Tiv), Ngbana, Ikim, Itut (Ubaghara), Ugban (Uhami-Iyayu), Eki (Ukpe), Okpan, Òwàrá (Urhobo), Lì-Ggó (Uzekwe), Hebi, Maruadde, (Yedina), Àdó, Agbè, Aha, Akèngbè, Akèrengbe, Akoto, Arọ̀, Atọ́, Igbá, Irere Atiowoeyo, Itakun Igbá, Koto, Pánsá (Yoruba), Dagumra (Yungur);
Nepalese: Laukaa, Tito Tumba;
Pakistan: Ghiya, Lauki (Urdu);
Papiamento: Kalabas Di Kore Abou;
Paraguay:Duchubire;
Peru: Mati, Chucña, Yumi;
Philippines: Kalubai, Sikai (Bisaya), Tabungau (Bontok), Tabungau (Illoko), Buliangin (Subanum), Labu (Sulu), Opo, Upo (Tagalog);
Polish: Tykwa Pospolita;

Portuguese: Cabaco, Cajombre, Calabaza;
Russian: Gorljanka, Kalebasa;
Rwanda: Inzuzi Z'ibamba;
Senegal: A-Ngʉ̀ẁ (Basari), Gi-Ngóm (Bedik), Ka Tuk (Diola), I-Ntyen, I-Yawù (Konyagi), Bara, Fié, File (Manding- Bambara), Kalamaa (Mandinka), Fed, Limb, Mbed (Serer), Gamba, Kok, Leket, Mbag, Mbatu, Nanu, Patu, Som, Taglu, Tah, Teletj, Yad, Yomba (Wolof);
Sierra Leone: Sasa, Taga, Chãsa-Lɛ, Pɛpɛ-Lɛ (Bulom), Hσore˚dɛ, Pɛlɛtɛ (Fula-Pulaar), Gɛrɛ, K-Pai, K-Pali, K-Puo, K-Puσ (Gola), Bala, Hemdo,Tala (Kissi), Ba, G-Bala, G-Bara, Ta, Tala (Kono), Kalbas (Krio), Datogo, Kale˚mã, Ke˚bulo (Limba), Kua (Loko), Kpula, Segbula, Tawa, Taw-Tawa, E-Pepe (Mende), Koŋgoe (Vai);
Singapore: Peh Poh (Hokkien);
Slovašcina: Vodnjača;
Slovencina: Flaškovec Obyčajný;
South Africa: Kalbas (Afrikaans),Moraka (North Sotho); Segwana (Tswana), Iselwa (Xhosa, Zulu);
Spanish: Acocote, Cajombre, Calabaza, Calabaza De Peregrino, Calabaza De San Roque, Calabaza Vinatera, Cogorda, Guiro Amargo, Mazo, Pierna De Pobre, Trompeta;
Sri Lanka: Diya Labu (Sinhala);
Sawhili: Mbuyu, Mmumunye, Mmung'unye;
Swedish: Flaskkurbits, Kalebass;
Thai: Khi Luu Saa, Manamtao, Namtao;
Tibetan: Ku Ba, Ku Ba Kha Bo;
The Gambia: Ka Tuk (Diola), Miran (Manding-Mandinka);
Togo: Difrimi (Adélé), Tréka (Ewé), Calebasse (French), Kingkitom (Gurmantché), Filinga (Moore-Nawdam), Langa, Sununga, Dschola, Dshendsha, Langa, Tjikare (Tem);
Tunisia: Qar'a Tawil; Dubb'a; Qar'a Dubba, Qar'a Duruf; Qar'a Aslawiya (Arabic), Takhsait, Ouowi, Laqttine, Tafe- Qeloujla (Berber), Calebasse; Calebasse D'urope, Bouteille, Congourde, Gourde (Local French):
Vietnamese: Bầu Bình Rượu, Bầu Hồ Lô;
West Cameroons: Eyengo (Bafok), Èkáŋgà, Mbàmbe (Duala), Ekondokia (Kundu), Eyengo (Long), Ekodokon (Lundu), Efimbiriki (Mbonge), Ekodokori (Tanga).

Note: In Africa, there is a myriad of vernacular names given to bottle gourd and its varieties in accordance with the fruit size, shape, colour and diverse specific uses in the ethnocultural context of the various ethnic groups found in the different African states.

Origin/Distribution

It is generally accepted that *Lagenaria siceraria* is indigenous to Africa; it reached East Asia and from there was introduced by humans or ocean currents to the Americas (Richardson 1972; Erickson et al. 2005). Accelerator mass spectrometer radiocarbon dating of archaeological specimens indicated that the bottle gourd was present in the Americas as a domesticated plant by 10,000 B.P. (before present), placing it among the earliest domesticates in the New World. Ancient DNA sequence analysis of archaeological bottle gourd specimens and comparison with modern Asian and African landraces identify Asia as the source of its introduction. Today, bottle gourd is widely cultivated throughout the tropics and subtropics and in places further to the north (e.g. USA, Balkans, Transcaucasus).

Agroecology

Bottle gourd is sub-spontaneous in savannah and bushland and is widely cultivated in the tropics and sub tropics from sea-level to 2,500 m altitude. It is also found as an escape especially along riversides and lakeshores. It needs a well-distributed rainfall of 600–1,500 mm and is adapted to semi-arid conditions. The optimum temperature for germination is 20–25°C and the germination rate declines below 15°C or above 35°C. It tolerates low temperatures, but if the temperature drops below 10°C flowering is reduced; it does not tolerate frost. Low temperatures and drought lead to flower and fruit abortion. Bottle gourd grows in a wide range of soil types but prefers well-aerated, fertile soils with pH 6–7. In southern

Africa, it grows from about 245–1,265 m above sea level, in areas with a rainfall of about 400–600 mm annually. It thrives in moderate amount of sunshine.

Edible Plant Parts and Uses

The young, tender, non-bitter bottle gourd fruits, young shoots, leaves and flower buds of non-bitter varieties are eaten as vegetables in Asia and Africa. The fruit is cut or peeled, boiled till soft and eaten with or without salt as snack and also used as pickles. The young fruits are also steamed, fried, used in curries or made into fritters The young fruits are also mashed, salted and fried and used as a stew. In Japan, long strips of fruit skin are commonly boiled, soaked in soya sauce with a little sugar, and used as an ingredient of 'sushi'. Young shoots are boiled with milk or coconut milk to reduce the unpleasant, peculiar flavour. They may also be mixed with other leafy vegetables, e.g. *Asystasia gangetica*, *Cleome gynandra*, *Corchorus olitorius*, *Cucurbita moschata*, *Launaea cornuta* or *Vigna unguiculata*. In southern Africa, the leaves are commonly eaten as a vegetable and are added fresh to maize porridge, or a relish is prepared from them, mixed with other vegetables. Dried leaves are stored for use in the lean season. In Congo, some cultivars have edible leaves, but in most communities the leaves are eaten only as an emergency food. In West Africa, Botswana, Zimbabwe and South Africa, edible oil is extracted from the seed. In southern Africa this oil is used for cooking when alternative vegetable oils are scarce or when disposable incomes are very low, but in West Africa the oil is commonly available in markets. The seeds of less bitter types are roasted and consumed as a snack or pounded and mixed with maize or millet flour. Cooked seeds which are rich in oil are also added to soups. A vegetable curd similar to tofu is made from the seeds. In China, the seeds are boiled in salt water and eaten as an appetizer. Flower buds are used in tea in Madagascar.

Botany

Bottle gourd is a vigorous, monoecious, annual, climbing or prostrate, branching herb, with angular, ribbed, thick, softly hairy stem and proximally bifid tendrils. Leaves are alternate, simple, exstipulate borne on petiole 2.5–12.5 cm long, pubescent, with two small, lateral nectary glands inserted at the leaf base. Leaf blade is broadly ovate to kidney-shaped in outline, 3–33 cm by 4.5–33 cm, undivided or shallowly palmately 5–9-lobed, cordate at base, shallowly sinuate-dentate, palmately veined (Plates 1 and 2). Flowers are unisexual, scented, solitary in leaf axils, regular, pentamerous, up to 15 cm across; receptacle tube obconic-cylindrical, 10–15 mm long, lobes remote; petals free, white, obovate. Staminate flowers on 7–31 cm long pedicels, with 3 free stamens inserted on the receptacle tube and broad connectives. Pistillate flowers on shorter 2–10 cm long pedicels, densely hairy with an inferior ovary, three rudimentary stamens, thick style and 3-lobed stigma. Fruit is a berry, very variable in size and shape, often globular, bottle-shaped or club-shaped, cylindrical, or elongated up to 1 m long, white-yellow to dark green when young (Plates 1–7), sometimes whitish speckled, usually brown when mature and dried, with hard, durable rind, flesh white, spongy and soft, many-seeded. Seeds are oblong, compressed, up to 2 cm long, emarginate at base, with two flat facial ridges, whitish to brownish, smooth, sometimes rugose.

Plate 1 Bottle-shaped fruits and leaves

Plate 2 Clavate fruits and leaves

Plate 3 Clavate, irregularly white-speckled fruits

Plate 4 Elongate fruits with constricted necks

Plate 5 Clavate pale green fruits

Plate 6 Bottle-shaped, non-striated fruits

Nutritive/Medicinal Properties

The nutrient composition of raw fruits of bottle gourd (*Lagenaria siceraria*) per 100 g of fresh edible portion (refuse 30% of ends, skin and seeds) was reported as: water 95.54 g, energy 59 kJ (14 kcal), protein 0.62 g, fat 0.02 g, ash 0.43 g, carbohydrate 3.39 g, calcium 26 magnesium, phosphorus 13 mg, iron 0.20 mg, potassium 150 mg, sodium 2 mg, zinc 0.70 mg, manganese 0.066 mg, selenium 0.2 μg, vitamin C 10.1 mg, thiamine 0.029 mg, riboflavin 0.022 mg,

Plate 7 Bottle-shaped fruits with longitudinal striations

Plate 8 Decorative bottle gourd ornaments

niacin 0.320 mg, pantothenic acid 0.152 mg, vitamin B-6 0.04 mg, total folate 6 μg, vitamin A 16 IU, vitamin A RAE 1 μg, total saturated fatty acids 0.002 g, 16:0 (palmitic acid) 0.002 g, total monounsaturated fatty acids 0.004 g, 18:1 undifferentiated (oleic acid) 0.004 g; total polyunsaturated fatty acids 0.009 g, 18:2 undifferentiated (linoleic acid) 0.009 g; tryptophan 0.003 g, threonine 0.018 g, isoleucine 0.033 g, leucine 0.036 g, lysine 0.021 g, methionine 0.004 g, phenylalanine 0.015 g, valine 0.027 g, arginine 0.014 g and histidine 0.004 g (USDA 2010).

Another analysis reported the following nutrient composition of immature fruits of bottle gourd per 100 g of fresh edible portion (Leung et al. 1968) as: water 93.9 g, energy 88 kJ (21 kcal), protein 0.5 g, fat 0.1 g, carbohydrate 5.2 g, fibre 0.6 g, Ca 44 mg, P 34 mg, Fe 2.4 mg, β-carotene 25 μg, thiamine 0.03 mg, niacin 1.2 mg and ascorbic acid 10 mg. The composition of the leaves per 100 g of fresh edible portion was reported as water 83.7 g, energy 180 kJ (43 kcal), protein 4.4 g, fat 0.3 g, carbohydrate 8.3 g, fibre 1.8 g, Ca 560 mg, P 88 mg, Fe 7.4 mg. This composition is in line with other medium-green leafy vegetables. The seed was reported to contain per 100 g edible portion: water 3.2 g, energy 2,410 kJ (574 kcal), protein 28.2 g, fat 49.8 g, carbohydrate 14.6 g, fibre 2.0 g, Ca 75 mg, P 1,100 mg, Fe 5.3 mg, thiamine 0.40 mg, riboflavin 0.26 mg and niacin 4.6 mg (Leung et al. 1968).

Proximate analysis of the dried seeds of three varieties of *Lagenaria siceraria*: African wine kettle (Akeregbe), Basketball gourd (Igbaademu) and Bushel Giant Gourd (Igbaje) in Nigeria used for flour reported the seeds to have the following nutrient content and functional properties: fat 46.03%, 53.34%, 50.91%; protein 34.64%, 27.71%, 32.70%; total ash 3.75%, 4.07%, 4.5%, moisture 5.67%, 5.13%, 5.67%, carbohydrate 8.29%, 9.00±%, 5.12%; water absorption capacity 65.00%, 101.70%, 75.00% and oil absorption capacity 111.51%, 84.46%, 167.44% respectively (Ogundele et al. 2010). These results showed the three varieties of *Lagenaria siceraria* to be good sources of oil and fat, with functional properties favourable for human consumption and for industrial applications.

Amino acid composition of *L. siceraria* seeds per 100 g (Axtell and Fairman 1992) was found as follows: aspartic acid 2.4 g, threonine 0.85 g, serine 1.24 g, glutamic acid 4.71 g, glycine 1.44 g, alanine 1.22 g, cystine 0.49 g, valine 1.33 g, methionine 0.70 g, iosleucine 0.99 g, leucine 1.80 g, tyrosine 0.80 g, phenylalanine 1.72 g, histidine 0.72 g, lysine 0.87 g, arginine 4.77 g. The fatty acid composition comprised C14:0 (myristic acid) 0.1 g, C16:0 (palmitic acid) 13.8 g, C18:0 (stearic acid) 6.6 g, C20:0 (arachidic acid) 0.1 g, C16:1 (palmitoleic acid) 0.1 g, C18:1 (oleic acid) 17.4 g, C18:2 (linoleic acid) 61.4 g, C18:3 (linolenic acid) 0.1 g (Axtell and Fairman 1992). The seed was found to be rich in linoleic acid, oleic acid, palmitic acid and stearic acid.

Two sterols, fucosterol and campesterol were isolated and identified from petroleum ether

fractions of ethanol extract of dried fruit pulp (Shirwaikar and Sreenivasan 1996). The fruit was reported to have higher amount of soluble dietary fibres (SDF) than insoluble fibres. Pectin was found as the predominant component of SDF which showed a profound effect in lowering serum cholesterol (Chang et al. 1995). The fruit juice was reported to contain β glycosidase-elasterase enzyme (Duke et al. 1992; Van WyK and Gericke 2000).

Flavonoid complexes occurring in *Lagenaria siceraria* were found to be flavone C-glycosides with saponarin being the major C-glycosides (Baranowska and Cisowski 1994). Two flavonoids isoquercitrin (quercetin-3-O-β-D-glucose) and kaempferol, a triterpenoid oleanolic acid, and a mixture of sterols β sitosterol and campesterol were isolated from methanol extract of fruits of *Lagenaria siceraria* (Gangwal et al. 2010). The plant also contained the very bitter compounds cucurbitacins especially in mature fruits, with cucurbitacin B dominating (Enslin and Rehm 1958). Elaterase, an active β-glucosidase, involved in the hydrolysis of the bitter principles of the *Cucurbitaceae,* was isolated from the juice of bitter Cucurbitaceous fruits including *Lagenaria siceria*; it had been reported to split glucose from tri-glucosides and tetra-glucosides (Enslin et al. 1956). A water-soluble polysaccharide isolated from the aqueous extract of the stem of *Lagenaria siceraria* was found to consist of methyl d-galacturonate, 2-O-methyl-D-xylose, and d-xylose in a ratio of 1:1:1. (Ghosh et al. 2008).

Numerous scientific studies have been conducted on various extracts of bottle gourd fruit and seeds revealing the different pharmacological attributes and their potential medicinal application.

Antioxidant Activity

Various extracts of *L. siceraria* fruit showed antioxidant activity (Deshpande et al. 2007). Maximum DPPH scavenging was observed in the acetone extract of the fruit epicarp and was attributable to ellagatannins Ethanol and hydroalcoholic extract also showed antioxidant activity in the order of acetone extract > ethanol > hydroalcoholic but not with petroleum ether, benzene, chloroform and aqueous extracts. The antioxidant activity of the fruit was in the order of epicarp > mesocarp > pulp with seeds. Jiwajinda et al. (2002) found that ethanol fruit extract of *L. siceraria* exhibited 30% inhibition of superoxide formation in xanthine and xanthine-oxidase medium.

Fresh and dried fruits *of L. siceraria* were found to have similar antioxidant activity. Studies by Erasto and Mbwambo (2009) demonstrated that ethyl acetate (EA) extract of the fresh fruits displayed higher DPPH radical scavenging activity than other samples. At 0.01 mg/ml the order of activity was: EA dried fruits (50.6%) < Bt (n-butanol) fresh fruits (53.3%) < Bt (n-butanol) dried fruits (64.8%) < EA fresh fruits (68.6%) < Gallic acid (81.8%). A small change of activity was noted at 0.1 mg/ml, where the sequence was; EA dried fruits (70%) < Bt dried fruits (71.8%) ≤ Bt fresh fruits (72%) < EA fresh fruits (81.6%) < Gallic acid (88.5%). In the reducing capacity assay, n-butanol fresh fruits extract exhibited higher reducing power than all test samples.

The crude ethanol extract of *L. siceraria* fruit exhibited in-vitro antioxidant activity (Deore et al. 2009). At concentrations of 20, 40, 60 mg/ml, the extract produced DPPH radical scavenging inhibition of 79.12%, 83.34% and 91.03% respectively. The reducing power value of the ethanol extracts was concentration dependent. At 20, 40 and 60 mg/ml, reducing powers of both extracts were around 0.12, 0.17 and 0.23, respectively, while a solution of 60 mg/ml of vitamin C, the positive control used in this test, had a reducing power value of 0.3. *Lagenaria siceraria* fruit extracts also scavenged hydrogen peroxide in a concentration-dependent manner. The ethanol extracts of fruits of *Lagenaria siceraria* showed strong H_2O_2 scavenging activity with 0.219 mg/ml IC_{50} value whereas that of the standard, vitamin C was 0.152 mg/ml. In the FTC (ferric thiocyanate) assay the extracts carried the antioxidative potential for chain-breaking inhibition of lipid peroxidation with

inhibition percentage of 73.45%, 81.12%, 93.95% at levels of 10, 20, 30 mg/ml respectively. The crude ethanol extract was found to have flavonoids, saponins, glycosides and phenolic compounds. Total phenolic content was found to be 79.43%.

Anticancer Activity

Four new D:C-friedooleanane-type triterpenes, 3 β-O-(E)-feruloyl-D:C-friedooleana-7,9 (11)-dien-29-ol (1), 3 β-O-(E)-coumaroyl-D:C-friedooleana-7,9(11)-dien-29-ol (2), 3 β-O-(E)-coumaroyl-D:C-friedooleana-7,9(11)-dien-29-oic acid (3), and methyl 2 β, 3 β-dihydroxy-D:C-friedoolean-8-en-29-oate (6), together with five known triterpenes with the same skeleton, 3-epikarounidiol (4), 3-oxo-D:C-friedoolena-7,9(11)-dien-29-oic acid (5), bryonolol (7), bryononic acid (8), and 20-epibryonolic acid (9), were isolated from the methanol extract of *Lagenaria siceraria* stems (Chen et al. 2008). Compounds 3 and 9 exhibited significant cytotoxic activity against the SK-Hep 1 cell line with IC_{50} values of 4.8 and 2.1 μg/ml, respectively. A water-soluble polysaccharide composed of methyl-α-d-galacturonate, 3-*O*-acetyl methyl-α-d-galacturonate, and β-d-galactose in a ratio of nearly 1:1:1 was isolated from *L. siceraria* fruit (Ghosh et al. 2009). This polysaccharide showed cytotoxic activity in-vitro against human breast adenocarcinoma cell line (MCF-7).

Antihyperglycemic Activity

Deshpande et al. (2008) reported that *Lagenaria siceraria* fruit had antihyperglycemic activity in alloxan–induced hyperglycaemic rats. Alloxan elevated serum lipid levels of total cholesterol (TC), trigycerides (TGL), low density lipoprotein (LDL-C) and very low density lipoprotein cholesterol (VLDL-C) and reduced that of high density lipoprotein cholesterol (HDL-C). Administration of ethanol extract of *Lagenaria siceraria* fruit at doses of 100 and 200 mg/kg effectively prevented these changes.

Antihyperlipidemic Activity

Chang et al. (1995) reported that the soluble dietary fibre in *Lagenaria siceraria* fruits had a profound effect in reducing serum cholesterol and found that pectin was the predominant component of the soluble fibres. Oral administration of the petroleum ether, chloroform, alcoholic and aqueous extracts from bottle gourd, at doses of 200 and 400 mg/kg body weight in rats, concentration-dependently inhibited total cholesterol, triglycerides, low-density lipoproteins level, and significantly elevated the high density lipoproteins content in normocholesterolemic and Triton-induced hyperlipidemic rats (Ghule et al. 2006a). However, petroleum ether extract did not show the significant effects. Both the chloroform and alcoholic extract exhibited more significant effects in lowering total cholesterol, triglycerides and low density lipoproteins along with increase in HDL as compared to the others. Preliminary phytochemical screening revealed the presence of flavonoids, sterols, cucurbitacin saponins, polyphenolics, proteins, and carbohydrates. The results obtained suggested marked antihyperlipidemic and hypolipidemic activity of the *L. siceraria* fruit extracts. In subsequent studies, Ghule et al. (2009) reported that the metabolic extract of *Lagenaria siceraria* fruits (100, 200 and 300 mg/kg; per os) administered to the high fat-diet-induced hyperlipidemic rats for 30 days also exhibited antihyperlipidemic activity. It elicited a highly significant decrease in lipid levels (total cholesterol, low-density lipoprotein cholesterol, very low-density lipoprotein cholesterol and triglyceride) in the fruit extract treated rats as compared to the rats fed with high-fat diet. Conversely, high-density lipoprotein cholesterol levels were significantly raised. The increase in weight in rats administered with the fruit extract was less when compared to rats fed with high-fat diet. Further, the fruit extract also exhibited significant increase in excretion of bile acids. Mohale et al. (2008) reported that high levels of blood cholesterol, triglycerides, LDL, were significantly reduced and low HDL was significantly increased by the administration of fractions of *L. siceraria* fruit juice. The blood content of cholesterol and trig-

lycerides were enhanced by 3.5 fold and 9.5 fold respectively 24 h after administration of triton. Administration of the ethanol fruit extract (100 and 200 mg/kg p.o.) effectively prevented the rise in cholesterol and triglyceride; the effect was comparable to that of simvastatin (Deshpande et al. 2008).

Hepatoprotective Activity

Ethanol extract of *L. siceraria* fruit at a dose of 250 mg/kg exhibited hepatoprotective activity against carbon tetrachloride induced hepatotoxicity with the petroleum ether fraction exhibiting comparatively greater activity (Shirwaikar and Sreenivasan 1996). Two steroids isolated from the petroleum ether fraction were identified as fucosterol and campesterol.

Deshpande et al. (2008) reported that the ethanol extract of *L. siceraria* fruit showed hepatoprotective activity. The ethanol fruit extract at 100 and 200 mg/kg dose prevented carbon tetrachloride induced increase in the levels of serum glutamate oxaloacetate, serum glutamate pyruvate transaminase, alkaline phosphatase and bilirubin and these data is also in correlation with histopathological findings. Carbon tetrachloride induced hepatotoxic rats showed significant rise in thiobarbituric acid (TBARS) and about 50% decrease in antioxidant enzymes: superoxide dismutase, catalase, and GPx (glutathione peroxidise) levels; administration of the fruit extract normalised these levels and also prevented lipid peroxidation.

Ribonucleolytic Activity

The lyophilized seed extract of *L. siceraria* was found to contain a ribosome-inactivating protein (RIP), designated lagenin with ribonucleolytic activity (Wang and Ng 2000). Lagenin inhibited cell-free translation in a rabbit reticulocyte system with an IC_{50} of 0.21 nM and exerted ribonuclease activity on yeast tRNA with an activity of 45 U/mg. It possessed a molecular weight of 20 kDa, smaller than the range of 26–32 kDa reported for other RIPs.

Analgesic and Antiinflammatory Activities

Fruit juice extract of *Lagenaria siceraria* was found to have analgesic and antiinflammatory effects (Ghule et al. 2006b). The fruit extract (150–300 mg/kg, p.o.) exhibited a concentration-dependent inhibition of writhing and also significantly inhibited both phases of the formalin pain test, but with a less intense effect on the first than on the second phase. The effects of the extract were significantly lower than those produced by morphine (10 mg/kg) and aspirin (300 mg/kg) in the same tests. In several acute inflammatory models, the extract (150 and 300 mg/kg, p.o.) elicited significant inhibitory effects viz. on the ethyl phenylpropionate-induced ear edema formation, carrageenan-induced paw edema, arachidonic acid-induced hind paw edema and of albumin-induced edema in rats. The extract did not produce mortality in concentration up to 4.2 g/kg, p.o. and 0.29 g/kg, i.p.

Lagenaria siceraria fruit juice extract exhibited analgesic and antiinflammatory activities (Shah et al. 2010). The fruit juice extract at a dose of 150–300 mg/kg-1, p.o. exhibited a concentration dependent inhibition of acetic acid induced-writhing in mice and also showed a signification inhibition of both phases of the formalin pain test, but with a less intense effect on the first than the second phase. The juice extract also displayed antiinflammatory activity against acute inflammatory models i.e., ethyl phenyl propionate-induced ear edema, carrageenan and arachidonic acid-induced hind paw edema model.

Diuretic Activity

Vacuum dried juice extract and methanol extract of *Lagenaria siceraria* fruits exhibited diuretic effect in albino rats (Ghule et al. 2007). The rats treated with vacuum dried *Lagenaria siceraria* juice extract (LSJE) and *Lagenaria siceraria* methanol extract (LSME) (100–200 mg/kg; p.o.) exhibited higher urine volume when compared to the respective control. Both LSJE and LSME exhibited concentration-dependent increase in

the excretion of electrolytes such as sodium, potassium and chloride when compared to control group. The elevated diuretic potential of LSFE and LSME was statistically significant and comparable to that of the standard diuretic agent, furosemide (20 mg/kg; i.p.).

Immunomodulatory Activity

Studies by Gangwal et al. (2008a) reported that oral administration of the fractions of methanol extract of *Lagenaria siceraria* fruits at levels of 100, 200 and 500 mg/kg significantly inhibited delayed type hypersensitivity reaction in rats. The n-butanol and ethyl acetate soluble fractions concentration- dependently and significantly inhibited sheep red blood cells induced delayed type hypersensitivity reaction response as indicated by decrease in foot pad thickness of rats compared to control group. Both the fractions, significantly elevated haemagglutination antibody titre in dose dependent manner, the total WBC, neutrophil and lymphocyte counts, while insignificant change were observed in monocyte, eosinophil and basophil numbers. A concentration-dependent elevation in both primary and secondary antibody titre suggested that test fractions possessed promising immunomodulatory activity. Purified saponin mixture (PSM) isolated from the fruits of *Lagenaria siceraria* was found to have immunomodulatory activity (Gangwal et al. 2008b). PSM increased haemagglutination antibody titre and carbon clearance significantly but inhibited delayed type hypersensitivity response in a dose dependent manner at three dose levels ranging from 50 to 150 mg/kg body weight in mice. Mixture of sterols and two flavonoids were isolated from the n-butanol and ethyl acetate soluble fractions of successive methanol extract of *Lagenaria siceraria* fruit and were identified as oleanolic acid (I), mixture of β-sitosterol (II) and campesterol (III), isoquercitrin (IV) and Kaempferol (V) (Gangwal et al. 2009). In immunomodulatory testing, compounds I and IV significantly enhanced haemagglutination antibody titre and significantly inhibited delayed type hypersensitivity response in rats compared to control group animals. They also raised the rate of carbon clearance from the blood of mice indicating increased phagocytosis.

Ethanol extract of *Lagenaria siceraria* fruit also prevented significantly the reduction in humoral immune response, cellular immune response and percent neutrophil adhesion in mice in the presence of chemical stressor i.e., Pyrogallol (Deshpande et al. 2008). The increase in humoral immune response was postulated to be due to increase in antibody responsiveness to SRBC (sheep red blood cells) because of enhanced responsiveness to macrophages and β-lymphocytes in antibody synthesis. The increase in neutrophil adhesion of blood to nylon fibres indicated the process of migration to blood vessels.

Cardioprotective Activity

The fruit powder of *Lagenaria siceraria* showed good cardioprotective effects against doxorubicin induced cardiotoxicity in rats (Fard et al. 2008). Administration of *L. siceraria* fruit powder and doxorubicin to rats significantly decreased QT interval of the heart electric cycle, and was non-significant in ST interval and heart rate compared to the group of rats treated with doxorubicin. There was a significant decrease in serum creatine kinase-MB and aspartate aminotransferase, and significant increase in myocardial GSH (reduced glutathione) and malonaldehyde levels compared to the group of rats treated with doxorubicin. The level of lactate dehydrogenase decreased non-significantly. The increase in SOD (superoxide dismutase) was not statistically significant compared to doxorubicin group, whereas SOD in the doxorubicin group decreased significantly compared to control untreated group. Histopathological observations of *Lagenaria siceraria* treated group showed protection against myocardial toxicity induced by doxorubicin. Toxicity study showed that fruit powder was safe at 5,000 mg/kg. Deshpande et al. (2008) reported that the ethanol extract of *L. siceraria* fruits also elicited increase in force of contraction with decrease in rate of contraction (from 66 to 44) in isolated frog heart when perfused with normal

ringer solution. The cardiotonic action of *L. siceraria* extract was postulated as a beneficial effect on the prevention of disorders of the cardiovascular system in general.

Adaptogenic Activity

Studies by Lakshmi and Sudhakar (2009) reported that pre-treatment of rats with ethanol extract of fruits of *Lagenaria siceraria* at different doses significantly ameliorated the stress-induced variations in the biochemical parameters – serum glucose, triglyceride, cholesterol, BUN (blood urea nitrogen) and cortisol levels, blood cell numbers and organ weights in these stress models. The extract treated animals also showed increase in swimming endurance time. This ability of *Lagenaria siceraria* to prolong the swimming time and ameliorate the stress induced changes in both stress models, suggested an anti-stress and adaptogenic property.

Hyperthyroidism Regulation Activity

Dixit et al. (2008) reported that *Lagenaria siceraria* peel extract could regulate hyperthyroidism, hyperglycemia and hepatic lipid peroxidation in mice. Out of 50, 100 and 200 mg/kg of the peel extract, 100 mg/kg was found to be the most effective and safe concentration, as it could inhibit the levels of serum thyroxine (T4), triiodothyronine (T3) and glucose as well as hepatic LPO. This was further confirmed in T4-induced hyperthyroid animals. After 21 days of treatment, a decrease in the levels of serum thyroid hormones, glucose as well as in hepatic LPO with a parallel rise in antioxidants such as superoxide dismutase (SOD), catalase (CAT) and glutathione (GSH) indicated the efficacy of the test peel in the amelioration of hyperthyroidism, hyperglycemia and hepatic lipid peroxidation. Its antioxidant effect was also shown by in-vitro quenching potential of the peel extract (5–100 µg/ml) on the 1,1-diphenyl-2-picrylhydrazyl (DPPH)-dependent free radicals, carbon tetrachloride (CCl4)- and hydrogen peroxide (H2O2)-induced lipid peroxidation (LPO) in liver tissues.

Anthelminthic Activity

Studies indicated that the methanol and benzene extracts of *Lagenaria siceraria* seeds significantly caused paralysis, and also mortality of *Pheretima posthuma* worms especially at higher concentration of 100 mg/ml, as compared to standard reference piperazine citrate (Smita et al. 2009). The results supported the traditional use of seeds of the plant *Lagenaria siceraria* as an anthelmintic.

The ethanol extracts of the seeds of *Cucumis sativus, Cucurbita maxima* and *L. siceraria* exhibited a potent activity against tapeworm, *Hymenolepis nana*, which was comparable to the effect of piperazine citrate, reference standard (Elisha et al. 1987).

Toxicity studies

In a study, the flesh of bitter fruits fed to rabbits caused restlessness and dyspnoea with death from asphyxia, and paralysis in one animal (Duke et al. 2002).

Traditional Medicinal Uses

Various traditional medicinal uses of the leaves, fruit and seeds of *Lagenaria siceraria* have been recorded from various countries in Africa (Watt and Breyer-Brandwijk, Raponda-Walker and Sillans 1961; Bouquet 1969; Burkill 1985); America (Moerman 1998) and Asia (CSIR 1962; Burkill 1966; Chopra et al. 1986; Duke and Ayensu 1985; Duke et al. 2002; Rahman et al. 2008). *Lagenaria siceraria* is official in Ayurvedic Pharmacopoeia of India, and the fruits are traditionally used for their cardioprotective, cardiotonic, general tonic, diuretic, aphrodisiac, antidote to certain poisons and scorpion strings, alternative purgative, stomach-ache, skin rashes and cooling effects (Deshpande et al. 2008; Mohale et al. 2008; Smita et al. 2009). Cardiovascular disorder is claimed to be relieved following regular intake of bottle gourd juice for about 4–6 months. Juice of fruit used for stomach acidity, indigestion and ulcers. The fruit pulp is considered cool, diuretic, antibilious, and is used as

purgative adjunct; also useful for coughs, asthma, and poison antidote. Poultice of pulp is applied to the head in delirium; to the soles for burning feet. In China, the fruit is traditionally used for its cardioprotective, cardiotonic, general tonic, and aphrodisiac properties. It is also used in treatment of various allergic and inflammatory disorders like bronchial asthma, rhinitis, bronchitis and rheumatism and diabetes. A decoction of *L. siceraria* is employed in the treatment of anasarca, ascites and beriberi.

Seeds are nutritive and diuretic, are used in dropsy and as anthelmintic; and a poultice used for boils. In India, the seed is taken internally, or the seed-oil is applied externally in India for headache. The seed-oil is considered anthelmintic. Leaves are used in Indian medicine as a purgative and a soup of young shoots is tonal against constipation. Leaf juice or decoction is used as emetic. Crushed leaves are employed for baldness and applied for headache. Young shoots and leaves used for enema. In Benin, leaf decoction used for icterus. In India and in Nigeria a leaf-decoction is given for jaundice. A dressing of crushed leaves and palm-oil is applied for urticaria caused by caterpillars in Congo and the use of leaves as baby's nappies is recorded. Leaf sap or crushed leaf decoction is used for dystocia in Togo (Adjanohoun et al. 1986). In the Democratic Republic of Congo (Kivu province – Bushi area) a decoction of grounded leaves of some plant species including *L. siceraria* is used for babesiosis (Chifundera 1998). Flowers are also mentioned as poison antidote. Stem bark is sued as diuretic and roots used as emetic and for dropsy. A root decoction is used as enema in Madagascar (Pernet 1957).

Other Uses

Dried bottle gourd fruits are used as containers for storing and transporting drinking water, porridge, fresh or fermented milk, local beer and wine, liquor (toddy), honey, ghee, animal fat, salt, tobacco, perfume, medicinal herbs, crop seeds or food grains. The dried fruit shells are also made into beehives, containers for brewing beer or keeping clothes (like a suitcase), utensils, cannabis pipes, cups, bottles, bowls, ladles, spoons or into animal traps and decoys, animal feeders, air pumps, well buckets, vases, funnels, floats for fishing nets, beds for babies, washbasins, irrigation pots, cages for chicks, masks and containers for seedlings. Large halves are commonly used for winnowing grain. Dried bottle gourds are used to make many musical instruments and various decorative ornaments (Plate 8). The Luo of Kenya makes a large traditional bugle from bottle gourds, blown during ceremonies and for chasing away wild animals. In West Africa the dried fruit may be used as resonance boxes for the kora (harp or lute) and balafon (xylophone). The Bavenda of southern Africa also use the gourd to make xylophones. Smaller types are used to make single-wire traditional guitars or fiddles. Other musical instruments made from calabashes include drums, wind instruments, rattles and hand pianos.

The gourd is also used to make various ornaments such as necklaces, earrings and other accessories and decorative items. Kikuyu sorcerers of Kenya use calabashes for divination by the casting of lots and to anoint circumcision initiates and marriage couples. The Luo in Kenya traditionally use them for smoking cannabis (*Cannabis sativa*). They are also used for manufacturing Large halves are commonly used for winnowing grain, the smaller sizes are cut at the top or in halves and used as a drinking cup or as ladles. The use of bottle gourd is deeply associated with local culture among African communities. Songs, proverbs, stories, beliefs and myths are associated with bottle gourd in almost every community. In Asia, where many of the abovementioned uses are also found, some bottle gourd cultivars are used as a rootstock for grafting musk melon, watermelon and cucumber to control soilborne diseases.

The cake after expression of the oil from the seeds is suitable for cattle-fodder

Comments

The two botanical subspecies can be differentiated using the following salient characters (Heiser 1973; Teppner 2004):

Lagenaria siceraria subsp. *siceraria* : leaves with smooth or crenate margins not lobe or with round lobes; flowers small to medium; male flowers up to 7 cm across, sepals of male flowers short and broad (2–10 mm long); seeds mostly dark, lesser than two times long as broad. Distribution basically in Asia and Americas

Lagenaria siceraria subsp. *asiactica* (Kobiak.) Heiser: leaves serrate margins sharply 3–5 lobed, triangular lobes; flowers large; male flower 7–12 cm diameter; sepals of male flowers longer and narrower (6–20 mm long); seeds mostly pale, more than two times long as broad. Distribution in Asia and the Pacific.

Selected References

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Luffa acutangula

Scientific Name

***Luffa acutangula* (L.) Roxb.**

Synonyms

Cucumis acutangulus L., *Cucurbita acutangula* (L.) Blume, *Luffa acutangula* (L.) Roxb. var. *acutangula*, *Luffa foetida* Cav., *Luffa fluminensis* M.J. Roem., *Luffa hermaphrodita* Singh & Bandhari, *Luffa plukenetiana* Ser., *Momordica luffa* Vell.

Family

Cucurbitaceae

Common/English Names

Angled Loofah, Angled Luffa, California Okra, Chinese Okra, Ribbed Gourd, Ribbed Loofah, Ridged Luffa, Ribbed Gourd, Ridged Gourd, Silk Gourd, Silky Gourd, Silk Squash, Sinqua Melon, Sinkwa Towelsponge, Strainer Vine, Vegetable Sponge

Vernacular Names

Arabic: Bamya Seeny;
Bangladesh: Jhinga;
Brazil: Bucha De Purga, Bucha-Pepino, Maxixe-Do-Pará (Portuguese);
Burmese: Bju: Da, Byú Dá;
Chinese: Leng Si Gua, Leng SSu Kua, Yue Si Gua, Yueh Ssu Gua, Si Gua, Ssu Kua;
Czech: Lufa Ostrohranná;
Danish: Kantagurk, Kantlufa, Singkwa-Melon;
French: Concombre Papengaie, Papngaye, Eponge Vegetale Torcho;
German: Luffa;
India: Jhinga, Jika (Assamese), Jhinga, Jinga, Sataputi, Titotorai, Titojhinga, Titodhundul (Bengali), Gudari, Jhimani, Jinga, Kali Tori, Karvi Tori, Karvi-Tori, Karviturai, Sataputitorai, Torai, Tori, Turi, Turai, (Hindu), Eere Kaayi, Heere Balli, Heere Kaayi Balli, Heere-Kai, Hire Balli, Hire Kaayi, Hirekayi, Kadupadagila, Kahire, Kahi heere, Kahiheere Balli, Naaga daali balli (Kannada), Cheru-Peeram, Djinji, Peechhakam, Piccil, Piccinna, Picinna, Puichenggah, Puttalpiram (Malayalam), Mayang-Shebot (Manipuri), Dodaki, Dodka, Dodke, Ghosavala Shiralla, Gomsali, Sataputi, Shirola, Turai (Marathi), Ghosala Kunduru, Toorai, Tooria (Oriya), Dhamargava, Dhamargavah, Dhamargowa, Dharaphala, Dirghaphala, Ghantali, Ghosa, Gramya, Jalini, Jhingaka, Karkashachhada, Karkotaki, Katukoshataki, Kausataki, Kesataki, Kosataki, Koshataki, Krishna, Kritachhidra, Kritavedhana, Kritawedhana, Krtavedhana, Krtavedhanah, Kshveda, Ksvedah, Laghukoshataki, Mrdangaphala, Mrdangaphalam, Mridangaphalika, Pitapushpa, Rajakosataki, Rajakoshataki, Rajimatphala, Saptaputri, Sukosha, Supushpa,

T.K. Lim, *Edible Medicinal And Non-Medicinal Plants: Volume 2, Fruits*,
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Sushodhani, Sutikta, Svadukosataki, Svaduphala, Tikta, Tiktakoshataki, Turai (Sankrit), Atalai, Atalakkay, Atalankay, Cakaram, Cakati, Cakkarakkoti, Cakkaram, Calini, Canikappuri, Canikappurikkoti, Canikkappuri, Catini, Catinikkoti, Cattiyam, Cinkakam, Cittirakunam, Curiyanaiyariyappanni, Itukal, Itukalam, Itukali, Itukalikkoti, Kalalapu, Kalapu, Kecattiyam, Kiritaveni, Kirukampali, Kirutacittiram, Kiruttuvetan, Kirutukakkoti, Kirutukam, Kirutuvetan, Kirutuvetanan, Kocamam, Kocari, Kocarppam, Kocavati, Koccam, Kolakakkoti, Kolakam2, Kolunkiri, Kolunkirikkoti, Kosam2, Kovaritaki1, Macukam, Makacalini, Malinavalli, Maruvarikam, Maruvarikkoti, Mirutankapalam, Nacukam, Nacukatitakkoti, Nacukatitam, Narpikkankoti, Narpirkku, Nilappirkku, Pampikai, Patarkay, Patarkaykkoti, Patarkoti, Peerakai, Peerkankaai, Peerkku, Pekankai, Peyppichukku, Peyppirkam, Peyppirkku, Pikangai, Pikunkai, Pirkkangai, Pirkku, Pirkkil, Pikumkai, Picukku, Pir, Pirankoti, Pirkkakkoti, Pirkkankay, Pirkkankoti, Pitaputpi, Racakakkoti, Racakam, Tamarakkavam,Tamarkkatam,Tamarkkatavakkoti, Tamarkkavakkoti, Tamarkkavam, Tamarkkavam, Tikkay, Tinpirkku, Varippirkku, Velakakkoti, Velakam, Velam (Tamil), Beera, Beerakaaya, Beerakaya, Birakaya, B Burkaai, Urkai (Telugu), Bhol (Urdu);

Indonesia: Oyong, Petola (Malay), Langker, Langker Batang, Langker Ghaltek (Madurese), Kimput, Oyong (Sundanese), Gambas, Jeme, Kajur, Oyong, (Javanese);

Japanese: Shokuyou Hechima, Hechima, Togado Hechima;

Khmer: Ronôông Chrung;

Laotian: Mai Loi, Looy;

Malaysia: Ketola, Petola, Petola Segi, Petola Sanding;

Madascagar: Papengaye, Lian Torchon Des Antilles, Papangay (French);

Mauritius: Courge Anguleuse De Chine, Papengaye, Papangay (French);

Nepal: Pate Ghirola, Pate Toriya;

Persian: Khiyar;

Philippines: Buyo-Buyo, Saykua (Bisaya), Patula Baibing (Sulu), Patola, Kabtiti, Patolang, Cabatiti, Patola (Tagalog);

Polish: Trukwa Ostrokątna;

Portuguese: Gousalim, Bucha De Purge, Lufa Riscada;

Singapore: Sin-Kwa (Cantonese), Kak Kuey (Hokkien);

Spanish: Calabaza De Aristas, Dringi;

Sri Lanka: Dara Veta Kola, Veta Kola, Vata Kolu, Wetakolu (Sinhalese);

Taiwan: Si Gua;

Thai: Buap, Buap-Liam, Manoi-Liam;

Tibetan: Ko Sa Ta Ki, Ko-Sa-Ta-Ki;

Vietnam: Skoo Ah (Hmong); Mướp Khía, Mướp Tau.

Origin/Distribution

Luffa is indigenous to the old world tropic, probably India, now naturalized throughout South and south-east Asia and cultivated elsewhere in the tropics and subtropics.

Agroecology

Luffa grows best in areas with maximum temperature range of 30–35°C and a minimum of 20°C. It thrives in full sun and on a well-drained sandy loam soils, with a pH 6.5–7.5 and rich in organic matter. It is found in the lowlands up to 500 m elevation. It is fairly drought tolerant but cold and frost sensitive. Excessive nitrogen fertilisers should be avoided as this reduces flower numbers and fruit set.

Edible Plant Parts and Uses

The young fruits and leaves are used as vegetables, e.g., in China, India, southeast Asia and West Africa. In Indonesia, the young fruit and leaves are eaten raw or steamed as *lalab*. The young fruit are peeled, also sliced and cooked with coconut milk and other ingredient for the preparation of *sayur* and *sambelan*. The immature fruit is also steamed, stir fried, grated into an omelette or fritter or added to soup.

Botany

A vigorous climbing, coarse, monoecious, annual herb with branched, 3-fid tendrils and slender pentagonal, furrowed, densely hairy, green stem. Leaves are distichous to 25 cm long and borne on short, subterete, longitudinally grooved petioles. Lamina is broad ovate in outline, scabrous, shallowly five-seven lobed (Plate 1), lobes mucronate, base forming a deep rounded sinus, 5–7 nerved, gland-toothed and hispid along the margin. Flowers are yellow, 4–5 cm across, axillary, male flowers in long-peduncled raceme, 15–20 flowered, stamen three within campanulate, 5-lobed calyx tube, yellowish green and pubescent; corolla five yellow petals, female solitary with three staminodes and tomentose ovary. Peduncle is hairy and furrowed, elongate after anthesis. Fruit is ellipsoid, clavate or fusiform, narrowed at base and rounded at the apex, 10-ribbed, thinly hairy, densely punctate, shining, grayish green, 30 cm or more long when mature (Plates 1–2), 5 cm across, containing many seeds – broad ellipsoid, 1–1.2 cm by 0.7–0.8 cm and closely packed.

Plate 1 Leaves and fruits of angled luffa

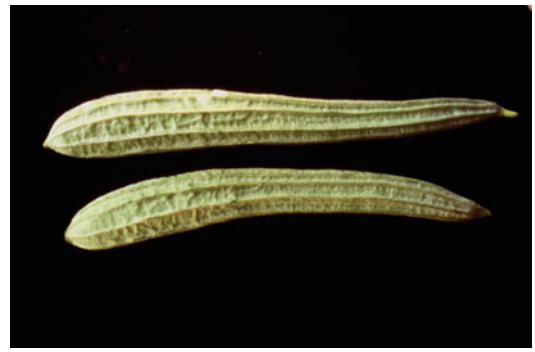

Plate 2 Close up of angled luffa fruits

Nutritive/Medicinal Properties

Food composition of raw angled luffa fruit per 100 g edible portion (54%) was reported as: moisture 94.9 g, energy 53 kJ, (12 kcal), protein 1.2 g, fat 0.1 g, carbohydrate 1.7 g, sugars 1.5 g, starch 0.2 g, dietary fibre 1.4 g, K 160 mg, Ca 14 mg, Mg 14 mg, Fe 0.3 mg, Zn 0.2 mg, retinol equivalent 15 μg, β-carotene equivalent 93 μg, thiamin 0.05 mg, riboflavin 0.01 mg, niacin equivalent 0.4 mg, niacin 0.2 mg, vitamin C 18 mg (English and Lewis 1991).

Seven oleanane-type triterpene saponins, acutosides A-G were found in *Luffa acutangula* and their structures elucidated (Nagao et al. 1991). Acutoside A elucidated as oleanolic acid 3-O-β-D-glucopyranosyl-(1→2)-β-D-glucopyranoside; acutoside B as 28-O-[O-β-D-xylopyranosyl-(1→4)-O-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranosyl] ester; acutoside C as a machaelinic acid (=21 β-hydroxyoleanolic acid) saponin; acutoside D as 28-O-[O-β-D-xylopyranosyl-(1→3)-O-β-D-xylopyranosyl-(1→4)-O-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranosyl] ester; acutoside E as a 28-O-[O-α-L-arabinopyranosyl-(1→3)-O-β-D-xylopyranosyl-(1→4)-O-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranosyl] ester, acutoside F as a 28-O-[O-β-D-xylopyranosyl-(1→3)-[O-β-D-xylopyranosyl-(1→4)-O-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranosyl] ester, and acutoside

G as a 28-O-β-D-xylopyranosyl-(1→3)-[O-α-L-arabinopyranosyl-(1→3)-O-β-D-xylopyranosyl-(1→4)]-O-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranosyl] ester.

Plants of the Cucurbitaceae family are characteristically but not exclusively, producers of cucurbitacins, highly oxygenated triterpenes glycosides. Cucurbitacins isolated from plants of the genus *Luffa* had been reported to various pharmacological properties including antiinflammatory, antimicrobial, antitumoral, cytotoxic and hepatocurative effects (Miró 1995). Cucurbitacin B was isolated from seeds of *Luffa acutangula* (Teo et al. 1990). Other compounds isolated from *Luffa* species included luffaculins, ribosome-inactivating proteins from *L. acutangula* seeds (Ng et al. 1992; Chan et al. 1994; Lin et al. 2002; Wang and Ng 2002; Hou et al. 2006), a glycoprotein from seeds of *Luffa acutangula* with abortifacient effect (Yeung et al. 1991) the trypsin inhibitors LA-1 and LA-2 from *L. acutangula* seeds (Haldar et al. 1996) and a chitotetrose specific lectin from the fruit that was specific for chitooligosaccharides (Anantharam et al. 1985).

Hepatoprotective Activity

Luffa fruit was found to have antihepatotoxicic property (Mukerjee et al. 2007). The ethanolic and aqueous extract (l00 mg/kg) of the fruit displayed significant hepatoprotective effect by reducing the serum level of serum glutamic pyruvic transaminase (SGPT) and serum glutamic oxaloacetic transaminase (SGOT), alkaline phosphatase (ALP) and bilirubin in hepatoxic druckrey rats induced by carbon tetrachloride and paracetamol. The significant hepatoprotective activity of *Luffa acutangula* was comparable to the standard hepatoprotective agent, silymarin.

Administration of the standard drug- silymarin and hydroalcoholic extract of *Luffa acutangula* showed significant hepatoprotection against CCl_4 and rifampicin induced hepatotoxicity in rats (Jadhav et al. 2010). Hepatoprotective activity of angled luffa extract was due to the decreased levels of serum marker enzymes viz., (AST, ALT, ALP and LDH) and increased total protein including the improvement in histoarchitecture of liver cells of the treated groups as compared to the control group. Angled luffa extract also showed significant decrease in malondialdehyde (MDA) formation, increased activity of non-enzymatic intracellular antioxidant, glutathione and enzymatic antioxidants, catalase and superoxide dismutase. Results of the study demonstrated that endogenous antioxidants and inhibition of lipid peroxidation of membrane contributed to hepatoprotective activity of angled luffa extract.

Antiviral Activity

A ribosome inactivating peptide designated luffangulin was isolated from *L. acutangula* seeds (Wang and Ng 2002). It had a N-terminal sequence exhibiting pronounced similarity to that of the 6.5 kDa-arginine/glutamate-rich polypeptide from *Luffa cylindrica* seeds. Luffangulin was found to inhibit cell-free translation with an IC_{50} of 3.5 nM but lacked inhibitory activity toward HIV-1 reverse transcriptase.

Abortifacient Activity

A glycoprotein with a molecular weight of 28,000 was isolated from seeds of *Luffa acutangula* and in immunodiffusion studies it was found to be immunologically distinct from abortifacient proteins isolated from other members of the Cucurbitaceae family including *Momordica charantia, Momordica cochinchinensis, Trichosanthes kirilowii* and *Trichosanthes cucumeroides* (Yeung et al. 1991). The protein from *L. acutangula* was capable of inducing mid-term abortion in mice and inhibiting protein synthesis in a cell-free system.

A glycoprotein protein, luffaculin from *L. acutangula* seeds was reported to be capable of inducing mid-term abortion in mice and inhibiting protein synthesis in a cell-free system (Chan et al. 1994). Luffaculin exhibited abortifacient,

antitumour, ribosome inactivating and immunomodulatory activities. Luffaculin was also reported to have teratogenic effects. Luffaculin at a concentration of 100 μg/ml caused only reductions in embryo somite number and axial length, but at 200 μg/ml produced additional teratogenic defects in yolk sac circulation, body axis, optic placodes, branchial apparatus, forelimb buds and cranial neural tube and defects in optic placodes in developing mouse embryo.

The tea made from fruits of *Luffa acutangula* had been widely used by women for induction of abortion and as a purgative (Lorenzi and Matos 2002), and abortions occurred in ruminants that had ingested the fruits (Silva et al. 2006). Studies conducted by Fernandes et al. (2010) reported that *Luffa acutangula* tea had an abortive effect in rats. No difference between pregnant rats treated with the tea extract or with saline solution on body weight and body weight gain and no sign of maternal toxicity was noticed in females throughout the experiment. The number of points of implantation, live and dead fetuses, corpora lutea and points of reabsorption did not differ between groups but reduced fetal weight was observed in the group treated with *L. acutangula*. The search for external malformations revealed a fetus with cleft palate from a plant-treated mother. No lesion was found at histological evaluation of placentas. The scientists concluded that the ingestion of *L. acutangula* during pregnancy may promote developmental toxicity.

Trypsin Inhibition Activity

Two trypsin inhibitors, LA-1 and LA-2, were isolated from *Luffa acutangula* seeds (Haldar et al. 1996). Both inhibitors strongly inhibited trypsin by forming enzyme-inhibitor complexes at a molar ratio of unity. A chemical modification study suggested the involvement of arginine of LA-1 and lysine of LA-2 in their reactive sites. The inhibitors were very similar in their amino acid sequences, and showed sequence homology with other squash family inhibitors.

Traditional Ethnomedicinal Uses

All parts of the plant are reported to be purgative. In folkloric medicine, the fruit juice was reported to be aperients, demulcent and diuretic. It was administered to women after childbirth in Kelantan, Malaysia. The juice is used as an effective natural remedy for jaundice. Bitter luffa seeds and dry crusts are also available and can be used for the same purpose. A decoction of the leaves has been used for uraemia and amenorrhoea in Java. Juice of leaves was used as eye drop for conjunctivitis and also to prevent the lids adhering at night from excessive meibomian secretion; and externally for sores, itch and various animal bites. A poultice of leaves has been used as poultice for enlarged spleen (splenitis), haemorrhoids and leprosy in India and Bangladesh. Seed oil has been used for dermatitis and an infusion of seeds used as purgative and emetic.

Other Uses

Mature fruits have been reported to be used as plant sponge and soles of beach sandals. In Paraguay, luffa mixed with other plant materials and recyled plastic have been fabricated into panels, furniture and used for house construction. The seeds can be used as cattle fodder and for extraction of a fixed oil.

Comments

Luffas are propagated from seeds.

Selected Reference

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Luffa aegyptiaca

Scientific Name

***Luffa aegyptiaca* P. Miller**

Synonyms

Cucumis lineatus Bosc, *Luffa cathu-picinna* Ser., *Luffa clavata* Roxb., *Luffa cylindrica* (L.) T. Durand & H. Durand nom. illeg., *Luffa cylindrica* M.J. Roem., *Luffa insularum* A. Gray, *Luffa leiocarpa* F. Muell., *Luffa leucosperma* M.J. Roem., *Luffa pentandra* Roxb., *Luffa petola* Ser., *Luffa racemosa* Roxb., *Luffa scabra* Schumach., *Luffa striata* Schrad., *Luffa veitchii* Naud., *Luffa vittata* Spanoghe nom. inval., *Momordica cylindrica* L., *Momordica luffa* L., *Momordica operculata* Blanco nom. illeg., *Turia cordata* J.F. Gmel.

Family

Cucurbitaceae

Common/English Names

Bath Sponge, Common Luffa, Dish Cloth Gourd, Dish-Cloth Gourd, Dishrag Gourd, Rag Gourd, Scrubber Gourd, Smooth Luffa, Sponge Gourd, Towel Gourd, Vegetable Sponge, Wild Vegetable Sponge, Wash-Rag Sponge

Vernacular Names

Arabic: Lûf, Luff;
Bangladesh: Dhundol;
Bolivia: Estropajo;
Brazil: Bucha, Bucha-Dos-Paulistas, Esponja, Gonçalinho;
Chinese: Si Gua, Ssu Kua, Shui Gua, Shui Kua;
Chuukese: Mororof;
Columbia: Estropajo;
Cook Islands: Pō‘Ue, Pō‘Ue, Pō‘Ue, Puru (Maori);
Czech: Lufa Válcovitá, Tivuk Egyptský;
Danish: Egyptisk Luffa, Frottersvamp, Luffa, Luffasvamp, Vegetabilsk Svamp;
Dutch: Loofah, Loefahspons, Nenwa, Plantaardige Spons, Sponskomkommer;
French: Courge Cylindrique De Chine, Courge Torchon, Eponge Végétale;
German: Ägyptische Schwammkürbis, Luffa, Luffa-Gurke, Luffaschwamm, Netzgurke, Schwammgurke, Schwammkürbis;
Guatemala: Estropajo;
Honduras: Estropajo;
Hungarian: Halostök, Luffatök; Szivacstök;
India: Bhatkakrel, Bhatkerela, Bhol (Assamese), Dhundul, Dundul, Hastighasha (Bengali), Dhodka, Dhodka Ghiya Turai, Ghia-Torai, Ghiatarui, Ghiatarul, Ghiaturai, Ghiya Tori, Khiya Tori, Nenua, Purula, (Hindu), Araheere, Bolaheere, Thipri Kaayi, Thuppada Heere, Thuppeere Kayi, Tiprikayi, Tuppahire (Kannada), Cattu-Picinna, Kattupiccil, Kattupiram,

T.K. Lim, *Edible Medicinal And Non-Medicinal Plants: Volume 2, Fruits*,
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Perumpiram, Piccinna, Puttalpiram, Puttilpiram (Malayalam), Shebot (Manipuri), Ghadaghosali, Ghosali, Ghosaalen, Marti-Gomasali, Paarose, Paroshi (Marathi), Dhamargava, Dhamargavah, Dhamargawah, Ghiyatarvi, Kosaphala, Kosataki, Kosathaphala, Kothaphalah, Mahajalini, Mahakosataki, Rajakausataki, Rajakosataki, Sodhani, Enua, Aibhi, Brihatkoshataki, Dirgha-Patola, Dirghapatolika, Ghoshaka, Hastighosha, Hastikoshataki, Hastiparna, Mahaphala, Mahapushpa, Raja-Koshataki, Sapitaka (Sanskrit), Mulukkupperakkai, Meluku Pirk, Pirkku, Guttibira, Mozhukupirkankai, Nuraippirkku, Melukupirkku, Melukuppeyppirkku, Parpirkku, Pichukku, Pikku, Pontukapirkku, Tirkkapatolikam, Virutukacakkoti, Virutukacam, Vattuka, Vattuvakkoti, Vatukikakkoti, Vatukikam (Tamil), Netibirakaya, Nunibeera, Gutti Beera, Nethi Beera, Guttibira, Netibira, Nunebira, Neti Beera (Telugu);
Indonesia: Blestru, Bestru, Blustru (Javanese), Bludru, Ghaludhru, Ghludhru (Madurese), Blustru (Malay), Bulustu, Lopang, Oyong, Emes (Sundanese), Ketola, Timput, Hurunh Jawa (Sumatran), Petulo Panjang;
Italian: Luffa, Luffa D'egitto, Petola, Spugna Vegetale, Zucca Da Spunge;
Japanese: Hechima, Hohima, Ito-Uri, Naga Ito-Uri,;
Khmer: Ronôông Muul;
Korean: Su Sa Mi Oe;
Laotian: Bwàp Khôm, Mak Bouap;
Malaysia: Ketola Manis, Petola Manis, Petola Buntal;
Mauritius: Courge Torchon, Luffa D'egypte, Eponge Végétale, Pétole (French);
Mexico: Estropajo
Nepal: Palo, Ghiroula, Ghiu Toriya;
Nicaragua: Estropajo;
Pakistan: Ghia Tori;
Panama: Estropajo
Peru: Estropajo;
Persian: Khujar;
Philippines: Patola, Tabobog (Bisaya), Patola (Bikol), Kabatiti (Bontok), Kabatiti-Aso, Tabau-Tabau (Iloko), Pepinillo De San Gregorio (Spanish), Patula-Amu (Sulu), Patola, Patolang Bilog, Patulang-Uak, Salag-Salag, Tobobok, Tabubok, Tabobog (Tagalog);
Polish: Trukwa Egipska;
Portuguese: Lufa, Esponja Vegetal, Bucha, Bucha Dos Paulistas, Esfregão, Fruta Dos Paulistas;
Samoan: Meleni Vao;
Russian: Ljufa;
Spanish: Esponja, Esponja Vegetal, Estropajo, Limpiaplatos, Lufa, Pepino Para Paste, Paste, Servilleta Del Pobre;
Sri Lanka: Vatakolu (Sinhala);
Swedish: Luffa;
Tahitian: Aroro, Atiuaea, Huaroro, Huerhaho;
Thai: Buap- Klom, Buap-Rom;
Tibetan: Ra Dza Ko Sa Ta Ki;
Tongan: Fangu 'A Kuma, Mafa'I;
Turkish: Luf;
Uganda: Kyangwe (Luganda), Ekyangwe (Runyoro, Rutooro);
Venezuela: Estropajo;
Vietnam: Mướp Hương;
Wallisian: Mafa'I.

Origin/Distribution

This species is indigenous to the old world tropics, probably Asia.

Agroecology

Luffa grows best in area with mean maximum temperature range of 30–35°C with a mean minimum of 20°C, in full sun and on a well-drained, organic matter rich sandy loam soils, with pH 6.5–7.5. It is fairly drought tolerant but cold and frost sensitive. Excessive nitrogen fertilisers should be avoided as this promotes foliage growth reduces flower numbers and fruit set.

Edible Plant Parts and Uses

Young fruit, flowers and leaves are used as a vegetable either prepared like squash or eaten raw like cucumbers. Young leafy shoots are eaten in Malaysia but not very popular. Common luffa is used in stir-fries with meat or sea food, omelettes,

in soups, stews and curries. In Indo-China, the male flowers and flowers buds are used as vegetables. In Indonesia, the young fruit is sliced and boiled with coconut milk for *sayur* or *sambal*. For *lalab* or *kulub*, the tops of leafy shoots, young leaves, flower buds and flowers are usually steamed first. The seeds are treated with salt and roasted and eaten as a delicacy.

In Maharashtra, India, it is a common vegetable prepared with either crushed dried peanuts or with beans.

Botany

Vigorous climbing, coarse, monoecious, annual herb with branched, 2-3-fid tendrils and slender quadrangular, furrowed, densely hairy, green stem. Leaves alternate, large, broad ovate in outline, or reniform, cordate base, scabrous, hairy, punctate, 5–7 lobed, lobes acute and dentate, 6–25 cm by 7–27 cm wide, petiole hispid, 5–10 cm long. Flowers yellow, 5–7 cm across, axillary, unisexual (Plates 1–2). Male inflorescence, 4–20 flowered crowded into a globe, 3–5 cm diameter, calyx tube cylindrical, 5-lobed, corolla rotate, yellow, stamens 5. Female flower solitary or in raceme, pentamerous, staminodes 5, ovary smooth, cylindrical. Fruit fusiform, ellipsoid-cylindrical, clavate, elongate-cylindrical, smooth with numerous longitudinal streaks or broken longitudinal streaks (Plates 1, 3–4), 10–50 cm by 5–10 cm wide containing many seeds. Seeds flat ovate, smooth, black, 1–12 cm long with wing-like margin.

Plate 1 Fruit, Flower and leaves of sponge gourd

Plate 2 Close-up of flower

Nutritive/Medicinal Properties

Food composition of raw common luffa fruit per 100 g edible portion (73%) was reported as: moisture 93.85 g, energy 84 kJ, (20 kcal), protein 1.2 g, fat 0.2 g, ash 0.40 g, carbohydrate 4.36 g, K 139 mg, Ca 20 mg, Mg 14 mg, Fe 0.36 mg, P 32 mg, Na 3 mg, Zn 0.07 mg, Cu 0.035 mg, Mn 0.092 mg, Se 0.2 µg, vitamin C 12 mg, thiamine 0.05 mg, riboflavin 0.060 mg, niacin 0.400 mg, pantothenic acid 0.218 mg, vitamin B-6 0.043 mg, total folate 7 µg, vitamin A 21 µg RAE, vitamin A 410 IU; total saturated fatty acids 0.016 g, 16:0 0.011 g, 18:0 0.005 g; total monounsaturated fatty acids 0.037 g, 18:1 undifferentiated (oleic) 0.037 g; total polyunsaturated fatty acids 0.087 g and 18:2 undifferentiated (linoleic) 0.087 g (USDA 2010).

Plate 3 Club-shaped fruits

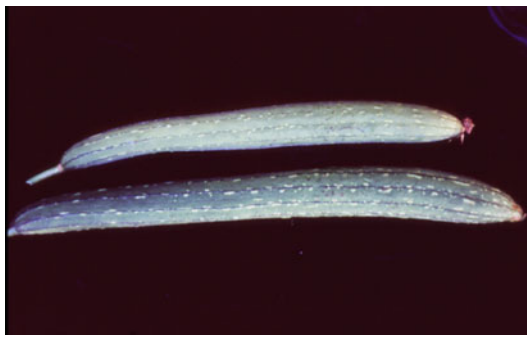

Plate 4 Elongate, cylindrical fruits

Other Phytochemicals

The spongy fibre of the fruit contained cellulose, xylan, mannan, galactan, and lignin. The seeds contained 45.72% fixed oil (Stuart 2010). The fruit also contained saponin and mucilage. Xiong et al. (1994) found the fruit to contain lucyosides C, E, F, H, a mixture of α-spinasterol and stigmasta-7,22,25-trien-3 β-OH and a mixture of α-spinasteryl glucoside and δ-7,22,25-stigmasteryl-β-D-glucoside.

From *L. cylindrica* fruit 9 saponins were isolated: lucyoside-J(3,28-O-bis-β-D-glucopyranosyl 21β-hydroxygypsogenin), lucyoside-K (3-O-β-D-glucopyranosyl gypsogenin), lucyoside-L (3-O-β-sophorosyl-28-O-β-D-glucopyranosyl gypsogenin) and lucyoside-M (3-O-(6′-acetoxy-β-O-D-glucopyranosyl)-28-O-β-D-glucopyranosyl gypsogenin) (Takemoto et al. 1984). The saponins 6, 10, 11, 14 and 15 were identified as lucyoside-A, lucyoside-E, lucyoside F, 3-O-β-D-glucopyranosyl hederagenin and 3-O-β-D-glucopyranosyl oleanolic acid, respectively, the three former of which have already been isolated from this plant. lucyoside-A, lucyoside-E, lucyoside F and lucyoside-I (3-O-β-D-glucopyranosyl arjunolic acid) were also isolated from other plant parts. A new flavone glycoside, methyl ester of diosmetin 7-O-β-D-glucuronide was isolated from the fruits of *Luffa cylindrica* (Du and Cui 2007).

Two new fibrinolytic saponins, lucyosides N and P, were isolated from the seeds of *Luffa cylindrica* (Yoshikawa et al. 1991). Lucyoside N was characterized as 3-O-β-D-galactopyranosyl-(1→2)-β-D-glucuronopyranosyl-28-O-β-D-xylopyranosyl-(1→4)-[β-D-glucopyranosyl-(1→3)]-α-L-rhamnopyranosyl-(1→2)-α-arabinopyranosyl quillaic acid. Lucyoside P was characterized as a gypsogenin glycoside with the same sugar moiety as lucyoside N. *Luffa cylindrica* seeds also contained 4 arginine/glutamate rich polypeptides: 5 k-AGRP, 6.5 k-AGRP, 12.5 k-AGRP and 14 k-AGRP (Ishira et al. 1997; Kimura et al. 1997). 5 k- and 6.5 k-AGRPs were single polypeptides, but 12.5 k- and 14 k-AGRPs consisted of two polypeptide chains, linked by disulfide bond(s). Comparison of the sequences with those of proteins in the protein data base demonstrated that 5 k- and 6.5 k-AGRPs had a significant homology with a basic peptide from pumpkin seeds and with cocoa seed vicilin, respectively, and that 12.5 k- and 14 k-AGRPs were related to 2S seed storage proteins.

A new pentacyclic triterpenoid saponin, lucyoside R, was isolated from the leaves of *Luffa cylindrica* along with lucyoside G (Liang et al. 1997). Other chemicals including bioactive antioxidants and the ribosome inactivating proteins (RIPs) are discussed below.

Antioxidant Activity

The fruit has antioxidant activity as determined by the radical scavenging DPPH (1,1-diphenyl-2-picrylhydrazyl) assay. Eight bioactive constituents identified included: *p*-coumaric acid,

1-*O*-feruloyl-β-D-glucose, 1-*O*-*p*-coumaroyl-β-D-glucose, 1-*O*-caffeoyl-β-D-glucose, 1-*O*-(4-hydroxybenzoyl) glucose, diosmetin-7-*O*-β-D-glucuronide methyl ester, apigenin-7-*O*-β-D-glucuronide methyl ester and luteolin-7-*O*-β-D-glucuronide methyl ester (Du et al. 2006).

The oil obtained from seed kernels of *L. cylindrica* exhibited significant antioxidant activity (Prakash Yoganandam et al. 2010). The free radical scavenging activity of the different concentrations of the seed oil (1%, 2%, 4%, 8% and 10% (v/v) in dimethyl suphoxide) increased in a dose dependent fashion. In DPPH method, the seed oil in 10% (v/v) showed 90.91%. In the nitric oxide and hydroxyl radical scavenging assays, the activities were found to be almost identical. The 10% (v/v) oil concentration also inhibited the peroxide generated from chick liver homogenate by 58.89%. The antioxidant potential was attributed to the presence of polyunsaturated fatty acids.

Ribosome Inactivating Proteins and Associated Activities

Numerous papers have been published on the isolation of ribosome inactivating proteins from *Luffa cylindrica* and their antitumorous, abortifacient, antitumour, anti-viral and immunomodulatory activities (Gao et al. 1994; Li et al. 2003a, b; Ng et al. 1992a; Parkash et al. 2002; Poma et al. 1998; Poma et al. 1999; Wang and Ng 2001; Wang et al. 2010; Zhang et al. 1998). A ribosome inactivating protein is a protein synthesis inhibitor that acts at the ribosome.

A protein with a molecular weight of about 30,000 was purified from the seeds of *Luffa aegyptiaca* (Ramakrishnan et al. 1989). This protein inhibited cell free translation at pM concentrations. In spite of functional similarity to other ribosomal inhibitory proteins, the NH2-terminal analysis did not show any significant homology. Competitive inhibition studies indicated no immunological cross-reactivity between the inhibitory protein from *Luffa aegyptiaca*, pokeweed antiviral protein and recombinant ricin A chain. Chemical linkage of the protein to a monoclonal antibody reactive to transferrin receptor resulted in a highly cytotoxic conjugate.

Another peptide, designated Luffin P1 from the seeds of *Luffa cylindrica* exerted potent inhibition on protein synthesis in the cell-free rabbit reticulocyte lysate with IC_{50} of 0.88 nM (Li et al. 2003b). The purified luffin P1 not only strongly inhibited protein synthesis in rabbit reticulocyte lysate cell-free translation system with IC_{50} of 0.6 nmol/L, but also exhibited trypsin inhibitory activity with IC_{50} of 22 μmol/L (Li et al. 2003a). Luffacylin isolated from *L. cylindrica* seeds inhibited translation in a rabbit reticulocyte lysate system with an IC_{50} of 140 pM and reacted positively in the N-glycosidase assay for ribosome inactivating proteins (Parkash et al. 2002). Luffacylin also exerted anti-fungal activity against *Mycosphaerella arachidicola* and *Fusarium oxysporum*.

Three new proteins which inhibited protein synthesis in rabbit reticulocyte lysates were isolated from an extract of Luffa *cylindrica* seeds (Watanabe et al. 1990). These three protein-synthesis inhibitory proteins (PSIs) had molecular masses of 19 kDa, 15 kDa, and 9 kDa, and were designated 19 K-PSI, 15 K-PSI, and 9 K-PSI, respectively. Although the 19 K-PSI had no effect on protein synthesis in HeLa cells, its inhibitory activity on the cell-free protein synthesis was 340-times and 83-times more potent than those of ricin A-chain and luffin-a, respectively, probably attributable to hydrolysing mRNA. The inhibitory activities of 15 K- and 9 K-PSIs on the cell-free protein synthesis were weaker than those of ricin A-chain and luffin-a.

Luffin-S a small novel ribosome-inactivating protein was isolated from the seeds of *Luffa cylindrica* (Gao et al. 1994). Luffin S was found to be different from Luffin-A and B, both RNA N-glycosidases with molecular weights of 27 and 28 kDa, respectively, Luffin-S had a molecular weight of only approximately 10 kDa, much smaller than any other RIPs thus far investigated. Its abundant resources, toxicity similar to trichosanthin (TCS) in a cell-free protein synthesis system and unique mechanism as phosphodiesterase, like α-sarcin, made it a potential toxic moiety of

immunotoxin. A group of novel RIPs—Luffin S(1), Luffin S(2), Luffin S(3) with similar molecular weights of about 8 kD were purified from the seeds of *L. cylindrica* (Xiong and Zhang 1998). The N-terminal amino acid is Ala, Pro and Thr in Luffin S(1), Luffin S(2) and Luffin S(3) respectively. The N-terminal nine amino acid sequence of Luffin S(2) was determined as Pro-Arg-Arg-Gly-Gln-Glu-Ala-Phe-Asp. The reaction mechanism of Luffin Ss was similar to that of TCS (trichosanthin), an RNA N glycosidase. Luffin Ss were more toxic than TCS, with IC_{50} of 1.3×10^{-11}, 1.0×10^{-10} and 6.3×10^{-11} mol/L respectively in a cell-free protein synthesis system. The studies indicated that Luffin Ss may have promising potential to be used as an efficient toxin moiety of immunotoxins.

Anticancer Activity

Two immunologically distinct glycoproteins, fractions C4 and C6, with a molecular weight of 28,000 and 28,500 respectively, were isolated from seeds of *Luffa cylindrica* (Ng et al. 1992a, b). They differed in the content of aspartic acid, threonine, proline and alanine but were otherwise identical in amino acid composition. They were capable of causing mid-term abortion in mice, inhibiting protein synthesis in a cell-free system and inhibiting thymidine uptake by human choriocarcinoma cells. Fractions C4 and C6 corresponded to luffin-a and luffin-b, respectively. The two proteins exhibited abortifacient, antitumour, ribosome inactivating and immunomodulatory activities. In separate studies, an immunotoxin was constructed with luffin B (isolated from *L. cylindrica* seeds) plus Ng76, a monoclonal antibody to human melanoma cell M(21) (Zhang et al. 1998). Luffin B-Ng76 was 4 000-times more cytotoxic to target melanoma cells than free luffin B. The IC_{50} of luffin B-Ng76 for human melanoma M(21) cells and non-target HeLa cells was 2.5×10^{-11} mol/L and 3.0×10^{-8} mol/L, respectively. The results suggested luffin B to be a new potent immunotoxin effector.

Luffin from *Luffa cylindrica* seeds had been successfully incorporated into lecithin /cholesterol and lecithin/cholesterol/dicetylphosphate negatively charged liposomes (Poma et al. 1999). The exposure of melanoma cells to the two types of liposomes resulted in the suppression of protein synthesis and cell growth. Apoptotic cell mortality was verified by means of TUNEL reaction and quantitation of cytosolic oligonucleosome-bound DNA. The toxicity of encapsulated luffin varied with the lipid composition of the liposomes; the strongest effect was observed with lecithin/cholesterol liposomes. These results identified liposome-incorporated luffin to be a possible alternative to immunotoxins for the treatment of human melanoma in-situ. Studies also indicated that luffin, was cytotoxic to human metastatic melanoma cells and in murine Ehrlich ascites tumour cells, with approximately 10-fold greater potency in Ehrlich cells (Poma et al. 1998). Luffin was found to induce an increase in cytosolic oligonucleosome-bound DNA in both melanoma and Ehrlich ascites tumour cells, the level of DNA fragmentation in the former cell line being higher than in the latter. Experiments with melanoma cells indicated that an increase in cytosolic nucleosomes could be supportive of apoptosis as the type of cell death induced by luffin.

Poylsaccharides prepared from the immature fruits of *Momordica charantia, M. balsamina* and *Luffa cylindrica* significantly decreased the viability of the treated Ehrlich Ascites tumour cells (EAC) (Ibrahim et al. 1999). The reduced viability was accompanied by drastic decrease in DNA synthesis in these cells. Both *Momordica* species were more superior to *Luffa*. Water extracts of the immature fruits of the three species significantly reduced the numbers of EAC. The effect was related to their polysaccharide contents in the order of *M. balasmina* > *M. chrantia* > *Luffa cylindrica*. The seed proteins of the three species also exhibited appreciable activity in reducing the numbers of EAC cells and DNA synthesis.

Mature α-luffin, a single-chain Type I ribosome-inactivating protein, was cloned from *L. cylindrica* and found to share 96% amino acid similarity with luffin-a (Liu et al. 2010). The recombinant mature α-luffin was successfully expressed in a partly soluble form in *Escherichia coli* after optimization of expression conditions.

The recombinant α-luffin was found to be slightly toxic to *E. coli*. It inhibited protein synthesis in the rabbit reticulocyte lysate system and also suppressed the growth of the tumour cell lines in a concentration- and time-dependent manner. Additionally, recombinant α-luffin was able to induce cell death by apoptosis. The cytotoxicity of α-luffin towards tumour cells indicated its potential as an antitumour agent.

Antiviral Activity

An **e**xtract of *L. cylindrica* vine was found to have antiviral activity (Xu et al. 1984, 1985, 1987). The extract afforded 66.7–80% protection against Japanese B encephalitis when administered prior to infection but weak protection when given 3.5 hours after infection. The extract had no direct inactivating activity and had no toxic effect both on tissue-cultured cells and in animals when administered considerable large doses. The extract was highly active in inducing resistance to cytopathic alterations in primary rabbit kidney cell cultures challenged with vesicular stomatitis virus. Interferon was induced in rabbit by intravenous injection with the extract. The circulating serum interferon level peaked at 2 hours after injection. The antiviral activity of the luffa vine extract was greatly reduced by heating at 100°C for 45 min and was partially resistant to RNase at concentration of 20 μg/ml. Ultraviolet spectrum of the extract revealed a pattern of nucleic acids.

Several studies have shown that some ribosome inactivating proteins (RIPs) possess strong anti-human immunodeficiency virus (HIV) activity. RIPs are a group of proteins that are able to inactivate eukaryotic protein synthesis by attacking the 28S ribosomal RNA. Recent studies demonstrated that all the RIPs tested (agrostin, gelonin, luffin (from *Luffa cylindrica*), α-momorcharin, β-momorcharin, saporin and trichosanthin) exhibited a very weak inhibitory effect on HIV-1 RT and on HIV-1 protease (Au et al. 2000). In contrast, with the exception of agrostin, all the RIPs tested could strongly suppress HIV-1 integrase, the extent of inhibition varying from 26.1% to 96.3% in an ELISA-based assay. Two RIPs (ribosome inactivating proteins), saporin and luffin, elicited over 90% inhibition in the ELISA-based assay (Au et al. 2000). Both of these two RIPs evoked a potent concentration-dependent inhibition in the 3′-end processing and strand-transfer activities of integrase. The results from this study suggested that the anti-HIV property of RIPs may be due to inhibition of HIV-1 integrase.

Luffin P1, the smallest ribosome-inactivating peptide from *Luffa cylindrica* seeds, exhibited anti-HIV-1 activity in HIV-1 infected C8166T-cell lines (Ng et al. 2011). It was able to bind with HIV Rev Response Element. Nuclear magnetic resonance spectroscopy showed that luffin P1 consisted of a helix-loop-helix motif, with the two alpha helices tightly associated by two disulfide bonds. The findings demonstrated that luffin P1 had a novel inactivation mechanism probably through the charge complementation with viral or cellular proteins.

Abortifacient Activity

Luffin-b was found to have teratogenic activity. (Chan et al. 1994). At a concentration of 100 μg/ml Luffin –b brought about reductions in embryo somite number and axial length and caused defects in yolk sac circulation, body axis, optic placodes, branchial apparatus, forelimb buds and cranial neural tube in developing mouse embryos. Luffin-a did not affect organogenesis in embryos. Luffin-a, luffin-b, ribosome-inactivating proteins from the seeds *of L. cylindrica* elicited a reduction in the circulating titer of estradiol-17β (a potent female sex hormone) in mice (Ng et al. 1994).

Antimitogenic and Antiphage Activity

Luffin also exhibited anti-mitogenic and anti-phage activity. The ribosome inactivating proteins, Luffin from *L. cylindrica*, agrostin and saporin were found to elicit a concentration-dependent inhibition of the mitogenic response of murine splenocytes to concanavalin A (Wang and Ng 2001). The three RIPs were approximately equipotent in this regard, with near maximal

inhibition attained at a dose of 83 nM and approximately 50% inhibition at 830 pM. Trichosanthin was slightly more potent than the three aforementioned RIPs. All of these RIPs were capable of suppressing the replication of phage M13 in the bacterium *Escherichia coli*, the sequence of potencies being luffin > trichosanthin > agrostin when tested at a dosage of 3.5 μM.

Immunomodulatory Activity

Two triterpenoids (sapogenins 1 and 2) isolated from *Luffa cylindrica* showed immunomodulatory activity in male Balb/c mice (Khajuria et al. 2007). Sapogenins 1 and 2 displayed significant concentration-dependent decrease and increase in lymphocyte proliferation assay and phagocytic activity of macrophages. Overall, sapogenins 1 and 2 showed dose relative immunostimulatory effect on in-vivo immune functions in mice. The seeds also possessed fibrinolytic saponins, lucyosides N and P.

Wang et al. (2010) identified a novel class of small molecule RIPs with molecular weights <10 kD from *Luffa cylindrica* seeds. The smallest member of this family, Luffin P1, had a molecular weight of 5226.8 Da, yet possessing a highly potent inhibitory activity on cell-free protein synthesis with IC_{50} of 0.88 nM. They also reported a recombinant hIL-2-Luffin P1 immunotoxin, which potently inhibited T-cell proliferation in mixed lymphocyte reaction and ConA response with IC_{50} of 1.8–10 nM. In-vivo, hIL-2-Luffin P1 significantly extended the survival of major MHC (major histocompatibility complex)-mismatched skin and kidney allografts in animal models. They demonstrated the efficacy of the smallest immunotoxin that could be further combined with other pharmacological and immunological reagents for synergistic control of pathogenic lymphocytes in immune-mediated diseases.

Antidiabetic Activity

Treatment with ethanolic extracts of *Luffa aegyptiaca* (seeds) and *Carissa edulis* (leaves) significantly lowered the blood glucose level in streptozotocin diabetic rats during the first 3 h of treatment (El-Fiky et al. 1996). *L. aegyptiaca* extract decreased blood glucose level with a potency similar to that of the biguanide, metformin. The total glycaemic areas were 589.61 mg/dl/3 hours and 660.38 mg/dl/3 hours for *L. aegyptiaca* and metformin, respectively, vs. 816.73 mg/dl/3 hours for the control. In contrast, in normal rats, both treatments produced insignificant changes in blood glucose levels compared to glibenclamide treatment.

Antiinflammatory Activity

Studies showed that the unsaponifiable matter of the *L. cylindrica* seed oil significantly inhibited the paw edema formation induced by carrageenan when compared to the seed oil or cucurbitacin (Susithra et al. 2010). However the percentage of inhibition was lesser when compared to the standards diclofenac sodium gel and flurbiprofen gel.

Antimicrobial Activity

Ethanol, chloroform and methanol extracts of *L. cylindrica* seeds and leaves showed antimicrobial activity against *Escherichia coli, Staphylococcus aureus, Salmonella typhi* and *Bacillus typhi* (Oyetayo et al. 2007). The extracts were found to contain alkaloids, saponins and cardiac glycosides.

Shaheed et al. (2009) tested aqueous extracts of the seeds and fruit of *L. cylindrica* against total and faecal coliform bacteria in surface water by varying the extract doses and contact times. Inactivation of both faecal coliforms and total coliforms was highly variable and dose-dependent. The maximum coliform inactivation achieved in any trial was 86%. Fruit extracts were more successful at inactivating total coliforms than faecal coliforms. Seed extracts achieved higher coliform inactivation levels than fruit extracts generally. Overall, the antimicrobial potential of seeds and fruit from *L. cylindrica*

was demonstrated; however the disinfection performance was less than would be required for these extracts to be considered reliable disinfectants for drinking water treatment.

Oxytocic Activity

In-vitro experiments using the rat uterus showed that the aqueous leafy extracts of *L. cylindrica* increased rat uterine motility suggesting their oxytocic nature (Kamatenesi-Mugisha et al. 2007).

Traditional Medicinal Uses

Various parts of the plant have been used in folkloric ethnomedicine. *Luffa cylindrica* is reputed to be carminative, pectoral, cooling to the blood, antiseptic, anthelmintic, emmenagogue, facilitate circulation, and galactagogue. It has been reported to be used in the treatment of haemorrhage from bowels or bladder, hemorrhoids, toothache, smallpox, and scarlet fever. The fresh fruit is considered to be cooling, demulcent and beneficial to the intestines, warming to the stomach, and tonic to the genital organs. The more mature or ripe fruit is purgative and the dried fruit steeped used as an emetic. Leaf juice has been reported to be used for amenorrhea in Java, for snake bites and dysentery in India. In the Philippines, the leaves used for skin diseases and orchitis. The seeds are reported emetic and cathartic. An infusion of seeds or an alcoholic emulsion is described as a drastic purgative and anthelmintic. The root is described as hydragogue and cathartic. The vine and root extracts have been prescribed for tooth decay, ozoena, and parasitic affections. In western Uganda the leaf extract is used in inducing labour (Oxytocics) during childbirths.

Other Uses

The fruit is sometimes cultivated primarily for the manufacture of sponges and filters. The sponges (Plate 5) are used for washing dishes, pots, and also for the body as a bath sponge or body scrub commonly used in tandem with shower gels/lotions. The sponges are also used as oil and water filters, sound insulation, shoe/boot insoles, soles of beach sandals, tropical helmets, etc. Mature fruit are harvested and processed by soaking for several days, peeled and adhering flesh is removed from the spongiform network of xylem vessels. In Paraguay, luffa mixed with other plant materials and recyled plastic have been fabricated into panels, furniture and used for house construction. The sponges are bleached, cleaned and dried in the sun. The seeds can be used as cattle fodder and for extraction of a fixed oil.

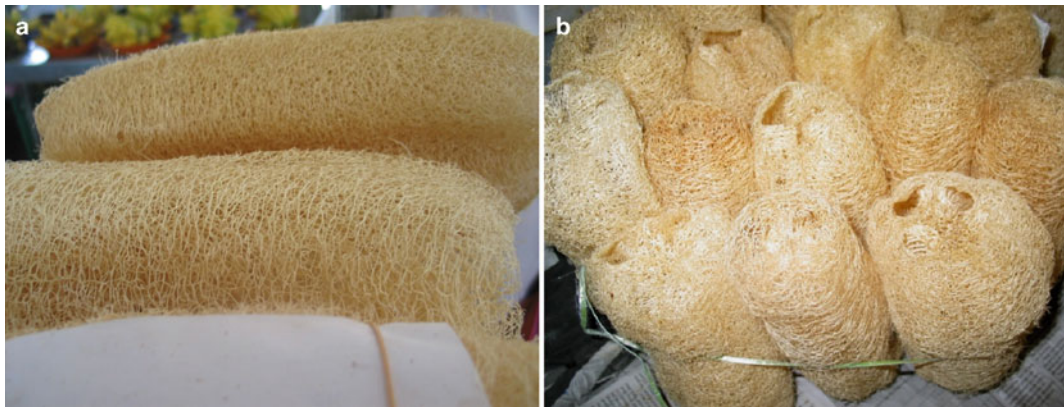

Plate 5 (**a**) and (**b**) Dried, peeled sponge gourds

Comments

Luffas are propagated from seeds.

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Momordica charantia

Scientific Name

***Momordica charantia* Descourt.**

Synonyms

Cucumis africanus Lindl., *Cucumis argyi* H. Lév., *Cucumis intermedius* M.J. Roem., *Momordica anthelmintica* Schumach., *Momordica balsamina* Blanco, *Momordica charantia* subsp. *abbreviata* (Ser.) Grebenšč., *Momordica charantia* var. *abbreviata* Ser., *Momordica charantia* var. *minor* Naud., *Momordica chinensis* Sprengel, *Momordica cylindrica* Blanco, *Momordica elegans* Salisb., *Momordica indica* L., *Momordica jagorana* C. Koch, *Momordica muricata* Willd., *Momordica operculata* Vell., *Momordica senegalensis* Lam., *Momordica sinensis* Spreng., *Momordica zeylanica* Mill., *Sicyos fauriei* H. Lév.

Family

Cucurbitaceae

Common/English Names

Alligator Pear, Balsam Pear, African Cucumber, Balsam-Apple, Balsam Pear, Bitter Cucumber, Bitter Gourd, Bitter Melon, Bitter Momordica, Carilla Gourd, Cerasee, La-Kwa (USA), Leprosy Pear, Leprosy Gourd, Squirting Cucumber, Tuberculated Momordica

Vernacular Names

Arabic: Hanzal;
Bahamas: Wild Balam Pear;
Brazil: Melão-De-São-Caetano, Melãozinho (Portuguese);
Burmese: Kyethinkhathee;
Chamorro: Almagosa, Atmagoso, Atmagosu;
Chinese: Fu Kwa, Foo Gwa, Foo Kwa, Ku Gua, Jin Li Zhi, Lao Pu Tao (Fruit) Ku Gua Ye, Foo Gwa Yip (Leaves);
Cook Island: Menemene, Pō Kutekute, Pōkutekute Rengarenga (Maori);
Danish: Agurkagtig Balsamæble, Balsamaeble, Balsampære, Bitteragurk, Karela, Momordica Balsamagurk;
Dutch: Balsempeer, Sopropo, Springkomkommer;
Fiji: Armagosa, Karela, Poiyoi, Naere;
Finnish: Karvaskurkku;
French: Concombre Africain, Concombre Amer, Liane Merveille, Margose, Margose Amère, Momordique, Momordique Amère, Paroka;
German: Balsambirne, Bittergurke, Balsamgurke;
Haiti: Asosi (Creole);
Hungarian: Balzsamkörte, Balzsamuborka;
India: Karalla (Assamese), Kôrolla (Bengali), Kareli (Gujerati), Karelā, Kerala, Kerela, Tita Kerala (Hindu), Hāgala Kāyi (Kannada), Kārate

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(Konkani), Kaippa, Kaipakka, Pavakkya, Paval (Malayalam), Karol (Manipuri), Kārle (Marathi), Kalara (Oriya), Karelā (Punjabi), Karavellam (Sanskrit), Pava Aki, Pavakka (Tamil), Kākara (Telugu), Kānchaal (Tulu), Karelā (Urdu);
Indonesia: Pare, Pare Alas (Javanese), Pari, Pepare, Peria (Malay), Paria, Paria Leuweng (Sundanese), Paria, Parea, Pepareh (Madurese);
Iran: Sinahang;
Italian: Balsamini Lunghi, Pomo Meraviglia, Momordica Amara;
Ivory Coast: Acoatiango (Abure), Sing Biep (Adyukru), Nia-Nia (Akan-Asante), Ato M-Bomu (Akye), Nia-Nia (Anyi), Bobobo, N'guéné Boué, N'guéré (Guere), Nienbélé (Kru-Bete), Nania-Nania (Neyo), Zagué Zru (Kru);
German: Balsambirne, Balsamgurke, Bittergurke;
Ghana: Nya-Nya (Akan-Asante), Nya-Nya (Fante), Nyanylã (Ga), Kaklẽ (Gbe-Vhe), Nya-Nya, Nyinya (Tiwi), Kaklẽ (Vhe);
Guinea-Bissau: Sancaetano (Crioulo), Burbóqui, Buroki (Fula-Pulaar), Cassêlaha, Cosselaha (Jakhankhe), Isróbódô (Manding-Mandinka);
Jamaica: Cerasee;
Japanese: Gōyā (Okinawa), Ki-Uri, Niga Uri, Nigai Uri, Reishi, Tsuru Reishi;
Kampuchea: Mreah;
Korean: Yôju;
Laos: Bai Mak Phak Sai, Bai Maha, Haix, Phak Hai, S'aix;
Liberia: Gã Gĕ Su Lu (Mano);
Malaysia: Peria, Peria Laut, Periok;
Mali: Lumba-Lumba (Songhai), Manamat (Tamachek);
Mauritius Islands: Margose;
Nepal: Karelaa, Tito Karela;
Nigeria: Ndakđì (Dera), Dagdaggi, Habiiru, Lele Duji (Fula-Fulfulde), Hashinashiap (Goemai), Daddagu, Gàraàfúnií, Garahuni (Huasa), Iliahia, Ilialihia (Igala), Kakayi, Akban Ndene (Igbo), Dàgdágθ (Kanuri), Akara Aje, Ejìnrìn, Ejìnrìn Nla, Ejìnrìn Wẹ̀ẹ̀ri, Ejirin, Ejirin-Wẹ́wẹ́, Ìgbólé Ajá (Yoruba);
Norwegian: Balsamfrukt, Bitter Gord, Bitteragurk, Bittermelon;
Pakistan: Karelā (Urdu);
Palau: Markoso;
Panama: Balsamino;
Persian: Komboze;
Philippines: Marigoso, Paria (Bikol), Palia (Bontok), Palia (Bisaya), Apape (Ibanag), Palia (Ifugao), Paria (Iloko), Apapet (Itogon), Aplia (Pampangan), Paria, Saligun (Sulu), Pulia (Subanun), Ampalaya, Ampalia, Apalaya, Margoso (Tagalog);
Polish: Przepękla Ogórkowata;
Portuguese: Melão-De-São-Caetano;
Puerto Rico: Cun De Amor, Machete;
Réunion: Margose (French);
Senegal: Beurbŏh (Fula-Tukulor), Zara (Manding-Bambara), M-Barböf, M-Burböf, Yombebute (Wolof);
Sierra Leone: Sapodila (Krio), Kuru-Kurinyi (Susu), Agini (Vulgar);
Singapore: Kor Kuey (Hokkien);
Slovaščina: Momordika;
Spanish: Achoccha Silvestre, Achocha China, Balsamina, Balsamito, Bálsamo, Calabaza Africana, Cunde Amor, Melo De Ratón, Momordica Amarga, Papayiyo, Pepinillo, Pepino Amargo, Pepino Cimarrón;
Sri Lanka: Karawila (Sinhalese);
Swedish: Bittergurka;
Taiwan: Kŭguā
Thai: Maha, Mara, Marajin, Phakha;
Tobago: Caraili;
Tonga: Meleni 'Ae Kuma, Vaine 'Initia;
Trinidad & Tobago: Karailī (Hindu), Caraili, Caraille, Carilley;
Turkish: Kudret Narı;
Vietnamese: Khổ Qua (Southern), Mướp Đắng (Northern), La Khoqua (Leaves);
West Indies: Balsam Pear, Carilla, Kuguazi, Mexicaine, Pomme Z'indiens.

Origin/Distribution

The exact origin of bitter gourd is unknown; it is found in the old world tropics probably in India or China. Bitter gourd is widely distributed and cultivated throughout the tropics and is adventive in the New World.

Agroecology

In many areas in tropical Asia, bitter gourd has naturalized in thickets, waste places, forest margins in dry to moist areas from sea level to 1,300 m elevation. The crop thrives in areas where squashes and melons grow best. It is frost sensitive and low temperature will delay plant growth and affect yield. The crop needs to be supported by growing on stakes or trellises if the fruit are to be kept off the ground. Being shallow rooted it needs adequate water for good plant growth and yield and grows best on light–textured, free draining, and loamy soils rich in organic matter. Water-logged soils should be avoided. It benefits from good mulching.

Edible Plant Parts and Uses

The mature, unripe green fruits and young tender leafy shoots are eaten as vegetables (Plates 1–6). The seeds are edible but are usually discarded as they can cause nausea. Bitter melons are seldom mixed with other vegetables due to the strong bitter taste, although this can be moderated to some extent by salting and then washing the cut melon before use. Bitter melon is often used in Chinese cooking for its bitter flavor, typically in stir-fries (often with pork, chicken and *douchi*), soups, and or sliced and stuffed with minced pork or fish paste. Bitter melon slices are dried and used as herbal tea. This is very popular in China and Vietnam. In Vietnam, raw bitter melon slices are consumed with dried meat floss and stuffed to make bitter melon soup with shrimp or sliced and used with eggs in soup. Bitter melons stuffed with minced pork are served as a popular summer soup in the South. Bitter melon is rarely used in mainland Japan, but is a significant component of Okinawan cuisine and is deemed as its national vegetable and honoured with a special festive day – Goya honouring day. There is a myriad of recipes with Goya including Goya dumplings, Goya omelettes, soups, stir fries (Goya *chanpuru*), steamed Goya and stews. Fermented bitter melon tea is popular in Okinawa. Goya has also been credited with the long life expectancies of the Okinawans.

Plate 1 (**a**) and (**b**) Different bitter melon varieties

Plate 2 Mature but unripe marketable bitter melons

Bitter melon is relished in various dishes in the Philippines. The fruit of the wild form is usu-

Plate 3 White bitter melon variety

Plate 4 Flower and foliage of bitter melon

Plate 5 Whole and halved bitter melon fruit

Plate 6 Young leafy shoots sold as vegetable greens

ally roasted over fire and eaten with either salt or "*heko*". That of the cultivated form is eaten as a vegetable with shrimps or meat, eggs and diced tomatoes or as stir fries with minced beef. Sliced bitter melon is mixed with salt, washed and made into salads with sprinkling of shredded '*tinapa*' (cooked or smoked fish), onions and vinegar. A very popular dish from the Ilocos region of the Philippines, *pinakbet*, consists mainly of bitter melons, eggplant, okra, string beans, tomatoes, lima beans, and other various regional vegetables stewed with a little *bagoong*-based stock. *Bagoon* is fermented salted fish. The young shoots and leaves may also be eaten as greens in the Philippines.

In Indonesia, bitter melon is prepared in various dishes, such as stir fry, cooked in coconut milk, or steamed. In one receipe, the fruit is cut length-wise and the halves are stuffed with fried fish, meat or spices and then tied stuffing with sereh (*Piper sarmentosum*) leaves and stewing them. Another version is to stuff the sliced fruit with *sambal goreng* made of minced lombok (large chillies), red onions, dried shrimps, salam leaves, *tras*i (pounded, salted dried fish or shrimps), tamarind and salt and wrapping them in banana leaves and stew. Alternatively, the bitter melon fruit is wrapped in *trasi* and wrapped in a banana leaf and roasted in the ashes. The fruit is also cut into pieces and boiled with lombok, salt, onions and coconut milk. The tender leaves and young fruits are also eaten as *lalab* or *sepan* (steamed vegetable) or as *belem* (roasted over a fire).

In Malaysia, bitter melon is used in soups, stirs fries with chicken or beef slices and ginger, or stuffed with various types of minced meat. One simple and delicious recipe is to fry thin slices of bitter melon with eggs in an omelette. It is popularly used in curries as also in India. Bitter melon is much relished in Indian cuisine. It is often prepared with potatoes and served with

yogurt on the side to offset the bitterness, or used in *sabji* curry. Bitter melon is stuffed with spices and then fried in oil, which is very popular in Punjabi and Tamil cuisine. In Kerala it is popularly used in a dish called *thoran* mixed with *theeyal* (burnt coconut) and pachadi (a type of pickle). In Karnataka, bitter melon is featured in a delicacy called *gojju* (spicy curry) which tastes great with *dosa*s and *chapatis*. Bitter melon *achar* is popular in Nepal, so is bitter melon curry on its own, or mixed with potato, or as stuffed vegetables. In Pakistan, whole bitter melon is boiled unpeeled and stuffed with cooked ground beef and the dish is served with hot *tandoori* bread, *nan, chappati* or with *khichri* (a mixture of lentils and rice). Sliced bitter melon is frequently cooked with lots of onion. In Trinidad and Tobago, bitter melon is sautéed with garlic, onion and scotch bonnet pepper.

Botany

An herbaceous, slender perennial, climber with slightly pubescent stems and leaves and long, unbranched tendril. Leaves are alternate, suborbicular or broadly reniform in outline, 10–12 cm long, 5–8 cm wide, palmately 5-9-lobed; the lobes are sinuate-dentate, margin remotely serrate and petiole 3–8 cm (Plates 4, 6, and 7). The flowers are axillary, solitary, unisexual to monoecious, yellow on long, slender peduncle bearing a foliaceous, reinform bract below the middle (Plate 4). The male flower on shorter pedicel, calyx campanulate, 5-lobed, tube short and thick, yellowish-green, petals 5, yellow, inserted in the throat of the calyx tube and with 3 stamens bearing white anthers. female flower – calyx small with 5 oblong-lanceolate, pubescent, yellowish-green sepals, 5 elliptic or oblong-obovate, yellow, free petals, 5 staminodes, ovary inferior, fusiform, green and warty, style short with 5–6 stigmas. Fruit long-peduncled, obovoid or oblong-cylindric, coarsely ridged and bumpy-tuberculate (warty), 7–30 cm, light green when young (Plates 1–5), orange or dark yellow when ripe, splitting open to reveal numerous ovate-oblong, flattened seeds, 12–16 mm long by 0.6–10 mm wide, covered with a soft, fleshy red aril. There is also a white-fruited cultivar (Plate 3).

Plate 7 Leaves and tendrils

Nutritive/Medicinal Properties

Food composition of raw bitter gourd fruit per 100 g edible portion (refuse 17% stems, leaves) is reported as: moisture 94.03 g, energy 71 kJ, (17 kcal), protein 1.0 g, fat 0.17 g, ash 1.10 g, carbohydrate 3.70 g, K 296 mg, Ca 19 mg, Mg 17 mg, Fe 0.43 mg, P 31 mg, Na 5 mg, Zn 0.80 mg, Cu 0.034 mg, Mn 0.089 mg, Se 0.2 µg, vitamin C 84 mg, thiamin 0.04 mg, riboflavin 0.040 mg, niacin 0.400 mg, pantothenic acid 0.212 mg, vitamin B-6 0.043 mg, total folate 72 µg, vitamin A 24 µg RAE, vitamin A 471 IU, β-carotene 190 µg, α-carotene 185 µg, lutein + zeaxanthin 170 µg (USDA 2010).

Food composition of raw bitter gourd leafy tips per 100 g edible portion (refuse 62% tough stems and leaves) is reported as: moisture 89.25 g, energy 126 kJ, (30 kcal), protein 5.3 g, fat 0.0.69 g, ash 1.47 g, carbohydrate 3.29 g, K 608 mg, Ca 84 mg, Mg 85 mg, Fe 2.04 mg, P 99 mg, Na 11 mg, Zn 0.30 mg, Cu 0.201 mg, Mn 0.536 mg, Se 0.9 µg, vitamin C 88 mg, thiamin 0.181 mg, riboflavin 0.362 mg, niacin 1.11 mg, pantothenic acid 0.063 mg, vitamin B-6 0.803 mg, total folate 128 µg, vitamin A 87 µg RAE and vitamin A 1,734 IU (USDA 2010).

The fruit is a rich source of minerals calcium, potassium, magnesium, phosphorus and iron, vitamin C, vitamin Bs, folate, vitamin A and also has α- and β-carotene. The tender leafy tips are also very nutritious and are excellent source of minerals like the fruit, vitamin C, Bs, folate and vitamin A.

M. charantia fruit (pericarp) is rich in carotenoids. The number of carotenoids isolated increased from five in the immature fruit to six at the mature-green and 14 at the partly-ripe and ripe stages (Rodriguez et al. 1976). Cryptoxanthin, which could not be isolated at the immature and mature stages, accumulated rapidly at the onset of ripening to become the principal pigment of the ripe fruit. Moderate increases were seen in ß-carotene, zeaxanthin and lycopene concentrations as ripening progressed. The reverse trend was observed with lutein and α-carotene which were the major pigments of the immature fruit. Prior to the colour break, only the hydroxy derivatives of α-carotene (zeinoxanthin and lutein) could be detected; the ß-hydroxy compounds (cryptoxanthin and zeaxanthin) appeared and predominated thereafter. The hydroxy carotenoids of the ripe fruit were almost entirely esterified in contrast to those of the unripe fruit which were mainly unesterified. Traces of flavochrome, 5, 6-monoepoxy-ß-carotene, mutatochrome, ζ-carotene, δ-carotene, γ-carotene and rubixanthin were detected in the partly-ripe and ripe fruits but not in the immature and mature-green fruits. Phytofluene was observed in trace levels at all stages (Rodriguez et al. 1976).

The main protein fractions of defatted ripe bitter melon seeds were albumin (49.3%), followed by globulin (29.3%) and glutelin (3.1%) (Horax et al. 2010c). No prolamin was detected, and 18.3% of the protein was non-extractable. The surface hydrophobicities of albumin, globulin, and glutelin were 757, 1,034, and 292, respectively. The molecular sizes of all the fractions were mostly about 45 and 55 kDa. The denaturation temperatures of albumin, globulin, and glutelin were 111.9°C, 117.3°C, and 133.6°C, respectively. The authors asserted that the levels of all essential amino acids in the bitter melon protein fractions met the minimum requirements for preschool children (FAO/WHO/UNU) with the exception of threonine. Bitter melon protein fractions with unique protein profiles and higher denaturation temperatures could impart novel characteristics when used as food ingredients.

Moisture, starch, and total dietary fibre contents of pericarp, from all maturity stages (immature, mature, and ripe), were significantly higher than those of ripe and mature seeds, while lipid and protein contents of seeds were statistically higher than those of pericarp (Horax et al. 2010b). Maturity did not change the lipid content of the pericarp, while maturity progression decreased the protein content of bitter melon pericarp. A significant increase in the protein (30.4%) and lipid (37.6%) contents was observed in bitter melon seeds as the maturity progressed. Ripe seeds that have more than 30% protein could be a good protein source for functional ingredients in a food system. Bitter melon can be considered a good source of these nutrients.

Twenty-five components, representing 90.9% of the oil obtained from the seeds of *Momordica charantia* were identified (Braca et al. 2008). The main constituents were trans-nerolidol, apiole, cis-dihydrocarveol and germacrene D.

Other Phytochemicals from Fruits

Five compounds were isolated from the fresh fruits of *Momordica charantia* (Begum et al. 1997). These include three pentacyclic triterpenes 13-hydroxy-28-methoxy-urs-11-en-3-one (momordicin), 13β,28-epoxy-urs-11-en-3-one (momordicinin), 24-[1′-hydroxy,1′-methyl-2′-pentenyloxyl]-ursan-3-one (momordicilin), a sterol 3β-hydroxy-stigmasta-5,14-dien-16-one (momordenol) and a monocyclic alcohol 1-hydroxy-1,2-dimethyl-2-[8′,10′-dihydroxy-4′,7′-dimethyl-11′-hydroxy methyl-trideca]-3-ethyl-cyclohex-5-en-4-one (momordol). Xie et al. (1998) isolated vincine, mycose, momordicoside A and momordicoside B from the immature green fruits of *M. charantia*. Murakami et al. (2001) isolated eight cucurbitane-type triterpene

glycosides called goyaglycoside-a, goyaglycoside-b, goyaglycoside-c, goyaglycoside-d, goyaglycoside-e, goyaglycoside-f, goyaglycoside-g and goyaglycoside-h and three oleanane-type triterpene saponins termed goyasaponin I, goyasaponin II andgoyasaponin III from the fresh fruit of Japanese bitter melon together with five known cucurbitane-type triterpene glycosides momordicoside A, momordicoside C, momordicoside F1, momordicoside I and momordicoside K.

Kimura et al. (2005) isolated three new cucurbitane-type triterpenoids from the methanol extract of the fruit of Japanese bitter melon: (19R,23E)-5β,19-epoxy-19-methoxycucurbita-6,23,25-trien-3β-ol (1), (23E)-3β-hydroxy-7β-methoxycucurbita-5, 23,25-trien-19-al (2) and (23E)-3β-hydroxy-7β,25-dimethoxycucurbita-5,23-dien-19-al (3). These compounds were accompanied by the known (19R,23E)-5β,19-epoxy-19, 25-dimethoxycucurbita-6,23-dien-3β-ol (4) and (19R,23E)-5β,19-epoxy-19-methoxy-cucurbita-6,23 diene-3β,25-diol (5). This is the first report on the isolation of tetracyclic triterpenoids possessing a delta 23, 25-conjugated diene system, viz., 1 and 2, from a natural source. Nakamura et al. (2006) isolated three cucurbitane-type triterpene called karavilagenin A, karavilagenin B and karavilagenin C and new cucurbitane-type triterpene glycosides called karaviloside I, karaviloside II, karaviloside III, karaviloside IV and karaviloside V from the dried fruit of Sri Lanka bitter melon. Three new cucurbitane-type triterpenoid saponins, named momordicoside M, momordicoside N and momordicoside O, respectively, along with one known saponin momordicoside L were isolated from the fresh fruits of *M.* charantia by Li et al. (2007a, b). Two new (1 and 2) and eight known cucurbitane-type triterpene glycosides and one cucurbitane-type triterpene were isolated from the fruits of *M. charantia* (Liu et al. 2008). The glycosides (7β,25-dimethoxycucurbita-5 (6),23(E)-dien-19-al 3- O-β-D-allopyranoside (1); 25-methoxycucurbita-5(6),23(E)-dien-19-ol 3-O-β-D-allopyranoside (2); momordicoside A, momordicoside F (1), momordicoside F (2), momordicoside G, momordicoside K, and momordicoside L; and goyaglycoside-c and goyaglycoside-d and the triterpene [3 β,7 β,25-trihydroxycucurbita-5,23(E)-dien-19-al].

Three new cucurbitane triterpene glycosides, momordicoside U, momordicoside V, and momordicoside W (1–3) were isolated from *M. charantia* fruits (Nguyen et al. 2010a, b). The structures of these compounds were determined to be (19R, 23R)-5β, 19-epoxy-19-methoxycucurbita-6,24-diene-3β, 23-diol 3-O-β-D-allopyranoside (1), (23R)-5β, 19-epoxycucurbita-6,24-diene-3β, 23-diol 3-O-β-D-allopyranoside (2), and (19R)-5β, 19-epoxy-19,25-dihydroxycucurbita-6,23 (E)-diene-3β-ol 3-O-β-D-glucopyranoside (3). One new cucurbitane-type triterpenoid saponin, 5β,19-epoxycucurbita-6,23-diene-3β,19,25-triol-3-*O*-β-d-allopyranoside, named momordicoside P was isolated from the fresh fruits of *Momordica charantia* (Li et al. 2007a, b). Three new cucurbitane triterpenoids 1–3 and one new steroidal glycoside 4, were isolated together with ten known compounds from *Momordica charantia* fruits (Liu et al. 2009). The structures of new compounds were determined to be 19(R)-n-butanoxy-5β, 19-epoxycucurbita – 6,23-diene-3β,25-diol 3-O-β-glucopyranoside (1), 23-O-β-allopyranosylecucurbita-5,24-dien-7α,3β,22(R),23(S)-tetraol 3-O-β-allopyranoside (2), 23(R),24(S),25-trihydroxycucurbit-5-ene 3-O-{[β-glucopyranosyl (1→6)]-O-β-glucopyranosyl}-25-O-β-glucopyranoside (3), and 24(R)-stigmastan-3β,5α, 6β-triol-25-ene 3-O-β-glucopyranoside (4), respectively. The ten compounds were: karaviloside II, karaviloside III, momordicoside K, kuguaglycoside B, momordicoside L, momordicoside M, momordicoside N, momordicoside B, momordicoside S and momordicoside A. Eight compounds: momordicolide ((10E)-3-hydroxyl-dodeca-10-en-9-olide, 1), monordicophenoide A (4-hydroxyl-benzoic acid 4-O-β-D-apiofuranosyl (1→2)-O-β-D-glucopyranoside, 2), dihydrophaseic acid 3-O-β-D-glucopyranoside (3), 6,9-dihydroxy-megastigman-4,7-dien-3-one (blumenol, 4), guanosine (5), adenosine (6), uracil (7) and cytosine (8) were isolated from *M. charantia* fruits (Li et al. 2009b).

Other Phytochemicals from Stem

Five cucurbitane-type triterpenes, (23E)-25-methoxycucurbit-23-ene-3β,7β-diol (1), (23E)-cucurbita-5,23,25-triene-3β,7β-diol (2), (23E)-25-hydroxycucurbita-5,23-diene-3,7-dione (3), (23E)-cucurbita-5,23,25-triene-3,7-dione (4) and (23E)- 5β19-epoxycucurbita-6,23-diene-3β,25-diol (5), together with one known triterpene, (23E)-5β,19-epoxy-25-methoxycucurbita-6,23-dien-3β-ol(6), were isolated from the methanol extract of the bitter melon stems (Chang et al. 2006). Four new cucurbitane-type triterpenes, cucurbita-5,23(E)-diene-3β,7β,25-triol(1), 3β-acetoxy-7β-methoxycucurbita-5,23(E)-dien-25-ol(2),cucurbita-5(10),6,23(E)-triene-3β,25-diol (5), and cucurbita-5,24-diene-3,7,23-trione (6), together with four known triterpenes, 3β,25-dihydroxy-7β-methoxycucurbita-5,23(E)-diene(3),3β-hydroxy-7β,25-dimethoxycucurbita-5,23(E)-diene (4), 3β,7β,25-trihydroxycucurbita-5,23(E)-dien-19-al (7), and 25-methoxy-3β,7β-dihydroxycucurbita-5,23(E)-dien-19-al (8), were isolated from the methyl alcohol extract of the stems of *Momordica charantia* (Chang et al. 2008). Two new cucurbitane triterpenes, (23E)-7β-methoxycucurbita-5,23,25-trien-3β-ol and 23,25-dihydroxy-5β,19-epoxycucurbit-6-ene-3,24-dione, and a new D:C-friedooleanane triterpene, 3α-[(E)-feruloyloxy]-D:C-friedooleana-7,9(11)-dien-29-oic acid, together with two known D:C-friedooleanane triterpenes, 3β-[(E)-feruloyloxy]-D:C-friedooleana-7,9(11)-dien-29-oic acid and 3-oxo-D:C-friedooleana-7,9(11)-dien-29-oic acid, were isolated from the stems of *Momordica charantia* (Chen et al. 2010).

Other Phytochemicals from Whole Plant, Seeds

Two triterpene glycosides, momordicoside A and momordicoside B, were isolated from the seeds of *Momordica charantia* (Okabe et al. 1982). Their structures were determined as the 3-O-β-gentiobioside and 3-O-β-D-xylopyranosyl (1→4)-[β-D-glucopyranosyl(1→6)]-β-D-glucopyranoside, respectively, of cucurbit-5-ene-3β, 22(S), 23(R), 24(R), 25-pentaol.

One new cucurbitane-type triterpenoid glycoside, momordicoside U (1), together with five known cucurbitane-type triterpenoids and related glycosides, 3β,7β,25-trihydroxycucurbita-5,23(E)-dien-19-al (2), momordicine I (3), momordicine II (4), 3-hydroxycucurbita-5,24-dien-19-al-7,23-di-O-β-glucopyranoside (5), and kuguaglycoside G (6), were isolated from the whole plant of *M. charantia* (Ma et al. 2010).

Five compounds: vacine, mycose, 3-O-(β-D-glucopyranosyl)-24β-ethyl-5α-cholesta-7, trans-22E, 25 (27)-trien-3 β-ol, momorcharaside A and momorcharaside B were isolated from the seeds of *Momordica charantia* (Zhu et al. 1990). Momordin II, a ribosome inactivating protein from bitter melon was found to be homologous to momordin I and trichosanthins (Ortigao and Better 1992).

Other Phytochemicals from Leaves

Three new unidentified cucurbitane triterpenoids and two known compounds, momordicine I and momordicine II, were isolated from bitter melon leaves (Fatope et al. 1990) The following cucurbitane glucosides were isolated from *M. charantia* leaves which exhibited strong oviposition deterrence to the leafminer, *Liriomyza trifolii:* momordicine I (3,7,23-trihydroxycucurbita-5,24-dien-19-al), momordicine II (7,23-dihydroxy-3-O-malonylcucurbita-5,24-dien-19-al), momordicine IV(7-O-β-D-glucopyranosyl-3,23-dihydroxycucurbita-5,24-dien-19-al,) (Mekuria et al. 2005, 2006) and momordicine V (23-O-β-D-glucopyranosyl-7-hydroxy-3-O-malonylcucurbita-5,24-dien-19-al) (Kashiwagi et al. 2007). Momordicine II (23-*O*-β-glucopyranoside of 3,7,23-trihydroxycucurbita-5,24-dien-19-al), a triterpene diglucoside, isolated from the leaves of *M. charantia* exhibited inhibitory effects on the feeding activities of *Spodoptera litura* and *Pseudaletia separata.* Ling et al. (2009) isolated 3 compounds from *M. charantia* with inhibitory effects on the feeding and oviposition of

Liriomyza sativae: (19S, 23E)-5β,19-epoxy-19-methoxy-cucurbita-6,23-dien-3β and 25-diol; (19R,23E)-5β,19-epoxy-19-methoxy-cucurbita-6, 23-dien-3β and 25-diol and 3β, 7β,25-trihydroxycucurbita-5,23-dien-19-al-3-O-β-D-glucopyranoside. Fourteen cucurbitane triterpenoids, kuguacins F-S (1–14), including two pentanorcucurbitacins (6 and 7), one octanorcucurbitacin (8), and two trinorcucurbitacins (11 and 12), along with six known analogues were isolated from the vines and leaves of *M. charantia* (Chen et al. 2009).

Other cucurbitane triterpenoids and phytochemicals isolated are discussed under the various pharmacological activities of the plant. Among the secondary metabolites of *M. charantia,* cucurbitane-type triterpenoids are one of the main bioactive constituents. These compounds and their aglycones have shown various pharmacological and biological activities including antidiabetic, anti-obesity, anticancer, anti-tumour, anti-HIV, antidiabetic, antifeedant and antioviposition activities (Raman and Lau 1996; Grover and Yadav 2004; Beloin et al. 2005; Chen et al. 2005; Lee et al. 2009; Nerurkar and Ray 2010).

Antioxidant Activity

The extracts of leaf, stem and fruit fractions of *M. charantia* were found to have different levels of antioxidant activity in the in-vitro antioxidant systems tested (Kubola and Siriamornpun 2008). The leaf extract showed the highest value of antioxidant activity, based on DPPH radical-scavenging activity and ferric reducing/antioxidant power, while the green fruit extract showed the highest value of antioxidant activity, based on hydroxyl radical-scavenging activity, β-carotene–linoleate bleaching assay and total antioxidant capacity. The predominant phenolic compounds were gallic acid, followed by caffeic acid and catechin. The present study demonstrated that the water extract fractions of bitter gourd have different responses with different antioxidant methods. Total phenol content was shown to provide the highest association with FRAP assay in this present study ($R2 = 0.948$).

Myojin et al. (2008) reported that blanching of sliced bitter gourd resulted in considerable losses of radical-scavenging activity and total phenolics, and most extensively, of ascorbic acid. In the subsequent frozen storage at −18°C, radical-scavenging activity and total phenolic content of unblanched and blanched bitter gourd underwent little change for 90 days then gradually declined, but at −40°C, they practically remained unchanged throughout the entire storage period. However, ascorbic acid content of both unblanched and blanched bitter gourd decreased abruptly at the early stage in frozen storage. The results showed that blanching of bitter gourd improved the retention of radical-scavenging activity and total phenolics during subsequent frozen storage but markedly aggravated loss of ascorbic acid. It was also noted that radical-scavenging activity, total phenolics, and ascorbic acid originally contained in the raw bitter gourd were overall best retained by quick freezing followed by frozen storage at −40°C without preceding blanching.

Hyperammonemic rats (induced by intraperitoneal injections of ammonium chloride (AC), 100 mg/kg body weight thrice a week) showed a significant increase in the activities of thiobarbituric acid reactive substances, hydroperoxides and liver markers (alanine transaminase, aspartate transaminase and alkaline phosphatase), and decrease in the levels of glutathione peroxidase, superoxide dismutase, catalase and glutathione in the liver and brain tissues (Thenmozhi and Subramanian 2011). Treatment with *Momordica charantia* fruit extract (MCE) (thrice a week for 8 consecutive weeks) at 300 mg/kg body weight, normalized the above-mentioned changes in hyperammonemic rats by reversing the oxidant-antioxidant imbalance during AC-induced hyperammonemia, and offered protection against hyperammonemia.

Bitter melon phenolic extracts contain natural antioxidant substances, and could be used as antioxidant agents in suitable food products. Main phenolic constituents in the ethanol extracts of bitter melon fruit (flesh and seeds) were found to be catechin, gallic acid, gentisic acid, chlorogenic acid, and epicatechin (Horax et al. 2010a). Free radical scavenging assay using 2,2-diphenyl-

1-picrylhydrazyl (DPPH) demonstrated the bitter melon extracts acted as slow rate free radical scavenging agents. Kumar et al. (2010) reported that for fibroblasts, total phenolic extract (TPE) of *Momordica charantia* fruit at 200 and 300 μg/ml showed maximum and consistent cytoprotection against oxidants. The extract at 50 μg/ml also had significant and slightly protective effects on rat cardiac fibroblasts against hydrogen peroxide and hypoxanthin-xanthin oxidase-induced damage, respectively. Rat cardiac fibroblast was more tolerant toward the damage. For keratinocytes, a dose-dependent relationship of oxidant toxicity was only seen with hydrogen peroxide but the protective action of the extract correlated with oxidant dosage. At 200 and 300 μg/ml TPE, cytoprotection was dose-dependent against oxidants. Extracts had no effect on hypoxanthin-xanthin oxidase toxicity at 50 μg/ml. Pre-treatment with both the extracts did not show any cytoprotection.

A new multiflorane triterpenoid and two new cucurbitane triterpenoids were isolated from the stems of *Momordica charantia* (Liu et al. 2010). These three new compounds, 1, 2 and 3 displayed ABTS (2,2'-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid)) radical cation scavenging activity with IC_{50} values of 268.5, 352.1 and 458.9 μM, respectively and an inhibitory effect on xanthine oxidase (XO) activity with IC_{50} values of 142.3, 36.8 and 124.9 μM, respectively. This finding indicated that compounds 1–3 could be used as antioxidants.

Anticancer Activity

Numerous studies have shown the efficacy of various extracts of *Momordica charantia* in various cancers (lymphoid leukemia, lymphoma, choriocarcinoma, melanoma, breast cancer, skin tumour, prostatic cancer, squamous carcinoma of tongue and larynx, human bladder carcinomas and Hodgkin's disease) (Grover and Yadav 2004). However, there are only a few reports available on clinical use of *Momordica charantia* in diabetes and cancer patients that have shown promising results.

Crude and purified extracts from *M. charantia* plant was found to cause a slight increase in the life expectancy of mice bearing tumours of Sarcoma 180, and suppressed the growth of Her2 cells in tissue culture (West et al. 1971). Oral administration of the crude whole plant extract to a lymphatic leukaemic patient caused a marked increase in the haemoglobin content of the blood and a noticeable decrease in the white blood cells.

A guanylate cyclase [GTP pyrophosphate-lyase (cyclising)] inhibitor (GCI) was isolated from the aqueous extract of balsam pear fruit (Vesely et al. 1977). The aqueous extract of balsam pear containing GCI was found to inhibit the growth of the rat prostatic adenocarcinoma in-vitro and [3H]thymidine incorporation into DNA (Claflin et al. 1978). The extract containing GCI inhibited the G2 + M phase of the cell cycle. Guanylate cyclase activity was significantly greater in the tumour than normal prostate tissue and was decreased by the extract containing GCI. Cyclic GMP levels in the tumour in culture were also decreased by addition of the extract. In another study, a crude preparation from bitter melon (*M. charantia*) was reported to both inhibit guanylate cyclase activity from various tissues and to prevent growth of concanavalin A-stimulated (con A) rat splenic lymphocytes (Takemoto et al. 1980) The crude extract killed human leukemic lymphocytes in a dose-dependent manner while not affecting the viability of normal human lymphocyte cells at similar doses (Takemoto et al. 1982). The crude preparation also exhibited both cytostatic and cytotoxic activities which are heat stable and trypsin-sensitive. This crude extract also exhibited anti-viral activity (Takemoto et al. 1983). This preparation was inhibitory to both viral and host cell RNA and protein synthesis. The purified factor inhibited both RNA and protein synthesis in intact tissue culture cells and inhibits protein synthesis in a cell-free wheat germ system. DNA synthesis was slightly stimulated. The purified factor was cytostatic for both BHK-21 and for the IM9 leukemic cell lines for at least 120 hours The cytostatic component had no effect on cellular cyclic GMP metabolism. Follow-up studies by Cunnick et al.

(1990) suggested that at least part of the anti-leukemic activity of the bitter melon fruit extract was due to the activation of NK (Natural Killer) cells in the host mouse. NK cells are a type of cytotoxic lymphocyte that constitute a major component of the innate immune system. When the extract was injected twice a week at 8 μg of protein per ip injection for 0–4 weeks, the peritoneal exudate cells from the treated mice were cytotoxic in a long-term (18 h) Cr-release assay against a range of labeled targets; L1210, P388, and MOLT-4 tumour cells. Cytotoxicity was also observed against YAC-1 myeloma cell targets.

Several fractions of the ethanol extract of bitter gourd fruit were found to inhibit growth and induced apoptosis in HL60 human leukemia cells (Kobori et al. 2008b). Among them, fraction 7 had the strongest activity in inhibiting growth and inducing apoptosis in HL60 cells. A component that induced apoptosis in HL60 cells was then isolated from fraction 7 and identified as (9Z,11E,13E)-15,16-dihydroxy-9,11,13-octadecatrienoic acid (15,16-dihydroxy α-eleostearic acid). 15,16-Dihydroxy α-eleostearic acid induced apoptosis in HL60 cells within5 hours at a concentration of 160 μM (50 μg/ml). (9Z,11E,13E)-9,11,13-Octadecatrienoic acid (α-eleostearic acid) is known to be the major conjugated linolenic acid in bitter gourd seeds. Alpha-eleostearic acid strongly inhibited the growth of some cancer and fibroblast cell lines, including those of HL60 leukemia and HT29 colon carcinoma. Alpha-eleostearic acid induced apoptosis in HL60 cells after a 24 hours incubation at a concentration of 5 μM. Thus, α-eleostearic acid and the dihydroxy derivative from bitter gourd were suggested to be the major inducers of apoptosis in HL60 cells.

Momorcharaside A isolated from *M. charantia* seeds exhibited inhibition of DNA and RNA syntheses in S 180 tumour cells in preliminary pharmacological studies (Zhu et al. 1990). Alpha-momorcharin an abortifacient protein extracted from bitter melon showed in-vitro cytotoxicities on cultured choriocarcinoma and melanoma cells (Taso et al. 1990). Alpha-momorcharin inhibited cellular protein synthesis. The marked decrease in secretion of human chorionic gonadotrophin and progesterone by choriocarcinoma cells after treatment with the protein could be attributed mainly to loss of cells. In another study, α-momorcharin, isolated from seeds of the bitter gourd, inhibited incorporation of [3H]thymidine, [3H] leucine and [3H]uridine into P388 (mouse monocyte-macrophage), J774 (Balb/c macrophage), JAR (human placental choriocarcinoma) and sarcoma S180 cell lines (Ng et al. 1994). The most potent inhibitory effect was exerted on P388 cells and the smallest effect on sarcoma cells. Alpha-momorcharin also enhanced the tumoricidal effect of mouse macrophages on mouse mastocytomal (P815) cells. Alpha-momorcharin (alpha-MMC), a ribosome-inactivating protein (RIP) had been reported with excellent cytotoxicity to tumour cells; however, its strong immunogenicity and short plasma half-life limited its clinical applications (Bian et al. 2010). This problem was overcome by PEGylation of α-momorcharin. Homogeneous mono-, di- and tri-PEGylated α-MMCs were synthesized, purified and characterized. In-vitro and in-vivo analysis indicated that the serial PEG-conjugates preserved moderate anti-tumour activity with 36% acute toxicity and at most 66% immunogenicity decrease. These results suggested the potential application of α-MMC-PEG conjugates as an anti-tumour agent (Bian et al. 2010).

Terenzi et al. (1996) reported that the anti-CD30 immunotoxin (IT) Ber-H2/saporin was effective in patients with refractory Hodgkin's disease. However, responses were short and partial, one of the main reasons being the inability to repeat IT doses because of formation of human antibodies against the murine antibody and/or the toxin. They overcame the problem by constructing two new anti-CD30 ITs by covalently linking the mouse monoclonal antibody Ber-H2 to the type 1 ribosome-inactivating proteins (RIPs) momordin (MOM) from balsam pear and pokeweed antiviral protein from seeds (PAP-S), which did not cross-react with each other or with saporin. Both immunotoxins inhibited protein synthesis by Hodgkin's disease and anaplastic large-cell lymphoma (ALCL)-derived CD30+ target cell lines with a very high efficiency (IC_{50} ranging from $<5\times10^{-13}$ M to 2.75×10^{-11} M, as

RIP). In a SCID mouse model of xenografted CD30+ human anaplastic large-cell lymphoma, a 3-day treatment with non-toxin doses of Ber-H2/mormodin (50% LD50), started 24 h after transplantation, prevented tumour development in about 40% of the animals and significantly delayed tumour growth rate in the others. In-vitro and in-vivo results of studies by Porro et al. (1993) suggested that the anti-CD5-momordin conjugate formed by linking the anti-CD5 monoclonal antibody (mAb) to the plant toxin momordin, from *Momordica charantia*, may be useful for graft-versus-host disease therapy and potentially in the treatment of CD5-positive leukemias and lymphomas. The potency of the immunotoxin on peripheral blood mononuclear cells PBMC was very high (IC_{50} = 1–10 pM) and was not affected by blood components. A significant inhibition of the tumour development (80%) in the animals bearing Jurkat leukemia treated with immunotoxin was observed. The conjugate was also very efficient in the inhibition of the proliferative response in a mixed lymphocyte reaction (IC_{50} = 10 pM). Moreover, the in-vitro performances of the immunotoxin compared favourably with those reported for other anti-CD5-based immunoconjugates containing ricin A chain.

Aqueous extract of bitter melon (0.5%) fed to SHN virgin mice significantly inhibited the development of mammary tumours and also inhibited uterine adenomyosis (Nagasawa et al. 2002). No adverse effects of chronic treatments were observed. Bitter melon extract (BME) treatment of human breast cancer cells, MCF-7 and MDA-MB-231, and primary human mammary epithelial cells resulted in a significant decrease in cell proliferation and induced cell apoptosis (Ray et al. 2010). Apoptosis of breast cancer cells was accompanied by increased poly(ADP-ribose) polymerase cleavage and caspase activation. Subsequent studies showed that BME treatment of breast cancer cells inhibited survivin and claspin expression. Further studies revealed that BME treatment enhanced p53, p21, and pChk1/2 and inhibited cyclin B1 and cyclin D1 expression, suggesting an additional mechanism involving cell cycle regulation. Together, these results showed that BME modulated signal transduction pathways for inhibition of breast cancer cell growth and could be used as a dietary supplement for prevention of breast cancer.

Treatment of MDA-MB-231 breast cancer cells with MAP30 (*Momordica* anti-HIV protein, 30 kDa) inhibited cancer cell proliferation as well as suppression of the expression of HER2 gene in-vitro (Lee-Huang et al. 2000). When MDA-MB-231 human breast cancer cells were transferred into SCID mice, the mice developed extensive metastases and all mice succumbed to tumour by day 46. Treatment of the human breast cancer bearing SCID mice with MAP30 at 10 μg/injection for 10 injections resulted in significant increases in survival, with 20–25% of the mice remaining tumour free for 96 days. Thus, antitumour agent MAP30 was found to be effective against human breast cancer MDA-MB-231 in-vitro and in-vivo and may therefore be a potential therapeutic use against breast carcinomas. Wang et al. (2003) demonstrated that MAP30 could effectively inhibit HBeAg expression in HBV DNA-transfected hepatocarcinoma G2.2.15 cells. Lower dose of MAP30 (8.0 μg/ml) could inhibit the expression of HBsAg and HBeAg. Ribosome-inactivating protein from bitter melon seed displayed strong apoptosis-inducing activity and suppressed cancer cell growth (Li et al. 2009a). This was attributed to the activation of caspases-3. The inhibition activity of both polyethylene glycolated (PEGylated) and non-PEGylated RIP against cancer cells was much stronger than against normal cells, and the antigenicity of PEGylated RIP was reduced significantly. The results suggested that the PEGylated RIP might be potentially developed as anti-cancer drugs. The gene of ribosome inactivating protein MAP30 from the seeds of *Momordica charantia* was successfully cloned (Zhang et al. 2010). The recombinant MAP30 showed a greater cytotoxicity to cancer cells than that to normal cells. The recombinant MAP30 protein expressed by *E.coli* was bioactive.

Studies by Fan et al. (2008) showed that the proliferation of human colorectal carcinoma LoVo cells were significantly suppressed by MAP30 in time- and dose-dependent manner at the concentration ranging from 0.67 to 4.67 μM.

The apoptotic nuclei of LoVo cells induced by MAP30 were obviously observed, and the genomic degradation was detected by single-cell gel electrophoresis (comet assay). Nuclear condensation and boundary aggregation or split, apoptotic bodies were seen by fluorescence and electron microscopy. The proportion of the periodic tumour cells was altered by MAP30. The transcription and expression of Bax, a member of pro-apoptotic proteins, were gradually up-regulated as treated time increased. On the contrary, the transcription and expression of Bcl-2, an anti-apoptotic protein, were down-regulated. These data provided strong evidences that recombinant MAP30 can induce the apoptosis of the human colorectal carcinoma LoVo cells.

MAP30 (*Momordica* anti-HIV protein, 30 kDa) was found to have both antiviral and anti-tumour activities. Sun et al. (2001) reported that MAP30 inhibited the proliferation of BC-2, an AIDS-related primary effusion lymphoma (PEL) cell line derived from an AIDS patient. BC-2 cells were latently infected with Kaposi's sarcoma-associated herpes virus (KSHV), also known as human herpes virus 8 (HHV8). The researchers found that MAP30 downregulated the expression of egr-1, ATF-2, hsp27, hsp90, IkappaB, mdm2, and Skp1, while it upregulated the pro-apoptotic-related genes Bax, CRADD, and caspase-3. Thus, MAP30 modulated the expression of both viral and cellular genes involved in Kaposi's sarcoma pathogenesis.

It was found that the ethyl acetate extract of bitter gourd, activated peroxisome proliferator-activated receptor alpha (PPARalpha) to an extent that was equivalent to or even higher than 10 μM Wy-14643, a known ligand of PPARalpha (Chao and Huang 2003). PPARs are ligand-dependent transcription factors that belong to the steroid hormone nuclear receptor family and regulate lipid and glucose homeostasis and tumorigenesis in the body. PPARgamma ligands inhibit primary tumour growth and metastasis by inhibiting angiogenesis. This extract also activated significantly PPARgamma which was comparable to 0.5 μM BRL-49653. The activity towards PPARalpha was mainly in the soluble fraction of the organic solvent. The ethyl acetate extract prepared from the whole fruit showed significantly higher activity than that from seeds or flesh alone. When the extract was incorporated into the medium for treatment of a peroxisome proliferator-responsive murine hepatoma cell line, H4IIEC3, treated cells showed significantly higher activity of acyl CoA oxidase and higher expressions of mRNA of this enzyme and fatty acid-binding protein, indicating that the bitter gourd ethyl acetate extract was able to act on a natural PPARalpha signalling pathway in this cell line. Results of studies suggested that dietary supplementation of rats with bitter melon seed oil, rich in cis(c)9, trans(t)11, t13-conjugated linolenic acid (CLN) significantly suppressed azoxymethane (AOM)-induced carcinogenesis (Kohno et al. 2004). The inhibition was postulated to be caused in part by modification of lipid composition in the colon and liver and/or increased expression of PPARgamma protein level in the colon mucosa. In subsequent studies, 9cis, 11trans, 13trans-conjugated linolenic acid (9c, 11t, 13t-CLN) was identified as a PPARalpha activator in bitter gourd (Chuang et al. 2006). The isolated 9c, 11t, 13t-CLN rich fraction also significantly induced acyl CoA oxidase (ACO) activity in a peroxisome proliferator-responsive murine hepatoma cell line, H4IIEC3, implying that 9c, 11t, 13t-CLN was able to act on a natural PPARalpha signalling pathway as well. The concentration of 9c, 11t, 13t-CLN and activation activity in the hydrolysed EA extract of the seeds was higher than that of the flesh.

Bitter gourd seed oil (BGO) was found to be a unique oil containing 9cis, 11trans, 13trans-conjugated linolenic acid (9c, 11t, 13t-CLN) at a high level of more than 60% (Yasui et al. 2005). Both the oil and free fatty acid exhibited anti-proliferative and apoptosis-inducing effects using colon cancer Caco-2 cells. BGO-FFA and purified free fatty acids 9c,11t,13t-CLN remarkably reduced the cell viability of Caco-2. In Caco-2 cells treated with BGO-FFA, DNA fragmentation of apoptosis indicators was observed in a dose-dependent manner. The expression level of apoptosis suppressor Bcl-2 protein was also decreased by BGO-FFA treatment. The GADD45 and p53, which play an important role in

apoptosis-inducing pathways, were remarkably up-regulated by BGO-FFA treatment in Caco-2 cells. Up-regulation of PPARgamma mRNA and protein was also observed during apoptosis induced by BGO-FFA. These results suggested that BGO-FFA rich in 9c,11t,13t-CLN may induce apoptosis in Caco-2 cells through up-regulation of GADD45, p53 and PPARgamma and prevent colon carcinogenesis. In subsequent studies, 9c,11t,13t-CLN and troglitazone, a synthetic ligand for peroxisome proliferator-activated receptor gamma (PPARgamma), decreased cell viability and induced apoptosis in three colon cancer cell lines (Yasui et al. 2006). The susceptibility of HT-29, which expresses PPARgamma at high levels, to troglitazone and 9c,11t,13t-CLN was higher than that of Caco-2 cells with low levels of PPARgamma. The results indicated that troglitazone and 9c,11t,13t-CLN exhibited more effective chemotherapeutic effects on HT-29 cells than on Caco-2 cells.

Agrawal and Beohar (2010) found that the tumour incidence, tumour yield, tumour burden and cumulative number of papillomas were found to be higher in the controls (without either extract) as compared to the Momordica fruit extract (MFE) and Momordica leaves extract (MLE) treated experimental groups. In a melanoma model, the mice which received fruit and leaf extracts of Momordica at the doses of 500 and 1,000 mg/kg body weight for 30 days showed increase in life span of animals and tumour volume was significantly reduced as compared to control values. In cytogenetic studies, a single application of Momordica extracts at doses of 500, 1,000 and 1,500 mg/kg body weight, 24 h prior the i.p. administration of cyclophosphamide, significantly prevented micronucleus formation and chromosomal aberrations in a dose dependent manner in bone marrow cells of mice. The present study demonstrated chemopreventive potential of Momordica fruit and leaf extracts on DMBA induced skin tumorigenesis, melanoma tumour and cytogenicity.

Bitter melon leaf extract (BMLE) was found to exhibit anti-metastatic activity both in vitro and in vivo in rats (Pitchakarn et al. 2010). The results indicated that non-toxic concentrations of BMLE significantly inhibited the migration and invasion of rat prostate cancer cell line (PLS10) in-vitro. The results of zymography showed that BMLE inhibited the secretion of MMP-2, MMP-9 and urokinase plasminogen activator (uPA) from PLS10. BMLE also markedly increased the mRNA level of TIMP-2, known to have inhibitory effects on the activity of MMP-2. In the in vivo study, intravenous inoculation of PLS10 to nude mice resulted in a 100% survival rate in the mice given a BMLE-diet as compared with 80% in the controls. The incidence of lung metastasis did not show any difference, but the percentage lung area occupied by metastatic lesions was slightly decreased in the 0.1% BMLE treatment group and significantly decreased with 1% BMLE treatment as compared with the control.

Antiviral Activity

Bitter melon (and several of its isolated phytochemicals) also had been documented with in-vitro antiviral activity against numerous viruses including Epstein-Barr, herpes, and HIV viruses. Proteins isolated from the seeds extracts of bitter melon was found to inhibit replication of Herpes Simplex virus, Type (HSV-1) and poliovirus 1 (Zhang 1992). An inhibitor of human immunodeficiency virus (HIV) was isolated and purified to homogeneity from the seeds and fruits of the *Momordica charantia* (Lee-Huang et al. 1990). This compound, MAP 30 (*Momordica* Anti-HIV Protein), is a basic single-stranded protein of about 30 kDa. It exhibited dose-dependent inhibition of cell-free HIV-1 infection and replication. as measured by: (i) quantitative focal syncytium formation on CEM-ss monolayers; (ii) viral core protein p24 expression; and (iii) viral-associated reverse transcriptase (RT) activity in HIV-1 infected H9 cells. The doses required for 50% inhibition (ID_{50}) in these assays were 0.83, 0.22 and 0.33 nM, respectively. No cytotoxic or cytostatic effects were found under the assay conditions. These data suggested that MAP 30 may be a useful therapeutic agent in the treatment of HIV-1 infections. The sequence of the N-terminal 44 amino acids of MAP 30 had been

determined. MAP 30 is also a type-I ribosome inactivating protein (RIP) possessing anti-tumour and anti-HIV activities. It bound both ribosomal RNA and the HIV-1 long-terminal repeat DNA (Wang et al. 2000). It was found to share similar secondary structure and beta-sheet topology with the A chain of ricin, a type-II RIP. MAP30 (Momordica Anti-HIV Protein), α- and β-momorcharins were found to inhibit HIV replication in acutely and chronically infected cells and thus could be considered potential therapeutic agent in HIV infection and AIDS (Zhang 1992). Further, MAP30 improved the efficacy of anti-HIV therapy when used in combination with other anti-viral drugs. MAP30 holds therapeutic promise over other RIPs because not only it is active against infection and replication of both HSV and HIV but is non toxic to normal cells. The antiviral and anti-tumour activities of MAP30 was found to be independent of ribosome inactivation activity (Huang et al. 1999). In addition, it was demonstrated that portions of the N- and C-termini were not essential for antiviral and anti-tumour activities, but do appear to be required for ribosome inactivation.

MAP 30 was found capable of inhibiting infection of HIV type 1 (HIV-1) in T lymphocytes and monocytes as well as replication of the virus in already-infected cells. They were not toxic to normal uninfected cells because they were unable to enter healthy cells (Lee-Huang et al. 1995b). MAP 30 exhibited dose-dependent inhibition of HIV-1 integrase with an EC_{50} of about 1 μM. The cloned recombinant MAP 30 (re-MAP 30) also exhibited anti-tumour and anti-HIV activities (Lee-Huang et al. 1995a; b). In the dose range of the assay, re-MAP30 exhibited little toxicity to the uninfected viral target cells and other normal human cells. Identical to nMAP30, re-MAP30 was also active in topological inactivation of viral DNA, inhibition of viral DNA integration and cell-free ribosome inactivation. In human lung WI-38 fibroblasts cultures, the effective concentrations for 50% inhibitions (EC_{50}) of MAP 30 were 0.1 μM for HSV-2 and 0.3 μM for HSV-1 (Bourinbaiar and Lee-Huang 1996). In comparison, the EC(50) for acyclovir (ACV), a commonly used anti-HSV drug, was 0.2 and 1.7 μM for HSV-2 and HSV-1, respectively. The cytotoxicity of all three antivirals was negligible and comparable. However, the antiherpetic activity of the plant proteins against acyclovir-resistant strains was two to three logs more potent than ACV. These results suggest that MAP30 may be useful for the therapy of herpesvirus infections. In the presence of 1.5 nM MAP30, from *Momordica charantia* the IC_{50} dose of HIV antagonists, dexamethasone and indomethacin was lowered in acutely infected MT-4 lymphocytes, without concurrent cytotoxicity, at least a 1,000-fold to 10^{-7} M and 10^{-8} M, respectively (Bourinbaiar and Lee-Huang 1995). This observation indicated that MAP30, a multifunctional antiviral plant protein was capable of topological inactivation of viral DNA and specific cleavage of 28S ribosomal RNA, and may regulate HIV replication in concert with steroid and non-steroidal inhibitors of prostaglandin synthesis. The results suggested that use of MAP30 in combination with low pharmacological doses of dexamethasone and indomethacin may improve the efficacy of anti-HIV therapy.

MAP 30 was found to have multiple functions (Wang et al. 1999). First, MAP30 was found to act like a DNA glycosylase/apurinic (ap) lyase, an additional activity distinct from its known RNA N-glycosidase activity toward the 28S rRNA. Glycosylase/ap lyase activity could explain MAP30's apparent inhibition of the HIV-1 integrase. MAP30's ability to irreversibly relax supercoiled DNA may be an alternative cytotoxic pathway that contributes to MAP30's anti-HIV/anti-tumour activities. Secondly, two distinct, but contiguous, subsites were found to be responsible for MAP30's glycosylase/ap lyase activity. Thirdly, Mn2+ and Zn2+ interacted with negatively charged surfaces next to the catalytic sites, facilitating DNA substrate binding instead of directly participating in catalysis. MAP30 was found to be not toxic to human sperm cells at the doses at which they inhibited HIV-1 and herpes simplex virus (Schreiber et al. 1999). It had no effect on the motility of spermatozoa, even at a dose of 1,000 times the maximum effective concentration. These results indicated that MAP30 may be useful as nonspermicidal protection

against sexually transmitted diseases. Studies by Fan et al. (2009) showed that exposure of human hepatoma G2.2.15 cells to MAP30 resulted in inhibition of Hepatitis B virus (HBV) DNA replication and HBsAg secretion. MAP30 could inhibit the production of HBV dose-dependently. The expression of HBsAg was significantly decreased by MAP30 dose-dependently and time-dependently.

Studies in Thailand isolated a bitter gourd protein (MRK29) from *Momordica charantia* ripe fruit and seed that inhibited the HIV-1 reverse transcriptase with 50% IR at the concentration of 18 μg/ml (Jiratchariyakul et al. 2001). MRK29 was concentrated in the 30–60% salt precipitated fraction, at which the concentration of 0.175 μg/ml exerted 82% reduction of viral core protein p24 expression in HIV-infected cells. MRK29 might have modulatory role on immune cells, because it increased threefold TNF activity.

Akihisa et al. (2007) isolated thirteen cucurbitane-type triterpene glycosides, including eight new compounds named charantosides I (6), II (7), III (10), IV (11), V (12), VI (13), VII (16), and VIII (17), and five known compounds, 8, 9, 14, 15 and 18, from a methanol extract of the fruits of Japanese bitter melon. These triterpene glycosides and five other cucurbitane-type triterpenes, 1–5, exhibited inhibitory effects on the induction of Epstein-Barr virus early antigen (EBV-EA) by 12-O-tetradecanoylphorbol-13-acetate (TPA) in Raji cells with IC(50) values of 200–409 mol ratio/32 pmol TPA. Compounds 1 and 2 showed anticancer activity in induced mouse skin carcinogenesis tests. Five cucurbitacins, kuguacins A- E (1–5), together with three known analogues, were isolated from bitter melon roots by (Chen et al. 2008). Compounds 3 and 5 showed moderate anti-HIV-1 activity and exerted minimal cytotoxicity. Cucurbitane triterpenoids, kuguacins F-S (1–14), isolated from bitter melon vines and leaves exhibited weak anti-HIV-1 activities in-vitro (Chen et al. 2009.)

Antimutagenic Activity

Green fruit of *Momordica charantia* was found to contain a mixture of novel acylglucosylsterols which had antimutagenic activity (Guevara et al. 1990). The major component of the mixture was *3-O-*[*6′-O-*palmitoyl-*β-d-*glucosyl]-stigmasta-*5,25*(*27*)-dien and the minor component was the stearyl derivative (Guevara et al. 1989). At a dosage range in mice of 50–12.5 μg extract/g, the mixture reduced by about 80% the number of micronucleated polychromatic erythrocytes induced by the well-known mutagen, mitomycin C.

Antidiabetic/Hypoglycaemic Activity

Momordica charantia fruit is commonly used as a traditional remedy for diabetes in Asia, Africa and South America. A plethora of papers have been published on the antidiabetic/ hypoglycaemic effects of bitter gourd (*Momordica charantia*) since the last four decades. For centuries, Ayurveda (Indian traditional medicine) had recommended the use of bitter melon (*Momordica charantia*) as a functional food to prevent and treat diabetes and associated complications (Abascal and Yarnell 2005). It was reported that bitter melon extract had no-to-low side effects in animals as well as in humans. (Nerurkar and Ray 2010). Paul and Raychaudhuri (2010) focused their review on the antidiabetic properties of *M. charantia*. They reported that mixture of steroidal saponins known as charantins, insulin-like peptides and alkaloids were the hypoglycemic constituents of *M. charantia* and these constituents were concentrated in the fruits *Momordica charantia* could be considered as an alternative therapy for lowering blood glucose levels in diabetic patients. However, available scientific data was not sufficient to recommend its use for treating diabetes, in the absence of careful supervision and monitoring.

Bitter gourd was found to contain substances with antidiabetic properties such as charantin, vicine, polypeptide-p, as well as other unspecific bioactive components such as antioxidants (Krawinkel and Keding 2006); 5β,19-epoxy-3β,25-dihydroxycucurbita-6,23(E)-diene and 3β,7β,25-trihydroxycucurbita-5,23(E)-dien-19-al (Harinantenaina et al. 2006); d-chiro-inositol (Xia and Wang 2007); a water-soluble

peptide MC2-1-5 (Yuan et al. 2008); cucurbitane-type triterpene glycosides such as momordicosides Q, R, S, and T, and karaviloside XI (Tan et al. 2008); momordicoside U (Ma et al. 2010), and charantosides (Nguyen et al. 2010a, b). Metabolic and hypoglycemic effects of bitter gourd extracts had been demonstrated in cell culture, animal, and human studies. However, its mechanism of action, whether it is via regulation of insulin release or altered glucose metabolism and its insulin-like effect, is still under debate. Adverse effects are also known. Nevertheless, bitter gourd has the potential to become a component of the diet or a dietary supplement for diabetic and prediabetic patients. Better-designed clinical trials are needed to further elucidate its possible therapeutic effects before a dietary recommendation can be given and a product brought to the market (Leung et al. 2009).

Momordica charantia extract showed a consistent hypoglycaemic effect in patients with diabetes mellitus in a clinical trial (Baldwa et al. 1977). The average fall in blood sugar level at the peak was found to be statistically significant. No hypersensitivity reaction to this extract was observed in the group of patients studied. It was found that *M. charantia* fruit juice caused an increased glucose uptake by tissues in-vitro without concomitant increase of tissue respiration (Welihinda and Karunanayake 1986). Oral treatment with the juice prior to a glucose load was found to increase the glycogen content of liver and muscle while it had no effect on the triglyceride content of adipose tissue. Pre-treatment of fasted rats with *M. charantia* fruit juice had no significant effect on the gluconeogenic capacity of kidney slices. Similar results were obtained with kidney slices pre-incubated with *M. charantia* fruit juice.

The pulp juice of *M. charantia* was found to lower fasting blood glucose levels in normal rats; the effect was more pronounced with the saponin-free methanol extract of the pulp juice (Ali et al. 1993). The pulp juice also had a significant hypoglycemic effect in the glucose-fed normal rats when the extract was fed 45 minutes before the oral glucose load. In the IDDM (insulin-dependent diabetes mellitus) model rats the pulp juice had no significant effect on blood glucose levels either in fasting or postprandial states. In the NIDDM (noninsulin-dependent diabetes mellitus) model rats, the saponin-free methanol juice extract produced a significant hypoglycemic effect both in fasting and in postprandial states. Methanol extracts of seed and of whole plant, and saponin-free methanol extract of whole plant produced no hypoglycemic effects in normal or IDDM model rats either in fasting or in postprandial states. Sarkar et al. (1996) found in the normal glucose primed rat model, *M. charantia* fruit extract, 500 mg/kg, depressed the plasma glucose levels by 10–15% at 1 hour Under similar conditions, tolbutamide (100 mg/kg) caused approximately 40% reductions in plasma glucose both at 1 and 2 hours At 500 mg/kg, the efficacy of *M. charantia* was 25–30% of tolbutamide. The reduction in plasma glucose in normal glucose primed rat was not accompanied by increased insulin secretion. There was no evidence of tachyphylaxis to the effect of *M. charantia* extract on repeated dosing. In streptozotocin diabetes rats, it improved the oral glucose tolerance causing significant reduction in plasma glucose of 26% at 3.5 h while metformin caused 40–50% reduction at 1, 2 and 3.5 hours *M. charantia* extract (500 mg/kg) caused a four to fivefold increase in the rate of glycogen synthesis from U-14 C-glucose in the liver of normally fed rats. The data suggested that the mechanism of action of *M. charantia* could be partly attributed to increased glucose utilization in the liver rather than an insulin secretion effect.

Effect of *Momordica charantia*, on fasting and post-prandial (2 hours after 75 g oral glucose intake) serum glucose levels was studied in 100 cases of moderate non-insulin dependent diabetic subjects (Ahmad et al. 1999). Consumption of the aqueous homogenized suspension of *Momordica charantia* pulp led to significant reduction of both fasting and post-prandial serum glucose levels. This hypoglycaemic action was observed in 86 (86%) cases of moderate non-insulin dependent diabetic subjects. Five cases (5%) showed lowering of fasting serum glucose only.

In another study, *M. charantia*-treated animals had a significant increase in the number of β cells when compared with untreated diabetics, however, their number was still significantly less than

that obtained for normal rats (Ahmed et al. 1998). There was also a significant increase in the number of δ cells in streptozotocin (STZ)-diabetic rats compared to non-diabetic rats. This increase in the number of δ cells was not affected by *M. charantia* treatment. The number of α cells did not change significantly in *M. charantia*-treated rats when compared with untreated diabetic rats. The results suggested that oral feeding of *M. charantia* fruit juice may have a role in the renewal of β cells in STZ-diabetic rats or alternately may permit the recovery of partially destroyed β cells. Feeding of *M. charantia* juice to diabetic rats was also found to modulate the enzyme expression and catalytic activities in a tissue- and isoenzyme-specific manner (Raza et al. 2000). A marked decrease (65%) in hepatic GSH content and glutathione S-transferase (GST) activity and an increase (about twofold) in brain GSH and GST activity were observed in diabetic rats. On the other hand, renal GST was markedly reduced, and GSH content was moderately higher than that of control rats. *M. charantia*-juice feeding, in general, reversed the effect of chronic diabetes on the modulation of both cytochrome P450 and -dependent monooxygenase activities and glutathione (GSH)-dependent oxidative stress related lipid peroxidation and glutathione S-transferase activities. The results suggested that the modulation of xenobiotic metabolism and oxidative stress in various tissues may be related to altered metabolism of endogenous substrates and hormonal status during diabetes.

The water extract of the fruit of *Momordica charantia* (MC) reduced the blood glucose of KK-Ay mice with type 2 diabetes and hyperinsulinemia, 3 weeks after oral administration and also significantly lowered the serum insulin of KK-Ay mice under similar conditions (Miura et al. 2001). However, MC did not affect the blood glucose in normal mice. MC-treated KK-Ay mice blood glucose significantly decreased in an insulin tolerance test. Moreover, the muscle content of facilitative glucose transporter isoform 4 (GLUT4) protein content in the plasma membrane fraction from muscle significantly increased in the orally MC-treated mice when compared with that of the controls. The results suggested that the antidiabetic effect of MC was derived, at least in part, from a decrease in insulin resistance because of the increase of GLUT4 protein content in the plasma membrane of the muscle.

The aqueous extract powder of fresh unripe whole *Momordica charantia* fruits at a dose of 20 mg/kg body weight was found to reduce fasting blood glucose by 48%, an effect comparable to that of glibenclamide, a known synthetic drug (Virdi et al. 2003). The extract did not show any signs of nephrotoxicity and hepatotoxicity in diabetic rats as judged by histological and biochemical parameters. Thus the aqueous extract powder of *Momordica charantia* appeared to be a safe alternative to reducing blood glucose.

Studies by Shetty et al. (2005), provided experimental evidence that dried bitter gourd (*Momordica charantia*) powder in the diet at 10% level improved diabetic status signifying its beneficial effect during diabetes. Bitter gourd, a commonly consumed vegetable is used as an adjunct in the management of diabetes mellitus. Water consumption, urine volume and urine sugar were significantly higher in diabetic controls compared to normal rats and bitter gourd feeding alleviated this rise during diabetes by about 30%. Renal hypertrophy was higher in diabetic controls and bitter gourd supplementation, partially, but effectively prevented it (38%) during diabetes. Increased glomerular filtration rate in diabetes was significantly reduced (27%) by bitter gourd. An amelioration of about 30% in fasting blood glucose was observed with bitter gourd feeding in diabetic rats.

Momordica charantia (MC) juice and alcoholic extracts induced a significant decrease in serum glucose levels in normal and diabetic rats (El Batran et al. 2006). The two extracts did not show any significant effect in urea, creatinine, ALT (alanine transaminase), AST (aspartate aminotransferase) and AP (alkaline phosphatase) in normal rat, while in diabetic rats the two extracts caused a significant decrease in serum urea, creatinine, ALT, AST, AP, cholesterol and triglyceride levels. Also, these results suggested that MC

extracts possesses antidiabetic, hepato-renal protective and hypolipidemic effect in alloxan-induced diabetic rats.

The treatment combination of 0.2 mg/ml water extract of *M. charantia* and 0.5 nM insulin was associated with significant increases in glucose uptake (61%) and adiponectin secretion (75%) over control levels (Roffey et al. 2007). The ethanol extract was not associated with an increase in glucose uptake; however, a dose-dependent decrease in basal glucose uptake and insulin-mediated glucose uptake was observed with the ethanol extract in combination with 50 nM insulin. In the absence of insulin, no effects on glucose uptake were observed in adipocytes exposed to the water extracts whereas the highest concentration (0.4 mg/ml) of the ethanol extract was associated with a significant decrease in glucose uptake relative to controls. The results indicated that water-soluble component(s) in *Momordica charantia* enhanced the glucose uptake at suboptimal concentrations of insulin in 3T3-L1 adipocytes, which was accompanied by and may be a result of increased adiponectin secretion from the 3T3-L1 adipocytes.

All doses of alcoholic extract of *M. charantia* were able to decrease the blood sugar level significantly in alloxan diabetic mice (Singh et al. 2008). Extract feeding showed definite improvement in the islets of Langerhans. No toxic effect was observed in the liver. The significant features of the study was that blood glucose once lowered by the treatment with *M. charantia* fruit extract remained static even after discontinuation of drug for 15 days.

Studies reported that both rosiglitazone and methanolic extract of *Momordica charantia* (MC) showed hypoglycaemic effect in oral glucose tolerance test (Nivitabishekam et al. 2009). The hypoglycaemic effect observed with combination of rosiglitazone and MC was significantly more compared to either of the drugs given alone. MC also augmented the hypoglycaemic effect of rosiglitazone in both streptozotocin (STZ) induced diabetes in adult animals and STZ induced diabetes in neonatal rats. Histopathological studies revealed that administration of rosiglitazone with MC increased the volume of islet cell in pancreas and prevented the hepatic damage when compared to control. It was concluded that MC augments hypoglycaemic effect of rosiglitazone. This could be important in reducing the dose of rosiglitazone to achieve enhanced therapeutic effect with minimal adverse effects.

Recent studies by Kumar et al. (2009) reported that the aqueous and chloroform extracts of *Momordica charantia* fruit at 6 μg/ml had a significant up-regulatory effect, on the battery of targets of glucose transporter (Glut-4), peroxisome proliferator activator receptor gamma (PPAR gamma) and phosphatidylinositol-3 kinase (PI3K), involved in glucose transport. The up-regulation of glucose uptake was comparable with insulin and rosiglitazone. The results demonstrated the significance of Glut-4, PPAR gamma and PI3K up-regulation by *Momordica charantia* in augmenting the glucose uptake and homeostasis.

The protein from Thai bitter gourd (*Momordica charantia*) fruit pulp was found to have hypoglycemic effect in diabetic rats (Yibchok-anun et al. 2006). Subcutaneous administration of the protein extract (5, 10 mg/kg) significantly and markedly decreased plasma glucose concentrations in both normal and streptozotocin-induced diabetic rats in a dose-dependent manner. This protein extract also raised plasma insulin concentrations by twofold 4 h following subcutaneous administration. In perfused rat pancreas, the protein extract (10 μg/ml) increased insulin secretion, but not glucagon secretion. Furthermore, the protein extract enhanced glucose uptake into C2C12 myocytes and 3 T3-L1 adipocytes. Thus, the *M. charantia* protein extract, a slow acting chemical, exerted both insulin secretagogue and insulinomimetic activities to lower blood glucose concentrations in-vivo.

Han et al. (2008) reported that after administration (i.g.) of mice with saponin fraction (SF) extracted from *M. charantia* (500 mg/kg), the blood glucose of alloxan-induced hyperglycaemic mice decreased, the level of insulin secretion and glycogen synthesis of alloxan-induced hyperglycaemic mice elevated and the sugar tolerance

of the normal mice was improved. Also, the body weight of the alloxan-induced hyperglycaemic mice was increased gradually. The saponin constituents extracted from *M. charantia* in an aqueous two-phase extraction system induced significant hypoglycaemic activity in hyperglycaemic and normal mice.

Charantin, an anti-diabetic compound, a typical cucurbitane-type triterpenoid in *M. charantia* and was found to be a potential and promising substance for the treatment of diabetes (Krawinkel and Keding 2006; Lee et al. 2009). Pitiphanpong et al. (2007) demonstrated that charantin, a mixture of two compounds, namely, sitosteryl glucoside and stigmasteryl glucoside, could be used to treat diabetes and can potentially replace treatment. They developed an efficient method, pressurized liquid extraction (PLE) of charantin from fruits of *M. charantia* using ethyl alcohol. *M. charantia* fruit also contained relatively high levels of d-chiro-inositol (d-CI) and may be a source of d-CI for reducing blood glucose concentrations in diabetics (Xia and Wang 2007). In streptozotocin (STZ) diabetic rats, a dose of *M. charantia* fruit extract containing 20 mg of d-CI/kg of body weight appreciably reduced blood glucose and plasma insulin after oral administration. A significant effect on oral glucose tolerance was also noted in fasted STZ rats.

Three new cucurbitane triterpenoids (1–3), together with eight known compounds (4–11) were isolated from the methanol extract of *Momordica charantia* dried gourds (Harinantenaina et al. 2006). The major compounds, 5β,19-epoxy-3β,25-dihydroxycucurbita-6, 23(E)-diene (4), and 3β,7β,25-trihydroxycucurbita-5,23(E)-dien-19-al (5) were found to have hypoglycaemic effects in the diabetes-induced male ddY mice strain at 400 mg/kg. The two aglycones of charantin did not show any hypoglycaemic effects.

Fourteen cucurbitane-type triterpene glycosides (1–14) were isolated from a methanol extract of *Momordica charantia* fruits, including three new compounds, charantosides A-C (1, 5, 6) (Nguyen et al. 2010a, b). Of the compounds, 12 and 13 showed moderate inhibitory activity against α-glucosidase. Whereas, 2, 3, 6–11, and 14 showed weak inhibitory activity, and 1, 4, and 5 were inactive. Momordicoside U, a new cucurbitane-type triterpene glycosides isolated from *M. charantia* plant displayed moderate insulin secretion activity in an in-vitro insulin secretion assay (Ma et al 2010).

Klomann et al. (2010) reported on the antidiabetic effects of various bitter gourd extracts in insulin-resistant db/db mice. Weight gain was significantly decreased in all the bitter gourd-treated groups. Glycated Hb levels were the highest in the control mice compared with all the four bitter gourd -treated mice. The lipid fraction had the strongest effect, and it tended to reduce glycated Hb levels from 9.3% (control mice) to 8.0% (lipid fraction-treated mice). The lipid and saponin fractions reduced lipid peroxidation of adipose tissue significantly. Additionally, the saponin fraction and the lipid fraction reduced protein tyrosine phosphatase 1B (PTP 1B) activity in skeletal muscle cytosol by 25% and 23% respectively. Inhibition of PTP 1B increased insulin sensitivity. This is the first study to demonstrate the involvement of bitter gourd in PTP 1B regulation, and thus elucidated one possible biochemical mechanism underlying the antidiabetic effects of bitter gourd in insulin resistance and type 2 diabetes.

Vikrant et al. (2001) found that treatment with 400 mg per day of aqueous extracts of *Momordica charantia* and *Eugenia jambolana* for 15 days substantially prevented hyperglycemia and hyperinsulinemia induced by a diet high in fructose (63.52 and 66.46 vs. 75.46, respectively). Fructose feeding of rats for 15 days increased serum glucose and insulin levels markedly and triglycerides levels marginally vs. control (75.46 vs. 55.59 mg/dl, 6.26 vs. 15.04 mg/dl and 50.93 vs.41.1 mg/dl, respectively).

Reyes et al. (2006) reported that rats that were treated with *Momordica charantia* and *Andrographis paniculata* had higher body weight (BW) compared with diabetic positive control from day 22 to day 27 (D27) but exhibited lower BW than the non-diabetic control. These rats had lower feed and liquid intakes compared with diabetic positive control from day 17 to day 27, but similar with the non-diabetic control. The blood

glucose levels in these groups were significantly reduced from day 12 to day 27 compared with diabetic positive control, however, comparable with non-diabetic control. The diabetic positive control had extended mean estrous cycles (8 days) compared to *Momordica charantia* and *Andrographis paniculata*-treated diabetic rats (5 days). The results suggested that the anti-diabetic potentials of *Momordica charantia* and *Andrographis paniculata* could restore impaired estrous cycle in alloxan-induced diabetic rats.

Feeding bitter gourd and spent turmeric (*Curcuma longa*) to streptozotocin-induced diabetic rats decreased total sugar content in the liver, spleen, and brain, while an increase was observed in heart and lungs (Vijayalakshmi et al. 2009). Uronic acid content in liver, spleen, and brain also decreased, and marginal increase was observed in the testis. Amino sugar content also decreased in liver, spleen, lungs and heart during diabetes, and augmentation was observed to different extents. Decrease in sulfation of glycoconjugates was observed in liver, spleen, lungs and heart during diabetes and was significantly ameliorated by bitter gourd and spent turmeric, except in the brain. Protein content decreased in liver, while an increase was observed in brain. The studies revealed that there was alteration in glycoconjugate metabolism during diabetes and amelioration to different extent by feeding bitter gourd and spent turmeric. Improvement was postulated to be due to slow release of glucose by fiber in the gastrointestinal track and short-chain fatty acid production from fiber by colon microbes.

A recent pilot study reported that a freeze dried *M. charantia* extract in its present dose form did not affect plasma glucose/insulin levels, energy expenditure, substrate mixture and appetite scores following an oral glucose load in non-diabetic overweight men (Kasbia et al. 2009). Administration of *Momordica charantia* (13.33 g pulp/kg body weight/day) and *Trigonella foenum-graecum* (9 g seeds powder/kg body weight/day) extracts in diabetic rats was found to significantly improve the elevated levels of fasting blood glucose (Tripathi and Chandra 2009). A significant decrease in lipid peroxidation and significant increase in the activities of key antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), glutathione-s-transferase (GST) and reduced glutathione (GSH) contents in heart tissue of diabetic rats were observed upon MC and TFG treatment. The results demonstrated the anti-hyperglycemic and anti-oxidative potential of *Momordica charantia* and *Trigonell*a *foenum-graecum*, which could exert beneficial effects against the diabetes and associated free radicals complications in heart tissue.

Oral administration of two varieties of *M. charantia* seed extracts at a concentration of 150 mg/kg body weight for 30 days showed a significant decrease in fasting blood glucose, hepatic and renal thiobarbituric acid reactive substances and hydroperoxides (Sathishsekar and Subramanian 2005). The treatment also resulted in a significant increase in reduced glutathione, superoxide dismutase, catalase, glutathione peroxidase and glutathione-s-transferase in the liver and kidney of diabetic rats. The results clearly suggested that seeds of *Momordica charantia* treated group may effectively normalize the impaired antioxidant status in streptozotocin induced-diabetes than the glibenclamide treated groups. The extract exerted rapid protective effects against lipid peroxidation by scavenging of free radicals there by reducing the risk of diabetic complications.

Chen et al. (2008) demonstrated that a new cell-based, non-radioactive, and non-fluorescent screening method could be used to screen for natural hypoglycemic components from the stem of *M. charantia*, that can overcome cellular insulin resistance. The results suggested that triterpenoids were the potential hypoglycemic components and the mechanism underlying their action involved AMP-activated protein kinase.

Antihyperlipidermic/Antiobesity Activity

APIII. API, APII and APIII are acetone fractions of saline extracts of bitter melon seeds enriched with lectins, abortifacient proteins and saponins (Wong et al. 1985). The fractions API and APIII inhibited hormone-induced lipolysis; the purified

lectin and saponin similarly possessed antilipolytic activity. *M. charantia* seed APII and abortifacient proteins (α- and β-momorcharins), however, lacked such activity. The acid acetone powder of *M. charantia* seeds and the acetone powder of *M. charantia* fruits also exhibited antilipolytic activity. The results indicated that *M. charantia* fruits and seeds contained components that resembled insulin in inhibiting hormone-induced lipolysis. In separate studies, decorticated *Momordica charantia* seeds were found to contain molecules with insulin-like bioactivity (Ng et al. 1986a, b). Of the seven fractions collected, three fractions were obtained with antilipolytic and lipogenic activities in isolated adipocytes and one fraction with only lipogenic activity. (Ng et al. 1987a) reported that a fruit "p-fraction" (containing proteins and peptides) of *M. charantia* extracted with acidic ethanol exhibited antilipolytic activity in hamster adipocytes and stimulated 3H-glucose incorporation into lipids. F1, a saponin containing unretarded fraction from the seed "p-fraction", inhibited both lipolysis and 3H-glucose incorporation into lipids. F2 (retarded fraction) enhanced 3H-glucose incorporation into lipid. The results were indicative of the presence of compounds with insulinomimetic activities in *M. charantia* fruits and seeds. Acidic ethanol extract of decorticated bitter melon seeds also contain peptides which exhibited antilipolytic and lipogenic activities (Ng et al. 1987b).

Studies by Chen et al. (2003) revealed that bitter melon (BM) reduced adiposity in rats fed a hyperinsulinemic high fat (HF; 30%) diet. BM appeared to have multiple influences on glucose and lipid metabolism that strongly counteracted the adverse effects of a high fat diet. In a dose-response (0.375%, 0.75% and 1.5%) study, oral glucose tolerance was improved in rats fed a high fat (HF; 30%) diet supplemented with freeze-dried BM juice at a dose of 0.75% or higher. At the highest dose, BM-supplemented rats had lower energy efficiency and tended) to have less visceral fat mass. Rats switched to the HF + BM diet gained less weight and had less visceral fat than those fed the HF diet. The addition of BM did not change apparent fat absorption. BM supplementation to the HF diet improved insulin resistance, lowered serum insulin and leptin but raised serum free fatty acid concentration.

Bittermelon juice (BM) exhibited antiobesity activity (Chan et al. 2005). In a dose-response experiment, BM-supplemented rats had lower energy efficiency, visceral fat mass, serum glucose, and insulin resistance index, but higher plasma norepinephrine than unsupplemented rats. Hepatic and skeletal muscle triglyceride concentrations were lower in supplemented HF diet–fed rats than in unsupplemented HF diet–fed rats. An HF diet supplemented with BM elevated activities of hepatic and muscle mitochondrial carnitine palmitoyl transferase-I (CPT-I) and acyl-CoA dehydrogenase (AD). In another experiment, BM (1.0 g/100 g) lowered visceral fat mass but increased serum adiponectin concentration in HF diet–fed rats. In the final study, rats were fed the HF diet with 0%, 1.0% or 1.25% BM. Both groups of BM-supplemented rats had higher uncoupling protein 1 in brown adipose tissue and uncoupling protein 3 in red gastrocnemius muscle, than the controls. The expression of the transcription coactivator PGC-1{in both tissues was also significantly elevated in the BM-supplemented rats. The results suggested that decreased adiposity in BM-supplemented rats may result from lower metabolic efficiency, a consequence of increased lipid oxidation and mitochondrial uncoupling.

Slower weight gain and less visceral fat had been observed when rats fed a high-fat diet were supplemented with freeze-dried bitter melon (BM) juice (Chen and Li 2005). In a 4-week experiment, BM (7.5 g/kg or 0.75%)-supplemented rats had lower energy efficiency, visceral fat mass, plasma glucose and hepatic triacylglycerol, but higher serum free fatty acids and plasma catecholamines. In the second experiment, 7-week BM supplementation in high-fat diet rats led to a lowering of hepatic triacylglycerol and steatosis score (similar to those in rats fed a low-fat diet. BM supplementation did not affect serum and hepatic cholesterol. However, plasma epinephrine and serum free fatty acid concentrations were increased. In the third experiment, BM (7.5 and 15 g/kg) and 1.5% BM lowered triacylglycerol concentration in red gastrocnemius and

tibialis anterior muscle, but a dose-response effect was not observed. These data suggested that chronic BM feeding led to a general decrease in tissue fat accumulation and that such an effect may be mediated in part by enhanced sympathetic activity and lipolysis. The researchers concluded that bitter melon or its bioactive ingredient(s) could be used as a dietary adjunct in the control of body weight and blood glucose.

The effects of treatment of *Momordica fruit* extract (MFE) and sodium orthovanadate, separately and in combination, on serum and tissue lipid profile and on the activities of lipogenic enzymes in alloxan induced diabetic rats was reported by Yadav et al. (2005). The results showed that there was a significant increase in serum total lipids, triglycerides and total cholesterol levels after 21 days of alloxan diabetes. In the liver and kidney of diabetic rats the levels of total lipids and triglycerides also increased significantly while levels of total cholesterol decreased significantly. The lipogenic enzymes showed decreased activity in the diabetic liver, while in kidney they showed an increased activity. When compared with the controls these changes were significant. The treatment of alloxan diabetic rats with MFE and sodium orthovanadate prevented these alterations and maintained all parameters near control values. Most effective prevention was however observed in a combined treatment of MFE with a reduced dose of sodium orthovanadate (0.2%). The results suggested that *M. charantia* fruit extract and SOV exhibited hypolipidemic as well as hypoglycemic effect in diabetic rats and their effect was pronounced when administered in combination.

Nerurkar et al. (2006) found that *Momordica charantia* ameliorated protease inhibitor-associated apoB and lipid abnormalities in HepG2 cells. They demonstrated that bitter melon juice (BMJ) significantly reduced apolipoprotein B (apoB) secretion and apoC-III mRNA expression and normalized apoA-I expression in PI-treated HepG2 cells. BMJ also significantly reduced cellular triglyceride and microsomal triglyceride G transfer protein, suggesting that lipid bioavailability and lipidation of apoB assembly may play a role in decreased apoB secretion. Their study suggested that identifying molecular targets of BM may offer alternative dietary strategies to decrease protease inhibitor-associated hyperlipidemia and improve quality of life among HIV-1-infected patients. In subsequent studies they found that BMJ not only improved glucose and insulin tolerance but also lowered plasma apoB-100 and apoB-48 in high fat diet (HFD)-fed mice as well as modulated the phosphorylation status of IR and its downstream signalling molecules (Nerurkara et al. 2008). Results of separate studies showed that bitter gourd extract supplementation of rats for 2 weeks of high-fat feeding improved the glucose tolerance and insulin sensitivity, glucose tolerance and insulin signalling in high fat diet-induced insulin resistance (Sridhar et al. 2008). In addition bitter gourd extract reduced the fasting insulin, triacyl glyceride, cholesterol and epididymal fat which were increased by high-fat diet. Identification of potential mechanism(s) by which bitter gourd improves insulin sensitivity and insulin signalling in high-fat-fed rats may open new therapeutic targets for the treatment of obesity/dyslipidemia-induced insulin resistance

Four cucurbitane glycosides, momordicosides Q, R, S, and T, and karaviloside XI isolated from bitter melon and their aglycones exhibited a number of biologic effects beneficial to diabetes and obesity (Tan et al. 2008). In both L6 myotubes and 3 T3-L1 adipocytes, they stimulated GLUT4 translocation to the cell membrane – an essential step for inducible glucose entry into cells. This was associated with increased activity of AMP-activated protein kinase (AMPK), a key pathway mediating glucose uptake and fatty acid oxidation. Furthermore, momordicoside(s) enhanced fatty acid oxidation and glucose disposal during glucose tolerance tests in both insulin-sensitive and insulin-resistant mice. Their findings indicated that cucurbitane triterpenoids, the characteristic constituents of *M. charantia*, may provide leads as a class of therapeutics for diabetes and obesity.

Bittermelon juice was found to be a potent inhibitor of lipogenesis and stimulator of lipolysis activity in human adipocytes (Nerurkar et al. 2010). Preadipocytes treated with varying

concentrations of bittermelon juice (BMJ) during differentiation demonstrated significant reduction in lipid content with a concomitant reduction in mRNA expression of adipocyte transcription factors such as, peroxisome proliferator-associated receptor gamma (PPARgamma) and sterol regulatory element-binding protein 1c (SREBP-1c) and adipocytokine, resistin. Similarly, adipocytes treated with BMJ for 48 hours demonstrated reduced lipid content, perilipin mRNA expression, and increased lipolysis as measured by the release of glycerol. BMJ may therefore prove to be an effective complementary or alternative therapy to reduce adipogenesis in humans.

M. charantia was found to be effective in ameliorating insulin resistance and visceral obesity (Shih et al. 2008). Treatment of insulin resistance is a critical strategy in the prevention and management of type 2 diabetes. Studies demonstrated that bitter melon was effective in ameliorating the high-fat (HF) diet-induced hyperglycemia, hyperleptinemia, and decreased the levels of blood glycated hemoglobin (HbA1c) and free fatty acid (FFA), and increased the adipose PPARgamma and liver PPARalpha mRNA levels. Additionally, bitter melon significantly decreased the weights of epididymal white adipose tissue and visceral fat, and decreased the adipose leptin and resistin mRNA levels. It was speculated that at least a portion of bitter melon effects was involved PPARgamma-mediated pathways, resulting in lowering glucose levels and improving insulin resistance, and partly through PPARalpha-mediated pathways to improve plasma lipid profiles. Yuan et al (2008) purified a water-soluble peptide MC2-1-5 from *Momordica charantia* L. var. *abbreviata*, with hypoglycemic effect, MC2-1-5 reduced the blood glucose level in alloxan-induced diabetic mice by 61.70% and 69.18% at 2 and 4 hours, respectively, after oral administration at a dose of 2 mg/kg. The oral glucose tolerance test (OGTT) showed MC2-1-5 produced a reduction of 25.50%, 39.62% and 41.74% in blood glucose level after 1, 2 and 3 hours, respectively, of oral administration compared with a diabetic control.

Bittermelon extract was found to reduce preadipocyte proliferation by a G2/M arrest of the cell cycle and reduced lipid accumulation of the adipocyte (Popovich et al. 2010). Bitter melon contains a variety of potentially bioactive compounds which includes two classes of saponins known as cucurbitane and oleanane-type triterpenoids. Bittermelon extract contained at least five different triterpenoids and reduced preadipocyte viability with an LC_{50} concentration after 24 hours determined to be 0.402 mg/ml, 0.314 mg/ml for 48 hours and 0.310 mg/ml for 72 hours. Bittermelon treatment increased the release of lactate dehydrogenase (LDH) from cells and significantly increased cells in the G2/M while reducing cells in the G1 phase of the cell cycle. Bittermelon treatment of 3 T3-L1 cells resulted in a fall in lipid accumulation and significantly lowered intracellular triglyceride amount compared to untreated control cells. PPARgamma expression was significantly down-regulated. Adiponectin expression was significantly decreased after 12 and 24 hours of treatment and was increased in response to troglitazone, a positive control.

Momordin, was found to have a stimulatory effect on the production and activation of human peroxisome-proliferator activated-receptor (PPAR) delta (Sasa et al. 2009). 10 and 25 nM Momordin significantly increased the expression of PPARdelta mRNA 1.5-fold (relative to the control). Moreover, 10 and 25 nM momordin significantly increased PPARdelta promoter activity in a dose-dependent manner, reaching more than 1.5-fold relative to the control. Data obtained through successful cloning of the PPARdelta promoter demonstrated that PPARdelta production and activation were upregulated through PPARdelta promoter activity following momordin treatment. PPARdelta (nuclear receptor transcription factor) was found to enhance fatty acid catabolism and energy uncoupling in adipose tissue and muscle, and to suppress macrophage-derived inflammation (Barish et al. 2006).

Antihypercholesterolemic Antihyperlipidemic Activity

Dietary bitter melon resulted in a consistent decrease in serum glucose levels in rats fed

cholesterol-free diets, but not in those fed cholesterol-enriched diets, although no dose-response was noted (Jayasooriya et al. 2000). No adverse effect of dietary bitter melon powder on growth parameters and relative liver weight were noted. Addition of cholesterol to the diets as compared to those without added cholesterol caused hypercholesterolemia and fatty liver. Bitter melon had little effect on serum lipid parameters, except for high density lipoprotein (HDL)-cholesterol; HDL-cholesterol levels tended to decrease by dietary cholesterol, while they were consistently elevated by dietary bitter melon both in the presence and absence of dietary cholesterol, indicating an antiatherogenic activity of bitter melon. In addition, bitter melon exhibited a marked reduction in the hepatic total cholesterol and triglyceride levels both in the presence and absence of dietary cholesterol; the reduction of triglyceride levels in the absence of dietary cholesterol was in a dose-dependent fashion. Their results suggested that bitter melon could be used as a health food.

Adminstration of methanol extract of *Momordica charantia* fruit extract to diabetic rats for 30 days showed a significant decrease in triglyceride, low density lipoprotein and a significant increase in high density lipoprotein (HDL) level (Chaturvedi et al. 2004). A significant effect on oral glucose tolerance was also noted. Chronic administration showed an improvement in the oral glucose tolerance curve. Studies showed that the methanol extract of *M. charantia* normalised blood glucose level, reduced triglyceride and LDL levels and increased HDL level in diabetic rats but the animals reverted to a diabetic state once the *M. charantia* extract was discontinued (Chaturvedi 2005).

The feeding of dietary methanol fraction (BMMF) extracted from bitter melon at 0.5% and 1.0% levels in the diets for 4 weeks tended to reduce food intake and growth of male golden Syrian hamsters, although there was no difference in food efficiency (weight gain/food intake) (Senanayake et al. 2004a). An effect of dietary BMMF on serum triglyceride was not seen in hamsters fed diets free of cholesterol, while hypertriglyceridaemia induced by dietary cholesterol was significantly lowered in a dose-dependent manner in those fed diets containing the BMME. Serum total cholesterol concentration also tended to decrease in a dose-dependent manner following feeding of increasing amounts of BMMF in the presence and absence of cholesterol in the diet. The effects of dietary BMMF on liver triglyceride and total cholesterol levels were marginal, although dietary cholesterol caused a marked accumulation of these lipid molecules in the liver. These results suggested that the BMMF contained components that could ameliorate lipid disorders such as hyperlipidaemia. Feeding of diets containing either bitter melon or various fractions isolated by organic solvents caused no adverse effects on food intake or growth of rats (Senanayake et al. 2004b). When the effect of three different varieties of bitter melon was compared, the Koimidori variety was found to be the most effective in lowering hepatic triglyceride levels as compared to the other two varieties, Powerful-Reishi, and Hyakunari, suggesting a variety-dependent difference in their activity. Furthermore, the active component(s) responsible for the liver triglyceride lowering activity of Koimidori variety was assumed to be concentrated in the methanol fraction, but not in other fractions such as the n-hexane, the acetone, or the residual fraction. The triglyceride lowering activity was furthermore confirmed by the dose-dependent reduction of hepatic triglyceride, resulting the lowest level in rats fed 3.0% supplementation. In these experiments, the effects on serum lipids were marginal. The results of the present and previous studies clearly showed that bitter melon, especially Koimidori variety, exhibited a potent liver triglyceride-lowering activity.

Data from studies conducted by Nerurkar et al. (2005) suggested bitter melon juice (BMJ) to be a potent inhibitor of apolipoprotein B (apoB) secretion and triglycerides synthesis and secretion that may be involved in the plasma lipid- and VLDL-lowering effects observed in animal studies. Human hepatoma cells, HepG2, treated with bitter melon juice (BMJ) for 24 h reduced apoB secretion with and without the addition of lipids. BMJ reduced the secretion of new triglycerides and decreased microsomal

triglyceride transfer protein (MTP) mRNA expression, suggesting that lipid bioavailability and lipidation of lipoprotein assembly are likely involved in decreased apoB secretion. Interestingly, BMJ increased the nuclear translocation of the mature form of sterol regulatory element-binding protein-1c (SREBP-1c), involved in MTP secretion.

Wound Healing Activity

Studies showed that administration of *Momordica charantia* extract was found to improve and accelerate the process of wound healing in diabetic Sprague-Dawley rats induced by streptozotocin (Teoh et al. 2009). The diabetic group exhibited delayed wound healing as compared to the normal group. Interestingly, the diabetic group treated with topical *Momordica charantia* extract showed better results than the nontreated group. In subsequent studies, they (Teoh et al. 2010) reported that the administration of *Momordica charantia* extract prevented oxidative damage in diabetic nephropathy. The kidneys of the diabetic rats showed thickening of the basement membrane of the Bowman's capsule, edema and hypercellurarity of the proximal tubules, necrosis and hyaline deposits. These features were found to be reversed when the *Momordica charantia* extract was administered to the experimental animals. The normal wound healing process can be divided into four overlapping phases i.e. haemostasis, inflammation, proliferation and remodeling (Laitiff et al. 2010). In diseased condition like diabetes mellitus, the wound healing process is grossly impaired, resulting in chronic wounds which fail to heal.

Antiinflammatory Activity

The butanol-soluble fraction of bitter gourd placenta extract was found to strongly suppress LPS (lipopolysaccharide)-induced TNFalpha production in RAW 264.7 cells (Kobori et al. 2008a). The bitter gourd butanol fraction suppressed expression of various LPS-induced inflammatory genes, such as those for TNF, IL1alpha, IL1beta, G1p2, and Ccl5. The butanol fraction significantly suppressed NFkappaB DNA binding activity and phosphorylation of p38, JNK, and ERK MAPKs. Components in the active fraction from bitter gourd were identified as 1-α-linolenoyl-lysophosphatidylcholine (LPC), 2-α-linolenoyl-LPC, 1-lynoleoyl-LPC, and 2-linoleoyl-LPC. Purified 1-α-linolenoyl-LPC and 1-linoleoyl-LPC suppressed the LPS-induced TNFalpha production of RAW 264.7 cells at a concentration of 10 μg/ml.

Antispermatogenic and Androgenic Activities

Petroleum ether, benzene and alcohol extracts of the seeds of *Momordica charantia* tested in rats at the dose level of 25 mg/100 g body weight for 35 days showed antispermatogenic activity as evidenced by the decrease in number of spermatocytes, spermatids and spermatozoa (Naseem et al. 1998). There was an increase in cholesterol level and Sudanophilic lipid accumulation indicating inhibition in the steroidogenesis. At the same time the weight of epididymis, prostate gland, seminal vesicle and levator ani was increased which showed its androgenic property. Out of the three extracts, the alcohol extract was more potent in its antispermatogenic, antisteroidogenic and androgenic activities.

Immunosuppressive Activity

Two abortifacient proteins, α- and β-momorcharin purified from the seeds of the bitter melon significantly inhibited the mitogenic responses of mouse splenocytes to concanavalin A, phytohaemagglutinin and lipopolysaccharide in a dose-dependent manner (Leung et al. 1987). The proteins severely suppressed the alloantigen-induced lymphoproliferation and the in-vitro generation of a primary cytotoxic lymphocyte response. In contrast, the cytolytic activity of cytotoxic lymphocytes and natural killer cells was unimpaired by in-vitro exposure to

momorcharin. On the other hand, a clear decrease in the functional capacity of macrophages, such as the cytostatic and phagocytic activities, was observed under similar conditions. In-vivo studies showed that single injections of non-toxic microgram amounts of momorcharin into mice resulted in a significant depression of the delayed-type hypersensitivity response as well as the humoral antibody formation to sheep red blood cells. Similarly, the thioglycollate-induced in-vivo migration of macrophages was also suppressed. The data suggested that the observed potent immunosuppressive effect of α- and β-momorcharin was unlikely to be due to direct lymphocytotoxicity or due to a shift in the kinetic parameter of the immune response.

Hepatoprotective Activity

The hydroalcoholic extract of leaves of *Momordica charantia* showed significant hepatoprotective activity (Chaudhari et al. 2009). In the hydroalcoholic extract treated animals, the hepatotoxic effect of carbon tetrachloride in albino wistar rats was controlled significantly by restoration of the increased levels of SGOT, SGPT, ALP and total bilirubin as compare to the toxicant control.

Four novel octanorcucurbitane triterpenes, octanorcucurbitacins A-D (1–4), together with one known octanorcucurbitane triterpene, kuguacin M (5), were isolated from the methyl alcohol extract of the stems of *Momordica charantia*. Octanorcucurbitacin C inhibited tert-butyl hydroperoxide (t-BHP)-induced hepatotoxicity against HepG2 cells (Chang et al. 2010).

Antiulcerogenic Activity

The healing of acetic acid induced gastric ulcer was increased by both doses 100 mg/kg and 500 mg/kg of the methanolic fruit extract of *Momordica charantia* (Alam et al. 2009). The extract also prevented development of gastric ulcers and duodenal ulcers in rats. In pylorus-ligated rats, the extract showed significant decrease in ulcer index, total acidity, free acidity and pepsin content and an increase in gastric mucosal content. The extract also reduced the ulcer index in stress induced, ethanol induced and indomethacin induced gastric ulcers and cysteamine induced duodenal ulcer.

Antidiarrhoeal Activity

The aqueous leaf extract of *Momordica charantia* was found to increase enzymes activities (maltase, sucrase and lactase) in the extract treated diarrhoeagenic mice (induced by castor oil) enhancing the absorptive role of these enzymes in the small intestine (Bakare et al. 2010). This could prevent malnutrition and loss of these enzymes in diarrhoeal conditions. Graded doses (100–400 mg/kg) of *M. charantia* decreased the activity of intestinal alkaline phosphatase at 48 hours in the diarrhoeagenic mice. The reduction in protein concentration was also observed in the castor oil group compared to the control and extract treated groups.

Abortifacient Activity

Momordica charantia was found to contain a basic glycoprotein, β-momorcharin, which was found to have abortifacient activity (Chan et al. 1984). β-momorcharin differed immunologically from α-momorcharin also of the same source but possessed similar mid-term abortifacient activity. Intraperitoneal administration of β-momocharin into mice on days 4 and 6 of pregnancy led to an inhibition of pregnancy. In-vitro study showed that the protein disturbed peri-implantation development by: (a) blocking the hatching of embryos from the zona pellucida; (b) decreasing the incidence of successful attachment of the blastocyst; (c) reducing the trophoblast outgrowth; and (d) disrupting the development of inner cell mass. It was postulated that β-momorcharin inhibited embryonic implantation by a similar biological action previously described for α-momorcharin. In another study, α- and β-momorcharins, abortifacient proteins isolated from *Momordica*

charantia seeds, were found to diminish the number of oocytes ovulated in mice when given on the day prior to or on the day of PMSG (pregnant mare sereum gonadotropin) treatment, but not when given after the gonadotropin injection; they also increased the incidence of follicular atresia (Ng et al. 1988). The plant proteins did not affect follicular recruitment and maturation as evidenced by ovarian histology and serum 17 β-estradiol level. The number of corpora lutea was slightly reduced by treatment with the proteins, but there was no long-term suppression of the serum progesterone level. After mating, animals which have previously been treated with the plant proteins underwent pregnancy resulting in a litter size similar to that of controls.

RibosomeInactivating Protein (RIP) Activities

Gamma-momorcharin, a novel ribosome-inactivating protein with a low molecular weight of 11,500 was purified from the seeds of bitter gourd (Pu et al. 1996). It inhibited protein synthesis in the rabbit reticulocyte cell-free system with ID_{50} of 55 nM. Two RIPS, α- and β-momorcharins (isolated from seeds of *Momordica charantia*), 30 kDa glycoproteins were reported to have abortifacient, ribosome inactivating, immunomodulatory, antitumour and anti-AIDS activities (Ng et al. 1992). Both α- and β-momorcharins, showed specific N-glycosidase activity at nanomolar concentrations, when rRNA from rabbit reticulocyte lysate was used as substrate (Fong et al. 1996). Both RIPs, α- and β-momorcharins from *M. charantia* seeds, demonstrated ribonuclease activity (Mock et al. 1996). The momorcharins preferentially acted on polyU polymerase, but exerted negligible effects on polyA, polyC and polyG polymerases. β-momorcharin, and to a lesser extent α-momorcharin, also acted on tRNA to release acid-soluble UV-absorbing products. Similar to the results obtained with tRNA as substrate, β-momorcharin was about 15-fold more active than α-momorcharin on polyU.

In another study, β-momorcharin, and a lectin were isolated from seeds of the bitter melon *Momordica charantia* were subjected to amino acid sequencing (Wang and Ng 1998). β-momorcharin exhibited considerable homology in sequence to other Cucurbitaceae RIPs, and also to the A chains of abrin and ricin, both type II (double-chained) RIPs. The resemblance between α-momorcharin and other RIPs was closer than that between β-momorcharins and other RIPs. *M. charantia* lectin manifested a certain extent of sequence similarity to β-momorcharin and other RIPs, and some degree of homology in sequence to lectins from *Cucurbita maxima, Cucurbita argyrosperma, Sambucus nigra* and *Ricinus communis*.

A new ribosome-inactivating protein (δ-momorcharin) and a candidate RIP (ε-momorcharin) were isolated, respectively, from the seeds and fruits of the bitter gourd *Momordica charantia* (Tse et al. 1999). δ- and ε-momorcharins possessed a molecular weight of 30 and 24 kDa respectively and inhibited cell-free translation in rabbit reticulocyte lysate with an IC_{50} of 0.15 and 170 nM. A peptide designated charantin, with a molecular mass of 9.7 kDa, was isolated from bitter gourd seeds (Parkash et al. 2002). The N-terminal sequence of charantin exhibited marked similarity to that of the 7.8-kDa napin-like peptide previously isolated from bitter gourd seeds. Charantin inhibited cell-free translation in a rabbit reticulocyte lysate system with an IC_{50} of 400 nm, a potency lower than that of the previously reported small ribosome-inactivating protein γ-momorcharin (IC_{50} = 55 nm) which also exhibited an abundance of arginine and glutamate/glutamine residues. Charantin reacted positively in the N-glycosidase assay, yielding a band similar to that formed by the small ribosome-inactivating proteins γ-momorcharin and luffin S.

A galactose-binding lectin (MCL1) purified from *M. charantia* seeds showed highest hemagglutinating activity toward human type-O(H) erythrocytes followed by A, B and Omh (para-Bombay phenotype, also known as H-deficient secretor) erythrocytes (Tanaka et al. 2009). MCL1

also inhibited the cell-free synthesis of luciferase in a rabbit reticulocyte lysate system.

Recent studies aimed at unravelling the enzymatic activities of the *M. charantia* RIPs provided a structural basis for their activities (Puri et al. 2009). They reported that RIPs being members of the single chain ribosome inactivating protein (SCRIP) family could act irreversibly on ribosome by removing adenine residue from eukaryotic ribosomal RNA. Various activities of RIPs include anti-tumour, broad anti-viral, ribonuclease and deoxyribonuclease.

Antimicrobial Activity

M. charantia plant extract exhibited antimicrobial activity against a broad spectrum of bacterial pathogens including *Staphylococcus, Pseudomonas, Streptobacillus, Streptococcus* and *Helicobacter pylori* (Khan and Omoloso 1998) and a leaf extract had antimicrobial activity against *Escherichia coli, Salmonella paratyphi* and *Shigella dysenteriae* (Omoregbe et al. 1996). *M. charantia* fruit extract exhibited anti-*Helicobacter pylori* activity (Yesilada et al. 1999). The oil from the seeds of *Momordica charantia* also exhibited antibacterial activity (Braca et al. 2008). *Staphylococcus aureus* was found to be the most sensitive microorganism with MIC values < 500 μg/ml. In a recent study, the ethanol extract of *Momordica charantia* exhibited modifying antibiotic activity against a methicilin-resistant *Staphylococcus aureus* (MRSA) strain (Coutinho et al. 2010). A potentiating effect between this extract and all aminoglycosides was demonstrated on the growth of the MRSA. The results showed that extracts from *M. charantia* could be used as a source of plant-derived natural products with resistance-modifying activity and provide a new weapon against multi-resistant bacteria such as MRSA.

Aqueous and organic fractions of the leaves, fruits, and seeds of *Momordica charantia* showed antimicrobial properties against 8 clinical isolates of bacteria and 2 strains of fungi (Mahomoodally et al. 2010). The MIC for bitter melon ranged from 0.5 to 9 mg/ml and the lowest MIC value (0.5 mg/ml) was recorded for the unripe fruits against *E. coli*. In contrast, higher concentration of the unripe fruit extract of 9 mg/ml was needed to be effective against a resistant strain of *Staphylococcus aureus* (MRSA). The antimicrobial effect against MRSA was lost upon ripening of the fruits. The methanolic extract showed highest MIC values compared to the aqueous extract.

Antileishmanial Activity

Aqueous extract of the green fruits of *Momordica charantia* and purified momordicatin, 4-(o-carboethoxyphenyl) butanol, exhibited in-vitro and in-vivo efficacy against kala-azar caused by *Leishmania donovani* (Gupta et al. 2010). The IC_{50} value against *Leishmania* promastigotes in-vitro were 0.6 mg/l and 0.02 mg/l for the crude extract and momordicatin, respectively. When administered in the hamster model of visceral leishmaniasis, 100% parasite clearance was achieved at a dose of 300 mg/kg body weight of crude extract and 10 mg/kg body weight of momordicatin. Fe containing parasite superoxide dismutase (SOD) was totally inhibited when treated with 0.72 mg/l crude extract and 0.20 mg/l momordicatin, respectively, whereas Cu-Zn containing SOD present in the host remained unaffected. Results revealed that the mode of action of these antileishmanial agents was mediated through inhibiting parasite SOD which is one of the key enzymes of oxidative burst. Both crude extract of *Momordica charantia* and momordicatin obtained from the fruits had potential towards developing new chemotherapeutics against leishmaniasis.

Larvicidal Activity

Among *M. charantia* fruit wall extracts tested, petroleum ether (LC_{50} = 27.60; 17.22 ppm and 41.36; 15.62 ppm) extract was found to be more effective than carbon tetrachloride (LC_{50} = 49.58;

16.15 ppm and 80.61; 27.64 ppm) and methanol (LC_{50} = 142.82; 95.98 ppm and 1,057.49; 579.93 ppm) extracts towards *Anopheles stephensi* and *Culex quinquefasciatus* larvae after 24 and 48 hours of exposure respectively (Maurya et al. 2009). All the fruit wall extracts of *M. charantia* were toxic to both larval species and may act as effective biolarvicide against mosquitoes. Batabya et al. (2009) reported that methanol extract of *M. charantia* seeds exhibited larvicidal activity against the larvae of filaria vector, *Culex quinquefasciatus*. However, it was less potent than the methanol extract of *Azadirachta indica* fruits but more potent than the carbon tetrachloride extract of castor seeds (*Ricinus communis*). It showed a LC_{50}at 101.18 and 93.58 ppm and LC_{90} at 322.81 and 302.62 ppm.

Antiprotozoal Activity

Studies in the Democratic Republic of Congo reported that *M. charantia* plant extract displayed good antiprotozoal efficacy against *Trypanosoma brucei brucei* (Mesia et al. 2008)

Contraindication

A case of atrial fibrillation due to *Momordica charantia* consumption was reported in Turkey (Erden et al. 2010). A 22 year-old man was admitted to the hospital emergency department with complaints of palpitation and weakness. He had crushed *Momordica charantia* and drank two tablespoons of its juice three times a day, and had also drunk *Momordica charantia* juice on the morning of admission. No recurrence of arrhythmia was observed after 10 h of infusion with intravenous administration of amiodarone.

Traditional Medicinal Uses

Almost all parts of the plant are used in traditional medicine. Bitter melon has been used in traditional folk medicine especially in Asia (CSIR 1962; Burkill 1966; Quisumbing 1978; Lu 2005; Grover and Yadav 2004; Nerurkar et al. 2005; Chaudhari et al. 2009) and Africa (Burkill 1985; Kerharo and Adam 1974; Bouquet 1969; Watt and Breyer-Brandwijk 1962; Dalziel 1955) and West Indies (Lans 2006).

Momordica charantia is popularly used in various systems of traditional medicine for several ailments (antidiabetic, abortifacient, anthelmintic, contraceptive, dysmenorrhoea, eczema, emmenagogue, antimalarial, galactagogue, demulcent, purgative, gout, jaundice, abdominal pain, kidney stone, laxative, leprosy, leucorrhoea, pectic ulcers, piles, pneumonia, psoriasis, purgative, rheumatism, fever and scabies) (CSIR 1962; Quisumbing 1978; Burkill 1966; Grover and Yadav 2004). *Momordica charantia* is traditionally used as an antidiabetic agent in Asia, Africa, and South America (Nerurkar et al. 2005). The plant is traditionally used in Ayurvedic system as antidiabetic, anthelminitic, antibacterial, antitumour and also used in liver disorders (Chaudhari et al. 2009). The whole plant plus other medicinal herbs are used for snake-bites in Senegal. In West Africa, the plant is used as a laxative, for stomachache, a taenifuge and anthelmintic, and to treat fevers. In Congo, the plant is used as taenifuge especially in children. In India and Japan, the plant is used with other medicinal plants is processed into an ointment for skin affections such as for psoriasis, scabies and other diseases.

M. charantia fruit is used in Nigeria as a bitter stomachic and a purgative (Fatope et al. 1990). Bitter melon fruit is used as a folk medicine in Togo to treat gastrointestinal diseases, and extracts have shown activity in-vitro against the nematode worm, *Caenorhabditis elegans* (Beloin et al. 2005). In traditional Chinese medicine the fruit is used as an appetite stimulant and as a treatment for gastrointestinal infection and against breast cancer. In China bitter gourd fruit is regarded as good for liver diseases; also good for sunstroke, dysentery inflamed eyes, tonic and purgative. Bitter melon is traditionally regarded by Asians, as well as Panamanians and Colombians, as useful for preventing and treating malaria. The fruit is claimed to have medicinal properties with potential for reducing diabetes mellitus. The fruit is considered tonic and

stomachic, and is useful in rheumatism and gout and in diseases of the spleen and liver. The fruit is also considered a remedy for fluxes, catarrh, and children's coughs. In the Philippines it is reported that juice expressed from the green fruit is administered for chronic colitis. Olive or almond oil infusions of the fruit (minus the seeds) are applied to chapped hands, haemorrhages, burns, etc and as a vulnerary; mashed fruit is used in the preparation of poultices. Regardless of its efficacy in diabetes, bitter melon is sold in the Philippines as a food supplement and elixir for this purpose.

In Brazil, the seeds are used as anthelmintic and for round worms in Zaire.

Leaves are used as external application in leprosy, skin aliments, burns and scalds and as poultice for headaches. Leaves are also reported to be used as stomachic, anthelmintic, antipyretic, a powerful emmenagogue and an effective vermifuge. The sap of the leaves is used as a parasiticide, and when macerated in oil, is employed as a vulnerary. It is also found to be good for bacillary dysentery. An infusion of the leaves acts as a febrifuge and the juice of the fresh leaves acts as a mild purgative for children. In Malaysia and India, the pounded leaves are applied to the body for skin diseases, burns, scalds and to the abdomen of children for stomach-ache. A mixture is administered for diarrhoea. A leaf infusion is drunk for headache. In Malaysia, leaf juice is taken as vermifuge for children or gargle for sprue; leaf poultice for headache and flowers used in an infusion for asthma. Leaf juice is taken in India for bilious complaints. In Senegal, the leaves are used as febrifuge; a plaster of crushed leaves is used as plaster for skin parasites such as filarial and Guinea-worm, and for menstrual problems. In Congo, crushed are massaged into the body for fever aches and pains, and also used in vapour-baths, and with other drug-plants for heart conditions especially tachycardia.

In India, the root is used as an astringent and applied to haemorrhoids, and used as abortifacient in tropical America. The root is sometimes used as an ingredient in aphrodisiac prescriptions and, along with the fruit or seeds, is also used as an abortifacient, as well as a remedy for urethral discharges and is applied externally to haemorrhoids In the West Indies, the vine is used for diabetes and urinary complaints. In Senegal, the roots are used for treating syphilis, rheumatism and yaws.

Other Uses

The leaves are used to clean metals. The leaves contain cucurbitane glucosides which are toxic to certain insects and can be used as insecticides. The cucurbitane glucosides deter oviposition of *Liriomyza trifolii* (Mekuria et al. 2005, 2006), oviposition and feeding activities of *Liriomyza sativae* (Ling et al. 2009) and feeding activity of *Spodoptera litura* and *Pseudaletia separata* (Kashiwagi et al. 2007).

Comments

Bitter melon has become an important weed in sugarcane, rubber and oil palm plantations in Indonesia.

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Momordica cochinchinensis

Scientific Name

***Momordica cochinchinensis* (Lour.) Spreng.**

Synonyms

Momordica macrophylla Gage, *Momordica meloniflora* Hand.-Mazz., *Momordica mixta* Roxburgh, *Momordica trifolia* L. nom. rej., *Muricia cochinenchinensis* Loureiro, *Zucca commersoniana* Ser.

Family

Cucurbitaceae

Common/English Names

Chinese Bitter Cucumber, Chinese Cucumber, Cochinchin Gourd, Gac, Giant Spine Gourd, Spiny Bitter Cucumber, Spiny Bitter Gourd, Sweet Gourd

Vernacular Names

Bangladesh: Kakrol;
Chinese: Da Ye Mu Bie Zi, Mu Bie, Mù-Biē-Guǒ, Mu Bie Zi, Teng Tong, Tu Mu Bie;
Czech: Tykvice Končičinská;
French: Margose À Piquants, Muricie;
India: Bhat Kerala (Assamese), Golkara, Kakrol (Bengali), Bhat-Karela, Gangerua, Gulkakra, Kakur, Kakrol, Kantola, Kathaamla (Hindu), Karkataka, Kaadu Kaakara (Kannada), Karol, Karot (Manipuri), Gulkara, Kshudramalakasanda (Malayalam), Kakana, Kartalen (Marathi), Gangeruka, Jalakaravalli, Karka, Karkaphala, Karkata, Karkataka, Katamala, Krindana, Kshudradhatri, Kshudramalakasandna, Mrigalendaka, Mrigavitsadrisha, Todana (Sanskrit), Palupakal, Adavi-Kakara (Tamil), Adavikakara, Adavikaakara, Varivalli (Telugu);
Indonesia: Pupia, Torobuk, Toropu;
Italian: Cetriolino Spinoso;
Japanese: Mokube Tsushi, Nanban Kikarasuuri;
Khmer: Makkao;
Laos: Khaawz;
Malaysia: Teruah;
Nepal: Jhuse Karelaa;
Philippines: Tabog-Ok, Tabog-Uak (Bikol), Tambua-Uang (Bontok), Malakaban, Taboo (Cebu Bisaya), Parum-Parung (Ibanag), Tambaching (Igorot), Libas, Parug-Parug, Parog-Parog-Ti-Noang, Parog-Parog-Ti-Tau, Sugod-Sugod (Iloko), Tabala (Manabo), Tambalosan (Panay Bisaya), Tabola (Subanum), Balbas-Bakiro, Buyok-Buyok, Patolang-Uak (Tagalog);
Spanish: Cundeamor, Pepino Amargo Espinoso, Pepinillo Del Diablo;
Sri Lanka: Tumba Karavila (Sinhalese);
Thailand: Bai-Khai-Du, Fakkhao, Phak-Khao, Khika-Khrua Yawd-Fak-Kao;
Vietnam: Dia Ta Pieu (Dao), Ga'c, Day Ga'c, Moc Miet Tu, Mac Khau (Tay), Ma Khau (Thai).

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Origin/Distribution

The species is distributed from south China through southeast Asia to north-eastern Australia. It is cultivated in southern China, Indo China and Thailand.

Agroecology

Giant spine gourd thrives in the warm humid tropics with mean annual temperatures of 20–35°C and annual average rainfall of 1,500–2,500 mm. It does well in the lowlands in fertile organic, humus-rich and moist but well-drained soils, e.g. around ponds, rice-fields, and abandoned areas, and home backyards. It is hygrophilous, prefers sunny positions but is slightly shade tolerant. It is planted from seeds, tubers or stem cuttings. Few seeds need to be planted in the same hole in the ground to ensure male and female plants are planted close for good fruit set. Most male plants are removed. Prolific fruiting occurs usually in the second year and thereafter. Plants survive for 10–12 years.

Edible Plant Parts and Uses

The fruit is used for food and medicine in Southeast Asia. The aril – red, oily pulp surrounding the seeds, is cooked along with seeds to flavour and give its red colour to a rice dish, *xoi gac*, which is served at festive occasions such as weddings, birthdays, Lunar New Year (Tet) in Vietnam. Elsewhere the unripe fruits are used as vegetables and in curries. Recently Ga'c has been promoted and marketed outside of Asia as dietary health juice supplements because of its high phytonutrients (lycopene, β-carotene and antioxidants) content. The young leaves are eaten as vegetables by the Karen communities in Thailand, in Bali, Indonesia and in the Philippines. In Thailand, the young fruits, leafy shoots and flowers are used in curries. After boiling they are eaten with chili sauce and rice. Young leafy shoots are also fried with oyster sauce and pork or shrimp.

Botany

The plant is a perennial twining, dioecious vine, with an angular robust, glabrous stem and tuberous roots. Tendrils are simple and stout. Leaves are fairly large, alternate and deeply 3–5 palmately lobed with faintly dentate margins, cordate bases, glabrous, dark green above and lighter green below and petiolated (2–3 cm) (Plate 4). Flower is monoecious, unisexual, solitary in leaf axils, white to ivory yellow. Female flowers have small bracts and a scabrous ovary while male flowers have broad reniform bracts, calyx tube is short with triangular lobes, corolla has 5 yellow, ovoid-oblong petals, stamens 5. Fruit is large, 12–17 cm diameter, ovoid, globose to oval, with sharp pointed protuberances and a rigid peduncle; green when young turning orangey-red to dark red when mature and ripe (Plates 1–3). Seed is large, ovoid, compressed

Plate 1 Large, orangey, spiny globose Gac fruits

Plate 2 Large, orangey-red, spiny oval Gac fruits

Plate 3 Immature, green gac fruit on a long pedicel

Plate 4 Deeply, three-palmately lobed leaves

Plate 5 Red, oil-rich pulpy arils

Plate 6 Large, irregularly sculptured gac seeds

with a wavy outline, blackish-brown with irregularly sculptured seed coat (Plate 6) covered in a red oily, pulpy aril (Plate 5).

Nutritive/Medicinal Properties

Gac fruit was reported to have the following proximate nutrient composition per 100 g edible portion based on analysis by the Institute of Nutrition and Food science, Dhaka University, Bangladesh (INFS/WFP 1988): moisture 79.4 g, energy 80 kcal, carbohydrate, 17.4 g, protein 2.1 g, fibre 1.6 g, fat 0.3 g, ash 0.9 g, calcium 36 mg and β-carotene 410 μg. The young leaves which are eaten in Thailand by the Karen community was reported to have the following nutrient composition based on analysis conducted at Food Chemistry Laboratory, Institute of Nutrition Mahidol University, Thailand, moisture 88 g, energy 43 kcal, protein 5.6 g, fat 1 g, carbohydrate 3.0 g, fibre 5.4 g, ash 1.1 g, calcium 114 mg, iron 0.9 mg, vitamin C 147 mg, vitamin A (RE) 306 μg, vitamin A (RAE) 153 μg and β-carotene 1836 μg (INMU Institute of Nutrition and Mahidol 2005; Smitasiri 2005).

Gac is a valuable and rich source of phytonutrients like lycopene, β-carotene and antioxidants. It is used not only for culinary but also for nutritional and medicinal purposes. The fruit contains by far the highest content of β-carotene of any known fruit or vegetable. Relative to mass, it was found to contain up to 70 times the amount of lycopene found in tomatoes, up to 10 times the amount of β-carotene in carrots or sweet potato (Vuong 2003). Additionally, the carotenoids present in gac were found to be bound to long-chain fatty acids. The mean total lycopene in all the fruit aril tissues was determined to be 2,227 μg/g total lycopene, 1,342 μg/g trans-lycopene, 204 μg/g

cis-lycopene, and 718 μg/g mean total β-carotene, 597 μg/g trans β-carotene, 39 μg/g cis β-carotene , and 107 μg/g α-carotene FW (Ishida et al. 2004). The fruit mesocarp contained 11 μg/g trans-β-carotene, 5 μg/g cis-β-carotene FW, trace amounts of α-carotene, and no lycopene. Gac aril contained 22% fatty acids by weight, composed of 32% oleic, 29% palmitic, and 28% linoleic acids. Seeds contained primarily stearic acid (60.5%), smaller amounts of linoleic (20%), oleic (9%), and palmitic (5–6%) acids, and trace amounts of arachidic, cis-vaccenic, linolenic, and palmitoleic, eicosa-11-enoic acids, and eicosa-13-enoic (in one fruit only) acids (Ishida et al. 2004). The total carotene concentration in gac fruit oil was 5,700 μg/ml. (Vuong and King 2003). The concentration of β-carotene was 2,710 μg/ml. Sixty-nine percent of total fat was unsaturated, and 35% of that was polyunsaturated.

The fatty acid composition of gac pulp (Vuong 2003; Vuong and King 2003) was reported as follows: SFA – C14:0 (myristic acid) 0.87%, C16:0 (palmitic acid) 22.04%, C18:0 (stearic acid) 7.06%, C20:0 (eicosanoic acid) 0.39%, C22:0 (docosanoic acid) 0.19% C24:0 (tetracosanoic acid) 0.14%; MUFA −16:1 (palmitoleic acid) C18:1, n-9 (oleic acid) 34.08%, C18:1n7 (vaccenic acid) 1.13%, C20:1 (gadoleic acid) 0.15%; PUFA- C18:2 (linoleic acid) 31.43%, C18:3, n-3 (α-linolenic acid) 2.14%, C20:4 (arachidonic acid) 0.10%.

Lycopene was found to be predominantly present in the Gac seed membrane (aril) at a concentration of up to 380 μg/g of seed membrane (Aoki et al. 2002). The concentration of lycopene in the Gac seed membrane was about 10-times higher than that in known lycopene-rich fruit and vegetables, indicating that Gac fruit could be a new and potentially valuable source of lycopene. Besides β-carotene and lycopene, Gac also had other carotenoids like zeaxanthin and β-cryptoxanthin. The total carotenoid concentration in the fruit was determined to be 497 μg/g fresh material with lycopene dominating and exceeding β-carotene concentrations by a factor of approximately 5 (408 μg/g versus 83 μg/g) (Vuong et al. 2006). A sample of pulp mixed with mesocarp had significantly lower concentrations of total carotenoids. The α-tocopherol (vitamin E) concentration in the pulp was found to be 76 μg/g.

In-vitro and in-vivo (human) studies confirmed gac fruit to be an outstanding natural source of bioavailable carotenes (Vuong et al. 2002; Failla et al. 2008). In a double-blind study with 185 Vietnamese preschool children, some were given Xoi Gac containing 3.5 mg/day β-carotene, while others were given an identical-looking dish containing 5 mg β-carotene powder, for 30 days (Vuong et al. 2002). At the end of the trial, the gac fruit group had significantly higher plasma levels of β-carotene than the latter. Increases in plasma retinol, α-carotene, zeaxanthin, and lycopene levels were also significantly greater in children given gac (Vuong et al. 2002). It was postulated that the fatty acids in gac made its β-carotene more bioavailable than that of the synthetic form (Kuhnlein 2004; Vuong et al. 2002). Conversely, consumption of certain β-carotene- rich foods had been shown to produce little increase in plasma β-carotene or retinol concentrations (Vuong et al. 2002). Failla et al. (2008) studied the digestive stability, efficiency of micellarization, and uptake and intracellular stability of cis and all-trans isomers of lycopenes and carotenes in gac fruit oil using the coupled in-vitro digestion and Caco-2 human intestinal cell model. The ratio of cis:trans isomers of lycopenes and β-carotene was similar before and after simulated gastric and small intestinal digestion with recovery of total carotenoids in the digesta exceeding 70%. Micellarization of cis isomers of lycopenes during digestion of meals with both gac aril and oil was significantly more than that of the all-trans isomer but less than for the carotenes. Uptake of cis isomers of lycopenes by Caco-2 cells was similar to that of carotenes and significantly greater than all-trans lycopenes. Micellarized carotenoids were relatively stable in micelles incubated in the cell culture environment and after accumulation in Caco-2 cells. The data suggested that the greater bioaccessibility of cis compared with all-trans isomers of lycopenes contributed to the enrichment of the cis isomers in tissues implying gac fruit to be an excellent bioaccessible source for lycopenes and provitamin A carotenoids.

Gac seed aril was found to contain high concentrations of carotenoids, especially the provitamin A, β-carotene (Vuong et al. 2003). The total carotene concentration in gac fruit oil was 5,700 μg/ml. The concentration of β-carotene was 2,710 μg/ml. Sixty-nine percent of total fat was unsaturated, and 35% of that was polyunsaturated. The average daily consumption of gac fruit oil was estimated at 2 ml per person. The daily β-carotene intake (from gac fruit oil) averaged approximately 5 mg per person. Gac fruit oil was found to be a rich source of β-carotene, vitamin E (Vuong and King 2003; Kuhnlein 2004), and essential fatty acids. Although the β-carotene concentration declined with time without preservative or proper storage, it was still high after 3 months. The oil was readily accepted by women and their children, and consumption of the oil increased the intake of β-carotene and reduced the intake of lard (Vuong et al. 2002; Vuong and King 2003).

Six compounds: heptacosane; ursolicacid; oleanolic acid; 18-pentatriacontanone; stigmast-4-ene-3β,6a-diol; and stearic acid were isolated and identified from *M. cochinchinensis* fruit (Liu et al. 2010).

Phytochemicals from Other Plant Parts

A new triterpenoid ester 3,29-di-O-(p-methoxy) benzoylmultiflora-8-ene-3α,29-diol-7-one was isolated from the seeds of *Momordica cochinchinensis* (De Shan et al. 2001). Gao (2005) reported that dried ripe seeds of *Momordica cochinchinensis*, known for its antiinflammatory activity against suppurative skin infection, were found to compose of compounds including fatty acids, saponins, proteins, α-spinasterol, oleanolic acid, and momordica acid. Among these compounds, momordica saponin I, glycoside, a triterpenoid saponin containing disaccharide chain, was found to be a major active ingredient (Kubota et al. 1971). Chemical constituents of unsaponifiable matter from seed oil included karounidiol, isokarounidiol, 5-dehydrokarounidiol, 7-oxodihydrokarounidiol, β-sitosterol, stigmast-7-en-3β-ol, and stigmast-7,22-dien-3β-ol (Kan et al. 2006).

A pentacyclic steroid was isolated from the hexane extract of *M. cochinchinensis* leaves (Nantachit and Patoomrat 2008). Three saponins named momordins I, II and III were isolated from the roots (Iwamoto et al. 1985). Momordin II was proven to be identical with hemsloside Ma_1 isolated from the tubers of *Hemsleya macrosperma* and *H. chinensis*. Ten minor saponins, momordin Ia, momordin Ib, momordin Ic, momordin Id, momordin Ie and momordin IIa, momordin IIb, momordin IIc, momordin IId and momordin IIe, were isolated from the root of *Momordica cochinchinensis*, along with the known major saponins, momordin I and momordin II (Kawamura et al. 1988). Chondrillasterol was isolated from the tubers of *Momordica cochinchinensis*. (Hasan et al. 1987) and columbin from the root (Waterman et al. 1985). Momorchochin isolated from tubers of *Momordica cochinchinensis* was found to be a glycoprotein with high Asx and Glx residues, a molecular weight of approximately 30,000 (Ng et al. 1992).

Scientific studies have reported on the pharmacological properties of the gac plant in particular in the aril, seed, leaves and roots.

Antioxidant Activity

Pretreatment of rat hepatocytes with chymotrypsin-specific potato type I inhibitor from *Momordica cochinchinensis* (MCoCI) for 24 h significantly reversed tert-butyl hydroperoxide-induced cell damage, and the associated glutathione depletion and lipid peroxidation (Tsoi et al. 2005). The activities of glutathione-S-transferase and superoxide dismutase were also increased. These results suggested that MCoCI possessed antioxidative activity which may account for some of the pharmacological effects of *Momordica cochinchinensis* seeds, the traditional Chinese medicine known as Mubiezhi, from which MCoCI was isolated.

Anticancer and Antiviral Activities

The water extract of Ga'c fruit inhibited the growth of the colon 26–20 adenocarcinoma cell

line, transplanted in Balb/c mice, reducing wet tumour weight by 23.6% (Tien et al. 2005). Histological and immunohistochemical results indicated that Gac water extract reduced the density of blood vessels around the carcinoma. The water extract also produced a marked suppression of cell proliferation in colon 26–20 and HepG2 cells. Treatment of colon 26–20 cells with Gac extract induced necrosis rather than apoptosis. The antitumour component was confirmed as a protein with molecular weight of 35 kDa, retained in the water-soluble high molecular weight fraction. The bioactive antitumour compound in Gac extract was a protein, which was different from lycopene, another compound in Gac fruit with potential antitumour activity. Gac aril with over 70 times more lycopene/gram than tomatoes, suggested interesting implications for prostate health. Epidemiological studies showed that high intakes of tomatoes and tomato products, rich in lycopene, as well as high blood levels of lycopene, were significantly associated with decreased prostate cancer risk (Deming et al. 2002; Giles and Ireland 1997; Vogt et al. 2002).

Cochinin B a novel ribosome-inactivating protein (RIP) purified from the seeds of *Momordica cochinchinensis*, displayed a strong inhibitory activity on protein synthesis in the cell-free rabbit reticulocyte lysate system with IC_{50} of 0.36 nM (Chuethong et al. 2007). Further, it exhibited N-glycosidase activity and cytotoxicity against Vero cell line with IC_{50} higher than 1,540 nM. Also, Cochinin B manifested strong anti-tumour activities on human cervical epithelial carcinoma (HeLa), human embryonic kidney (HEK293) and human small cell lung cancer (NCI-H187) cell lines with IC_{50} of 16.9, 114 and 574 nM, respectively. Zhao et al. (2010a) showed that the ethanol seed extract of *M. cochinchinensis* significantly inhibited the proliferation of A549, MDA-MB-231,TE-13 and B16 tumour cell lines in a dose-dependent manner by arresting cell cycle and inducing apoptosis of tumour cell. Ethanol seed extract of *M. cochinchinensis* (10–100 mg/l) strongly and dose-dependently inhibited the proliferation of melanoma B16 cells, through induction of differentiation and promotion of apoptosis of B16 cells (Zhao et al. 2010b). At 100 mg/l concentration, melanin production and tyrosinase activity.

Karounidiol at 2 μM/mouse markedly suppressed the promoting effect of TPA (12-*O*-tetradecanoylphorbol-13-acetate) (1 μg/mouse) on skin tumour formation in mice following initiation with 7,12-dimethylbenz[a]anthracene (50 μg/mouse) (Yasukawa et al. 1994). Karounidiol (1), isokarounidiol (2), 5-dehydrokarounidiol (3), 7-oxodihydrokarounidiol (4) showed an inhibitory effect against EBV-EA activation (Akihisa et al. 2001). Karounidiol also exhibited inhibitory activity against human cancer cell lines, it demonstrated cytotoxicity especially against a human renal cancer.

Chan et al. (2009) isolated and characterised from *M. cochinchinensis* seeds, two novel peptides, MCoCC-1 and MCoCC-2, containing 33 and 32 amino acids, respectively, which were toxic against three cancer cell lines. The two peptides were highly homologous to one another, but showed no sequence similarity to known peptides. Elucidation of the three-dimensional structure of MCoCC-1 suggested the presence of a cystine knot motif, also found in a family of trypsin inhibitor peptides from this plant. However, unlike its structural counterparts, MCoCC-1 did not inhibit trypsin. Of the cell lines tested, MCoCC-1 was the most toxic against a human melanoma cell line (MM96L) and was non-hemolytic to human erythrocytes.

Gastroprotective and Antiulcerogenic Activities

Kang et al. (2009) reported that SK-MS10, an extract from *Momordica cochinchinensis* seeds rich in *Momordica* saponins, exhibited gastroprotective effects against acute gastric mucosal damage by suppressing proinflammatory cytokines, down-regulating cytosolic phospholipase A2 (cPLA2), 5-lipoxygenase (5-LOX), and enhancing the synthesis of mucus in an acute gastric mucosal damage model in rats. It was also demonstrated that the calcitonin gene-related peptide (CGRP)-nitricoxide (NO) pathway played an important role in the gastroprotective effects of

SK-MS10. In further studies Kang et al. (2010) reported that treatment with SK-MS10 for 7 and 14 days significantly accelerated ulcer healing and increased the expression of mRNA (at day 7) as well as vascular endothelial growth factor (VEGF) protein (at day 14) compared to the vehicle-treated rats. The microvasculature density for factor VIII was also higher in the SK-MS10 treatment group compared to the vehicle-treated rats. The results suggested that SK-MS10 treatment accelerated the healing of gastric ulcers via upregulation of VEGF and angiogenesis in an acetic acid rat model.

Immuno-Enhancing and Antiinflammatory Activity

Female BALB/c mice were immunized with either dianthin32 or momochin, type 1 ribosome-inactivating proteins (RIPs) derived from *Dianthus charyophyllus* and *Momordica cochinchinensis*, respectively (Porro et al. 1994). Five anti-dianthin32 and 6 anti-momochin secreting hybridomas were obtained by somatic fusion of lymphocytes with myeloma (B-cancer) cell line NS0. The monoclonal antibodies (MAbs) produced were highly specific. The affinity constant of anti-RIPs MAbs ranged between 10^8/M and 10^{10}/M.

Chymotrypsin-specific potato type I inhibitor from *Momordica cochinchinensis* (MCoCI) was shown to possess immuno-enhancing and anti-inflammatory effects (Tsoi et al. 2006). MCoCI stimulated the proliferation of different cells of the immune system, e.g. splenocytes, splenic lymphocytes and bone marrow cells, in a manner comparable to that of Concanavalin A. Furthermore, MCoCI suppressed the formation of hydrogen peroxide in neutrophils and macrophages. Karounidiol and 7-oxodihydrokarounidiol from *M. cochinchinensis* seed oil inhibited the inflammatory activity induced by 12-O-tetradecanoylphorbol-13-acetate (TPA) and the 50% inhibitory dose for TPA-induced inflammation was 0.3 and 0.4 mg/ear, respectively (Yasukawa et al. 1994).

Studies showed that ovalbumin (OVA, 10 μg) when co-administered with an extract from *Momordica cochinchinensis* seeds (ECMS) in Balb/c mice, may induce significantly higher specific antibody production than OVA used alone (Xiao et al. 2007a, b). Analysis of antibody isotypes indicated that the ECMS could promote the production of both IgG1 and IgG2a, but favoured the IgG2a. Splenocyte proliferative responses to concanavalin A, lipopolysaccharides or OVA were significantly higher in mice immunized with OVA mixed with ECMS than immunized with OVA alone or mixed with aluminum hydroxide. No local reactions and negative effects on the body weight gain occurred after the injection of OVA mixed with various amounts of ECMS in mice. ECMS was found to be safe for injection and could be used as a potential vaccine adjuvant biasing the production of IgG2a in mice.

Ribsome Inactivating Protein Activity

A ribosome-inactivating protein, momorcochin-S, was purified from the seeds of *Momordica cochinchinensis* (Bolognesi et al. 1989). This protein could be considered as an iso-form of the previously purified momorcochin from the roots of *M. cochinchinensis*. Momorcochin-S inhibited protein synthesis by a rabbit-reticulocyte lysate and phenylalanine polymerization by isolated ribosomes, and altered rRNA in a similar manner as the A-chain of ricin and related toxins (Endo et al. 1987). Momorcochin-S was linked to a monoclonal antibody (8A) against human plasma cells, and the resulting immunotoxin was selectively toxic to target cells.

Abortifacient Activity

Momorcochin, glycoprotein from *M. cochinchinensis* root tubers was found capable of inducing mid-term abortion in mice (Yeung et al. 1987). The glycoprotein had a molecular weight of 32,000 and was characterised by an abundance of asparagine and glutamine amino acid residues. Momorchochin isolated from tubers was reported to exhibit abortifacient, antitumour, ribosome inactivating and immunomodulatory activities (Ng et al. 1992).

Hemolytic Activity

A hemolytic fraction was obtained from fresh tubers of *Momordica cochinchinensis* (Ng et al. 1986). The hemolytic activity of the fraction could be attributed to steryl glycoside(s). The hemolytic activity of the fraction was resistant to heat and proteolytic enzymes. The D_6 component exerted the strongest lytic activity.

Antipruritic Activity

Oleanolic acid glycosides from the roots of *M. cochinchinensis* exhibited antipruritic effect in compound 48/80-induced pruritic mice (Matsuda et al. 1998). Oleanolic acid 3-O-monodesmosides showed an antipruritic effect, while oleanolic acid 3,28-O-bisdesmosides and their common sapogenol oleanolic acid were devoid of activity. The results indicated that the 3-O-glycoside moiety and the 28-carboxyl group in oleanolic acid glycosides were essential for exhibiting the antipruritic effect. Moreover, it was found that the 3-O-glucuronides showed more potent activity than the corresponding 3-O-glucosides.

Hypoglycaemic Activity

Two glycosides, MG-1 containing glucose, and MG-2 containing arabinose were isolated from the tubers of *Momordica cochinchinensis* (Jalil et al. 1986). Both glycosides contained "oleanolic acid" as aglycone and showed hypoglycemic activities in the streptozotocin induced diabetic rats at a dose of 25 mg/kg. Intraperitoneal administration showed better activity than oral administration.

Antimicrobial Activity

A *Momordica* triterpenoid ester isolated from hexane leaf extract showed antimicrobial activity against ten pathogenic bacteria: *Staphylococcus aureus*, *Escheria coli*, *Pseudomonas aeruginosa*, Methicillin-resistant *Staphylococcus aureus* (MRSA), Methicillin-sensitive *Staphylococcus aureus* (MSSA) and the isolated strains from patients which were *Acintobacter baumannii, Pseudomonas aeruginosa, Escherichia coli, Enterobacter cloacae* and *Klebsiella pneumoniae.* (Nantachit and Tuchinda 2009). The *Momordica* triterpenoid ester also showed antifungal activity against three types of pathogenic fungi: *Candida albicans, Aspergillus flavus* and *Trichophyton mentagrophytes.*

Trypsin Inhibition Activity

A trypsin inhibitor, MCCTI-1, with a molecular weight of 3,479, was isolated from *Momordica cochinchinensis* seeds (Huang et al. 1999). Three trypsin inhibitors, MCoTI-I, MCoTI -II and MCoTI-III were isolated, purified and characterised from the seeds of *Momordica cochinchinensis* (Hernandez et al. 2000). In the case of MCoTI-I and -II, it was shown that their polypeptide backbones were cyclic. They were found to contain 34 amino acid residues with 3 disulfide bridges and measured molecular masses of 3,453.0 and 3,480.7, respectively. They represented the largest known macrocyclic peptides containing disulfide bridges and their sequences showed strong homology to other squash trypsin inhibitors. MCoTI-III was found as a minor species containing 30 amino acid residues with a molecular mass of 3,379.6. This component was found to possesses a linear backbone with a blocked N-terminus. MCoTI-II, macrocyclic squash trypsin inhibitor from *Momordica cochinchinensis* seeds was found to have a "knottin" fold in its structure (Heitz et al. 2001). The "knottin" fold represented a stable cysteine-rich scaffold, in which one disulfide crosses the macrocycle made by two other disulfides and the connecting backbone segments. MCoTI-II, displayed no significant antibacterial activity, unlike other cyclic knottins, i.e., kalata B1 or circulin A. Felizmenio-Quimio et al. (2001) found MCoTI-II, a novel trypsin inhibitor from *Momordica cochinchinensis*, to have different sequence and biological activity from known cyclotides. Based on its structural similarity, cyclic backbone, and

plant origin they proposed that MCoTI-II could be classified as a new member of the cyclotide class of proteins. While the cyclic inhibitors MCoTI-I and MCoTI-II were found to be very potent trypsin inhibitors, the open-chain variants displayed an approximately 10-fold lower affinity (Avrutina et al. 2005). The data suggested that the formation of a circular backbone in the MCoTI squash inhibitors resulted in enhanced affinity and therefore was a determinant of biological activity.

Recently, Sommerhoff et al. (2010) reported on the design, chemical and recombinant synthesis, and functional properties of a series of novel inhibitors of human mast cell tryptase beta, a protease of considerable interest as a therapeutic target for the treatment of allergic asthma and inflammatory disorders. These inhibitors were derived from a linear variant of the cyclic cystine knot miniprotein MCoTI-II, originally isolated from the seeds of *Momordica cochinchinensis*. These cystine knot miniproteins may therefore become valuable scaffolds for the design of a new generation of tryptase inhibitors.

Five trypsin inhibitors, with N-terminal sequences demonstrating homology to each other and exhibiting a molecular weight of 5,100, 4,800, 4,400, 4,100, and 3,900, respectively, were isolated from *Momordica cochinchinensis* seeds (Wong et al. 2004). Tsoi et al. (2004) isolated an inhibitor, named MCoCl that belonged to the potato I inhibitor family from *M. cochinchinensis* seeds. MCoCl, possessed remarkable thermostability and was stable from pH 2 to 12. MCoCl also inhibited subtilisin, but had at least 50-fold lower inhibitory activity towards trypsin and elastase. Amino acid sequencing of a peptide fragment of MCoCl revealed a sequence of 23 amino acids.

Traditional Medicinal Uses

The seeds of the *Momordica cochinchinensis* known in traditional Chinese medicine (TCM) as "Mubiezi", has been utilized in China for more than 1,200 years. It is traditionally used for a variety of internal and external purposes that include the treatment of inflammatory swelling, scrofula, tinea, diarrhea as well as suppurative skin infections such as sore, carbuncles, furuncles and boils in both humans and animals (Xiao et al. 2007a, b). The seeds are thought to have resolvent and cooling properties, and are used for liver and spleen disorders, wounds, hemorrhoids, bruises, swelling, and pus (De Shan, et al. 2001).

In Vietnam, gac is prized by natives for promoting longevity and vitality (Burke et al. 2005). The National Institute of Materia Medica (1999) in Hanoi has listed a comprehensive list of medicinal uses of *M. cochinchinensis.* The oil is believed to invigorate the spleen and stomach and improve eyesight. The oil is recommended for the treatment of children rickets, xerophthalmia, nyctalopia, poor appetite and general weakness. It is beneficial for pregnant and breast feeding women. It is also laxative and used for constipation and also for diarrhoea. The oil is applied externally for wounds, burns and sores. The oil in combination with antibiotics is used for acne. The oil is also considered as a good source of vitamin A. The seeds are principally prescribed for external application and are recommended for furunculosis, scrofula, mastitis, galactophoritis and haemorrhoids. The powdered seeds are administered internally with warm rice wine for malaria with splenomegaly. The ground seed extract is also applied externally for boils, impetigo and scabies as liniment. The roots are believed to remove damp heat, activate blood circulation and promote urination. The roots are applied in the therapy of rheumatism, inflammation, swelling of legs and oedema. In addition to their use in xoi gac, the seed membranes (arils) are used to make a tonic for children and lactating or pregnant women, and to treat "dry eyes" (xerophthalmia) and night blindness (Guichard and Bui 1941). In Thai traditional medicine, the root extracts are used to remedy hair falling, insect bite, cough, haemorhoid and to eliminate poisonous substances, and as a contraceptive (Nantachit and Tuchinda 2009). In the Philippines, the pulverised seeds are pectoral and used for cough and also for haemorrhoids (Stuart 2010). Seeds and leaves are considered aperient and abstergent. The roots are used as soap substitute

and for treatment of head lice and a plaster made from roots are used to promote hair grown. In peninsular Malaysia, The Chinese were reported to use the seeds as an aperients and in treating tumours, malignant ulcers and for obstructions of the liver and spleen (Burkill 1966).

Other Uses

In Indo-China, the seed oil is used as illuminant. The roots are rich in saponins and are used as soap in laundering.

Studies reported that the extract of *M. cochinchinensis* seeds (ECMS) could be used as a supplement in enhancing the serological immune responses to foot-and-mouth disease (FMD) vaccine (Xiao et al. 2007a, b). Foot-and-mouth disease is a highly contagious disease affecting cloven-hoofed animals. Vaccination against FMD is a routine practice in many countries where the disease is endemic. The results indicated that ECMS and oil emulsion act synergistically as adjuvants to promote the production of FMDV- and VP1-specific immunoglobulin G (IgG) and subclasses in guinea pigs. A supplement of ECMS in a commercial FMD vaccine significantly enhanced FMDV-specific indirect hemagglutination assay titers as well as VP1-specific IgG and subclasses in pigs. Therefore, ECMS could be an alternative approach to improving swine FMD vaccination when the vaccine is poor to induce an effective immune response. In further studies, a supplement of extract of *Momordica cochinchinensis* seeds (ECMS) to Newcastle disease vaccine was found to enhance immune responses in chickens (Xiao et al. 2009). Results indicated that humoral immune response was enhanced by ECMS 14 days post-immunization. Eighty μg of ECMS was the best dose with the Newcastle disease vaccine.

Comments

Recent studies by De Wilde on Malesian cucurbits supported the recognition of *M. trifolia* L. (Ceram, Ambon) as a species distinct from the widespread and cultivated *M. cochinchinensis*.

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Momordica subangulata

Scientific Name

***Momordica subangulata* Blume**.

Synonyms

Momordica eberhardtii Gagnepain, *Momordica laotica* Gagnepain, *Momordica renigera* G. Don.

Family

Cucurbitaceae

Common/English Names

Frog Gourd, Teasel Gourd, Wild Bitter Gourd

Vernacular Names

Chinese: Ao E Mu Bie, Yun Nan Mu Bie;
India: Bhat Karela;
Indonesia: Pare Hutan (Malay, Sumatra), Repiye Imbo (Rejang, Sumatra);
Malaysia: Kambas, Peria Katak;
Thai: Phak Hai, Phakmae;
Vietnam: Gấc Cạnh.

Origin/Distribution

The species is endemic to the old World tropics – India, southeast Asia to south China.

Agroecology

In its native range it is a common vine in waste places, thickets, roadsides along forest margin and mountain slopes from sea level to 2,500 m elevation. It has similar agroecological conditions as described for bitter gourd (*Momordica charantia*) and Gac (*Momordica cochinchinensis)*. In cultivation, stakes have to be provided for the plant to climb.

Edible Plant Parts and Uses

Young fruits and shoots are occasionally seen in the local markets. They are eaten cooked in curries, steamed or boiled and eaten with chilli sauce.

Botany

A dioecious, perennial scandent herb with glabrous or puberulent, angular stem and unbranched, short, filiform tendrils. Leaves 3-5-palmately

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Plate 1 Short, stumpy, tuberculate and spinescent fruits of a whitish-green variety

Plate 2 Tuberculate fruits of a green fruited variety

lobed, thin, membranous, 3-5-veined on slender, 5 cm long, glabrous petiole (Plate 3). Leaf blade ovate-reniform, 6–13 by 4–9 cm, base cordate, margins denticulate. Flowers solitary in leaf axils, yellow, up to 5 cm across (Plate 3). Staminate flower with long pedicel up to 12 cm long, subtended with an apical, reniform bract 2 cm long; *calyx* tubular, 5-lobed, lobe ovate, apex emarginate; *corolla* 5, free petals; stamens 3. Female flowers on 6–7 cm long pedicel with minute bract at base; calyx and corolla as in male flower; ovary superior, ovate-oblong or fusiform, 8–12 × 2–4 mm, attenuate at base, ridged or verrucose, 3-carpellate; stigma 3-lobed. Fruit a pepo on slender, glabrous pedicel; ovoid or ovate-oblong, 3–7 cm, 2.5–4 cm in diameter, attenuate at both ends, longitudinally sulcate or with rows of tubercles, or spinescent, greenish-white or green (Plates 1 and 2) ripening yellow. Seeds

Plate 3 Flowers and leaves

gray or yellow-brown, oblong, ovoid or globose, 7–14 mm by 5–8 mm, both surfaces slightly sculptured.

Nutritive/Medicinal Properties

M. subangulata leaf extract had been reported to have hepatoprotective activity (Asha 2001). The leaf suspension (500 mg/kg, fresh weight; 50 mg/kg, dry weight) was found to protect rats from paracetamol-induced liver damage as evaluated from serum marker enzyme activities. It also stimulated bile flow in normal rats.

The Muthuvan (Marayoor) and Kattunaikan (Nilambur) tribals of Kerala use fresh expressed juice of leaves of this plant for jaundice (Asha 2001). In Malaysia, the fruit and foliage is consumed as vegetable and is believed can help to lower the blood pressure and cure diabetes (Saidin 2000).

Other Uses

Its non-edible uses would be similar to that described for bitter melon, *M. charantia.*

Comments

Two subspecies have been recognised (De Wilde and Duyfjes 2002; Lu et al. 2007):

Momordica subangulata subsp. *subangulata* (Synonyms: *Momordica eberhardtii* Gagnepain;

M. laotica Gagnepain) (Chinese vernacular name: ao e mu bie) commonly found in southern China - Guangdong, Guangxi, Guizhou, Yunnan and southeast Asia [Indonesia, Laos, Malaysia, Myanmar, Thailand, Vietnam]. Its distinguishing features are: leaf-blade puberulent at first on both surfaces, glabrescent; calyx segments ovate-oblong, pubescent, apex obtuse, retuse; fruit ovoid or ovate-oblong, longitudinally sulcate or with rows of tubercles, not spinescent.

Momordica subangulata subsp. *renigera* (G. Don) W. J. de Wilde (Synonym: *Momordica renigera* G. Don) (Chinese vernacular name: yun nan mu bie) commonly found in Yunnan [Bangladesh, India, Myanmar, Thailand]. Its distinguishing features are: leaf-blade abaxially puberulent, yellow-brown pubescent on nerves or glabrescent; calyx-segments lanceolate, apex acute; fruit ovate or broadly ovate, spinescent. This subspecies is found wild in mountainous areas of the southeastern Himalayas (De Wilde and Duyfjes 2002) and cultivated by indigenous people in north-eastern India (John et al. 2007). *M. subangulata* ssp. *renigera* can be differentiated from *M. dioica* and *M. sahyadrica* by its tubers. *M. subangulata* ssp. *renigera* has both taproot and adventitious tubers with shoot sprouts all over the tuber surface (John et al. 2009).

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Sechium edule

Scientific Name

***Sechium edule* (Jacq.) Sw.**

Synonyms

Cucumis acutangulus Descourt., *Chayota edulis* (Jacq.) Jacq., *Sechium americanum* Poiret, *Sechium cayota* Hemsley, *Sicyos edulis* Jacq., *Sicyos laciniatus* Descourt.

Family

Cucurbitaceae

Common/English Names

Chaco (West Indies), Chayote, Chayote Squash (USA), Choko (Australia, New Zealand), Choco, Cho-Cho (West Indies, Singapore), Custard Marrow, Madeira Marrow, Vegetable Pear

Vernacular Names

Argentina: Cayota, Papa Del Aire;
Barbados: Christophine;
Belize: Cho-Cho;
Bermuda: Christophine, Mirliton;
Bolivia: Zapallo;
Brazil: Chuchu Alcaiota, Chuchú, Caiota, Chocho, Xuxu, Machuchu;
Burmese: Gorakha Thee;
Chinese: Chun Jen Kua, Zhyn Ren Gua, Fo Zhang Gua, Fo Chang Kua, Fo Shou Gua, Fo Shu Kua;
Columbia: Chayote (Fruit), Chayotera (Vine), Guatila (Cundinamarca), Guasquilla (Boyacá), Sidra (Caldas), Chocho, Cidrayota, Papa De Los Pobre;
Costa Rica: Pís, Pog-Pog-Iku, Seuak, Surú, Tsua-Uá; Tayote, Tayón,Chocho;
Croatian: Meksički Krastavac;
Cuba: Chiote;
Czech: Čajot, Sladkojam;
Danish: Kayote;
Dominican Republic: Tayote, Tayón, Chocho, Chiote;
Dutch: Groente Peer, Laboe Siem;
Eastonian: Tuumkõrvits;
El Salvador: Güisquil, Bisquil, Huisquil, Chuma, Chima, Chimaa, Huisayote, Güisayote, Perulero (yellowish-white cultivar), Pataste (pale green cultivar);
English Caribbean: Christoferine, Christophene, Cho-Cho;
Ecuador: Achocha, Achojcha;
Fiji: Choco, Chayote (Indian), Fat Ahau Kwa (Chinese);
Finnish: Kajottikurpitsa;
French: Christofine, Christophine, Chou-Chou, Chouchoutte, Chayotter;
French Guyana: Christophine, Mirliton;

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French Reunion: Chayote, Chouchou, Christophine;
Guadeloupe: Christophine, Mirliton;
Guatamala: Güisquil, Bisquil, Huisquil, Chuma, Chima, Chimaa, Huisayote, Güisayote, Perulero (yellowish-white cultivar), Pataste (pale green cultivar), Rasi Cimá;
Haiti: Christophine, Mirliton;
Hawaii: Pipinola;
Honduras: Huisquil, Ñame, Patastilla Perulero (yellowish-white cultivar), Pataste (pale green cultivar);
India: Quash (Bengali), Ishkus (Darjeeling), Lanku (Himachal Pradesh), Chow Chow (Hindu), Seemae Ba DhneKayi, Seemebadane (Kannada), Das Goos, Dashkush (Manipuri), Bengaluru Katharikkai, Chocho, Seema-Kattirikkai (Tamil), Bengaluru Vankaaya, Seemae Vangakaaya (Telugu), Sumsum, Vilaiti Vanga;
Indonesia: Labu Siam, Labu Jepang, Waluh Jepang, Manisah (Javanese), Labu Siam, Labu Cina (Madurese), Gambas, Ledjet, Waluh Siam (Sundanese);
Italian: Zucca, Zucca Centenaria, Saiotta, Zuccheta Africana;
Jamaica: Chiote, Chocho, Chow Chow, Tayón, Tayote;
Japanese: Hayatouri;
Khmer: Su-Suu;
Laotian: Taub Thaj, Taub Maun (Hmong Tribe), Mak Noi Thai, Mak Sa Veu, Nooy Th'ai, Savëëx;
Malaysia: Labu Siam;
Maltese: Ċentinarja;
Mexico: Apupo, Apopu (Michoácan; Tarasco), Niktin (Oaxaca; Trique), Naña (Oaxaca; Mixteco), Itú-Ts', Jit-Jiap, Yape (Oaxaca; Dialectal variations of Zapoteco found in Ixtlán, Tlacolula and the Isthmus of Tehuantepec), Aj-Shá (Oaxaca; Mixe), Rign, Nñ (Oaxaca; Chinanteco), Mishi, Cal-Mishi (Oaxaca; Chontal), Tzihu, Tzihub (San Luis Potosí; Huasteco), Mú-U (State of Mexico; Mazahua), Shamú, Xamú (State of Mexico and Hidalgo; Mazahua), Chayoj, Chayojtli (Puebla and Morelos);
Nepalese: Iskul, Ishkus, Skul, Skush;
Nicaragua: Chaya;
Norway: Chavote;
Panama: Chayote;
Papua New Guinea: Choko, Sako, Kru Sago;
Paraguay: Pap Del Aire;
Peru: Gayota;
Philippines: Chayote, Hayuti, Sayote, Tsayote;
Polish: Kolczoch Jadalny;
Portuguese: Chahiota, Cahiota, Caiota, Chuchu, Pepinella, Pepinela, Pimpinela, Pipinella, Pepinello, Xuxu;
Puerto Rico: Pipinela, Talote, Tayote, Tayón, Chocho, Chiote;
Russian: Cajot, Čayot;
Slovaščina: Bodeča Buča, Bodičasta Bučka, Čajota;
Slovenian: Čajota;
Sri Lanka: Chjocho;
Swedish: Kayote;
Thai: Fak Maeo, Ma Kheua Kreua, Taeng Kariang;
Trinidad and Tobago: Christophine, Mirliton;
Turkish: Amcık Kabağı, Dikenli Kabak, Kıbrıs Kabağı,
Uganda: Ebisusuuti (Luganda);
United States: Christophine, Mirliton (Lousiana) Old Peopl Lips (Slang);
Vietnam: Su, Su Su, Trái Su;
Venezuela: Chayoto;
West Indies: Chiote.

Origin/Distribution

Choko is found wild in the cool mountains of Central America where it was first domesticated by the Aztecs. South Mexico and Guatemala are the centre of greatest diversity of the cultivated chayote and the most likely center of origin for this ancient crop (Newstrom 1991). Today, chayote is grown throughout the tropical (highlands) and subtropical world for the edible fruits and tubers.

Agroecology

Chayote is a cool climate species with optimum temperature range of 13–21°C, temperatures below 13°C damage small or unripe fruit while

beyond 28°C favour excessive growth and abortion of flowers and unripe fruit, all of which reduces production. It is a medium- to high-altitude crop (300–2,000 m above sea level), it requires a high relative humidity (80–85%), well-distributed, annual rainfall of at least 1,500–2,000 mm and has a day-length requirement of 12–12.5 h for flowering. It thrives best in full sun on a moist, well-drained, deep, fertile soil rich in organic matter. Waterlogged, clayey soil or sandy soil should be avoided. It is usually grown on trellises. It is cold and frost sensitive.

Edible Plant Parts and Uses

Fruit, young leaves, shoots, stems and tuberous roots are edible. The fruit, stems and young leaves as well as the tuberized portions of the roots are eaten as a vegetable, both alone and plain boiled, and as an ingredient of numerous stews.

Chayote fruit are sometimes eaten raw in salads and salsas, but are more often cooked by boiling, sautéing or baking or stuffed, mashed, fried, scalloped or pickled. The fruits are also used in curries. The fruit can be halved and bake like a winter squash and serve with butter. The peeled sections of the fruit can be cubed for frying or used in soups. Because of the softness of the flesh, the fruit has been used for baby and children's food, juices, sauces and pasta dishes. In Mexico, an attempt has been made to increase the life of the fruit by drying it. This has enabled jams and other sweets to be prepared while also producing dried fruit which can be used as a vegetable subsequently. In China, the fully grown light green fruit is cooked as vegetables. In Indonesia the young fruit and tendriled shoots are used in *sayur* or are boiled as *lalab.* The fruits are also made into *kolek.* The tubers are cooked as *huwi boled* and eaten as a delicacy and taste like sweet potatoes. The seeds are also edible and are fried or roasted.

Young leaves and tendrils are also eaten, and seeds can be sautéed in butter as a delicacy. In Taiwan, chayote is widely planted for its edible shoot, known as *lóng xü cài* (lit. Dragon-whiskers vegetable). Along with the young leaves, the shoot is a commonly consumed vegetable in the region as also in Vietnam and Thailand. Teas are prepared from the leaves.

The large storage roots represent a rich source of starch and are eaten. Tubers from vines at least 2 years old are candied, boiled, or roasted like potatoes.

Botany

A perennial, monoecious climbing vine, with thickened tuberous roots and slender, branching, grooved angular stems and 3–5 fid tendrils. Petioles are sulcate, glabrous and 8–15 cm in length bearing reniform –cordate to ovate-cordate leaves, measure 10–20 cm long and wide, shallowly 3–5 lobed, scabrid above and hairy below and with minutely denticulate margins (Plate 4). Flowers small, greenish-white, unisexual, normally pentamerous, coaxillary and with ten nectaries in the form of a pore at the base of the calyx. Staminate flowers in axillary racemose inflorescences that are 10–30 cm long, with patteliform calyx consisting of 5 triangular sepals, 5 triangular petals and 5 stamens with fused filaments forming a thickened column. Pistillate flowers solitary on in pairs and coaxillary with male flowers, with similar perianth, and a globose, ovoid or piriform, glabrous and unilocular ovary. Fruit fleshy, viviparous, sometimes longitudinally sulcate or cristate, of

Plate 1 Green fruited choko cultivar

Plate 2 Yellow-fruited choko cultivar

Plate 3 Choko fruits on sale in a local market

Plate 4 Leafy shoots on sale in a local market

variable shape and sizes, indumentum and spines, usually 8–18 cm long by 7–12 cm across the distal end, white and yellowish, or pale green to dark green or brown with a pale green to whitish flesh (Plates 1–3) and a single large seed. Seed is ovoid and compressed with a soft and smooth testa and often germinates within the fruit.

Nutritive/Medicinal Properties

Analyses carried out in the United States reported that raw, chayote (excluding 1% fruit end and stem) had the following proximate composition (per 100 g edible portion): water 94.24 g, energy 19 kcal (80 kJ), protein 0.82 g, total lipid 0.13 g, ash 0.30 g, carbohydrates 4.51 g, total dietary fibre 1.7 g, Ca 17 mg, Fe 0.34 mg, Mg 12 mg, P 18 mg, K 125 mg, Na 2 mg, Zn 0.74 mg, Cu 0.123 mg, Mn 0.189 mg, Se 0.2 μg, vitamin C 7.7 mg, thiamine 0.0.025 mg, riboflavin 0.029 mg, niacin 0.470 mg, pantothenic acid 0.249 mg, vitamin B-6 0.076 mg, total folate 93 μg, choline 9.2 mg, vitamin E (α-tocopherol) 0.12 mg, vitamin K (phylloquinone) 4.1 μg, total saturated fatty acids 0.028 g, total monounsaturated fatty acids 0.010 g, total polyunsaturated fatty acids 0.057 g, amino acids – tryptophan 0.011 g, threonine 0.040 g, isoleucine 0.044 g, leucine 0.077 g, lysine 0.039 g, methionine 0.001 g, phenylalanine 0.047 g, tyrosine 0.032 g, valine 0.063 g, arginine 0.035 g, histidine 0.015 g, alanine 0.051 g, aspartic acid 0.092 g, glutamic acid 0.125 g, glycine 0.042 g, proline 0.044 g, serine 0.047 g; β-carotene 2 μg, β-cryptoxanthin 2 μg (USDA 2010).

As noted from the above, the fruit is particularly rich in all the essential amino acids such as aspartic acid, glutamic acid, alanine, arginine, cysteine, phenylalanine, glycine, histidine, isoleucine, leucine, methionine, proline, serine, tyrosine, threonine and valine and have adequate micronutrients and macronutrients and traces of β-carotene and β-cryptoxanthin.

Starch was isolated with a yield of 49% and purity of 89.1% from Mexican chayote tubers (Hernandez-Uribe et al. 2011). Chayote starch

granules had diverse shapes such as spherical, oval, and polygonal, with size between 10 and 25 μm. Compared to potato starch, chayote starch had higher peak viscosity, hysteresis, Mw and Rz values and lower gelatinization temperatures.

Eight flavonoids, including three C-glycosyl and five O-glycosyl flavones, were detected, in roots, leaves, stems, and fruits of *Sechium edule* (Siciliano et al. 2004). The aglycone moieties were represented by apigenin and luteolin, while the sugar units comprised glucose, apiose, and rhamnose. The highest total amount of flavonoids was in the leaves (35.0 mg/10 g of dried part), followed by roots (30.5 mg/10 g), and finally by stems (19.3 mg/10 g).

Sechium edule possesses some pharmacological activities:-

Antioxidant Activity

Ethanolic leaves and seeds extracts of *Sechium edule* were found to have antioxidant properties as determined by β-carotene linoleate model,1,1-diphenyl-2 picrylhydrazyl (DPPH) radical-scavenging assay and potassium ferricyanide reduction method (Ordoñez et al. 2006). Leaf and seed extracts may be exploited as biopreservatives in food applications as well as for health supplements or functional food, to alleviate oxidative stress.

Diré et al. (2007a) found the macerated extract of chayote fruit to influence the survival of the strain of *Escherichia coli* AB1157 submitted to reactive oxygen species induced by stannous chloride (Diré et al. 2007a). Chayote reduced the lethal effect induced by stannous chloride on the survival of the *E. coli*. The results indicated a decrease in the content of glucose and globulin. The effect of the extract could be explained by its metabolic transformation inducing the generation of oxidant metabolites. The chayote extract could be reacting with stannous chloride ions when the bacterial culture was simultaneously treated with the chayote extract and stannous chloride, protecting them against the oxidation and avoiding the generation of reactive oxygen species.

Bio-catalyzer alpha.rho No.11 (Bio-normalyzer) and its by-product, natural health products made by yeast fermentation of glucose, *Carica papaya*, *Pennisetum pupureum*, and *Sechium edule* Swartz were found to have good free radical scavenging activities (Santiago et al. 1991). Their antioxidant effects on free radicals were studied by electron spin resonance spectrometry using spin trapping agent 5,5-dimethyl-1-pyrroline-1-oxide (DMPO). It was found that both Bio-catalyzer and its by-product quenched 95% of DMPO-OH spin adducts (89×10(15) spins/ml) generated by $FeSO_4$-H_2O_2-diethylene triamine pentaacetic acid system at 45.45 mg/ml each. Bio-catalyzer at 25 mg/ml scavenged 5% of DMPO-O2- spin adducts generated by hypoxanthine-xanthine oxidase system and 11% of 1,1-diphenyl-2-picrylhydrazyl radicals, while 5% of superoxide and nil DPPH radicals were quenched by its by-product. In-vivo tests revealed that oral administration of 1 g/kg body weight of Bio-catalyzer significantly inhibited thiobarbituric acid reactive substances formation, which is an index of lipid peroxidation, in the $FeCl_3$-induced epileptic focus of rats. The findings suggested that Bio-catalyzer or its by-product may be useful health foods against neural lipid peroxidation, traumatic epilepsy and aging.

Marotta et al. (2001) found that haemorheological abnormalities in alcoholics could be ameliorated by administration of an oral antioxidant in a random, double blind placebo trial. As compared to healthy controls, alcoholics on placebo treatment of flavoured sugar showed no change of plasma viscosity but a significantly higher red blood cell malonyldialdehyde, blood viscosity and lower plasma glutathione, whole blood filterability and red blood cell fluidity. Administration of the Bionormalizer (obtained from biofermentation of *Carica papaya, Pennisetum purpureum, Sechium edule*, Osato Res. Foundation, Gifu, Japan) 18 g/day for 2 weeks to patients resulted in a significant restoration to control values of either blood viscosity and whole blood filterability and a partial, although significant, improvement of red blood cell membrane fluidity, red blood cell malonyldialdehyde and plasma glutathione. Red blood cell aggregation decreased in alcoholics as compared

to healthy control and was not affected by Bionormalizer. The Bionormalizer significantly ameliorated the reduced blood cell deformability in alcoholics and this parameter correlated with red blood cell malonyldialdehyde. These preliminary data suggested that an effective antioxidant supplementation such as bionormalizer was able to improve the hemorrheology in alcoholics either by directly affecting the ethanol-related lipoperoxidation and xanthine oxidase system activation and/or by altering red blood cell membrane characteristics.

The macerated extract of chayote was found to affect the biodistribution and availability of technetium 99TcO4Na in the different organs of female Wistar rats with induced diabetes and to alter the mass of the different organs (Diré et al. 2007b). It was postulated that the chayote extract when metabolized in the liver may produce reactive metabolites with oxidant properties linked to the stress which was generated by the diabetic status.

Aqueous extracts of plants employed in Mexican traditional medicine for the treatment of cardiovascular diseases including *Sechium edule* were found to contain secondary metabolites that promoted vascular relaxation and exhibited antioxidant activities (Ibarra-Alvarado et al. 2010). Unsurprisingly, their antioxidant effects showed a significant correlation with the polyphenolics content. However, a lower correlation was noted between the antioxidant activity and the maximum vasodilatory effect, suggesting that the vasodilatation induced by the plant extracts could be only partly attributed to their antioxidant properties.

Antimicrobial Activity

Ethanolic extracts of *Sechium edule* showed activity against gram-positive bacteria (*Enterococcus faecalis, Staphylococcus aureus*, coagulase-negative staphylococci, *Streptococcus pyogenes, Streptococcus agalactiae, Staphylococcus aureus*, *Enterococcus faecalis*) (Ordoñez et al. 2003). The highest activity was obtained with the 80% aqueous-ethanolic leaf extract with MIC values of 4.16–8.32 μg/ml against staphylococci and enterococci; and with the 96% ethanolic seed extract with MIC values of 8.32–16.64 μg/ml and >8.32 μg/ml against staphylococci and enterococci, respectively. The results indicated that both fluid extract and tincture have very good antimicrobial efficacy against all strains of multi-resistant staphylococci and enterococci. In subsequent studies, Ordoñez et al. (2009) similarly reported that *Sechium edule* fluid extract exhibited antimicrobial activity against *Escherichia coli, Klebsiella pneumoniae, Proteus mirabilis, Enterobacter cloacae, Serratia marcescens, Morganella morganii, Acinetobacter baumannii, Pseudomonas aeruginosa, Stenotrophomonas maltophilia*, *Candida* spp. and *Aspergillus* spp. isolated from clinical samples from two hospitals in Tucuman, Argentina. Non-toxicity and mutagenicity on both *Salmonella typhimurium* TA98 and TA 100 strains until 100 μg/plate were observed. A hydrogel with carbopol acrylic acid polymer containing *S. edule* fluid extract as antibacterial, antimycotic and antioxidant agent was obtained. The semisolid system exhibited antimicrobial activity against all gram positive and gram negative bacteria and fungi assayed with MIC values ranging from 20 to 800 μg/ml. They suggested that the topical formulation may be used as antimycotic and as antibacterial in cutaneous infections.

Antihypertensive Activity

Water-soluble extracts were prepared from the pulp and peel components of two sub-species of cho-cho fruit produced a decline in mean arterial pressure (MAP) with minimal change in ECG intervals (Gordon et al. 2000). Changes in heart rate with all extracts appeared to be minimal. The mechanism(s) by which these extracts produce their hypotensive effects could not be determined in these preliminary experiments. However, it appeared not to involve direct effects on cardiac tissue as it took a minimum of 10–15 seconds for the hypotensive action to manifest post bolus.

An angiotensin-converting enzyme (ACE) inhibitor, nicotianamine, was purified from

Sechium edule by using some ion-exchange column chromatography (Hayashi et al. 2005). Crystal of nicotianamine (19.8 mg) was obtained from 75 kg of *S. edule*. This inhibitor was further studied as it may play a role in renin-angiotensin system of hypertension.

Antimutagenic and Anticancer Activity

Sechium edule extracts exhibited potent inhibitory effect towards the mutagenicity of 2-amino-3-methyl-imidazo[4,5-f]quinoline in *Salmonella typhimurium* TA98 and TA100, with the ID_{50} of <1 mg/plate (Yen et al. 2001). The antimutagenic activity of water extracts of choko was partly reduced by heating at 100°C for 20 min. Fractions with molecular weights higher than 30,000 showed the strongest anti-mutagenicity and peroxidase activity in all the fractions of the choko extracts.

A new ribosome-inactivating protein (RIP), sechiumin, was purified from the seeds, *Sechium edule* (Wu et al. 1998). It was found to inhibit the protein synthesis of rabbit reticulocyte lysate strongly with a concentration causing 50% inhibition (IC_{50}) of 0.7 nM, but has a much lower inhibitory effect on intact HeLa cells, with an IC_{50} of 5,000 nM. Sechiumin was found to have a highly specific RNA N-glycosidase activity towards 28S rRNA suggesting sechiumin to be one of the type-I ribosome-inactivating proteins. The sechiumin cDNA had 951 nucleotides, encoding a protein with 285 amino acids. Sechiumin exhibited nearly 60% similarity to several type-I RIPs purified from the Cucurbitaceae family, such as luffin-a (62.5%) and trichosanthin (64.8%), but less similarity to other type-I RIPs. Two amino acid residues, Glu160 and Arg163, at the putative active site of sechiumin, were known to be catalytically active in ricin and abrin. The N-terminal amino acid sequence of sechiumin was very similar to that of trichosanthin. The recombinant sechiumin was obtained as an insoluble protein, and the preparation of the active soluble form was achieved by renaturing the denatured protein. These studies suggested that the recombinant sechiumin could be used for the preparation of immunotoxin as a potential cancer chemotherapeutic agent.

Trypsin Inhibitor Activity

A low molecular weight trypsin inhibitor containing 31, 32 and 27 residues per molecule was isolated from chayote seeds (Laure et al. 2006).

Hypokalemia Activity

A case of severe hypokalemia in pregnancy was associated with ingestion of chayote (Jensen and Lai 1986). Chayote, a subtropical vegetable with potent diuretic action (Rodríguez et al. 1984), was implicated, as the potassium level returned to normal, without recurrence of hypokalemia, once the ingestion was stopped.

Traditional Medicinal Uses

The chayote fruit and leaves also have traditional medicinal uses. The leaves and fruit have diuretic, laxative, cardiovascular and anti-inflammatory properties. Decoctions made from the leaves or fruits have been employed to relieve urine retention and burning during urination or to dissolve kidney stones and to assist in the treatment of arteriosclerosis and hypertension. The raw pulp of the fruit is soothing for skin rashes and roasted leaves used in the suppuration of boils.

Other Uses

Vines and starchy tuberous roots are used as cattle fodder. In India, as in the Americas, the fruit and roots are not only used as food but also as fodder for cattle. Because of the flexibility and strength of the stem fibres, they are used in some places, such as Reunion, in handicrafts to make baskets and hats. In the Philippines, chayote plants are used effectively in mixed plantations designed specifically for soil recovery and/or conservation. The flowers are good nectar sources for bees.

Comments

Chayote is readily propagated from seeds.

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Siraitia grosvenorii

Scientific Name

***Siraitia grosvenorii* (Swingle) A. M. Lu & Zhi Y. Zhang**

Synonyms

Momordica grosvenorii Swingle, *Thladiantha grosvenorii* (Swingle) C. Jeffrey

Family

Cucurbitaceae

Common/English Names

Arhat Fruit, Buddha's Fruit, Fructus Mormodicae, Monk's Fruit, Longevity Fruit

Vernacular Names

Chinese: Luó Hàn Guǒ, Luo Han Kuo, Ge Si Wei Ruo Guo, Lor Hon Kor;
Japanese: Ra Kan Ka;
Vietnamese: La Hán Quả.

Origin/Distribution

The species is native to southern China – in the south-western Chinese province of Guangxi (mostly in the mountains of Guilin), as well as in Guangdong, Guizhou, Hunan and Jiangxi and Northern Thailand. Extensively cultivated by the Zhong enthic people in southern China.

Agroecology

The species occurs in the montane forests in the mountainous region of southern China above 600 m elevation. It prefers a moist, humid and cool area and well-drained, friable soil rich in organic matter.

Edible Plant Parts and Uses

All components of the ripe fruit are very sweet. Dried fruit is used whole, in powder form or in blocks for beverages, seasoning, in herbal soups, teas, cakes, candy and as traditional medicine. In China it is popularly and widely used in herbal tea (mixture of green tea and Luo han guo) or Luo han guo soup which also has the following ingredients besides lou han guo: wood ear (*Auricularia auricula*), onion, carrot, lotus root

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and *Sagittaria trifolia* corm, spare pork ribs and salt. Luo han guo boiled with dried longan is a popular and refreshing herbal drink. The beverage is consumed warm or chill.

Purelo® is a naturally produced Luo han guo fruit concentrate that is non-caloric and is 300 times sweeter than sugar. It has been developed by a joint commercial arrangement between a Chinese group, Bio-GFS, and a New Zealand company, Biovittoria. It has been accepted by FDA, USA and has been registered as a GRAS (Generally Regarded as Safe) food product (Anonymous 2004). It is a highly stable chemical, soluble in water and alcohol, and is said to have broad applications in natural medicine, food, beverage, confectionary and personal health care products. Purelo® has been used as a sweetening agent for beverages, yogurt, caramel and hard candies, chewing gum, mouthwash as muffins.

A whisk yoghurt made by adding *Siraitia grosvenorii* was found to be nutritious, sweet and had some medicinal and health properties (Bu 2004). The taste, flavour and stability of the product were satisfactory, catering to consumer demands for a yoghurt with low energy and low sugar contents.

Plate 1 Dried globose fruit

Plate 2 Fruit with dry, brownish-grey pulp

Botany

A robust, perennial, dioecious climbing herb with fusiform to sub-globose roots. The plant grows to 2–5 m long and climbs by axillary bifid tendrils. The leaves are ovate cordate to hastate to almost triangular leaves 8–15 cm long by 3–12 cm wide with 2–7 cm long, acute to acuminate apex deeply cordate-emarginate at base, entire margins and on a slender petiole. Female inflorescence are usually formed in axillary clusters, sometimes solitary, 5-merous with persistent reflexed sepals and, yellowish , lanceolate-acuminate thin petals. Ovary is inferior, oblong-ovoid 8–11 mm long by 4–5 mm wide, rounded at the base, trilocualr with numerous ovules in six rows. Male inflorescence are racemose and arise singulary from leaf axils. Fruit is broadly ellipsoid, ovoid or subglobose, with broadly rounded ends, 6–11 cm. long, 3–4 cm. broad, more or less densely pubescent with yellowish (sometimes reddish) hairs intermixed with numerous black hairlets imparting it a yellow-brownish or green-brownish colour and turned dark brown when dried (Plates 1 and 2). The epicarp is thin but hard with the three doubled locules each with two rows of seeds (about 10–12 in a row) surrounded by brownish grey pulp which dries to a light soft material (Plate 2). Seeds light brownish grey, broadly oval or ovate, flattened, 15–18 mm. long, 10–12 mm. broad, 3–4 mm. thick at edges but with a depressed area fibrous mass, intensely sweet in taste and with an aromatic odour and flavour.

Nutritive/Medicinal Properties

Luo han guo is collected as a round green fruit that turns brown upon drying. The sweet taste of luohanguo is derived mainly from mogrosides, a group of terpene glycosides, present at the concentration of about 1% in the fleshy part of the fruit (Hsu et al. 1986). Both the fresh and dried fruits are extracted to yield a powder containing 80% or more mogrosides. The mogrosides have been numbered, 1–5, and the primary component is called mogroside-5, previously known as esgoside. Other, similar compounds from luohanguo are siamenoside and neomogroside (Shi et al. 1996). The mixed mogrosides are estimated to be about 300 times as sweet as sugar by weight, so that the 80% extracts are nearly 250 times sweeter than sugar. Pure mogrosides 4 and 5 may be 400 times as sweet as sugar by weight.

From the unripe fruits of Lo han kuo (*Siraitia grosvenori*), two new cucurbitane triterpene glycosides, 20-hydroxy-11-oxomogroside IA(1) and 11-oxomogroside IIE , were isolated along with five known cucurbitane glycosides, 11-oxomogroside IA, mogroside IIE, mogroside III, mogroside IVA, and mogroside V, and two flavonoid glycosides, kaempferol 7-O-α-L-rhamnopyranoside and kaempferol 3,7-di-O-α-L-rhamnopyranoside (Li et al. 2006). *Siraitia grosvenorii* fruits were found to contain mogroside V, mogroside IV A, mogroside III, 11-oxomogroside III, mogroside II E and 11-oxomogroside II E (Lu et al. 2008). The average yields were 99.65% for mogroside V, 101.6% for mogroside IV A, 97.05% for mogroside m, 103.1% for 11-oxomogroside I, 99.25% for mogroside II E, and 103.0% for 11-oxomogroside II E.

A minor, sweet cucurbitane-glycoside, named iso-mogroside V, was isolated from Luo han guo (*Siraitia grosvenorii*) along with five previously reported mogrosides (Jia and Yang 2009). The structure of iso-mogroside V was established as 3-[(4-O-β-D-glucopyranosyl-β-D-glucopyranosyl)oxy]-mogrol-24-O-β-D-glucopyranosyl-(1→2)-O-[β-D-glucopyranosyl-(1→6)]β-D-glucopyranoside. The five known mogrosides were identified as mogroside V, 11-oxo-mogroside V, siamenoside I, mogrosides IVa and IVe. Iso-mogroside V was determined to be approximately 500 times sweeter than 0.5% (w/v) sucrose. *Siraitia grosvenorii* fruit also contained a polysaccharide, SGPS2, which was found to have a molecular weight of 650,000 and composed of rhamnose and curonic acid (Huang et al. 2010).

A new cucurbitane triterpene, siraitic acid F, 29-nor-4,24-diene-3,11-dioxo-19-hydroxy-6,19-cyclocucurbitane-26-oic acid was isolated from the roots of *Siraitia grosvenorii* (Si et al. 2005).

Recent research on luo han guo suggest that the fruit has antioxidant activities to prevent cancer, antiviral and antidiabetic activities.

Antioxidant Activity

The antioxidant effect of Fructus Momordicae (*Siraitia grosvenorii)* extract, FME (mogrosides 75 approximately 80%), exhibited potent antioxidant activity (Shi et al. 1996). FME reduced the stable free radical 1,1-diphenyl-2-picrylhydrazyl (DPPH) and scavenged superoxide radicals (O2-) generated by a hypoxanthine and xanthine oxidase system. It also scavenged hydroxyl radicals generated by Fenton reaction. Further, FME inhibited Fe(II) stimulated lipid peroxidation in rat cortex homogenates in a dose-dependent fashion, as indicated by decreased thiobarbituric acid-reactive substances (TBARS) formation. Oral administration of FME inhibited TBARS and malonaldehyde (MDA) formation in the ipsilateral cortex 30 min after iron-salt injection into the left cortex of rat. FME exhibited inhibitory effect on 4-hydroxy-2(E)-nonenal (4-HNE) formation induced by Fe(III) injection into the rat cortex. The data suggested that Fructus Momordicae extract had an antioxidant activity against free radicals and lipid peroxidation.

Sweet glycosides, having cucurbitane triterpenoid aglycon, mogroside V and 11-oxo-mogroside V, isolated from the fruits of *Siraitia grosvenori*, exhibited anti-oxidant activity as evaluated using chemiluminescence (Chen et al. 2007). The results showed that these glycosides

exhibited significant inhibitory effects on reactive oxygen species (O^{2-}, H_2O_2 and *OH) and DNA oxidative damage. 11-oxo-mogroside V showed a higher scavenging effect on O^{2-} with EC_{50} of 4.79 μg/ml and H_2O_2 (EC_{50} of 16.52 μg/ml) than those of mogroside V. However, mogroside V was more effective in scavenging *OH, with EC_{50} = 48.44 μg/ml compared with that of 11-oxo-mogroside V (EC_{50} = 146.17 μg/ml). In addition, 11 –oxo-mogroside V exhibited a marked inhibitory effect on *OH-induced DNA damage with EC_{50} = 3.09 μg/ml.

Sweet elements extracted from *Siraitia grosvenorii* (SG) were found to inhibit human umbilical vein endothelial cell (HUVEC)- mediated LDL oxidation (Takeo et al. 2002). The sweet cucurbitane glycosides consisted of Mogroside IV, Mogroside V, 11-Oxo-mogroside V and Siamenoside I. *Siraitia grosvenori* extract inhibited copper-mediated LDL oxidation in a dose-dependent manner, but neither glucose nor erythritol suppressed the oxidation. Among cucurbitane glycosides, 11-Oxo-mogroside V significantly inhibited LDL oxidation. The protraction of the lag time during LDL oxidation by 11-Oxo-mogroside V was concentration-dependent. The lag time (119.7 min) in the presence of 200 μM 11-Oxo-mogroside V was significantly longer than that (76.8 min) of control. Further, *Siraitia grosvenori* extract and 11-Oxo-mogroside V inhibited HUVEC-mediated LDL oxidation in a concentration-dependent manner. These results demonstrated that *Siraitia grosvenori* extract inhibited LDL oxidation and that 11-Oxo-mogroside V, a sweet element of *Siraitia grosvenori* extract, provided the anti-oxidative property of *Siraitia grosvenori* which may reduce the atherogenic potential of LDL.

Siraitia grosvenori extract (SGE) may exert hepatic antioxidant activity by up-modulating the genes under the control of the Nrf 2-Keap1-ARE transcriptional system; however, this activity was neither effective nor sufficient for suppression of piperonyl butoxide (PBO)-induced early hepatocarcinogenesis (Yasuno et al. 2008). Liver immunohistochemistry revealed that coadministration with SGE failed to alter the PBO-mediated rise in the number of glutathione S-transferase placental form (GST-P)-positive foci and proliferating cell nuclear antigen-positive cells, the area of the GST-P-positive foci was enhanced nevertheless. In contrast, real-time RT-PCR showed that coadministration of SGE increased hepatic GST and glutathione peroxidase (GSH-Px) antioxidant activities and mRNA expression levels of the phase II enzymes that were known to be transcriptionally up-regulated through the Nrf 2-Keap1-antioxidant responsive element (ARE) as well as the phase III enzymes. Further, measurement of thiobarbituric acid-reactive substances showed a decrease in lipid peroxidation by SGE coadministration.

Siraitia grosvenorii extract (SGE) inhibited the induction of gamma-glutamyltranspeptidase-positive hepatocytes, lipid peroxidation, and gene expression of Cyp1a1, all of which were induced by Dicyclanil (DC) (Matsumoto et al. 2009). Cyp1a1 gene expression was significantly lower in C57BL/6 J mice administered DC + SGE than in C57BL/6 J mice administered DC alone; there was no difference in the Cyp1a1 expression between DBA/2 J mice administered DC + SGE and DC alone. These results suggested that SGE suppressed the induction of Cyp1a1, leading to inhibition of ROS generation and consequently inhibited hepatocarcinogenesis, probably due to suppression of Ahr activity.

Anticancer Activity

Mogroside V and 11-oxo-mogroside V isolated from the fruits of *Momordica grosvenori*, exhibited potent inhibitory effect on the primary screening test indicated by the induction of Epstein-Barr virus early antigen (EBV-EA) by a tumour promoter, 12-O-tetradecanoylphorbol-13-acetate (TPA) (Konoshima and Takasaki 2002; Takasaki et al. 2003). Both glycosides, having cucurbitane triterpenoid aglycon, exerted significant inhibitory action on the two-stage carcinogenesis test of mouse skin tumours induced by peroxynitrite as an initiator and TPA as a promoter. Further, 11-oxo-mogroside V also exhibited the notable inhibitory effect on two-stage carcinogenesis test of mouse skin tumour induced

by 7,12-dimethylbenz[a]anthracene (DMBA) as an initiator and TPA as a promoter.

Antiviral Activity

Two new triterpene benzoates, 5-dehydrokarounidiol dibenzoate (1) and karounidiol dibenzoate (2), and two new triterpene glycosides, 5α,6α-epoxymogroside IE(1) (8) and 11-oxomogroside A(1) (9), along with 15 known triterpenoids one triterpene benzoate, (3); three triterpene mono-ols, (4–6); one triterpene aglycon, (7); and 10 triterpene glycosides, (10–19), were isolated from the ethanol extract of *Momordica grosvenori* fruit (Ukiya et al. 2002). All of the 18 triterpenoids (2–19) compounds and 11-oxomogrol (20), a hydrolysis product of 9, tested exerted potent inhibitory effects on Epstein-Barr virus early antigen (EBV-EA) induction by 12-O-tetradecanoylphorbol −13-acetate (TPA) in Raji cells, (70–100% inhibition).

In a separate study, six new cucurbitane glycosides, mogroside II B (2), 11-deoxymogroside III (4), 7-oxomogroside II E (5), 7-oxomogroside V (6), 11-oxomogroside II A1 (7), and 11-oxomogroside IV A (8), and two known but new naturally occurring cucurbitane glycosides, mogroside II A1 (1) and mogroside III A2 (3), were isolated from an ethanol extract from *Siraitia grosvenorii* fruits (Akihisa et al. 2007). All eight compounds exhibited inhibitory effects against the Epstein-Barr virus early antigen (EBV-EA) activation induced by TPA, with IC_{50} values of 346–400 mol ratio/32 pmol TPA. Further, compounds 1–8 showed weak inhibitory effects on activation of (+/−)-(E)-methyl-2-[(E)-hydroxyimino]-5-nitro-6-methoxy-3-hexemide (NOR 1), a nitric oxide (NO) donor.

Antihyperglycemic, Antidiabetic Activity

The increase in plasma glucose level in response to the oral administration of maltose was significantly suppressed in rats when *Siraitia grosvenorii* extract (SG-ex) was given orally 3 minutes before maltose administration (Suzuki et al. 2005). There was, however, no effect when glucose was administered instead, suggesting that the antihyperglycemic effect of SG-ex is caused by inhibition of maltase in the small intestinal epithelium. In-vitro, SG-ex inhibited rat small intestinal maltase. Similar effects were also observed both in-vivo and in-vitro when the concentrate of the sweet elements (triterpene glycosides) prepared from SG-ex was used. In addition, the main sweet element of SG-ex, mogroside V, and some minor elements such as mogroside IV, siamenoside I, and mogroside III also displayed maltase inhibitory effect with IC_{50} values of 14, 12, 10, and 1.6 mM, respectively. These results suggested that SG-ex exerted anti-hyperglycemic effects in rats by inhibiting maltase activity and that these effects were partially induced by its sweet elements, triterpene glycosides.

Mogroside extracts (MGC) was found to have distinct glucose-lowering effect on hyperglycaemic mice; its mechanism may be association with amelioration of antioxidation level and restoration of the blood lipid levels of hyperglycaemic mice (Zhang et al. 2006). MGC at dose of 100, 300,500 mg/kg bw significantly reduced the fasting blood glucose with maximum hypoglycemic effect at the dose of 100 mg/kg bw. MGC lowered the content of total cholesterol and total glycerides, and elevated the content of HDL-C of alloxan-induced diabetic mice, thus restoring the blood lipid levels of diabetic mice. MGC also decreased the MDA level and enhanced SOD and GSH-Px levels of alloxan-induced diabetic mice, reflecting its beneficial effect on the oxidative stress level of diabetic mice. Compared with XKW (a traditional hypoglycermic herb), MGC at dose of 100 mg/kg bw exerted similar hypoglycermic effect.

In oral glucose tolerance tests (OGTT), *Siraitia grosvenorii* extract (SG-ex) supplementation was found to improve the insulin response at 15 min and reduced the plasma glucose level at 120 min after glucose feeding (Suzuki et al. 2007). The total insulin content in whole pancreas taken from fasting rats was higher in the SG-ex-supplemented group, which may explain the greater capacity to secrete insulin during the OGTT. Thiobarbituric acid-reactive substances in both the liver and the

plasma were lower in the SG-ex-supplemented group, suggesting that an absorbable component in SG-ex had an antioxidative effect on lipid peroxidation, thereby counteracting the oxidative stress caused by the diabetic state. These data indicated that SG-ex supplementation may prevent complications and attenuate pathological conditions for type 2 diabetes.

Treatment of diabetic mice with mogroside extract MG (100, 300, and 500 mg/kg) for 4 weeks significantly lowered serum glucose, TC, TG, and hepatic malondialdehyde (MDA) levels, whereas it increased serum high-density lipoprotein cholesterol (HDL-C) level and reactivated the hepatic antioxidant enzymes in alloxan-induced diabetic mice (Qi et al. 2008). The hypoglycemic, hypolipidemic, and antioxidative activities of MG (100 mg/kg treatment) were all higher compared with all other diabetic groups and were similar to that observed for XiaoKeWan-pill (894 mg/kg), a Chinese traditional antidiabetic drug. Antioxidant capacity evaluated in-vitro showed that MG and mogroside V, which was the main component of MG, possessed strong oxygen free radical scavenging activities. These results demonstrated that the extract may have capacity to inhibit hyperglycemia induced by diabetes, and the data suggested that administration of the extract may be helpful in the prevention of diabetic complications associated with oxidative stress and hyperlipidemia.

In another study, low dose of *Momordica grosvenori* (MG) administration ameliorated hyperglycemia, inhibited heme oxygenase-1 (HO-1) and manganese superoxide dismutase (Mn-SOD) mRNA expression and reduced $HO^{\cdot}$, Mn-SOD and glutathione peroxidase (GSH-Px) activities (Song et al. 2007). Diabetic mice did not demonstrate early symptoms of diabetic nephropathy until the eighth week. This was characterized by hyperglycemia, hyperlipidemia, and renal damage. A progressive increment in MDA concentration and decrease in GSH concentration, as well as reduced mRNA expression and activity of Mn-SOD and HO-1 in the kidney were noted. Low dose of MG partially mitigated diabetic nephropathy symptoms, inhibited lipid peroxidation, up-modulated HO-1 and Mn-SOD mRNA expression, and enhanced HO-1 activity. The study confirmed the involvement of oxidative stress in the development of diabetes mediated by the pro- and antioxidant role of heme oxygenase, and elucidated the possible antioxidative mechanism of the antidiabetic and nephroprotective action of MG.

Separate studies showed that administration of *Siraitia grosvenorii* polysaccharide (SGP) could significantly decrease plasma total cholesterol, triglyceride, and glucose levels; and increase HDL-C levels after 4 weeks of treatment (Lin et al. 2007). The antihyperglycaemic effect of SGP at concentration of 100 mg/kg bw was the most significant in three dosage groups. Further, SGP normalised the blood lipid levels of diabetic rabbits. These data indicated that SGP not only ameliorated the lipid disorder, but also reduced plasma glucose levels. The results showed that SGP had marked glucose-lowering effect on hyperglycaemic rabbits and its mechanism may be related to amelioration of lipid metabolism and restoration of the blood lipid levels of hyperglycaemic rabbits.

Antimicrobial Activity

The growth and fermentation of *Streptococus mutans* in *Momordica grosvenori* macerate extract were significantly lower than these in the other groups including beet sugar group (Mu 1998). *S. mutans* adhering glass rod in *Momordica grosvenori* was the lowest. The data indicated that *Momordica grosvenori* possessed many advantages: high sweetness and low adherence, and its anti-cariogenicity was better than beet sugar. A new bioactive compound, (2R,3S,4S)-2,3-trans-3,4-cis-5,3′-bimethoxy-7-(trans-2-propenal)-3,4-flavandiol (1), named siraitiflavandiol was obtained from *Siraitia grosvenorii* fruit (Zheng et al. 2009). This new compound exhibited antimicrobial activity against the growth of oral bacterial species *Streptococcus mutans, Porphyromonas gingivalis*, and yeast *Candida albicans* with minimum inhibitory concentrations were 6, 24, and 6 μg/ml, respectively.

Protein Synthesis Inhibition Activity

Momorgrosvin, a single-chained glycoprotein with a molecular weight of 27.7 kDa and an isoelectric point of about 9 was isolated from the seeds of *Momordica grosvenorii* (Tsang and Ng 2001). Momorgrosvin inhibited protein synthesis in the rabbit reticulocyte lysate system with an IC_{50} of 0.3 nM and displayed RNA N-glycosidase activity. The protein acted on tRNA to produce acid-soluble UV-absorbing species.

Bioavailability

When administered to rats, mogroside V was mostly degraded by digestive enzymes and intestinal microflora, and was excreted in the feces as mogrol (aglycone) and its mono- and diglucosides (Murata et al. 2010). However, trace quantities of mogrol and its monoglucoside were detected in the portal blood as sulfates and/or glucuronide conjugates.

Toxicity Studies

A combined 28-day and 90-day oral (gavage) study of PureLo®, 3,000 mg/kg bw/day, conducted in male and female dogs found no toxicological effects (Qin et al. 2006). There were no significant adverse effects on clinical observations, body weight, food consumption, hematology, blood chemistry, urinalysis, gross necropsy, organ weight, and histopathology. PureLo® was well tolerated and produced no significant adverse effects in another 28-day dietary study conducted in a Groups of 20 Hsd:SD® rats (10/sex/group) fed diets containing 0, 10,000, 30,000, or 100,000 ppm PureLo® (Marone et al. 2008). Decreased body weight and body weight gain in high-dose animals of both sexes were attributed to sporadic reductions in food consumption; there were no overall differences in feed efficiency. Statistically significant changes in clinical chemistry (decreased bilirubin, elevated total protein) and relative organ weights of liver, adrenals, ovaries and/or testes, and epididymides were not correlated with any histopathological findings and were not considered adverse. Albeit a few clinical and pathological findings suggested possible treatment-related effects, particularly in the high-dose group, these findings were transient, not dose-dependent, non-adverse, inconsistent, occurred only in one sex, and/or not supported by histopathological findings.

Traditional Medicinal Uses

Siraitia grosvenorii is popularly used in traditional Chinese medicine. They are used for respiratory ailments, sore throats, minor stomach and intestinal troubles and reputed to aid longevity. *Siraitia grosvenorii*, has been used as a pulmonary demulcent and emollient for the treatment of dry cough, sore throat, dire thirst, and constipation in folk medicine (Lu et al. 2008). The fruit helps relieve sunstroke, moistens the lungs, eliminates phlegm, stops cough, and promotes bowel movements. The fruit is also used in the treatment of diabetes and obesity. The extract of this fruit has been used for the treatment of pharyngitis or pharyngeus pain, and as antitussive medicine in Japan (Konoshima and Takasaki 2002).

Other Uses

Four superior cultivars cv 'Changtan Fruit' (*Ch'ang-t'an kuo*), cv 'Lajian Pear' (*La-jian –kuo*), cv King LuoHan Guo' (*Dong-gua-han*) and cv green Ball (*Qing-pi-guo)* have been produced in 1979, all requiring assisted pollination for fruit production. The last cultivar is now the most widely cultivated in China covering 75% of the total acreage.

Comments

The farmers in China propagate the plant from seeds.

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Trichosanthes cucumerina

Scientific Name

***Trichosanthes cucumerina* L.**

Synonyms

Trichosanthes anguina L., *Trichosanthes brevibracteata* Kundu, *Trichosanthes colubrina* Jacq., *Trichosanthes cucumerina* L. var. *anguina* (L.) Haines, *Trichosanthes pachyrrhachis* Kundu.

Family

Cucurbitaceae

Common/English Names

Chinese Cucumber, Club Gourd, Gudda Bean, Serpent Cucumber, Serpent Gourd, Snake Gourd, Snake Tomato, Viper's Gourd

Vernacular Names

Arabic: Qar' El Hhanash;
Brazil: Abóbora-Serpente (Portuguese);
Burmese: Pe Lin New;
Chinese: She Gua**,** Sha Kua, She Xing Gua, Shi Yong She Gua, She Dou, Dou Jiao Huang Gua, Mao Wu Gua, Mao Wu Kua;
Danish: Lang Tomat, Slangeagurk, Slangegræskar, Slangemelon, Trikosantes;
Dutch: Haarbloem;
Finnish: Käärmekurkku;
French: Courge Serpent, Courge Serpent Du Népal, Courge Serpent Cultivée, Courge Longue De L'inde, Patole, Serpent Japonais, Serpent Vegetal;
French Guiana: Anguine Amere;
German: Haarblume, Schlangengurke, Schlangenhaargurke, Schlangen-Haargurke, Sinesischer Kürbis;
Guinea-Bissau: Camatom (Crioulo);
India: Dhunduli (Assamese), Chichinga, Chinchinge (Bengali), Chachinda, Chachinga, Chichinda, Chichinga, Chichindra, Chirchira, Padwal, Pepoodel, Podalangai, Chayud Pottah (Hindu), Padavali (Gujerati), Paduvalakaayi (Kannada), Padavalanga (Malayalam), Padwal (Marathi), Chichendara (Oriya), Galartori (Punjabi), Lingapotla, Potlakaaya, Potla (Telugu), Pudalankaai, Pudal (Tamil);
Indonesia: Paria Belut, Paria Ular, Pare Welut;
Italian: Zucchetta Cinese, Serpente Vegetale, Serpentona;
Japanese: Ebi Uri, Karasu-Uri-Zoku;
Malaysia: Ketolar Ular, Timun Bengkok, Petola Ular;
Nepal: Cicindo;
Nigeria: Tòmétò Eléjò (Yoruba);
Laos: Mak Noi Lay, Mak Ngo Ngieo, Ngoo Ngeewz;
Pakistan: Jangli Chachinda;

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Philippines: Parparia, Karkarabasa-Ti-Aso (Iloko), Melon-Daga, Melon-Melonan, Tabubok, Tabugok (Tagalog);
Portuguese: Abóbora Serpente, Quiabo De Metro;
Senegal: Mété Durubab (Serer);
Sierra Leone: Snɛk-Tamatis (Krio), An-Rɔthma (Temne);
Slovašcina: Kačasti Trihozant;
Spanish: Calabaza De Culebra, Calabaza Anguina;
Sri Lanka: Pathola (Sinhalese);
Surinam: Djidjinga (Hindu), Paredjawi (Javan);
Thai: Buap Ngu, Nom Phichit, Ma Noi;
Turkish: Yilan Kabagi;
Vietnamese: Day Na T'ay, Dan'i Muop Ta'y, Muop Ho.

Origin/Distribution

The genus is native to tropical south and southeast Asia and the islands of the western Pacific. This species was first domesticated in India from where non-bitter and long and large-fruited types were developed.

Agroecology

Snake gourd occurs naturally in thickets, along forest edges and in open forest, from sea-level to 1,500 m altitude in its native range. Snake gourd is well adapted to the tropical lowlands with minimum temperature of 20°C and a maximum of 35°C. It grows on many types of soil with a pH ranging from acid to alkaline in full sun but requires a free-draining soil with good water holding capacity. It is intolerant of water-logged soils.

Edible Plant Parts and Uses

The young fruit is cooked as a vegetable often in curries. It is a popular ingredient in the cuisine of south and southeast Asia. The leafy tendril shoots and leaves are also consumed as greens after cooking. In Sierra Leone, Liberia, Côte d'Ivoire, Ghana, Benin and Nigeria the red pulp of ripe fruits is used in stews, soups and sauces and as a tomato paste/puree substitute. The seed can be used for flour and seed oil.

Botany

A monoecious vigorous, climbing annual herb with angled, furrowed, green stem and 3-fid branched tendrils. Roots are tuberous and whitish. Leaves alternate, simple, palmately 5–7 lobed, 7–25 cm by 8–20 cm, pubescent with dentate margins and borne on a scabrid, hairy, furrowed petiole (Plate 1). Male flowers are borne on long peduncles in axillary racemes of five or more flowers. Flower with 5-lobed tubular calyx, 5 pubescent, white fimbriate oblong petals, and 3 stamens. Female flowers sessile, solitary, perianth as in male flowers, stigmas 3. Fruit is slender, soft-skinned, cylindrical long, 30–180 cm by 5–10 cm, often warped – curved or twisted, greenish-white or green (Plates 1–3) when immature and orange-red when ripe containing mucilaginous fleshy pulp in which is embedded many flattened 1–1.5 mm thick brown, semi-ellipsoid seeds with undulating margin.

Nutritive/Medicinal Properties

The nutritive composition of immature fruits of snake gourd per 100 g edible portion (94%) was reported as: water 92.9 g, energy 89 kJ (21 kcal), protein 0.5 g, fat 0.3 g, carbohydrate 4.1 g, fibre 1.7 g, Ca 26 mg, P 20 mg, Fe 0.3 mg, thiamin 0.04 mg, riboflavin 0.06 mg, niacin 0.3 mg, folate 15 μg, and ascorbic acid trace (Holland et al. 1991). Tee et al. (1997) reported the following nutrient values for the young fruit per 100 g edible portion: energy 18 kcal, water 94.6 g, protein 1.0 g, fat 0.1 g, carbohydrate 3.3 g, fibre 0.7 g, ash 0.3 g, Ca 19 mg, Fe 1.6 mg, P 3 mg, K 51 mg, Na 8 mg, carotenes 1,590 μg, vitamin A 265 μg, vitamin B1 0.04 mg, vitamin B2 0.08 mg, niacin 0.4 mg and vitamin C 11 mg. The proximate and vitamin analyses of ripe fruits yielded moisture

Plate 1 (**a** and **b**) Leaves and snake-gourd fruits

Plate 2 Green striped snakegourd fruits

Plate 3 Snake gourd fruits on sale in a local market

(93.15%), proteins (1.85%), carbohydrates (3.48%), vitamin C (18.9 mg/100 ml) and vitamin A (347.0 µg/100 ml) (Ojiako and Igwe 2007).

The mineral composition of *T. cucumerina* seed (in terms of mg/100 g) was reported as

follows (Yusuf et al. 2007): K 126.6 mg, Na 74.66 mg, Ca 27.62 mg, Mg 79.12 mg, Zn 87.25 mg, Fe 4.31 mg, Cu 0.31 mg, Mn 0.31 mg and P 135 mg. The nutritive value of the seed flour was reported as: moisture 3.13%, crude protein 30.18%, crude fibre 8%, ash 2.93% and carbohydrate 7.59% and the seed protein concentrate: moisture 2.54%, crude protein 88.14%, crude fibre 2.03%, ash 6% and carbohydrate 1%. The seed oil was reported to have the following characteristics: refractive index (40°C) 1.469, density (40°C) 0.864 cm^3, Iodine value 38 g Iodine/100 g, peroxide value 10 meq/kg, free fatty acid 240 mg KOH/g and acid value 5.02 mg KOH/g.

Other Phytochemicals

The triterpenes found in *T. cucumerina* fruit included 23, 24-dihydrocucurbitacin D; 23, 24-dihydrocucurbitacin B; cucurbitacin B; 3β-hydroxyolean-13(18)-en-28-oic acid; 3-oxo-olean-13(18)-en-30-oic acid; cucurbitacin E; isocucurbitacin B; and 23,24-dihydrocucurbitacin E (Jiratchariyakul and Frahm 1992; Buaprom 2006). The fruit also contained sterols: 3-O-β-D-glucopyranosyl-24ξ-ethylcholest-7,22-dien-3β-ol, *β*-sitosterol and stigmasterol (Buaprom 2006). Yadava and Syeda, (1994) characterized a novel isoflavone glucoside, 5,6,6′-trimethoxy-3′,4′-methylenedioxyisoflavone7-O-β-D-(2″-O-p-coumaroylglucopyranoside) from the seeds. Kongtun et al. (2009) reported the presence of the following chemical constituents in *T. cucumerina* roots: bryonolic acid, bryononic acid, cucurbitacin B, and dihydrocucurbitacin B.

Published studies on the pharmacological properties of snake gourd are discussed below.

Antioxidant Activity

The fruit pulp of two morphotypes of *T. cucumerina* was reported to possess valuable nutraceutical properties (Adebooye 2008) such as ascorbic acid levels of 25.7 and 24.8 mg/100 g fresh weight (FW), lycopene levels of 18.0 and 16.1 mg/100 g FW, carotenoids (lutein) contents of 15.6 and 18.4 mg/100 g FW, α-carotene levels of 10.3 and 10.7 mg/100 g FW while the β-carotene levels were 2.4 and 2.8 mg/100 g FW. The fruit also had total phenolics, total flavonoids and exhibited total ferric reducing antioxidant power (FRAP).

Antidiabetic Activity

Kar et al. in 2003 reported that the crude ethanolic extract of *Tricosanthes cucumerina* showed significant blood glucose lowering activity in alloxan diabetic albino rats. Blood glucose values were reduced to normal fasting level using herbal samples at a dose of 250 mg/kg once, twice or thrice daily. Separate studies in India confirmed that *Trichosanthes cucumerina* possessed antidiabetic activity (Kirana and Srinivasan 2008). Aqueous extract of *Trichosanthes cucumerina* significantly lowered the elevated blood glucose of Non Insulin Dependent Diabetes Mellitus (NIDDM) induced rats. The herbal drug significantly lowered the postprandial blood glucose of diabetic animals. Glycogen content of insulin dependent tissues such as liver and skeletal muscle was improved by 62% and 58.8% respectively with *Trichosanthes cucumerina* as compared to NIDDM control. Increase in tissue glycogen content indicated the effect of the drug on the uptake of glucose by the peripheral tissues to reduce insulin resistance NIDDM. The drug was found to improve the oral glucose tolerance of NIDDM subjects.

Hepatoprotective Activity

Studies by (Ojiako and Igwe 2007) revealed that consumption of raw or unprocessed *T. cucumerina* fruits or cooked seeds could be damaging and hepatotoxic. Rabbits fed raw fruit or cooked seeds lost 102.5 g and 47.5 g of their body weight, and levels of serum total (TB) and conjugated (CB) bilirubin, as well as aspartate aminotransferase (AST), alanine aminotransferase (ALT) and alkaline phosphatase (ALP) total (TB) and conjugated (CB) bilirubin, as well as aspartate aminotrans-

ferase (AST), alanine aminotransferase (ALT) and alkaline phosphatase (ALP) were all significantly raised. In contrast rabbits fed cooked fruits or cooked fruits without seeds gained 20.0 g and 25.0 g respectively, in relation to the control group fed grower's mash fed grower's mash. In the cooked fruit groups, only ALP activity was significantly elevated while TB, AST and ALT levels remained almost normal. The findings have nutritional and industrial relevance since the fruit is being used in place of tomatoes in many homes in Nigeria.

Kumar et al. (2007) reported that the methanolic extract of *Trichosanthes cucumerina* exhibited hepatoprotective activity. Rat groups treated with methanolic extract of *T. cucumerina* at doses of 250 mg/kg and 500 mg/kg body weight after carbon tetrachloride intoxication had significantly reduced serum alanine amino transferase, aspartate amino transferase, alkaline phosphatase and total bilirubin contents. Histopathological studies also supported the hepatoprotective activity of the extract. The results thus scientifically supported the usage of this plant in various Ayurvedic preparations and traditional medicine for treatment of liver disorders.

Antiinflammatory Activity

Hot aqueous extract of root tubers of *Trichosanthes cucumerina* was reported to have antiinflammatory activity as evaluated by the carrageenin induced mouse's hind paw oedema test (Kolte et al. 1996–1997). Mean changes in the paw volumes revealed the efficacy of the extract against carrageenin in comparison with standard steroidal (Predinisolone) and non-steroidal (lbuprofen) antiinflammatory drugs. The ED50 of hot aqueous extract was 82 mg/kg body weight for antiinflammatory activity. In a recent study in wistar rats, the hot water *T. cucumerina* extract at doses of 500, 750, 1,000 mg/kg exerted significant inhibition of the inflammation, which most pronounced at 5 hours after the injection of carrageenan (Arawwawala et al. 2010a, b). The antiinflammatory effect induced by 750 mg/kg, was comparable to that of the reference drug, indomethacin at 4 and 5 hours. Inhibition of nitric oxide (NO) production and membrane stabilization activities were postulated as probable mechanisms by which *Trichosanthes cucumerina* mediated its anti-inflammatory actions. Among the tested fractions, methanol fraction (MEF) and aqueous fraction at a dose of 75 mg/kg exhibited marked inhibition against carrageenan-induced hind paw oedema. The anti-inflammatory effect induced by MEF, was comparable to that of the reference drug, indomethacin and as well as to the 750 mg/kg of hot water extract.

Anticancer Activity

Trichosanthes cucumerina root extract and , its main constituent bryonolic acid, as well as the fruit juice and its main constituent cucurbitacin B, exerted cytotoxicity against four human breast cancer cell lines (SKBR3, MCF7, T47D, and MDA-MB435), two lung cancer cell lines (A549 and SKĐLU1), and one colon cancer cell line (Caco-2) (Jiratchariyakul et al. 1999; Kongtun et al. 2009). The IC_{50} values observed for the root extract were 267 µl/ml for MCF7; 316 µl/ml for T4TD, 140 µl/ml for MDA-MB435 and 106 µl/ml for the lung cancer line, A549. The IC_{50} values observed for bryonolic acid were lower, 121 µl/ml for MCF7; 124 µl/ml for T4TD, 90 µl/ml for MDA-MB435 and 100 µl/ml for the lung cancer line, A549. The IC_{50} values of the fruit juice against the 4 breast cancer cell lines were (SKBR3, MCF7, T47D, and MDA-MB435) were 131, 375, 249, and 156 µl/ml, respectively and 141 µl/ml for one lung cancer cell line and 101 µl/ml for the Caco-2. The IC_{50} values of cucurbitacin B were lower against the 4 breast cancer cell lines were (SKBR3, MCF7, T47D, and MDA-MB435) were 73, 35, 60, and 26 µl/ml, respectively and 41 µl/ml for one lung cancer cell line and 1.5 µl/ml for the Caco-2. However, the root extract inhibited SKĐLU1 more strongly than did the fruit juice, cucurbitacin B, and bryonolic acid with IC_{50} values of 149, 169, 180, and >500 µl/ml, respectively. The results showed that cucurbitacin B was most potent against all the cancer cell lines tested except for lung cancer, SKD-LU1.

Kummalue et al. (2009) showed that cucurbitacin B, extracted from *T. cucumerina* exerted modest antiproliferative effect against colon cancer cell lines, HCT15 and HT29, renal cancer cell, A498, and pancreatic cancer cell, NOR-P with ED_{50} values of 69.391, 106.431, 105.912, and 87.396 μg/ml respectively. The compound also inhibited growth of lung cancer cells, LK87 and QG95, in the modest to low activity with the ED_{50} values at 99.517 and 231.830 μg/ml respectively. The antiproliferative effect was observed in a in a dose dependent manner. Recent studies by Duangmano et al. (2010) reported that cucurbitacin B extracted from *T. cucumerina*, inhibited the growth and telomerase activity of three human breast cancer cell lines (T47D, SKBR-3, and MCF-7) and a mammary epithelium cell line (HBL-100). Their findings revealed that cucurbitacin B exerted an antiproliferative effect by inhibiting telomerase via down regulating both the human telomerase reverse transcriptase (hTERT) and c-Myc protein expression in breast cancer cells.

Gastroprotective Activity

Studies showed that the hot water extract of *Trichosanthes cucumerina* possessed significant and concentration dependent gastroprotective effects (Arawwawala et al. 2010a, b). The extract afforded significant protection against ethanol or indomethacin induced gastric damage in terms of the length and number of gastric lesions mediated by alcohol in wistar strain rats The extract increased the production of mucus by the rat gastro mucosa and pH of the gastric juice from 4.1 to 6 and decreased gastric acidity. The extract also exhibited potent antihistamine activity.

Larvicidal Activity

The crude hexane, ethyl acetate, petroleum ether, acetone, and methanol extracts of *T. anguina* plant showed moderate larvicidal effects (Rahuman and Venkatesan 2008). The highest larval mortality was found in acetone extract of *T. anguina* against the larvae of *Aedes aegypti,* vector of dengue fever (LC_{50} = 554.20 ppm) and against *Culex quinquefasciatus,* vector of lymphatic filariasis (LC_{50} = 842.34 ppm). In separate earlier studies, Prabakar and Jebanesan (2004) reported on the larvicidal efficacy of *T. anguina* plant extract against *Culex quinquefasciatus* with LC_{50} value of 567.81 ppm. Larval mortality was observed after 24 hours exposure.

Antifertility Activity

Snake gourd plant demonstrated antifertility (anti-ovulatory) effects in rats (Kage et al. 2009). The ethanol extract at concentrations of 200 and 400 mg/kg body weight (orally) affected the normal estrous cycle, inducing a significant increase in estrus and metestrus phases and a decrease in diestras and proestrus phases in female albino rats. The extract also significantly reduced the number of healthy follicles and corpora lutea and increased the number of regressing follicles. The protein and glycogen content in the ovaries were significantly lowered in treated rats. The cholesterol level was significantly elevated, whereas, the enzyme activities like 3b-HSD and 17b-HSD were significantly inhibited in the ovary of treated rats. Serum FSH (follicle-stimulating hormone) and LH (luteinizing hormone) levels were also significantly decreased in the treated groups. No mortality nor change in the behavior or any other physiological activities in mice were observed in the treated groups.

Antimicrobial and Nematicidal Activity

The chloroform extract of *Trichosanthes cucumerina* roots was reported to show significant antibacterial activity against *Pseudomonas aeruginosa*, and seed extracts showed nematicidal activity (Soladoye and Adebisi 2004). The ethyl acetate, chloroform and methanol extracts of *Trichosanthes cucumerina* leaves leaf ethyl acetate extract of *Cassia didymobotrya* leaves

exhibited pronounced activity on all organisms tested, *Bacillus cereus, Enterobacter faecalis, Salmonella paratyphi, Staphylococcus aureus, Escherichia coli, Streptococcus faecalis, Proteus vulgaris, Klebsiella pneumoniae, Pseudomonas aeruginosa* and *Serratia marcescens* (Reddy et al. 2010). Their activity was quite comparable with the standard antibiotics such as tobramycin, gentamicin sulphate, ofloxacin and ciprofloxacin screened under similar conditions. The antimicrobial potency of these plant extracts was attributed to the presence of phenolic compounds, flavonoids and carotenoids.

Seed Lectin Activity

A galactose-specific lectin was purified from the seeds of snake gourd (Komath et al. 1996). No cross activity was found between this purified snake gourd seed lectin (SGSL) and antiserum raised against the *Momordica charantia* lectin and vice versa, suggesting that the two lectins were antigenically different. The agglutination activity of *Trichosanthes cucumerina* seed lectin was maximum in the pH range 8.0–11.0, diminishing rapidly below pH 7.0 (Kenoth et al. 2003). The lectin comprised three isoforms with pI values of 5.3, 6.2, and 7.1, with the isoform of pI 6.2 being the most abundant. Snake gourd lectin interacted with different saccahrides (Komath et al. 2001; Kenoth et al. 2003) and several free-base porphyrins and their corresponding copper(II) and zinc(II) derivatives (Komath et al. 2000; Komath et al. 2001) Studies showed that metalloporphyrins appeared to have higher affinity for the lectin compared with the free-base analogues. Both positively charged and negatively charged porphyrins bind to snake gourd seed lectin (SGSL) with comparable affinities, suggesting that binding occurred primarily via hydrophobic interactions. Further, binding of porphyrins was found to be largely unaffected by the presence of the sugar ligand, lactose, indicating that the binding sites for the carbohydrate and porphyrin were dissimilar. This study thus suggested that the lectin may serve as a receptor for some endogenous non-carbohydrate, hydrophobic ligand in-vivo, and also to the saccharide ligands. It also suggested the possibility of employing the *T. anguina* lectin in applications such as photodynamic therapy, involving the use of porphyrins.

A galactose-specific lectin with agglutination activity was purified from the seeds (Padma et al. 1999). Haemagglutination-inhibition data showed that the lectin was specific for the β-anomer of galactose with MeβGal and lactose being the best mono- and disaccharide inhibitors, respectively. Anuradha and Bhide, (1999) isolated an isolectin complex from *Trichosanthes anguina* seeds. The purified protein contained a mixture of isolectins varying in molecular weight from 30,000 to 50,000. Apparent homology of these two lectins was indicated by their identical molecular weight (45 kDa), subunit composition, non-glycoprotein nature and immunological identity. However, these two lectins exhibited minor differences in their biological and physicochemical properties.

Ribosome-Inactivating Protein and Associated Activities

The seeds of *Trichosanthes anguina* was found to contain a type I ribosome-inactivating protein (RIP), designated trichoanguin (Chow et al. 1996; Chow et al. 1999). The protein was found to be a glycoprotein with a molecular mass of 35 kDa and a pI of 9.1. It potently inhibited the protein synthesis of rabbit reticulocyte lysate, with an IC_{50} of 0.08 nM, but exhibited weak inhibition of HeLa cells, with an IC_{50} of 6 μM. Molecular homology modelling of trichoanguin indicated that its tertiary structure closely resembled those of trichosanthin and α-momorcharin. The large structural similarities may account for their common biological effects such as an abortifacient, an anti-tumour agent and anti-HIV-1 activities. It was held that trichoanguin may be a better type I RIP than any other so far examined for the preparation of immunotoxins, with a great potential for application as an effective chemotherapeutic agent for the treatment of cancer.

Traditional Medicinal Uses

T. cucumerina is one among the many constituents in various Ayurvedic formulations used for the treatment of liver disorders and other diseases. *T. cucumerina* is used as an abortifacient, vermifuge, stomachic, refrigerant, purgative, antimalaria, laxative, hydragogue, hemagglutinant, emetic, cathartic, bronchitis and anthelmintic.

In India, the fruit is considered to be anthelmintic, emetic and purgative and the seed is reported to be cooling, astringent, anthelmintic, antiperiodic, anti-diarrhoeal and anti-spasmodic. The seeds are used as abortifacient, aphrodisiac, febrifuge, purgative and has anti-bacterial and insecticidal properties. Leaf is deemed alexiteric, astringent, diuretic and emetic. In the Konkan, the leaf-juice is rubbed over the liver in liver congestion, or over the whole body in remittent fevers. An infusion of tender shoots and dried capsules is regarded as aperient, and the expressed juice of the leaves as emetic. The leaves and stems are used for bilious disorders and skin diseases and as an emmenagogue. The bulbous part of the root is considered as a hydragogue and cathartic and the roots are used for expelling intestinal worms. In China, peptides in the plant are used as an abortifacient, the roots used for diabetes, skin swellings like boils and furuncles. Fresh root has anti-convulsant activity and the root sap has a potent purgative action. In West Africa, an infusion of the young shoots is deemed mildly aperient. The leaf sap is emetic, and the seeds are anthelmintic and antiperiodic.

Other Uses

Snake gourd is also planted as an ornamental for its decorative fruit as an object of curiosity. The seed of *Trichosanthes cucumerina* has a high oil content of 46.34% (Ekam 2003). The oil has a high heat of combustion (32.8 kcal/g), high refractive indices at 400°C, boiling point, smoke point and flash points, relative density and low melting point. From the chemical parameters, the high ester value and saponification values of *T. cucumerina* qualifies it to be used in industries for soap making.

Comments

The plant is usually propagated from seeds but recent studies have reported that it can be rapidly propagated by in-vitro clonal propagation (Devendra et al. 2008).

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Dillenia indica

Scientific Name

***Dillenia indica* L.**

Synonyms

Dillenia elliptica Thunb., *Dillenia speciosa* Thunb.

Family

Dilleniaceae

Common/English Names

Chalta Tree, Chulta, Dillenia, Elephant Apple, Hondapara Tree, Indian Catmon

Vernacular Names

Brazil: Árvore-Da-Pataca, Árvore-Do-Dinheiro, Dilênia, Flor-De-Abril (Portuguese);
Burmese: Zinbyum;
Chinese: Wu Ya Guo;
Czech: Hodara Indická;
Eastonian: India Dilleenia;
German: Indischer Rosenapfel, Elefantenpfel;
India: Chalita, Outenga (Assamese), Chalta, Chalta Korkot (Bengali), Chalta, Girnar, Kanigala, Karambel (Hindu), Betkanagalu, Betta Kanigala, Bettakangala, Bettakanagalu, Bettakanigala, Ganagalu, Kaadu Kanigala, Kadkanagula, Kal Tega, Kalthaega, Kalthega, Kanagalu, Kanigala, Muchhilu, Muchiru, Naitaku, Naaythaeku, Neyi-Taaku, Neyi Vaakju, Neyitaku (Kannada), Dieng Soh Korbam (Khasi), Calita, Chalita, Pinnay, Punna, Syalita, Valapunna, Valappunna, Vazchapunna, Vazhapunna (Malayalam), Heigri (Manipuri), Karambel, Karmbel, Mota Karmal, Motaakambal, Motaakarmal, Motakarmal, Motakarmbal (Marathi), Kawrthindeng, Kawrthingdeng (Mizoram), Dong-Phng-Thai (Naga), Uhuba (Oriya), Avartaki, Bhavya, Bhavyam, Ruvya (Sanskrit), Akku, Kattarali, Kurukati, Ugakkay, Uka, Uva, Uvatteku, Uvav, Uvvattekku, Uvay (Tamil), Chalta, Kaalinga, Kalinga, Muchiru, Peda Kalinga, Pedda Klinga, Peddakalinga, Revadi, Revadi Chettu, Uppu Ponna, Uva, Uvva (Telugu);
Indonesia: Simpoh, Kosar (Javanese), Sempur Chay (Sudanese);
Japanese: Biwa Modoki, Direnia;
Malaysia: Chimpuh,Simpoh, Simpor;
Nepalese: Paanca Phal, Panca Kule, Ram Phal, Thuulo Taatarii;
Pakistan: Chalta;
Portuguese: Fruta-Estrela;
Spanish: Leña De Indigo;
Sri Lanka: Hondapara, Wampara (Sinhala), Ruvya (Sanskrit), Uva (Tamil);
Taiwan: Di Lun Tao;
Thai: Matad, Matat San Plao, Saan;
Tibetan: Bha Ba Na;
Vietnamese: So An, So Ba.

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Origin/Distribution

Elephant Apple is native to the East Indies – from India, Sri Lanka east to southwestern China (Yunnan) and Vietnam and south through Thailand to Malaysia and Indonesia.

Agroecology

The species occurs in warm tropical areas with high mean annual rainfall of 2,000 mm and temperatures of 24–35°C. It is found in tropical rainforests, usually near the banks of creeks or rivers from sea level to 1,100 m. It thrives in full sun or light shade, in moist soils of pH 5.5–7.0 and is frost intolerant.

Edible Plant Parts and Uses

Fleshy sepals enveloping the fruit are eaten. They are sourish and used to flavor food. The fruit pulp is used in jellies, jams, curries (particularly prawn curries) and drinks. A syrup is made from the sepals of the flowers. In Thailand, unripe fruits are cooked to make pickle and chutney. The young fruits are sliced and added to sweet and sour soup called *kang som*. The juicy pulp is aromatic but very acid. In China, the sour fruit are consumed by people living in the mountains of southern Yunnan and adjacent Guangxi.

Botany

An erect, much branched, perennial, medium-sized, evergreen tree growing to 15 m tall or more, with a dense, rounded, spreading crown and a robust trunk of 200–400 cm diameter. Leaves are spirally arranged, obovate, 15–35 cm long, serrate with a with a conspicuously corrugated surface with prominent impressed lateral veins running to each tooth (Plate 1). The flowers are very large, robust, nodding, fragrant, white, 15–20 cm diameter, with 5, oval, boat-shaped, fleshy sepals, five white, broadly obovate petals and numerous whitish cream stamens in two whorls, outer curved and the inner whorl reflexed at the apex, carpels numerous with spreading, white stylar branches with the concave stigma at the tip. The flowers do not fully expand even during anthesis. The fruit is large, knobbly, greenish-yellow and subglobose up to 12 cm diameter (Plates 2 and 3), consisting of aggregate of 15–20 carpels (Plate 4), each carpel containing 1–8 small, brown hairy fringed, exarillate, endospermic, compressed, reniform seeds embedded in an edible, glutinous pulp and is made up of the large fleshy imbricate sepals which tightly enclose the true fruit.

Plate 1 Large leaves of Elephant apple

Plate 2 Unripe Elephant apple fruit

Plate 3 Close up of knobbly Elephant apple fruit with overlapping sepals

Plate 4 Fruit with overlapping, fleshy sepals removed

Nutritive/Medicinal Properties

The outer part of the fruit (edible sepals) had been reported to contain 4.299% total ash, 1.889% soluble ash, 1.2% tannins, 7.19% total sugars, 7.05% reducing sugars and 142 titratable acid number, while the fruit proper has 4.453% total ash, 4.150% soluble ash, 1.2% tannins, 3.44% total reducing sugars and 94 titratable acid number (Shome et al. 1980). Using different solvents, the fruits were found to contain steroids, tripterpenoids, flavonoids, alkaloids besides tannins.

Squash prepared from ripe ou-tenga (*Dillenia indica*) fruit at its optimum maturity stage and stored for 60 days registered increases in pH from 1.37 to 2.61 (at day 0) to 2.24 to 2.88, total sugar percent from 26.56% to 48.48% (at day 0) to 31.15% to 55.05% (Saikia and Saikia 2002). A pH of 1.37, TSS (total soluble solids) (48.0%), acidity (0.65%) and total sugars (48.48%) were found to be an appropriate combination contributing to organoleptic qualities of the squash. Significant effects of storage were observed on pH, TSS, titratable acidity, reducing sugars, total sugars and non-reducing sugar. Significant effect of storage was also found in organoleptic parameters of colour, flavour, taste and astringency.

A pentacyclic triterpene lactone was isolated from *D. indica* (Banerji et al. 1975). The stem bark contained myricetin, isorrhamnetin, dillenetin and glucosides (Pavanasasivam and Sultanbawa 1976). The leaves were found to contain n-hentriacontanol, β-sitosterol, betulin and betulin acid (Mukerjee and Badruddoza 1981). The n-hexane and chloroform fractionate of the crude methanolic extract of *D. indica* leaves yielded 3,5,7-trihydroxy-3′,4′-dimethoxy flavone (dillenetin), betulinic acid, β-sitosterol and stigmasterol (Muhit et al. 2010).

Some of the few studies reported on the pharmacological properties of the various plant parts are discussed below.

Antioxidant Activity

Studies in India reported the fruit of *D. indica* to be rich in phenolics and may provide a good source of antioxidant. Antioxidant capacity of the extracts as equivalent to ascorbic acid (μM/g of the extract) was in the order of methanol extract > ethyl acetate extract > water extract (Abdille et al. 2005). The total phenolic contents of the fruit extracts as tannic acid equivalents were found to be highest in methanol extract (34.1%) followed by ethyl acetate extract (9.3%) and water extract (1.4%). The antioxidant and free radical scavenging activities of the extracts assayed through β-carotene-linoleate model system, and DPPH (α,α-diphenyl-β-picrylhydrazyl) method were also found to be highest with methanol extract followed by ethyl acetate and water extracts. The results indicated that the extent of antioxidant activity of the extract correlated with the amount of phenolics present in

the extract. The crude methanolic extracts and its n-hexane, carbon tetrachloride, dichloromethane and chloroform soluble partitionates of *D. indica* stem exhibited significant free radical scavenging activity when compared with the standard drug ascorbic acid (Parvin et al. 2009).

Antimicrobial Activity

A total of four compounds namely, lupeol, betulinaldehyde, betulinic acid and stigmasterol were isolated from the stem extract of *Dillenia indica* (Parvin et al. 2009). The crude methanolic extracts and its n-hexane, carbon tetrachloride, dichloromethane and chloroform soluble partitionates of *D. indica* stem demonstrated weak antimicrobial activity against a wide range of Gram-positive and Gram-negative bacteria and fungi. The extracts also exhibited significant cytotoxic activity when tested by brine shrimp lethality bioassay.

D. indica leaves were found to have antimicrobial activity (Apu et al. 2010). Among the four fractions tested of the methanolic extract of *D. indica* leaves, n-hexane, carbon tetrachloride, and chloroform fractions showed moderate antibacterial and antifungal activity compared to standard antibiotic, kanamycin. But the aqueous fraction was found to be insensitive to microbial growth.

Antiinflammatory Activity

The methanol extract of *Dillenia indica* leaves was found to have antiinflammatory activity (Yeshwante et al.). The methanol extract showed significant antiinflammatory activity in the paw edema test and acetic acid-induced capillary permeability at 200 mg/kg and 400 mg/kg. The extract at 100 mg/kg exhibited significant activity in acid-induced permeability. The findings supported the folkloric use of *Dillenia indica* in diseases related to inflammatory conditions.

Antinociceptive Activity

The crude methanol extract of *Dillenia indica* roots was found to produce significant writhing inhibition in acetic acid-induced writhing in mice at the oral dose of 250 and 500 mg/kg body weight comparable to the standard drug diclofenac sodium at the dose of 25 mg/kg of body weight (Bose et al. 2010).

CNS Depressant Activity

Alcoholic extract of *D. indica* demonstrated central nervous system (CNS) depressant activity (Bhakuni et al. 1968).

Antidiarrhoeal Activity

The crude nethanol extract of *Dillenia indica* roots of produced significant antidiarrhoeal effect at the dose of 500 mg/kg of body weight comparable to that produced by loperamide, used as standard drug (Bose et al. 2010). The extract also reduced significantly the charcoal induced gastro intestinal (GI) motility in mice and decreased the movement of GI tract in comparison to control animals.

Anticancer Activity

D. indica leaves were found to have potent cytotoxicty activities (Apu et al. 2010). Among the four fractions tested of the methanolic extract of *D. indica* leaves n-hexane and chloroform fractions demonstrated significant cytotoxic activity (LC_{50} of 1.94 μg/ml and 2.13 μg/ml, respectively) compared to vincristine sulfate (with LC_{50} of 0.52 μg/ml),. The LC_{50} values of the carbon tetrachloride and aqueous fraction were 4.46 μg/ml and 5.13 μg/ml.

The methanolic extract of *Dillenia indica* fruits showed significant anti-leukemic activity in human leukemic cell lines U937, HL60 and K562 (Kumar et al. 2010). A major bioactive compound, betulinic acid, was isolated from the ethyl acetate fraction of the methanolic extract.

Muco-adhesive Activity

Anew nasal gel formulation was developed using a natural muco-adhesive agent obtained from the fruit of *Dillenia indica* (Kuotsu and Bandyopadhyay 2007). The muco-adhesive strength and viscosity of this natural muco-adhesive agent was found to be higher in comparison to the synthetic polymers, such as hydroxy propyl methyl cellulose (HPMC) and carbopol 934. In-vitro drug release characteristics using a Franz-diffusion cell and excised bovine nasal membrane was also found to be better in comparison to the above synthetic polymers. The scientists asserted that this patient friendly, needle free dosage form may have potential to replace oxytocin injections (Metia and Bandyopadhyay 2008).

Traditional Medicinal Uses

Dillenia indica, is widely used in the indigenous systems of medicine; the leaf and bark as an astringent and laxative, the bruised bark, externally as a cataplasm in arthritis, and the fruit juice as a cough mixture, a cooling beverage as also for toning up the nervous system. It is considered a 'vat' suppressant, 'pitta' augmenting drug in Ayurveda (Shome et al. 1979). The fruit is slightly laxative and induce diarrhoea, if taken excessively. The juice of the fruit, mixed with sugar and water, is used as a cooling beverage in fevers and as a cough mixture and also as a cardiotonic.

Other Uses

The tree is highly appreciated for its large, handsome and fragrant flowers and planted for ornamental purpose and as a timber tree. The pulp of the fruit is used as hair shampoo. Timber has been used in India for gun stocks and helves, in house construction and ship building. In Java, it is used for telegraph posts.

Comments

The plant can be propagated from seeds or cuttings.

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Dillenia philippinensis

Scientific Name

***Dillenia philippinensis* Rolfe**

Synonyms

None

Family

Dilleniaceae

Common/English Names

Katmon, Philippine Dillenia

Vernacular Names

Philippines: Kalambok, Kalambug (Bagobo), Katmon (Bikol), Katmon (Bisaya), Balale, Palali (Ibanag), Bihis, Biskan (Igorot), Palali (Iloko), Kalamnugui (Lanao), Bolobayauak (Panay-Bisaya), Katmon (Pampangan), Palali, Pamamalien (Pangsingan), Diangin (Sambali), Palali (Subanum), Kambug (Sulu), Katmon (Tagalog).

Origin/Distribution

D. philippinensis is a native of the Philippines – it is endemic to the Babuyan islands and Sulu archipelago.

Agroecology

An evergreen tree which occurs in primary and secondary forest, at low and medium altitudes throughout the islands. The tree is shade tolerant and is moderately tolerant of occasional water-logging.

Edible Plant Parts and Uses

Fruits (including sepals), young shoots and flowers are used as flavoring for sour fish soup. Ripe fruits are eaten fresh but is sour. It makes excellent jams or sauce.

Botany

A small to medium sized, evergreen tree, growing to 6–15 m high with an erect to contorted bole with slight buttresses and smooth, shallowly

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Plate 1 Large elliptic leaves

Plate 3 Close-up of immature fruit

Plate 2 Young Katmon fruits

fissured, greyish brown bark. Branching starts midway up the trunk. The leaves are elliptic, large, 12–25 cm long, thick and coraiceous, glabrous, glossy green with serrated margins and prominently penni-veined (Plates 1 and 2). The flowers are white, large, showy, and about 15 cm across, more or less upright or directed to the side. The flower has 5 pale green cup-shaped sepals, 5 obovate, spreading white petals. The androecium is differentiated into two distinct sets of stamens, an outer (230) and an inner (ca 40) whorls. numerous stamens in two sets of 2 different forms and reddish colouration, spreading stylar branches. The outer stamens are shorter, slightly spreading and form a basket-like structure; they are dark red with white tips in the upper half of their length and conspicuously yellow in the basal half; in their entirety the stamen bases form a yellow ring around the floral centre. The inner stamens are longer, they are not spreading but are in contact with the carpels, and their tips are reflexed. Stamens have short stout filaments and long anthers. The gynoecium consist of a syncarpous, globose ovary of more than 13 red carpels. Each carpel have a separate firm, radiating stylar branch with a small concave stigma at the tip. The fruit is globose, 5–6 cm across, made up of the fleshy, imbricate, thin sepals (Plates 1–3) which enclose the syncarpous aggregate of carpels, each carpel contains 1–5 small brownish-black seeds embedded in the soft, gelatinous pulp.

Nutritive/Medicinal Properties

No information has been published on the nutritive value of the fruit.

The air-dried leaves of *Dillenia philippinensis* afforded betulinic acid (1) and 3-oxoolean-12-en-30-oic acid (2) (Ragasa et al. 2009). Compounds 1 and 2 exhibited moderate activity against the fungus *Candida albicans* and slight activity against the bacteria *Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus*, and *Bacillus subtilis*. Compound 2 exhibited slight activity against *Trichophyton mentagrophytes*, while 1 was inactive against this fungus. Both compounds were inactive against *Aspergillus niger*.

The fleshy sepals and carpels of the fruit are used in traditional medicine especially in the preparation of cough syrup by mixing the juice with sugar and also used as hair shampoo.

Other Uses

The tree is planted as an ornamental, urban greening tree, hedge, living fence, windbreak and is used also in riparian or wetland management. The tree is also a useful timber tree in Southeast Asia. The wood is used for general utility, construction, poles, interior works, furniture, boards and panels, veneers, plywoods and wooden articles. A red dye is obtained from the bark.

Comments

The species has been listed as vulnerable by the World Conservation Monitoring Centre (1998).

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Dillenia serrata

Scientific Name

***Dillenia serrata* Thunb.**

Synonyms

Dillenia elliptica Thunb.

Family

Dilleniaceae

Common/English Name

Dengen, Dongi (common name)

Vernacular Names

Indonesia: Dongi, Dengilo (Manado), Bintangur, Dengen, Songi (Sulawesi), Menampa (Tembuku).

Origin/Distribution

The species is endemic to Indonesia (Sulawesi) and is sometimes cultivated.

Agroecology

A tropical species that grows wild in the lowland primary forest in alluvial, sandy to clayey sites at 200 m above sea level.

Edible Plant Parts and Uses

The fruit is edible, sweetish-acid; used fresh or pickled as a substitute for lemon or lime.

Botany

Evergreen, medium-sized tree, up to 30 m tall with a 70 cm trunk diameter. Leaves are alternate, simple, oblong to lanceolate, 20–45 cm × 8–19 cm, penni-veined, with serrated margins and borne on winged petioles. Flowers are about 7.5 cm across, apetalous, yellow, crowded 2–6 in racemes. Sepals, 5 concave and fleshy, stamen numerous arranged in groups in two whorls, carpels 10–24 joined at base forming a syncarpous, globose ovary. Fruit is berry-like, indehiscent, depressed-globose, 3.5 cm high by 6 cm diameter, made up of 20–40 carpels (syncarpous) enclosed by the pale green, thin sepals. Ripe carpels are 25 mm × 16 mm, deep yellow to golden yellow (Plate 1). Each carpel has up 1–5 seeds. Seeds are small, black, without aril.

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Plate 1 Dengen fruit showing the ripe golden yellow carpels enclosed by the pale green sepals

Nutritive/Medicinal Properties

No published information is available on its nutritive attributes. In Sulawesi, the bark of the tree has been used traditionally for the treatment of *muntah darah* (vomiting of blood or haematemetesis).

Other Uses

An important commercial timber species. The wood is used in boat-making and house construction.

Comments

No research has been conducted or published on its pharmacology.

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Diospyros blancoi

Scientific Name

***Diospyros blancoi* A. DC.**

Synonyms

Cavanillea philippensis Desr., *Diospyros discolor* Willd. nom. illeg., *Diospyros kaki* Blanco non L., *Diospyros mabola* Lindl. nom. illeg., *Diospyros philippensis* (Desr.) Gürke non *D. philippinensis* A. DC., *Diospyros utilis* Hemsley.

Family

Ebenaceae

Common/English Names

Butter Fruit, Camogan Ebony, Mabolo, Mabola Persimmon, Mabola-Tree, Velvet Apple, Velvet Persimmon

Vernacular Names

Bangladesh: Gab;
Chinese: Yi Se Shi;
French: Pommier Velours,
India: Belanti Gab, Hong Nhung (Hindu);
Indonesia: Bisbul, Buah Mentega;
Japanese: Ke Gaki;
Malaysia: Buah Mentega, Buah Lemah, Buah Sagalat, Buah Sakhlat, Sagalat;
Philippines: Camagon, Kamagong, Mabolo, Mabulo (Tagalog);
Portuguese: Pécego-De-India;
Spanish: Camagón;
Taiwan: Mao Shi, Tai Wan Shi;
Thailand: Ma-Rit;
Vietnamese: Hồng Nhung.

Origin/Distribution

Mabola is indigenous to the low and medium altitude forests of the Philippine Islands from the island of Luzon to the southernmost of the Sulu Islands, and is also found in southern Taiwan (Guishan Dao, Hengchun peninsula, Lanyu) and Celebes in Indonesia. The tree was introduced into Java, Malaysia, India and subsequently elsewhere in the tropics.

Agroecology

Mabolo thrives in areas with a tropical, monsoonal climate and is not fastidious of soil type. It can withstand typhoons. It is very common and widely distributed in primary and secondary forests at low and medium altitudes, from sea level to 800 m altitude in its native range. In Taiwan, it is found in coastal forests up to 200 m above sea level.

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Edible Plant Parts and Uses

The ripe fruit is peeled and eaten fresh, or used in salad or stew or fried like a vegetable. The flesh is also diced and combined with that of other fruits in salads. The flesh can be season with lime or lemon juice or Grenadine syrup and serve fresh as dessert. The flesh can be stewed in syrup. The flesh can be cut into strips and fried in butter and served with ham, sausage or other spicy meat.

Botany

A dioecious, much-branched, evergreen tree, 7–32 m high, with a stout, dark-brown to black, furrowed trunk 50–80 cm diameter and a conical crown. Branchlets green when young, sericeous, becoming gray and glabrous. Leaves are alternate, oblong, 8–30 cm by 2.5–12 cm, entire, coriaceous with obtuse base and acuminate apex, upper surface dark-green, glossy, glabrous (Plates 1–3) and lower surface silvery hairy, petiole up to 1.7 cm long and densely pubescent. Young leaves are pinkish to pale-green, silky-hairy (Plate 2). Male flowers are formed in 3–7 flowered axillary cymes or racemes on short pedicel. Calyx villous, deeply 4 lobed and tubular about 1 cm long; corolla creamy-white with 4 reflexed lobes; stamens 24–30 united in pairs at base. Female flowers are solitary, axillary, subsessile, slightly larger than male flowers, with 4–10 staminodes and 3-cleft style. Fruit is a globose or oblate berry, 5–12 cm by 8–10 cm, velvety, orange or brown-reddish, crowned with the persistent stiff, pale green calyx, the skin is thin and densely villous (coated with short golden-brown hairs) (Plates 2–4). The fruit pulp is whitish, firm, rather dry, sweet, astringent and aromatic. Seeds 0–10, three-sided, up to $4 \times 2.5 \times 1.5$ cm and dark brown. Each seed is covered with a whitish membrane that is transparent when fresh, opaque when dried.

Plate 1 Young pinkish leaves and old dark green glabrous leaves

Plate 2 Large leaves and immature fruit of mabola

Plate 3 Rusty, orangey brown, tomentose mabola fruit

Plate 4 Ripe mabolo fruit with persistent calyx

Nutritive/Medicinal Properties

Wong et al. (1997) identified 67 volatile compounds form mabola fruit. Esters were clearly dominant, accounting for 88.6% of the total volatiles. The major components were methyl butyrate (32.9%), ethyl butyrate (10.7%), butyl butyrate (10.2%) and benzyl butyrate (10.0%). Four of the esters found were sulfur-containing compounds. Pino et al. (2008) identified 96 volatile compounds from Mabola fruit. The volatile components were characterized by the existence of many esters, particularly benzyl butyrate (33.9% of the total composition), butyl butyrate (12.5%) and (E)-cinnamyl butyrate (6.8%). Fruit is edible and is a good source of vitamins A, C, and minerals and the tannin content declines as it ripens.

Four new lanostane-type triterpenes, 24-ethyl-3β-methoxylanost-9(11)-en-25-ol, 3β-methoxy-24-methyl-enelanost-9(11)-en-25-ol, 3β-methoxy-25-methyl-24-methylenelanost-9(11)-en-21-ol and 3β-methoxy-24-methyllanosta-9(11),25-dien-24-ol together with three known triterpenes, betulinaldehyde, betulinic acid methyl ester, and ursaldehyde were isolated from the methanol extract of the twigs of mabola (Chen et al. 2007). Dimeric naphthoquinones were also isolated from mabola (Ganapaty et al. 2005).

Mabola (ethanol leaf extract) was one of 6 Taiwanese plants that showed good DPPH (1,1-diphenyl-2-picrylhydrazyl) -scavenging activities with IC_{50} values ranged from 1.7 to 8.7 μg/ml (Lee et al. 2006). The plant extracts also displayed hydroxyl-scavenging activities (IC_{50} of 0.16–0.67 μg/ml). The extracts also showed good superoxide anion radical scavenging activities and IC_{50} values ranged from 12.9 to 28.5 μg/ml and potent reducing power. This active plant extracts also contained abundant phenolic constituents and represented potential candidates for isolation of the bioactive constituents and development of natural antioxidants. Recent studies reported that *D. discolor* was one of 8 Taiwanese native plants found to be rich in phenolic compounds (Lee et al. 2006). The extracted yields of plants ranged from 3.7% to 16.9%. The total phenolic contents ranged from 25.4 to 36.8 mg GAE/g dry material. All of these extracts (except *Vitis adstricta* Hance) were shown to inhibit matrix metalloproteinase-9 (MMP-9) activity of WS-1 cell after ultraviolet B irradiation. The results indicated that these plants including mabola, could be potent inhibitors of the ageing process in the skin and may be useful as prophylactic medicines and in the production of cosmetics.

The ethyl acetate extract of the air-dried leaves of *Diospyros blancoi* afforded isoarborinol methyl ether (1), a mixture of α-amyrin palmitate, α-amyrin palmitoleate, β-amyrin palmitate and β-amyrin palmitoleate (2) and squalene (Ragasaa et al. 2009). Compounds 1 and 2 exhibited antimicrobial activity against *Escherichia coli*, *Pseudomonas aeruginosa*, *Candida albicans*, *Staphylococcus aureus* and *Trichophyton mentagrophytes*, and were found inactive against *Bacillus subtilis* and *Aspergillus niger*. Compound 2 exhibited significant analgesic and antiinflammatory activities.

In the Philippines, the bark preparation has been reported to be used for fevers, dysentery and diarrhoea; a decoction of the bark for coughs; and barks and leaves preparations for itchy skin ailments in traditional medicine. In southeast Asia, the fruit infusion has been used as gargle in aphthous stomatitis, juice of unripe fruit used for wounds and oil from seeds used for diarrhoea and dysentery. In Bangladesh, preparations of bark and leaves were used for snakebites and as eyewash.

Other Uses

The tree is also planted as ornamentals, windbreaks, or roadside shade trees. Mabola seedlings are used as rootstock for Japanese persimmon. The wood is smooth, durable, streaked and mottled with gray and is sometimes all-black. It is much used in the Philippines in making handicrafts (carvings, hair combs), veneer, musical instruments, special furniture and exterior work.

Comments

Mabola is usually propagated by seeds but it can also be vegetatively propagated from budding, grafting and marcotting.

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Diospyros digyna

Scientific Name

***Diospyros digyna* Jacq.**

Synonyms

Diospyros ebenaster Hiern non Retz., *Diospyros laurifolia* A. Rich., *Diospyros membranacea* A. DC., *Diospyros nigra* (Blanco) Blanco, *Diospyros nigra* (J.F. Gmelin) Perrottet, *Diospyros sapota* Roxb., *Diospyros obtusifolia* Humb. et Bonpl. ex Willd., *Sapota nigra* Blanco, *Sapota nigra* J.F. Gmel.

Family

Ebenaceae

Common/English Names

Axle Grease Plant, Black Apple, Black Persimmon, Black Sapote, Chocolate Persimmon, Chocolate Pudding Fruit, Chocolate Pudding Tree, Sapote Negro

Vernacular Names

Antilles: Barbacoa, Barbaquois, Caca Poule;
Danish: Sort Ibenholt;
French: Barbaquois, Ébčnier Des Antilles, Kaki Noir, Sapote Noire, Sapotier;
Indonesia: Sawo Hitam;
German: Ebenholzbaum, Schwarze Sapote;
Japanese: Diosupirosu Nigura;
Mexico: Guayabota, Zapote Prieto, Tliltzapotl (Aztec);
Philippines: Zapoté Negro;
Portuguese: Ébano Das Antilhas;
Spanish: Ebano, Ébeno Agrio, Guayabota, Matasano De Mico, Sapote, Sapote Negro, Zapote, Zapote De Mico, Zapote Negro, Zapote Prieto;
Taiwan: Hei Shi.

Origin/Distribution

Black sapote is native to South America, occurring wild along both coasts of Mexico from Jalisco to Chiapas, Veracruz and Yucatan and in the forested lowlands of Central America, and it is frequently cultivated throughout this range. It has been introduced and cultivated elsewhere around the tropics including the Caribbean, Southeast Asia and Australia.

Agroecology

It is found in naturally in dry forests or on alluvial clay near streams or lagoons where it is frequently subject to flooding. It thrives on moist sandy loam,

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on well-drained sand or calcareous soil. It is cultivated from near sea level up to elevation of 1,800 m. Black sapote is cold tolerant and well-established trees can withstand low temperatures down to −2°C for brief periods.

Edible Plant Parts and Uses

Fruits are best picked and eaten when fully ripe, the pulp becomes soft and pudding like at this stage. The pulp is eaten fresh with lemon or orange juice, or in pastry creams or used in desserts and beverages. Popular desserts include Black sapote mousse, cakes, cheese cakes, bavarois, custards, stuffing for pies and pastry, black sapote torte, black sapote topping (pulp, icing sugar, rum or brandy) or serving it as a sauce with papaya and ice cream. One popular dessert is "Black Sapote Fairy Queen Boat" which comprises black sapote topping, ice-cream, mixed fruit and with sherry or port. In the Philippines, the pulp is served as dessert with a little milk or orange juice poured over it. In Mexico, the pulp can be blended, filtered and mixed with orange juice or brandy, and then served with or without whipped cream or the pulp is mixed with wine, cinnamon and sugar and serve as dessert. The pulp can be fermented to made a brandy-like liqueur as in Central America or blended with pineapple juice to give a foamy, delicious beverage.

Botany

A perennial evergreen tree with a broad canopy and grooved, black trunk growing to 25 m high. Leaves are alternate, simple, glossy green, leathery, elliptic-oblong to oblong-lanceolate, 10–30 cm long, rounded at the base, bluntly acute at the apex, entire in the margin and penni-veined (Plates 2 and 3). Flowers are axillary, solitary or in clusters of 3–7, with white tubular lobed perianth, 1–1.6 cm across with large persistent green calyx lobes. Some flowers are bisexual and some are male. The fruit is oblate, 5–12.5 cm wide, with a prominent, 4-lobed, undulate calyx 4–5 cm across, clasping the fruit base and occur singly or in clusters (Plates 1 and 2). The fruit is bright green to yellowish-green and shiny at first (Plates 1–4), on ripening, the smooth, thin skin becomes dull olive-green (Plates 3 and 4) to muddy-green. The pulp is white in immature fruit and turns very dark-brown to almost black, soft and somewhat sweetish in flavour when ripe.

Plate 1 Cluster of 3 unripe, green black sapote fruit

Plate 2 Black sapote leaves

Plate 3 Fruit with pellucid-dotted skin and persistent calyx

Plate 4 Ripe, dull green fruit with the persistent calyx

Seed 1 to several, flat, smooth brown and 2–2.5 cm long. The fruit is sometimes seedless.

Nutritive/Medicinal Properties

Approximate nutrient composition of raw black sapote fruit per 100 g edible portion was reported as: moisture 79.46–83.1 g, protein 0.62–0.69 g, carbohydrates 12.85–15.11 g, fat 0.01 g, ash 0.37–0.6 g, calcium 22.0 mg, phosphorus 23.0 mg, iron 0.36 mg, carotene 0.19 mg, riboflavin 0.03 mg, niacin 0.20 mg and ascorbic acid 191.7 mg (Morton 1987).

Black sapote fruit has antioxidant property. Of eight horticultural crops, namely, guava, avocado, black sapote, mango, papaya, prickly pear fruit, cladodes, and strawberry analysed for total antioxidant capacity (AOC) using six assays, black sapote had the highest value in the ORAC (oxygen radical absorbance capacity) assay. AOC values from hydrophilic extracts were about 95 times higher than lipophilic extracts values (Corral-Aguayo et al. 2008).

Traditional medicinal uses of black sapote are few. The crushed bark and leaves have been applied as a blistering poultice in the Philippines. In Yucatan, the leaf decoction was employed as an astringent and was taken internally as a febrifuge. Various preparations were used against leprosy, ringworm and itching skin conditions.

Other Uses

Unripe fruits are very astringent and are sometimes used as fish poison. The wood is yellowish to deep-yellow with black markings near the heart of old trunks; compact and suitable for cabinetwork but little used.

Comments

Black sapote is usually propagated from seeds. It can also be vegetatively propagated by grafting or budding onto seedling rootstocks.

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Diospyros kaki

Scientific Name

***Diospyros kaki* Thunb**

Synonyms

Diospyros argyi Lév., *Diospyros aurantium* André, *Diospyros bertii* André, *Diospyros chinensis* Blume nom. nud., *Diospyros costata* Carr., *Diospyros elliptica* André, *Diospyros kaempferi* Naudin, *Diospyros kaki* L.F. nom. illeg., *Diospyros kaki* var. *domestica* Mak., *Diospyros lycopersicon* Carr., *Diospyros mazelii* Carr., *Diospyros sahuti* André, *Diospyros schi-tse* Bunge, *Embryopteris kaki* G. Don.

Family

Ebenaceae

Common/English Names

Chinese Persimmon, Chinese Fig, Chinese Plum, Date Plum, Kakee Plum, Kaki, Kaki Persimmon, Japanese Persimmon, Keg Fig, Oriental Persimmon, Persimmon, Sahron Fruit

Vernacular Names

Arabic: Birsiimuun;
Armenian: Ark'ayanarinj, Xurma;
Brazil : Caqui, Caquizeiro;
Catalan: Banús, Caquier, Persimo;
Cherokee: Sali, Tsalalui, Tsali;
Chinese: Shi, Shih, Shi Ze, Ye Shi;
Czech: Tomel Japonský,
Danish: Almindelig Kakil, Kakitræ;
Eastonian: Hurmaa, Kaki, Kakiploom;
Esperanto: Persimono;
Finnish: Kaki, Kakihedelmä, Persimoni, Sharon;
French: Kaki, Plaqueminier, Plaqueminier De Chine, Rague Mine;
German: Chinesische Dattelpflaume, Kaki, Kakibaum, Japanische Aprokose, Kakipflaume, Persimone;
Greek: Lōtós;
Hebrew: Afarsmon;
Icelandic: Döðluplóma, Persimónía;
India: Belaiti-Gab, Halwa Tendu;
Indonesia: Kesemek, Buah Kesemak, Buah Samak;
Italian: Cachi, Kaki;
Ivatan: Vatinglaw;
Japanese: Kaki, Kakinoki, Yama Kaki;
Korean: Gam, Gamnamu, Kamnamu;
Laotian: Phap;
Macedonian: Rájsko Jábolko, Jáponsko Jábolko;
Malaysia: Buah Kaki, Pisang Kaki;
Nahuatl : Tliltzapotl;
Norwegian: Kaki, Daddelplomme, Kakifrukt, Kakiplomme, Persimon;
Philippines: Kamagong (Tagalog);
Polish: Hebanowiec Wschodni, Persymona;

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Portuguese: Caqui, Caquizeiro, Diospiro, Diospireiro;
Russian: Churma Vostočnaja, Xurma;
Serbian: Kaki, Persimmon;
Slovašcina: Kaki;
Spanish: Caqui, Kaki, Sapote Chino, Kaki Del Japón, Placa Minera;
Swedish: Kaki, Kakiplommon, Persimmon
Thailand: Plap, Plap Chin;
Vietnamese: Cây Hông, Hồng, Quả Hồng Vàng, Thi.

Origin/Distribution

Persimmon is native to China, where it has been cultivated for centuries and more than 2,000 different cultivars exist. It was introduced to Korea and Japan where additional cultivars were developed. Persimmon is an fruit crop in East Asia and is also grown in the cooler areas in north Thailand, Vietnam and in the sub temperate areas in USA, Australia, New Zealand, South Africa, South America and the Mediterranean areas in Europe.

Agroecology

Persimmons do best in cool areas that have moderate winters and relatively mild summers It can tolerate temperatures of −17.8°C when fully dormant. However, because of its low chilling requirement (less than 100 hours), it may break dormancy during early warm spells only to be damaged by spring frosts later. The foliage is killed by subzero temperatures when growing. Trees do not produce well in the high summer heat of desert regions, which may also sunburn the bark and fruit. It prefers full sun with protection from strong wind. It is grown from sea level to 2,500 m elevation. Persimmons can withstand a wide range of conditions as long as the soil is not excessively saline, but does best in deep, well-drained loam in the pH range of 6.5–7.5. Persimmon trees will withstand brief periods of drought, but the fruit will be larger and of higher quality with regular watering. Extreme drought will cause the leaves and fruit to drop prematurely.

Edible Plant Parts and Uses

Persimmons are eaten fresh or dried, raw or cooked. With some cultivars the peel is eaten with the flesh. With others, the peel is removed and the fruit quartered and eaten like an apple. The flesh ranges from firm to mushy and the texture is unique. The flesh is very sweet and when firm possesses an apple-like crunch. The fruit can be processed into crème and jam. In China, Korea, Japan, and Vietnam after harvesting, 'Hachiya' persimmons are prepared using traditional hand-drying techniques, outdoors for 2–3 weeks before being shipped to market. In Japan the dried fruit (Plate 9) is called *hoshigaki*, in Korea *gotgam*, and in Vietnam *hồng khô*. Dreid persimmons are eaten as a snack or dessert and used for other culinary purposes. In Korea, dried persimmon fruits are used to make the traditional Korean spicy punch, *sujeonggwa*, while the matured, fermented fruit is used to make persimmon vinegar. The persimmon also figures prominently in American culinary tradition. It can be used in cookies, cakes, pies, bread, puddings, salads and as a topping for breakfast cereal. Persimmon pudding is a baked pudding that has the consistency of pumpkin pie but resembles a brownie and is almost always topped with whipped cream. The peel of the fruit can be powdered and used as a sweetener. In some areas of Manchuria and Korea, the dried leaves of the fruit are used for making tea. The Korean name for this tea is *ghamnip cha*. The leaves are also used to improve the flavour of pickled radishes. The roasted seeds are used as a coffee substitute.

Botany

A deciduous, branched tree growing to 27 m high with densely pubescent to glabrous young branchlets, with reddish brown lenticels. Leaves are alternate, simple (Plates 1–3), borne on 0.8–2 cm petiole. Lamina is lanceolate, elliptic,

Plate 1 Non-astringent persimmon fruit and leaves

Plate 2 Close-sup of non-astringent persimmon fruit

Plate 3 Unripe astringent persimmon fruit

or ovate, occasionally obovate, 5–18 × 2.6–9 cm, papery, pubescent when young, adaxially often glabrescent, base cuneate, subtruncate, or rarely cordate, apex usually acuminate, pale green turning to glossy green and tuning to orange or red in autumn/winter, lateral veins 5–7 per side and with reticulate venation. Male flowers are small, inconspicuous in 3–5-flowered cymes; calyx more or less as long as corolla, hairy on both sides, lobes 4; corolla white, yellowish white, or red; stamens (14-)16–24. Female flowers are solitary; calyx 3–4 cm in diameter, persistent, lobes 4; corolla usually yellowish white, campanulate, lobes recurved and ovate; staminodes 8(−16); ovary glabrous or pubescent. Fruit yellow, orange to orangey red, globose, oblate, subglobose to ovoid, 2–9 cm across, 8-locular, glabrescent (Plates 1–8). Seeds dark brown, 13–16 mm × 7.5–9 mm × 4–5 mm.

Nutritive/Medicinal Properties

Nutrient values of raw Japanese persimmon (exclude 16% refuse) per 100 g edible portion (USDA 2010) was reported as : water 80.32 g, energy 70 kcal (293 kJ), protein 0.58 g, total lipid (fat) 0.19 g, ash 0.33 g, carbohydrate 18.59 g, total dietary fibre 3.6 g, total sugars 12.53 g, sucrose 1.54 g, glucose 5.44 g, fructose 5.56 g, Ca 8 mg, Fe 0.15 mg, Mg 9 mg, P 17 mg, K 161 mg, Na mg, Zn 0,11 mg, Cu 0.113 mg, Mn 0.355 mg, Se 0.6 μg, vitamin C, 7.5 mg, thiamin 0.030 mg, riboflavin 0.020 mg, niacin 0.100 mg, vitamin B-6 0.100 mg, total folate 8 μg, total chloline 7.6 mg, vitamin A 1627 IU, vitamin E (α-tocopherol) 0.73 mg, vitamin K (phylloquinone) 2.6 μg, total saturated fatty acids 0.020 g, 14:0 (myristic acid) 0.001 g, 16:0 (palmitic acid) 0.0016 g, 18:0 (stearic acid) 0.003 g; total monounsaturated fatty acids 0.037 mg, 18:1 undifferentiated (oleic acid) 0.037 g, total polyunsaturated fatty acids 0.043 g, 18:2 undifferentiated (linoleic acid)0.039 g, 18:3 undifferentiated (linolenic acid) 0.004 g, phytosterols 4 mg, tryptophan 0.010 g, threonine 0.030 g, isoleucine 0.025 g, leucine 0.042 g, lysine 0.033 g, methionine 0.005 g, cystine 0.013 g, phenylalanine 0.026 g, tyrosine 0.016 g, valine 0.030 g, arginine 0.025 g, histidine 0.012 g, alanine 0.029 g, aspartic acid 0.057 g, glutamic acid 0.076 g, glycine 0.025 g, proline 0.022 g, serine 0.022 g, β-carotene 253 μg, β-cryptoxanthin 1447 μg, lycopene 159 μg, lutein + zeaxanthin 834 μg.

A fat-soluble extract obtained from persimmon peel was found to contain a large amount of

Plates 4 (**a** and **b**) Different astringent varieties of persimmon

Plates 5 (**a** and **b**) Different astringent varieties of persimmon

Plates 6 (**a** and **b**) Different astringent, small-fruited varieties of persimmon

carotenoids; β-cryptoxanthin accounted for more than 50% of the total carotenoids identified (Izuchi et al. 2009) . The extract also contained six polyphenolic aglycons. Takahashi et al. (2006) found the following carotenoids in persimmon peels: α-carotene, β-carotene, β-cryptoxanthin, lycopene, lutein, and zeaxanthin. Bioactive compounds, oleanolic acid and ursolic

Plate 7 (**a** and **b**) Ripe, sweet, non-astringent persimmon

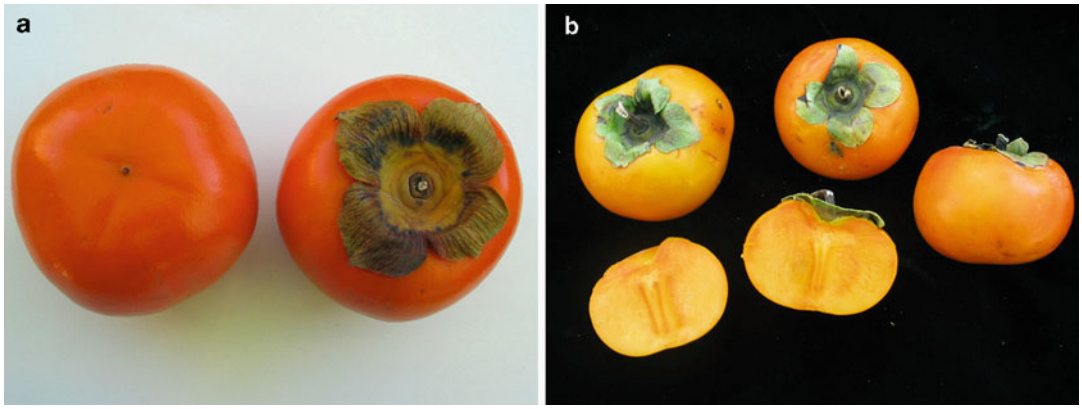

Plate 8 (**a** and **b**) Non-astringent Fuyu persimmon

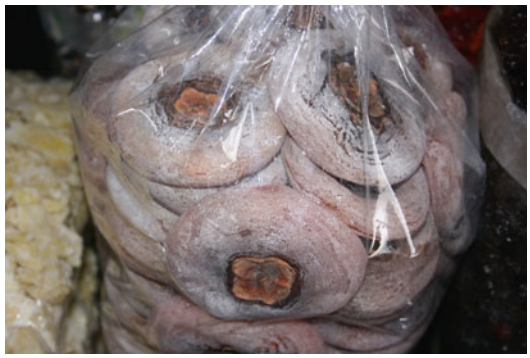

Plate 9 Dried persimmon fruits

acid were found in the flesh of many persimmon cultivars (astringent and non-astringent) in China (Zhou et al. 2010). The oleanolic acid content ranged from traces to 88.57 μg/g FW, and that of ursolic acid between traces and 27.64 μg/g FW.

Fruits of persimmon (*Diospyros kaki*) was found to accumulate large amounts of proanthocyanidins (PAs) in the early stages of development (Ikegami et al. 2009). Astringent -type fruits were found to be rich in soluble proanthocyanidins even after they reach full-mature stage, whereas non-astringent-type fruits were found to lose these compounds before full maturation. A novel 1-Cys peroxiredoxin and a new member of family 1 glycosyltransferases were identified.

The leaf of *Diospyros kaki*, which is a traditional Chinese medicine, had been reported to be used for the treatment of various diseases. Three bioactive triterpene acids: barbinervic acid and its epimer, rotungenic acid, along with 24-hydroxy ursolic acid were identified from persimmon leaves (Fan and He 2006). A new biphenyl derivative, 4′,5-dimethoxy-3-β-D-glucopyranosyloxy-4-hydroxy-biphenyl, named kakispyrol, was isolated

from *Diospyros kaki* leaves, together with three known compounds, vitexin, 2′-O-rhamnosyl vitexin and isorhamnetin-3-O-β-D-glucopyranoside (Chen et al. 2005). A novel C-glycosylflavone with unusual alpha-orientation at the anomeric center of d-glucose was isolated from *D. kaki* leaves (Chen et al. 2009). Its structure was elucidated as 8-C-[α-l-rhamnopyranosyl-(1→ 4)]-α- d-glucopyranosylapigenin.

Pharmacological properties of persimmon plant parts that have been reported are as follows:

Antioxidant Activity

The total phenolic content in persimmon fruits, estimated as gallic acid equivalents, varied from 15.7 mg/g dry weight for 08 TH 12 genotype to 42.3 mg/g gallic acid equivalent for the 08 TH 10 genotype (Ercisli et al. 2008). The highest antioxidant activity was observed in 08 TH 10 genotype at 91.6%, while the lowest was in 14 TH 01 (51.7%), respectively. The antioxidant activities of butylated hydroxyanisole and butylated hydroxytoluene were 93.4% and 91.8%, respectively. A low correlation (R = 0.711) was obtained between total phenolic content and antioxidant activity among genotypes. The results indicated that antioxidant activity in persimmon fruits was strongly governed by genotype.

The epigallocatechin contents in three astringent persimmons: Hiratanenashi, Tone-wase, Ishibashi-wase, were higher than those of two non-astringent persimmons Maekawa-jiro and Matsumoto-wase-fuyu (Suzuki et al. 2005). The epigallocatechin content in the astringent Hiratanenashi was the highest among the five Japanese persimmons. The epigallocatechin content in the non-astringent Maekawa-jiro was the lowest among the five Japanese persimmons. Therefore, astringent persimmons may be better sources of the natural antioxidant, epigallocatechin than non-astringent persimmons, and the astringent Hiratanenashi may be the best source of epigallocatechin among the five Japanese persimmons.

The radical scavenging activities against ABTS and DPPH radicals of the Mopan persimmon were 23.575 and 22.597 μM Trolox Eq/g fresh weight, respectively (Chen et al. 2008). These findings suggested that the Mopan persimmon's antioxidant activity was significantly stronger than that of reference materials. The Mopan persimmon had the highest amount of total phenolics among the four materials tested. Significant correlations ($R^2 = 0.993$, ABTS radical; $R(2) = 0.980$, DPPH radical) were found between the total phenolics and the radical scavenging activities. The total content of the six phenolic compounds (catechin, epicatechin, epigallocatechin, chlorogenic acid, caffeic acid, and gallic acid) was significantly correlated ($R^2 = 0.831$, ABTS radical; $R^2 = 0.745$, DPPH radical) with the individual radical scavenging activity of the 4 materials, although the total quantity of the six phenolics accounted for not more than 20% of the total phenolics in the Mopan persimmon. Gallic acid exhibited the strongest antioxidant activity among the 6 phenolics. Gallic acid content was the largest in the Mopan persimmon, presumably being responsible for its much higher antioxidant activity as compared to apple, grape, and tomato.

In another study, the contents of dietary fibres and trace elements in fresh and equivalent quantities of dried fruits were found to be comparable. The level of total polyphenols in fresh persimmon was higher than in dried fruit, but not significantly (Jung et al. 2005). Also the antioxidant potential in fresh persimmon as determined by three used tests was higher than in dried fruit, but not significantly. The methanol extracts of fresh and dried persimmon using the β-carotene-linoleate model system exhibited 91% and 88% of antioxidant activity at 50 μl, respectively. Radical scavenging activity with the 1,1-diphenyl-2-picrylhydrazyl (DPPH) method exhibited 88% and 84% for the same extracts and the nitric oxide test showed similar results. The best correlation was found between polyphenols, β-carotene, DPPH and nitric oxide values (R^2 ranges between 0.9535 and 0.9934). The study concluded that both fresh and dried persimmon possessed high contents of bioactive compounds and had a high antioxidant potential. When fresh fruits are not available, properly dried persimmon could be successfully used.

Heat treatment of persimmon peel increased the antioxidative activity of the 70% ethanolic extract and water extract from persimmon peel. Both extracts prevented H_2O_2-induced DNA

damage to human peripheral lymphocytes (Kim et al. 2006). The antioxidative and antigenotoxic activities of the persimmon peel extracts were significantly affected by heating.

Jang et al. (2010) found that persimmon seed and calyx extracts showed higher antioxidant activities and phenolic contents than peel and flesh extracts as evaluated by DPPH (1,1-diphenyl-2-picryllhydrazyl) radical scavenging activity (RSA), ABTS (2,2-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammononium salt) RSA and reducing power (RP). Ethanol was found to be more effective on the extraction of antioxidant compounds compared to other solvents (acetone, methanol and water). The antigenotoxic effects of the persimmon extracts on DNA damage induced by H_2O_2 in human leukocytes was evaluated by Comet assay. All persimmon extracts inhibited DNA damage induced by 200 μM of H_2O_2. The calyx and seed extracts showed stronger inhibition activity than peel and flesh extracts. The results suggested that persimmon extracts may have beneficial antioxidant and protective effects against oxidative DNA damage.

Diospyros kaki leaf, has been used traditionally in Korea to promote maternal health. The methanol extract of *D. kaki* leaf was found to be the most potent in scavenging activity against DPPH (1,1-diphenyl-2-picrylhydrazyl) radicals, with an IC_{50} value of 0.11 mg/ml (Han et al. 2002).

Five flavonoid compounds isolated from the leaves of *Diospyros kaki* : kaempferol 3-O-β-D-galactopyranoside (TR), kaempferol 3-O-β-D-glucopyranoside (AS), isorhamnetin 3-O-β-D-glucopyranoside (IS), quercetin 3-O-β-D-galactopyranoside (HY), quercetin 3-O-β-D-glucopyranosyl-(6 → 1)-α-L-rhamnopyranoside (RU) were found to suppress stimulus-induced superoxide generation and tyrosyl phosphorylation and may have pharmaceutical application. (Chen et al. 2002a). TR, AS, HY and RU suppressed arachidonic acid -induced superoxide generation. In contrast, the superoxide generation was weakly augmented by IS in low concentration (5–20 μmol/l), but was suppressed in high concentration (50 μmol/l). TR, IS, HY and RU suppressed superoxide generation induced by phorbol 12-myristate 13-acetate (PMA), but AS elicited no effect. On incubating cells with fMLP (formyl-methionyl-leucyl-phenylalanine) in the presence of TR, IS and RU, fMLP-induced tyrosyl phosphorylation of 45-kDa proteins of the cells was dose-dependently suppressed in parallel to the suppression of fMLP-induced superoxide generation. All five flavonoids exhibited negligible haemolytic effect even at a concentration of 500 μmol/l. Additionally, five triterpenoid compounds, isolated from persimmon leaves: α-amyrin (A), uvaol (UV), ursolic acid (UA), 19 α-hydroxy ursolic acid (HU) and 19 α,24-dihydroxy ursolic acid (DHU) were found to significantly suppress superoxide generation induced by N-formyl-methionyl-leucyl-phenylalanine (fMLP) in human neutrophils in a concentration-dependent manner (Chen et al. 2002b). These compounds also suppressed the superoxide generation induced by arachidonic acid in high concentrations. UA, HU and DHU suppressed the superoxide generation induced by phorbol 12-myristate 13-acetate (PMA) but A and UV gave no effect. On incubating cells with fMLP (formyl-methionyl-leucyl-phenylalanine) in the presence of UA, HU and DHU, fMLP-induced tyrosyl phosphorylation of 45 kDa proteins of the cells was dose-dependently suppressed in parallel to the suppression of fMLP-induced superoxide generation. The results showed that the triterpenoid compounds suppressed stimulus-induced superoxide generation and tyrosyl phosphorylation and may have pharmaceutical applications.

Studies showed that persimmon seed extracts could potentially be used as an inexpensive source of natural antioxidant in food and pharmaceutical industries (Akter et al. 2010). The EC_{50} values of persimmon seed the extracts from absolute ethanol and methanol in 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical–scavenging assay were 49.71 and 51.15 μg/ml, respectively, while the EC_{50} of butylated hydroxyanisole extract was 70.82 μg/ml. The EC_{50} value of reducing power for the absolute acetone extract was higher (210.06 μg/ml) than that of butylated hydroxyanisole extract (212.67 μg/ml). Although the absolute methanol extract exhibited the highest antioxidant activity, it had the lowest total phenolics and flavonoids. Contrariwise, the antioxidant activities of the aqueous solvent extracts showed a good correlation

with total phenolics and flavonoids when compared to the absolute solvent extracts.

Anticancer Activity

A flavone from *Diospyros kaki* leaves was found to dose-dependently inhibit low-density lipoprotein (LDL) -stimulated vascular smooth muscle cells proliferation growth associated with hypercholesterolemia compared with the control (Ouyang et al. 2004a). The flavone inhibited proliferation of rat vascular smooth muscle cells exposed to high levels of native LDL. The flavone also significantly inhibited the adventitial fibroblasts proliferation induced by AOPP (Advanced Oxidation Protein Products) in-vitro (Ouyang et al. 2004b). AOPP significantly stimulated the fibroblasts proliferation when the concentration was above 100 μg/ml. The flavone alone had no effect on fibroblasts proliferation . With AOPP stimulation, flavone from persimmon leaves significantly suppressed fibroblasts proliferation. Ouyang et al. (2007) also found the flavone to significantly inhibit expression of apoptosis ASK1 protein stimulated by TNF-α (tumour factor α) of rat vascular smooth muscle cells in-vitro. It was shown that TNF-α significantly induced rat vascular smooth muscle cells proliferation. Again, the flavone alone had no effect on rat vascular smooth muscle cells proliferation. With TNF-α stimulation, the flavone significantly inhibited rat expression of signal-regulating kinase 1 (ASK1) protein enhanced by TNF-α.

Studies demonstrated that persimmon extract (PS) and related polyphenol compounds such as catechin (C), epicatechin (EC), epicatechingallate (ECG), epigallocatechin (EGC), and epigallocatechingallate (EGCG) inhibited the growth of human lymphoid leukemia, Molt 4B cells (Achiwa et al. 1997). PS, ECG, EGC, and EGCG strongly inhibited the growth of Molt 4B cells in a dose-dependent fashion, while C and EC inhibited the growth only moderately. These polyphenol compounds also inhibited ornithine decarboxylase (ODC), a rate-limiting enzyme of polyamine biosynthesis by 10–20%. Molt 4B cells sustained severe damage 3 days after treatment with PS, ECG, EGC, and EGCG. Irregular shape of the cells and DNA fragmentation were observed in PS, ECG, EGC, or EGCG-treated cells. These results suggested that PS, ECG, EGC, and EGCG stimulated apoptosis (programmed cell death) of Molt 4B cells.

A new biphenyl derivative, 4′,5-dimethoxy-3-β-D-glucopyranosyloxy-4-hydroxy-biphenyl, named kakispyrol was isolated from *Diospyros kaki* leaves, together with three known compounds, vitexin, 2′-O-rhamnosyl vitexin and isorhamnetin-3-O-β-D-glucopyranoside (Chen et al. 2005). Kakispyrone and kakisaponin A, together with 11 known compounds, from *Diospyros kaki* leaves exhibited cytotoxic effects against several cancer cell lines (A549, HepG2 and HT29) (Chen et al. 2007).

Fractionated extracts of persimmon peels exhibited cytotoxic activity, multidrug resistance reversal activity, but were inactive against human immunodeficiency virus (HIV) activity and *Helicobacter pylori* activity (Kawase et al. 2003). The potent cytotoxic activity against human oral squamous cell carcinoma cells (HSC-2) and human submandibular gland tumour (HSG) cells was found in the acetone fractions (A4 and A5) with IC_{50} ranging from 21 to 59 μg/ml (Kawase et al. 2003). Three 70% methanol extract fractions (70M2-4) efficiently scavenged the O^{2-} radical produced by hypoxanthine and xanthine oxidase reaction. All of the fractions tested were not effective for anti-*H. pylori* and anti-HIV activities. Fractions H3 and H4 of the hexane extract, and M2 and M3 of the methanol extract showed a marked multidrug resistance reversal activity comparable with that of verapamil (a positive control). These results indicated the therapeutic value of persimmon peel extracts as potential antitumour and multidrug resistance -reversing agents.

Persimmon extract and its constituents like 24-hydroxyursolic acid, a triterpenoid was found to have potent antitumour activity against human cancer cells (Khanal et al. 2010). It was demonstrated that 24-hydroxyursolic acid inhibited cancer cell proliferation, strongly stimulated AMP-activated protein kinase (AMPK) and modulated critical anticancer effects by inhibition of cyclooxygenase (COX-2) expression in human colon adenocarcinoma HT-29 cells. Further,

24-hydroxyursolic acid stimulated cellular apoptosis by activation of poly (ADP-ribose) polymerase (PARP), caspase-3, and phosphorylation of p53 at Ser15. It also strongly induced DNA fragmentation in HT-29 cells and thereby significantly inhibited colony formation of HT-29 cells in soft agar. additionally, 24-hydroxyursolic acid blocked the epidermal growth factor-induced extracellular signal-regulated kinase (ERK) phosphorylation and led to the inhibition of activator protein, AP-1 activity and cell transformation in JB6 CL41 (promotion sensitive) mouse epidermal cell line. Taken together,, these findings revealed a molecular basis for the anticarcinogenic action of 24-hydroxyursolic acid and may account for the reported chemopreventive and chemotherapic effects of persimmon extracts.

Treatment of human leukemia HL-60 cells with zero to 100 μg/ml of acetone extract of *D. kaki* leaves (KV-1) for 72 hours induced a small rise in cell differentiation (Kim et al. 2010). A synergistic induction of differentiation was observed when the HL-60 cells were treated with all-trans retinoic acid (ATRA) or 1,25-dihydroxyvitamin D3 [1,25-(OH)2D3] and persimmon leaf extract. The inhibitors of protein kinase C (PKC) (α and β I) and extracellular signal-regulated kinase (ERK), but not of phosphoinositide 3-kinase (PI3-K) and c-Jun N-terminal kinase (JNK) inhibited the HL-60 differentiation induced by the extract in combination of ATRA or 1,25-(OH)2D3, suggesting that PKC and ERK were involved in the cell differentiation enhancement by the extract. The results indicated that the acetone extract of *D. kaki* leaves had the ability to enhance HL-60 cell differentiation and that it may be useful in acute promyelocytic leukemia therapy.

Antihypercholesterolemic/ Hypolipidaemic Activity

Diets supplemented with dried and powdered young and mature fruits of two cultivars of persimmon, Fuyu-kaki and Hachiya-kaki significantly decreased the rise in plasma lipids, including total cholesterol, triglyceride, and LDL cholesterol (Matsumoto et al. 2006). The young fruit-supplemented diets of both cultivars equally up-regulated three-fold expression of the cholesterol 7 α-hydroxylase (CYP7A1) gene in the liver. CYP7A1 plays an important role in maintaining cholesterol homeostasis by regulating bile acid synthesis, suggesting that increased conversion of cholesterol to bile acids may have caused the cholesterol-lowering effect of the young fruits. The results indicated that young persimmon fruits were beneficial in the development of preventive and therapeutic agents against dyslipidemia. In a follow-up study it was found that young persimmon fruit treatment significantly lowered plasma chylomicron, very low-density lipoprotein (VLDL) and low-density lipoprotein (LDL) cholesterols, and triglyceride, along with an increase of fecal bile acid excretion (Matsumoto et al. 2008). In the liver, sterol regulatory element binding protein-2 gene expression was significantly elevated in mice fed young persimmon, while the mRNA and protein levels of the LDL receptor did not change. These results indicated that acceleration of fecal bile acid excretion was a major mechanism of the hypolipidemic effect induced by young persimmon fruit in apolipoprotein E-deficient C57BL/6. KOR-ApoEshl mice.

In another study, in comparing the cholesterol/persimmon fed group against cholesterol (Chol) fed group, the persimmon-supplemented diet significantly attenuated the rise in plasma lipids due to dietary cholesterol (Gorinstein et al. 1998). Plasma lipid profile in cholesterol/persimmon fed group and cholesterol fed group were respectively as follows: total cholesterol (3.88 vs. 4. 88 mmol/l; −20%), LDL-Cholesterol (2.24 vs. 3.27 mmol/l; −31%), triglycerides (0.72 vs. 0. 89 mmol/l; −19%), lipid peroxides (2.20 vs. 3.25 mmol/l; −32%) and total cholesterol in liver (32.8 vs. 49.9 μmol/g; −34%). The cholesterol/persimmon diet significantly reduced the decrease in HDL-phospholipids due to dietary cholesterol (0.73 vs. 0.58 mmol/l; −25.8%) and decreased the level of total phospholipids (1.32 vs. 1.73 mmol/l; −23%). Persimmon in rats fed the basal diet without cholesterol did not significantly affect the variables measured. These results

demonstrated that persimmon possessed hypolipidemic and antioxidant properties that became evident when persimmon was added to the diet of rats fed cholesterol. These properties were attributed to persimmon's water-soluble dietary fiber, carotenoids and polyphenols.

In another study, a new type of cholesterol acyltransferase (ACAT) inhibitor was isolated from a methanol extract of *Diospyros kaki* (Rho et al. 2003). On the basis of spectral and structural evidence, the compound was identified as pheophorbide A-methyl ester. Pheophorbide A-methyl ester inhibited ACAT activity in a concentration dependent manner with an IC_{50} value of 1.85 μg/ml.

Kaki-tannin from young fruits of persimmon was found to have bile-acid binding ability (Matsumoto et al. 2010a). The kaki-tannin was composed mainly of epicatechin, epigallocatechin, epicatechin-3-O-gallate and epigallocatechin-3-O-gallate. Bile acid-binding ability of kaki-tannin was examined against cholic acid, glycocholic acid, taurocholic acid and deoxycholic acid in-vitro, and its in-vivo effect on fecal bile acid excretion in mice. Although the bile acid-binding ability of kaki-tannin was weaker than that of cholestyramine, kaki-tannin adsorbed all the bile acids tested and significantly enhanced faecal bile acid excretion in mice when administered at 1% (w/w) in the diet. In another study, the intake of dried young persimmon fruit (YP) was found to significantly promote faecal bile acid excretion and reduced the levels of hepatic lipids and plasma cholesterol in mice (Matsumoto et al. 2010b). Analysis of gene expression in liver tissue showed that 2% or 5% YP enhanced the expression of the sterol regulatory element-binding protein-2 gene. In the 5% group, there were enhanced expressions of the genes for cholesterol 7α-hydroxylase and the low-density lipoprotein receptor. In 100–2,000 μM cholic acid solutions, 1% (w/v) YP adsorbed approximately 60% of cholic acid, while dried mature persimmon fruit adsorbed approximately 20% of cholic acid. The positive control, cholestyramine, adsorbed approximately 80% of cholic acid in the 100–2,000 μM cholic acid solutions. A crude tannin extract from YP, which contained 54.7% condensed tannins, adsorbed approximately 78% of cholic acid in the 2,000 μM cholic acid solutions. These results suggested that the ability of YP to bind bile acid contributed to its hypolipidemic effect in mice.

Antidiabetic Activity

Dietary fibre was found to be the major component of persimmon peel, with a high component of 40.35% (w/w). Persimmon peel also contained high amounts of antioxidants including total carotenoids, vitamin C, and total phenolics. A 2-week dietary supplementation of persimmon peel at both 5% and 10% (w/w) significantly reduced food intake, blood glucose, plasma triglyceride, and total cholesterol levels in streptozotocin-induced diabetic rats (Lee et al. 2006). Dietary persimmon peel also normalised the reduced plasma high-density lipoprotein (HDL) – cholesterol levels in diabetic rats. Although regression of the hypertrophies of liver and kidney was not observed in diabetic rats, dietary persimmon peel showed the partial or complete restoration of plasma aspartate amino transferase (AST), and creatinine levels, indicators of liver and renal dysfunctions, respectively. The researchers concluded that persimmon peel containing high levels of dietary fibre and antioxidants with antidiabetic properties may represent a potential dietary supplement for improving hyperglycemia and diabetic complications.

The predominant polyphenols in fresh persimmon leaves were found to be water-soluble, and the contents reached a maximum (2.40% w/w) in June, and then gradually decreased (Kawakami et al. 2010). The major components were unique proanthocyanidin oligomers consisting of four heterogeneous extension units, including epigallocatechin-3-O-gallate. Persimmon leaf tea also contained similar proanthocyanidins with similar compositional units. Oral administration of starch with polyphenol concentrate of persimmon leaf tea resulted in a significant and dose-dependent decrease in the blood glucose level in Wistar rats. This effect was attributed to inhibition of pancreas α-amylase. These results indicated that persimmon leaf tea containing peculiar proanthocyanidins had

a significant role in suppressing blood glucose elevation after starch intake, and that the best harvest time was found to be in June in Japan.

Cardioprotective Activity

Apoptosis of neonatal rat cardiac myocytes was induced by hypoxia-reoxygenation in a time-dependent fashion (6.05% vs 12.45%), and flavone treatment of the cells significantly reduced the apoptotic rates (Ouyang et al. 2003). Advanced glycation end products (AGEs) alone induced apoptosis of neonatal rat cardiac myocytes (11.03vs 6.25,), which was significantly inhibited by flavone (8.40 vs 11.03). The results indicated that flavone extracted from persimmon leaves could inhibit the apoptosis of in-vitro cultured neonatal rat cardiac myocytes induced by hypoxia-reoxygenation and advanced glycation end products.

Neuroprotective Activity

Naoxinqing (NXQ, a standardized extract of *Diospyros kaki* leaves) is a patented and approved drug of Traditional Chinese Medicine (TCM) used for the treatment of apoplexy syndrome for years in China. NXQ was found to significantly protect the rats from middle cerebral artery occlusion (MCAO) ischemic injury in-vivo and the hippocampal neurons from glutamate-induced excitotoxic injury as well as cortical neurons from hypoxia injury in-vitro by synergistic mechanisms involving its antioxidative effects (Bei et al. 2007). Oral administrations of NXQ at 20, 40, 80 mg/kg/day for 7 days (3 days before MCAO and 4 days after MCAO) significantly decreased the lesion of the insulted brain hemisphere and improved the neurological behavior of the rats. In primary rat hippocampal neuron cultures, treatment with NXQ at 5–20 μg/ml concentration protected the neurons against glutamate-induced excitotoxic death in a concentration-dependent fashion. In primary rat cerebral cortical neuron cultures, pretreatment with 5–100 μg/ml of NXQ also attenuated hypoxia-reoxygenation induced neuron death and apoptosis in a concentration-dependent manner.

FLDK-P70, a standardized flavonoid extract from persimmon leaves, was found to significantly protect rats from both focal ischemia/reperfusion (I/R) injury induced by middle cerebral artery occlusion (MCAO) and on transient global brain ischemia induced by four-vessel occlusion (4-VO) in-vivo (Bei et al. 2009). FLDK-P70 was also found to protect hippocampal neurons from glutamate-induced excitotoxic injury as well as cortical neurons from hypoxia-induced injury in-vitro. Administration of FLDK-P70 for 12 days (40, 80 mg/kg body weight, p.o., 5 days before and 7 days after 4-VO) increased the survival of hippocampal CA1 pyramidal neurons after transient global brain ischemia. Similarly, administration of FLDK-P70 for 7 days (40, 80 mg/kg body weight, p.o., 3 days before and 4 days after MCAO) significantly decreased the lesion of the insulted brain hemisphere and improved the neurological behaviour of rats. In primary rat hippocampal neuronal cultures, pretreatment with FLDK-P70 (5, 10 μg/ml) protected neurons from glutamate-induced excitotoxic neuronal death in a concentration-dependent manner. In primary rat cerebral cortical neuronal culture, pretreatment with FLDK-P70 (25, 100 μg/ml) also reduced hypoxia-reoxygen induced neuronal death and apoptosis in a concentration-dependent manner. The results demonstrated that FLDK-P70 may be useful for the prevention and treatment of ischemia/reperfusion injury and other related neurodegenerative diseases.

Angiotensin-Converting Enzyme (ACE) Inhibitory Activity

Persimmon leaves have been traditionally used for treatment of hypertensive diseases in Japan. Studies showed that four flavonoids isolated from persimmon leaves: astragalin [1], kaempferol-3-O-(2″-O-galloyl)-glucoside [2], isoquercitrin [3], and quercetin-3-O-(2″-O-galloyl)-glucoside [4] inhibited the angiotensin-converting enzyme activity in a concentration-dependent fashion (Kameda et al. 1987). Compounds 1–4 at a

concentration of 300 μg/ml, elicited 67%, 53%, 33%, and 48% inhibition respectively. The 50% inhibitory concentrations (IC_{50}) of compounds 1 and 2 for the angiotensin-converting enzyme were 180 μg/ml and 280 μg/ml, respectively. In contrast, compounds 2 and 4 were shown to have tannin activities, but compounds 1 and 3 had no tannin activities. These results suggested that there was no relationship between the inhibition for angiotensin converting enzyme activity and the tannin activity for the four flavonoids.

DNA Polymerase Alpha Inhibitory Activity

Persimmon extract, epigallocatechin gallate and epicatechin gallate were found to strongly inhibit the activity of DNA polymerase α purified from calf thymus (Umekawa et al. 1999). Among these polyphenols, persimmon extract had the most potent effect on DNA polymerase α activity and the concentration of persimmon extract producing 50% inhibition of the activity was 0.191 μM. Persimmon extract showed a weaker effect on DNA polymerase β and slightly inhibited primase and DNA polymerase I. Moreover, persimmon extract inhibited [3H]thymidine incorporation of human peripheral lymphocyte cells stimulated by PHA (polyhydroxyalkanoates).

Antithrombotic Activity

An anticoagulant fraction was purified from persimmon leaves (Sa et al. 2005). It retarded thrombin time (TT), activated partial thromboplastin time (APTT), and prothrombin time (PT) using human plasma. TT was more sensitive than APTT and PT, suggesting that the anticoagulant activity may be caused by a degradation or a defect of fibrin or thrombin. It did not cause the hydrolysis of fibrin after incubation. However, it inhibited thrombin-catalyzed fibrin formation with a competitive inhibition pattern. These results indicated that the anticoagulant fraction may be an antithrombotic agent and that it was bound to fibrinogen binding sites of thrombin.

Antiaging/Antiwrinkle Activity

Studies confirmed that 8-Hydroxy-2′-deoxyguanosine (8-OHdG) expression in TIG-1 human fibroblasts was increased by treatment with 300 μM H_2O_2 for 2 hours (Lee et al. 2008). 8-OHdG is a critical biomarker for oxidative damage. In contrast, the nuclear SIRT1 (gene modulating longevity) level was decreased in H_2O_2-treated as compared with non-pretreated cells. However, pretreatments with polymers and oligomers (proanthocyanidin) from persimmon peels led to a fall in 8-OHdG and rise in nuclear SIRT1 expression in a dose-dependent manner. In particular, oligomers exerted a stronger effect. The present study supported the protective potential of proanthocyanidin from persimmon peel against oxidative damage under the aging process, and suggested that the polymerization of proanthocyanidin played an important role in retarding aging in a cellular senescence model.

In another study, when persimmon tannin was chronically ingested by stroke-prone spontaneously hypertensive rats (SHRSP), the life span was significantly prolonged, yet the effect on blood pressure was small (Uchida et al. 1990). The incidences of brain hemorrhage and infarction were also significantly decreased by this treatment. The scientists found that tannins had a potent, dose-dependent scavenging action toward active oxygen free radicals. These tannins strongly inhibited lipid peroxidation in rat brain homogenates, in a dose-dependent fashion. Persimmon tannin inhibited lipid peroxidation similarly to (−)-epigallocatechin. Persimmon tannin was 20 times more effective than α-tocopherol in terms of the 50%-inhibitory concentration. The radical scavenging action and inhibition of lipid peroxidation by persimmon tannin may explain, in part, the prolongation of the life span of the SHRSP ingesting persimmon tannin.

Skin Whitening Activity

The persimmon leaf fractions PFs II and III extracted with 80% ethanol inhibited xanthine oxidase activity by over 40% at a 100 ppm

concentration (An et al. 2005). PF II, with higher flavonoids concentrations, had a significantly higher tyrosinase inhibition than that of PF III. Collagenase inhibition was 16.3 and 8.1% for PF III and PF II, respectively, at 100 ppm. In contrast, elastase inhibition activity was significantly higher in PF II than PF III. Collagen biosynthesis rates of PF III were over 25% from a 1 to 10 ppm concentration. The results thus suggested that the fractions isolated from the persimmon leaf may be used as natural materials or additives in food or cosmetic compositions for human skin owing to their beneficial biologic functions, including the antiwrinkle effect and the inhibition of skin problems.

Phytochemical study on a methanol-soluble extract of persimmon leaves resulted in the isolation of two new ursane-type triterpenoids, 3α,19α-dihydroxyurs-12,20(30)-dien-24,28-dioic acid and 3α,19α-dihydroxyurs-12-en-24,28-dioic acid, together with 12 known ursane- and oleanane-type triterpenoids (3–14) (Thuong et al. 2008). Triterpenoids with a 3β-hydroxy group were found to inhibit protein tyrosine phosphatase 1B (PTP1B) activity, with IC_{50} values ranging from 3.1 to 18.8 μM, whereas those with a 3α-hydroxy moiety were inactive. The 2-methoxy-4-vinylphenol a component of persimmon peel, was found to have high antioxidant activity on the DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging and SOD (superoxide dismutase) assays (Fukai et al. 2009). The compound exhibited higher tyrosinase inhibiting activity than that of arbutin using both L-tyrosine and L-DOPA as substrates. Additionally, the synthesized 2-methoxy-4-vinylphenol glycoside also exhibited tyrosinase inhibiting activity, suggesting its potential as ingredient of cosmetics with whitening effect.

The acetone extract of the peel of Japanese persimmon (*Diospyros kaki* 'Fuyu') was found to inhibit melanin biosynthesis in mouse B16 melanoma cells (Ohguchi et al. 2010). Two active compounds, were isolated and identified as flavonoid glycosides, isoquercitrin (quercetin-3-O-glucoside) and hyperin (quercetin-3-O-galactoside). Isoquercitrin and hyperin strongly inhibited the production of melanin with IC_{50} values of 21.7 and 18.2 μM, respectively. The inhibitory effects were found to be mediated by suppression of tyrosinase expression.

Immunomodulating Activity

The major pectic polysaccharide DL-3B2 isolated from *Diospyros kaki* leaves was found to have immunomodulatory activity (Duan et al. 2010b). DL-3B2 was found to contain an α-1, 4-linked galacturonic acid (GalA) backbone with some insertions of α-1, 2-linked rhamnose residues. The arabinan- and arabinogalactan-side chains were attached to O-4 of the rhamnose residues, whereas the linear arabinoxylan was probably linked to O-3 of the GalA residues. Immunological tests in-vitro showed that DL-3B2 could help stimulate lipopolysaccharide-induced B lymphocyte proliferation, but not ConA-induced T lymphocyte proliferation, and that the arabinose residues participated in maintaining this immunological activity. A pectic fraction DL-4OAC-1 from the leaves of *Diospyros kaki* was shown by immunological assay to inhibit the LPS-induced B lymphocyte proliferation and had no effect on the ConA-induced T lymphocyte proliferation (Duan et al. 2010a). This polysaccharide possessed a backbone composed of a repeating disaccharide [→4)-α-GalAp-(1→2)-α-Rhap-(1→], substituted at some O-4 of Rhap residues and O-3 of GalAp residues by the side chains consisting of Araf, Galp, Xylp, and in particular terminal GlcAp residues.

Traditional Medicinal Uses

In traditional Chinese ethnomedicine, persimmon is deemed to regulate *ch'i* (energy flow). The ripe fruit is an appetizer and, sialagogue. The fruit is deemed to have different properties depending on its stage of maturity, though it is generally antitussive, astringent, laxative, nutritive and stomachic. The raw fruit is used to treat constipation and haemorrhoids, and to stop bleeding, mouth canker, stomach ache, endemic goitre, hiccups. The cooked fruit is used to treat diarrhoea

and dysentery. Juice from the unripe fruit is used in the treatment of hypertension. The fruits, picked green and ripened in containers with the leaves, become very sweet and are considered to be antifebrile, antivinous and demulcent. The dried ripe fruit is used in the treatment of bronchial complaints, whilst when ground into a powder it is used to treat dry coughs Dried persimmon with a crust of white powder are deemed to be anthelmintic, expectorant, antihaemorrhagic, febrifuge and restorative. The calyx is used to treat hiccups and the fruit peduncle is used to treat coughs and hiccups. The stem bark is astringent and styptic.

Other Uses

Persimmon tree makes a good ornamental tree. It can be grown as a hedge or screen with proper management. The pulp of unripe fruits is used in cosmetics to make face-packs because of its firming qualities. Persimmon wood is hard and durable with a beautiful grain. It has been used for making fine furniture and for panelling in traditional Korean and Japanese furniture. Persimmon wood was also heavily used in making the highest-quality heads of the golf clubs known as "woods," during the last years of the twentieth century. Persimmon wood has become popular among bow craftsmen, especially in the making of traditional longbows.

Diospyros kaki roots were found to possess acaricidal activity in particular against house dust mites, *Dermatophagoides farinae* and *D. pteronyssinus* (Lee and Lee 2008). The LD_{50} values of the chloroform extract of persimmon roots were 1.66 and 0.96 μg/cm^2 against *D. farinae* and *D. pteronyssinus*. The chloroform extract of persimmon roots was approximately 15.2 more toxic than benzyl benzoate against *D. farinae* and 7.6 times more toxic against *D. Pteronyssinus* The structure of the purified acaricidal component was identified as plumbagin. The acaricidal activity of plumbagin and its derivatives (naphthazarin, dichlon, 2,3-dibromo-1,4-naphthoquinone, and 2-bromo-1,4- naphthoquinone) was examined. On the basis of LD_{50} values, the most toxic compound against *D. farinae* was naphthazarin (0.011 μg/cm^2) followed by plumbagin (0.019 μg/cm^2), 2- bromo-1,4-naphthoquinone (0.079 μg/cm^2), dichlon (0.422 μg/cm^2), and benzyl benzoate (9.14 μg/cm^2). Plumbagin and its derivatives can be very useful for the potential control agents, lead compounds, and indicator of house dust mites.

Comments

Persimmons can be classified into two general categories: those that bear astringent fruit until they are soft ripe and those that bear non-astringent fruits. Fuyu and Jiro are the common varieties of non-astringent fruits. The heart-shaped Hachiya is the most common variety of astringent persimmon. Astringent persimmons contain very high levels of soluble tannins and are unpalatable if eaten before softening. Non-astringent persimmons are not actually free of tannins as the term suggests, but rather are far less astringent before ripening, and lose more of their tannic quality sooner. Non-astringent persimmons may be consumed when still very firm to very soft. There is a third type, less commonly available, the pollination-variant non-astringent persimmons e.g. Tsurunoko, sold as "Chocolate persimmon Maru, sold as "Cinnamon persimmon" for its spicy flavour, and Hyakume, sold as "Brown sugar" are the three best known. The flesh of this group is brown inside – and is known as *goma* in Japan, and the fruit can be eaten firm. These varieties are highly sought after and can be found at specialty markets or farmers markets only.

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Arbutus unedo

Scientific Name

***Arbutus unedo* L.**

Synonyms

Arbutus crispa Hoffmanns, *Arbutus salicifolia* Cels ex Hoffmanns., *Arbutus serratifolia* Salisb., *Unedo edulis* Hoffmanns. & Link.

Family

Ericaceae

Common/English Names

Arbutus, Cane Apples, Irish Strawberry Tree, Killarney Strawberry Tree, Strawberry Madrone, Strawberry Tree

Vernacular Names

Algeria: Ticisnou (Arabic);
Czech: Planika Obecná;
Danish: Almindelig Jordbærtræ, Vestlig Jordbærtræ;
Eastonian: Harilik Maasikapuu;
French: Arbousier, Arbousier Commun, Fraisier En Arbre;
German: Erdbeerbaum, Westlicher Erbeerbaum;
Greek: Koumaria;
Hungarian: Nyugati Szamócafa;
Italian: Corbezzolo, Sorbo Peloso;
Polish: Drzewo Poziomkowe;
Portuguese: Ervedeiro; Medronheiro;
Russian: Zemljaničnoe Derevo Krupnoplodnoe;
Saudi Arabia: Bagg, Outlub (Arabic);
Slovaščina: Jagodičnica Navadna;
Spanish: Albocera, Alborocera, Borrachín, Madroñera, Madroño;
Swedish: Smultronträd;
Turkish: Katlab.

Origin/Distribution

The species is indigenous to the Mediterranean countries (excluding Egypt and Libya), Asia Minor and western Europe north to western France and Ireland. It is cultivated as fruit tree and for technical uses in many European Mediterranean countries, also in south Switzerland and south Tyrol, in the Crimea and in the western Caucasus.

Agroecology

The Strawberry Tree is naturally adapted to dry summer climate in its native range but it also thrives well in the cool, wet summers of western Ireland. It is drought hardy as it has a long tap root system.

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Edible Plant Parts and Uses

The mealy and sweetish, but not very aromatic fruits are edible raw but are rarely eaten fresh. They have some importance in local agricultural communities where they are used for the production of alcoholic beverages, jams, jellies and marmalades (Alarcao-E-Silva et al. 2001; Pallauf et al. 2008). In Portugal the fruits are processed into liquers such as the Portuguese *medronho*, a type of strong brandy. In Morocco, *A. unedo* is used in cooking to bring out the flavor in a dish or to complement it (Bnouham et al., Although the fruits of the strawberry tree (*Arbutus unedo* L.) are consumed mainly as processed product, they may be a good source of antioxidants if consumed as fresh fruit (Pallauf et al. 2008). They contain a wide and excellent range of antioxidant components including phenolic compounds (e.g. anthocyanins, gallic acid derivatives, flavonoids, and tannins), vitamin C, vitamin E and carotenoids suggesting a potentially high value as a "health promoting food" (Fortalezas et al. 2010).

Botany

Evergreen shrub or small tree with erect, branched stem, 5–10 m tall, with reddish brown bark becoming flaky with age, young branchlets thinly tomentose. Leaves are alternate, elliptic, coriaceous, 5–10 cm long, 2–3 cm wide, with finely serrated margin and glabrous surfaces (Plate 1). Flowers bisexual, fragrant, in 10–30 flowered, drooping racemes. Sepals persistent, 5, connate basally, ovate to deltate; petals 5, connate nearly their entire lengths, creamy white, corolla urceolate; stamens 10, ovary 5-locular; stigma capitate. Fruit globose to subglobose berries, 2 cm diameter, roughened tuberculate, finely tomentose, green to yellow (Plates 1 and 2) to bright red when ripe with 5 pyrenes, each with 1 seed.

Plate 1 Young arbutus fruit and leaves

Plate 2 Close-up of young arbutus fruit

Nutritive/Medicinal Properties

Analysis of *Arbutus unedo* fruits in Turkey (Seker and Toplu 2010) yielded the following nutrient composition: total soluble solids 16%, titratable acidity 0.4%, protein 2.38%, moisture 47.21%, and ash content 2.82%, fructose 24.09%, glucose 19.09% and ascorbic high 270.50 mg/100 g, The general order of abundance of the minerals was K > Ca > P > Mg > Na.

The chemical composition of *Arbutus* fruit indicated the fruits to be good sources of minerals and ascorbic acid and high in phenolics and antioxidant capacity. Seven phenolic compounds

were purified and were characterized in the methanol extract of *A. unedo* fruits as arbutin, β-D-glucogalline, gallic acid 4-O-β-D-glucopyranoside, 3-O-galloylquinic acid, 5-O-galloylquinic acid, 3-O-galloylshikimic acid, and 5-O-galloylshikimic acid (Pawlowska et al. 2006). LC-PDA-MS analysis of the red pigment of the fruits revealed the presence of three anthocyanins identified as cyanidin 3-O-β-D-galactopyranoside, delphinidin 3-O-β-D-glucopyranoside, and cyanidin 3-O-β-D-arabinopyranoside. *Arbutus unedo* fruit was found to be a good source of vitamins, namely niacin 9.1 mg/100 g, ascorbic acid 346.3 mg/100 g and β-carotene 70.9 mg/100 g (organic acids (nearly 9%), total sugars (c. 42%) and tannins (1.75 mg/g) (Alarcao-E-Silva et al. 2001). The following phenolic acids were found and quantified in *A. unedo* fruits, gallic acid (10.7 mg,g DW) gentisic acid (1.9 mg/g) protocatechuic acid (0.6 mg/g) *p*-hydroxybenzoic acid (0.3 mg/g), vanillic acid (0.12 mg/g), and *m*-anisic acid (0.05 mg/g) (Ayaz et al. 2000). Non-volatile acids – fumaric acid (1.94 mg/g)DW), lactic (0.84 mg/g), malic (0.84 mg/g), suberic 0.23 mg/g) and citric acids were also present. Fructose (27.8% DW), glucose (21.5%), sucrose (1.8%) and maltose (1.11%) were the soluble sugars identified. Fructose, and glucose among the sugars, fumaric and malic acids among the non-volatiles acids, and gallic acid among the phenolic acids were found to be the major compounds contributing to the taste of the fruits. The values of mass, length, diameter, geometric mean diameter and sphericity of strawberry tree fruit (*A. unedo*) were established as 0.70 g, 8.51 mm, 10.7 mm, 9.91 mm and 1.17, respectively (Özcan. and Hacıseferoğulları 2007). At the same moisture content, fruit density, bulk density, projected area and terminal velocity were determined as 1146.43 kg/m^3, 602.23 kg/m^3, 0.976 cm^2 and 9.46 m/s, respectively.

Quercitrin, isoquercitrin, hyperoside and rutin were identified in all leaf samples of *A. unedo* (Males et al. 2006); the fruits contained only isoquercitrin. Chlorogenic acid was present in some leaf samples. Spectrophotometric determination of the flavonoids indicated that the leaves were richer in flavonoids (0.52–2.00%) than fruits (0.10–0.29%). α-tocopherol was found in the leaves of *A. unedo* with the highest amount of α-tocopherol detected in March collection (Kivçak and Mert 2001).

Thirty-seven constituents were characterized in the water-distilled essential oil from leaves of *Arbutus unedo* with (E)-2-decenal (12.0%), α-terpineol (8.8%), hexadecanoic acid (5.1%) and (E)-2-undecenal (4.8%) as the major constituents (Kivcak et al. 2001). Additionally, appreciable quantities of 2,2,6,8-tetramethyl-7-11-dioxatricyclo(6.2.1.0)-1,6-undec-4-ene, nonal, (E)-geranylacetone, B-ionone, nonanoic acid, myristic acid, hexahydrofarnesylacetone, and 3,4-dimethyl-5-pentylidene-2(5H)-furanone were also detected.

The fatty acid fractions of the leaves, stems and roots of *Arbutus unedo* were found to contain 38.5%, 31.3% and 14.1% palmitic acid, respectively, along with other long-chain fatty acids (up to C22) (Diba et al. 2010). The chemical composition of the unsaponifiable fractions differed: the leaf and stem fractions contained high levels of aliphatic (32.1% and 62.6%, respectively) and terpenic compounds (49.6% and 25.7%, respectively), and the root fraction mainly contained esters, of which the most abundant was benzyl cinnamate (36.6%).

Betulinin acid, lupeol, ursolic acid, monotropein, unedoside, and stilbericoside, the iridoids geniposide and monotropein methyl ester were isolated from *A. unedo* stem (Karikas et al. 1987).

Various pharmacological properties of different plant parts have been scientifically studied and reported.

Antioxidant Activity

Arbutus unedo fruits were found to be a very good source of antioxidants justifiably because they contained a high flavonoid content (32.37 mg/100 g edible portion) and, within this group of antioxidant compounds, proanthocyanidins were the most abundant, accounting for >80% of the total flavonoid contents (Pallauf et al. 2008). Anthocyanins were also present as glycosides of cyanidin and delphinidin, with

cyanidin-3-galactoside the most abundant. Other antioxidants present in this fruit were ellagic acid and its diglucoside derivative. Vitamin C, vitamin E and carotenoids were also detected.

The ethanol and methanol extracts of *A. unedo* leaves were found to display potent antioxidant activity as determined by an improved assay based on the decolorization of the radical monocation of [2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid)] (ABTS) (Pabuçcuoğlu et al. 2003). Of five species from the Ericaceae family (*Arbutus unedo, Bruckentalia spiculifolia, Calluna vulgaris, Erica arborea* and *Erica carnea*), a significant amount of arbutin was detected only in *Arbutus unedo* (Pavlović et al. 2009). The ethanolic extract showed excellent antioxidant activity as tested by means of FRAP (total antioxidant capacity), lipid peroxidation and DPPH free radical scavenging activity. The highest scavenging activity was obtained with leave extract of *Arbutus unedo* (IC_{50} = 7.14 μg/ml). The leaves of *A. unedo* contained a small amount of flavonoids but high content of non-tannins polyphenols.

Studies by Oliveira et al. (2009) found *A. unedo* leaves to be a potential source of natural antioxidants. Ethanol extracts of *A. unedo* leaves were the highest in reducing power (IC_{50} 232.7 μg/ml) and DPPH scavenging effect (IC_{50} 63.2 μg/ml) followed by water extracts (with IC_{50} of 287.7 for reducing power and 73.7 μg/ml, for DPPH); whereas diethyl ether extracts were the lowest. In the scavenging on superoxide radical (PMS-NADH-nitroblue tetrazolium) assay, methanol extracts obtained the best results (IC_{50} 6.9 μg/ml). For all the methods tested, the antioxidant activity was concentration dependent. In accordance with antioxidant activity, highest total phenols content were found in ethanol, followed by water, methanol and diethyl ether extracts. Fortalezas et al. (2010) found that *A. unedo* yielded a similar content in polyphenols and a slightly lower value of total antioxidant capacity in comparison to raspberry (*Rubus idaeus*). Although the chemically-measured antioxidant activity was similar between both fruits, *R. idaeus* increased neuroblastoma survival in a neurodegeneration cell model by 36.6% whereas *A. unedo* extracts caused no effect on neuroblastoma viability. These results clearly demonstrated that a promising level of chemically-determined antioxidant activity of a plant extract was not necessarily correlated with biological significance, as assessed by the effect of *A. unedo* fruit in a neurodegeneration cell model.

The ethanol and acetone/water extracts of *Cistus ladanifer* and *Arbutus unedo* showed scavenging activity for the DPPH radical (Andrade et al. 2009). Extract bioactivities were also tested by the evaluation of the viability effects on human fibroblasts primary culture cells using the MTT [3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide] method. Both extracts were found to be bioactive; *C. ladanifer* extracts were associated with an inhibitory effect and *A. unedo* were associated with an inducible effect on cells viability.

Antihypertensive Activity

Ziyyat and Boussairi, (1998) found that chronic oral administration of *Arbutus unedo* root aqueous extract slowly delayed the development of hypertension but did not change the final level of blood pressure and heart rate in the spontaneously hypertensive rats. In contrast, Arbutus (50 mg/kg/24 h) attenuated the pressor responses to phenylephrine and angiotensin I. Finally, a diuretic effect was evidenced in the group receiving the highest dose. The vascular and renal effects of this plant supported its use in folk medicine.

The co-administration of *Arbutus unedo* leaf (AuL) or root (AuR) aqueous extracts with N(G)-nitro-l-arginine methyl-ester (L-NAME) was found to reduce the development of increased systolic blood pressure (SBP), ameliorated the vascular reactivity as well as the baroreflex sensitivity and normalized the renal function in rats (Afkir et al. 2008). The root extract reduced ventricular hypertrophy but the leaf extract did not. Enalapril associated with L-NAME reversed the majority of alterations induced by L-NAME while l-arginine only lightly ameliorated the vascular reactivity. These results showed that chronic treatment with *Arbutus extract* regressed the development of hypertension and ameliorated cardiovascular and renal functions in NO deficient hypertension.

Vasorelaxant Activity

The root aqueous extract of *Arbutus unedo* (0.25 mg/ml) elicted a relaxation of noradrenaline-precontracted ring preparations of rat aorta with intact endothelium (Ziyyat et al. 2002). Relaxation by *Arbutus* did not occur in specimens without endothelium and was prevented by pretreatment with 100 μM N(G)-methyl-L-arginine (L-NMA), 10 μM methylene blue or 50 μM 1 H-[1,2,4] oxadiazolo [4,3-a] quinoxaline-1-one (ODQ) but not by 10 μM atropine. The results suggested that *Arbutus* produced an endothelium-dependent relaxation of the isolated rat aorta mediated mainly by a stimulation of the endothelial nitric oxide synthase by mechanisms other than activation of muscarinic receptors. In separate studies, the aqueous leaf extract of *A. unedo* at 10^{-2} g/l produced an endothelium dependent relaxation of 66% on rat aortic rings precontracted with 0.1 μm noradrenaline (Legssyer et al. 2004). On further successive extraction with different solvents, the methanol leaf extract was found the most active. When tannins (primarily condensed tannins) were precipitated from the methanol extract, they showed a strong vasorelaxant activity (87%), whereas the elimination of tannins in the methanol extract lowered significantly (42%) its vasorelaxant activity. On further fractionation of the methanol extract four fractions (Fr2, Fr3, Fr4 and Fr6) were found the most active and elicited 88%, 75%, 76% and 77%% relaxation, respectively. These four fractions corresponded to polyphenol compounds. Analysis of Fr6 indicated that this fraction contained catechin gallate. The results suggested that the vasorelaxant activity of *Arbutus* was likely attributable to polyphenol compounds, primarily condensed tannins and catechin gallate.

Antiplatelet Aggregation Activity

A. unedo plant extract produced a dose-dependent inhibition of thrombin and ADP-induced aggregation (Mekhfi et al. 2004). The crude aqueous leaf extract of *A. unedo* showed an inhibition of thrombin-induced platelet aggregation (IC_{50} = 1.8 g/l) (Mekhfi et al. 2006). The methanol and ethyl acetate extracts accounted for most of the anti-aggregant activity (IC_{50} = 0.7 g/l and 0.6 g/l, respectively). The tannins isolated from the methanol extract exhibited a strong antiplatelet effect (75.35% inhibition) and may be the major chemical compounds responsible for this activity. The results supported the traditional use of this plant in the preventive or therapeutic treatment of platelet aggregation linked to arterial hypertension. Further studies showed that platelet treatment with increasing concentrations (0.015–1.5 mg/ml) of crude aqueous, ethyl acetate or diethyl ether extracts reduced platelet aggregation evoked by thrombin (0.5 U/ml) and showed a potent ROS (reactive oxygen species) scavenger activity, preventing thrombin-induced endogenous generation of ROS (El Haouariet al. 2007). Treatment with *Arbutus unedo* leaf extracts did not changed thrombin-evoked Ca^{2+} release from the intracellular stores but reduced store-operated Ca^{2+} entry induced by thrombin or by selective reduction of the two Ca^{2+} stores in platelets, the dense tubular system and the acidic stores. Further, platelet treatment with the extracts lowered both basal and thrombin-induced protein tyrosine phosphorylation. It was concluded that *Arbutus unedo* extracts showed antiaggregant actions due to attenuation of Ca^{2+} mobilization, ROS production and protein tyrosine phosphorylation and may be used for the treatment and/or prevention of cardiovascular diseases.

Anticancer Activity

Mariotto et al. (2008a) showed that the aqueous leaf extract of *Arbutus unedo* exerted inhibitory action on interferon-gamma (IFN-gamma) elicited activation of STAT1 (Signal transducer and activator of transcription 1) a complex protein with multiple yet contrasting transcriptional functions, both in human breast cancer cell line, MDA-MB-231, and in human fibroblasts. This down-regulation of STAT1 was shown to result from a reduced tyrosine phosphorylation of STAT1 protein. Evidence was also presented indicating that the inhibitory effect of this extract

may be mediated through enhancement of tyrosine phosphorylation of SHP2 tyrosine phosphatase. collectively, the data suggested the employment of the *Arbutus unedo* aqueous extract to be promising, at least, as an auxiliary antiinflammatory treatment of diseases in which STAT1 plays a critical role. In another study, phytochemical analysis of the petroleum ether and ethyl acetate extracts of the entire plant of *Arbutus unedo* led to the isolation of a new sterol, 7β-hydroxystigmast-4-en-3-one (1), and nine known compounds of the flavan, steroid, and terpenoid types (Carcache-Blanco et al. 2006). Activity in the preneoplastic epidermal JB6 cell transformation assay was found for pomolic acid 3-acetate (4). All isolates obtained were evaluated in a cyclooxygenase-2 (COX-2) inhibition assay. Following fractionation by solid phase extraction, the apparent polyphenol content was reduced for both leaf and fruit samples of *A. unedo* by the elimination of vitamins and organic acids, but the antioxidant and metalloproteinases inhibitory activities were enhanced (Tavares et al. 2010). The antioxidant activity and the metalloproteinases MMP-9 inhibitory activity of the polyphenol-enriched fractions of *A. unedo* tissues were similar or greater than those of blackberry and green tea, which had been recognized in the literature as highly effective. Metalloproteinases are known to play a role in the initiation and proliferation of cancer cells. The phenolic profile of the *Arbutus* fruit was dominated by gallic acid and quercetin derivatives with lower quantities of proanthocyanidins and anthocyanins. The phenolic profile of the leaves was also dominated by gallic acid derivatives, flavonol derivatives and some tannins but lacked anthocyanins. The fractions obtained from both *A. unedo* tissues appeared to be quite promising as antioxidants and antiproliferative agents.

Antiinflammatory Activity

Mariotto et al. (2008b) demonstrated that acute lung inflammation of murine induced by intrapleural injection of carrageenan was significantly attenuated by the treatment with an aqueous extract of *Arbutus unedo*. Thee extract strongly down-modulated STAT3 activation induced in the lung by carrageenan with concomitant migationn of all parameters: (1) STAT1/3 activation, (2) TNF-alpha, IL-1beta and IL-6 production in pleural exudate, (3) lung iNOS, COX-2 and ICAM-1 expression, (4) neutrophil infiltration, (5) the nitration of cellular proteins by peroxynitrite, (6) lipid peroxidation, (7) prostaglandin E2 and nitrite/nitrate levels and (8) lung injury examined associated with inflammation, suggesting that STAT3 should be a new molecular target for antiinflammatory treatment.

Antidiabetic/Antihyperglycaemic Activity

The water extract of *A. unedo* was evoked a significant decrease in glycemia in rats after glucose loading in the Oral Glucose Tolerance Test (OGTT) (Bnouham et al. 2007). The addition of the water *A. unedo* extract induced a significant inhibition (31.6%) of jejunal glucose absorption which could partly explained the antihyperglycemic effect. Toxicity tests (high LD_{50} value) suggested no adverse effect of the use of the plant. Further studies found that treatment of diabetic rats with *A. unedo* extract resulted in 31.6% of plasma glucose reduction when compared with untreated diabetic rats (Bnouham et al. 2010). The in-vitro study of glucose utilization by isolated rat hemidiaphragm suggested that the extract in combination with insulin potentiated its activity and promoted the utilization of glucose indicating that *A. unedo* had antidiabetic activity.

Antiparasitic Activity

The ethyl acetate leaf extract of *Arbutus unedo* was found to be effective in-vitro against *Trichomonas vaginalis* trophozoites with growth inhibition rate (GI): 100%, at the concentration of 500 μg/ml) (Ertabaklar et al. 2009) suggesting its potential as a promising anti-trichomonacidal agent. *T. vaginalis* is a flagellated protozoan

commonly causing sexually transmitted disease. The ethanol leaf extract of *Arbutus unedo* at concentrations of 100, 250, 500 μg/ml were found to be more effective in-vitro against *Leishmania tropica* promastigotes than the aqueous and n-hexane extracts suggesting that the ethanol extract could be a promising antileishmanial agent Kivçak et al. (2009).

Antimicrobial Activity

The unsaponifiable leaf and stem extracts of *A. unedo* were found to inhibit the growth of *Klebsiella pneumoniae, Enterococcus faecalis* and *Candida albicans* (Diba et al. 2010).

Traditional Medicinal Uses

Arbutus unedo leaves had a long use in traditional medicine due to its antiseptic, diuretic, astringent and depurative properties (Oliveira et al. 2009).

Other Uses

Arbutus is sometimes planted as ornamental in England and Ireland. Leaves and bark are used in tannery and as medicine for its high tannin content.

Comments

Arbutus unedo is propagated by seeds and stem cuttings.

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Vaccinium corymbosum

Scientific Name

***Vaccinium corymbosum* L.**

Synonyms

Vaccinium amoenum Aiton, *Vaccinium arkansanum* Ashe, *Vaccinium ashei* Reade, *Vaccinium atrococcum* (Gray) Heller, *Vaccinium australe* Small, *Vaccinium caesariense* Mackenzie, *Vaccinium constablaei* A. Gray, *Vaccinium elliottii* Chapman, *Vaccinium fuscatum* Aiton, *Vaccinium marianum* Watson, *Vaccinium simulatum* Small.

Family

Ericaceae

Common/English Names

American Blueberry, Blueberry, High-Bush Blueberry, Northern Highbush Blueberry, Swamp Blueberry

Vernacular Names

Canada: Airelle En Corymbe (French);
Czech: Borůvka Chocholičnatá;
Eastonian: Kännasmustikas
Finnish: Pensasmustikka;
French: Airelle D'amérique, Bleuet À Corymbes, Corymbelle, Myrtille D'amérique, Myrtille Géante;
Danish: Amerikansk Blåbær;
Dutch: Trosveenbes;
German: Amerikanische Blaubeere, Amerikanische Blueberry, Kultur-Heidelbeere;
Italian: Mirtillo Gigante Americano;
Norwegian: Nordamerikansk Blåbær;
Polish: Borówka Wysoka;
Slovaščina: Ameriška Žlahtna Borovnica;
Spanish: Arándano Americano;
Swedish: Amerikansk Blåbär, Amerikanska Blåbär.

Origin/Distribution

Highbush berry is native to eastern North America, from Nova Scotia and Ontario south to Alabama, and west to Wisconsin. Outside of its natural range, it has been introduced into British Columbia and the state of Washington and, further afield, into Great Britain, Europe, Russia, South Africa, Japan, Korea, New Zealand, Australia, Chile, Argentina and Uruguay in south America. Hybridized forms, known as Southern Highbush Blueberries, have been introduced into southern parts of North America.

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Agroecology

Highbush berry grows best in wooded or open areas with moist, acidic, well-aerated, organic rich soils. Two habitats where it occurs as a dominant or codominant are open swamps or bogs and high-elevation balds in the Appalachian Mountains. It is frequently found at relatively low elevations along the edges of swamps, marshes and bogs; along the sandy margins of lakes, ponds, and streams and within open areas of moist woodlands. Plants can withstand extended periods of flooding. The plant requires about 100–400 h of temperatures less than 5–7°C to overcome the dormancy period. It requires cool nights during the fruit-ripening period. It is most often found in full sun to partial shade.

Edible Plant Parts and Uses

Vaccinium corymbosum is the most important blueberry-producing *Vaccinium* species used in the commercial fruit industry. The fruit is tasty, juicy, sweet and nutritious. The fruit is eaten raw, boiled, stewed, baked, smoke-dried, sun-dried and used like raisins. Blueberries are available fresh or processed as individually quick frozen (IQF) fruit, puree, juice or infused berries which in turn are used in a variety of edible products such as pies, pastries, cakes, muffins, cereals, snack food, jellies, jams and preserves. The fruits are also used to make beverages and spirits. A nutritious herbal tea is made from dried fruits and leaves.

Botany

Highbush blueberry is a slow-growing, deciduous, monoecious, erect shrub with several stems arising from the bole and growing to 1–3.5 m high. Leaves are glabrous or glaucous, simple, entire, elliptic to elliptic-lanceolate, 4–8 cm long by 1.4–4 cm wide, with acute apex and cuneate base (Plates 1 and 2). Flowers are bisexual, campanulate (bell-shaped), usually white or pale pink to reddish and occur in terminal or axillary racemes (Plate 3). Bracts caducous, calyx lobes are deltoid-oval, 0.5–2 mm long and spreading, corolla urceolate,

Plate 1 Simple leaves and clusters of developing blueberries

Plate 2 Close-up of leaf and ripening blueberries

Plate 3 Blueberry flowers

Plate 4 Ripe purplish-black blueberries

8–1 mm long by 4–6 mm wide, usually white. Fruit a glaucous berry, pale green (Plates 1 and 2) turning to dark blue, purple to black on ripening (Plate 4), 5–10 mm across, sweet and juicy containing several small seeds, 1–2 mm long.

Nutritive/Medicinal Properties

Nutrient Composition

Food value of raw, blueberries (*Vaccinium* spp) per 100 g edible portion was reported as follows (USDA 2010): water 84.21 g, energy 240 kcal (57 kJ), protein 0.74 g, total lipid (fat) 0.33 g, ash 0.24 g, carbohydrate 14.49 g; fibre (total dietary) 2.4 g, total sugars 9.96 g, sucrose 0.11 g, glucose 4.88 g, fructose 4.97 g, starch 0.03 g, minerals – calcium 6 mg, iron 0.28 mg, magnesium 6 mg, phosphorus 12 mg, potassium 77 mg, sodium 1 mg, zinc 0.16 mg, copper 0.057 mg, manganese 0.336 mg, selenium 0.1 μg; vitamins – vitamin C (total ascorbic acid) 9.7 mg, thiamin 0.037 mg, riboflavin 0.041 mg, niacin 0.418 mg, pantothenic acid 0.124 mg, vitamin B-6 0.052 mg, folate (total) 6 μg, choline 6 mg, betaine 0.2 mg, vitamin A RAE 3 μg, vitamin E (α-tocopherol) 0.57 mg, β-tocopherol 0.01 mg, γ-tocopherol 0.36 mg, δ-tocopherol 0.03 mg, vitamin K (phylloquinone) 19.3 μg, β-carotene 32 μg, lutein + zeaxanthin 80 μg; lipids – fatty acids (total saturated) 0.028 g, 16:0 (palmitic acid) 0.017 g, 18:0 (stearic acid) 0.005 g; fatty acids (total monounsaturated) 0.047 g, 16:1 undifferentiated (palmitoleic acid) 0.002 g, 18:1 undifferentiated (oleic acid) 0.047 g; fatty acids (total polyunsaturated) 0.146 g, 18:2 undifferentiated (linoleic acid) 0.088 g, 18:3 undifferentiated (linolenic acid) 0.058 g; amino acids – tryptophan 0.003 g, threonine 0.020 g, isoleucine 0.023 g, leucine 0.044 g, lysine 0.013 g, methionine 0.012 g, cystine 0.008 g, phenylalanine 0.026 g, tyrosine 0.009 g, valine 0.031 g, arginine 0.037 g, histidine 0.011 g, alanine 0.031 g, aspartic acid 0.057 g, glutamic acid 0.091 g, glycine 0.031 g, proline 0.028 g and serine 0.022 g. Glucose and fructose were found to be the predominant sugars in ripe blueberries (*Vaccinium corymbosum*), and were present in approximately equal proportion (glucose:fructose ratio of about 1) (Kader et al. 1993). Invertase activity was also detected. Invertase activity appeared to be inversely proportional to sucrose concentration.

Other Phytochemicals

Growing evidence from tissue culture, animal, and clinical models suggested that the flavonoid-rich fruits of the North American cranberry and blueberry (*Vaccinium* spp.) had the potential ability to limit the development and severity of certain cancers and vascular diseases including atherosclerosis, ischemic stroke, and neurodegenerative diseases of aging (Neto 2007) Blueberry fruits contained a variety of phytochemicals that could contribute to these protective effects, including flavonoids such as anthocyanins, flavonols, and proanthocyanidins; substituted cinnamic acids and stilbenes; and triterpenoids such as ursolic acid and its esters. Blueberries fruit and leaves contain a diverse range of phytochemicals with biological properties such as antioxidant, anticancer, antiviral, antineurodegenerative, and antiinflammatory activities.

The phenolic compounds of Highbush blueberries (*Vaccinium corymbosum* cultivar 'Coville') were analysed by high performance liquid chromatography and thin-layer chromatography (Kader et al. 1996). Fifteen anthocyanins were identified as the 3-monoglucoside, 3-monogalactoside and 3-monoarabinoside of delphinidin, cyanidin, malvidin, peonidin and petunidin. No acyl anthocyanin was detected. Derivatives of malvidin and delphinidin were the most abundant; the 3-monogalactoside constituted 41% of the anthocyanin. Four flavonol glycosides were also identified as the kaempferol-3-O-glucoside, 3-O-glucoside, 3-O-galactoside and 3-O-rhamnoside of quercetin. The major phenolic acid was chlorogenic acid. After hydrolysis of the phenolic neutral fraction, gallic, syringic and vanillic acids were identified. These acids appeared to be present in their ester forms, probably as glucoside esters.

Highbush blueberries (*V. corymbosa*) had more polar anthocyanins, than rabbiteye (*V. ashei*) cultivars (Lohachoompol et al. 2008). The anthocyanin profile was similar in all cultivars but proportions of each compound were cultivar-dependent. Delphinidin, petunidin and malvidin were the major contributors to total anthocyanin content. Rabbiteye had significantly higher total anthocyanin content than the highbush cultivars. *Vaccinium corymbosum* (highbush blueberry) berries also contained silbenes such as resveratrol and piceatannol (Rimando et al. 2004). These naturally occurring stilbenes, known to be strong antioxidants and to have cancer chemopreventive activities, will add to the purported health benefits derived from the consumption of these small fruits. Highbush blueberry from Michigan was found to contain only trans-resveratrol, 140.0 pmol/g (Lyons et al. 2003). The level of this chemoprotective compound in these fruits was <10% of that reported for grapes. Furthermore, cooking or heat processing of these berries would contribute to the degradation of resveratrol.

Blueberries and bilberries are recognized as some of the best sources of flavonoids, especially anthocyanins. All plant parts of bilberry (*Vaccinium myrtillus*) and 'northblue' blueberry (*Vaccinium corymbosum* × *V. angustifolium*) were found to be potential sources of phenolic compounds for use either as dietary botanicals or by the pharmaceutical industry (Riihinen et al. 2008). The most striking difference in the fruits was the predominance of hydroxycinnamic acids in blueberry, whereas in bilberry the anthocyanin content was much higher, particularly in the pulp. Differences in flavonoid contents of fruits were already apparent at the flower stage. Bilberry and blueberry leaves both contained high amounts of proanthocyanidins, flavonols and hydroxycinnamic acids. Blueberry rhizomes accumulated high amounts of hydroxycinnamic acids.

The phytochemical analysis of *Vaccinium corymbosum* var bluecrop leaves and callus biomass revealed ursolic acid, oleanolic acid, α-amyrin and β-amyrin in both plant materials (Migas et al. 2005). β-sitosterol was detected only in callus biomass.

Antioxidant Activity

Blueberries are one of the richest sources of antioxidant phytonutrients of the fresh fruits and vegetables. The total antioxidant capacity (oxygen radical absorbance capacity, ORAC) of different *Vaccinium* [*Vaccinium corymbosum*

(Highbush), *Vaccinium ashei* (Rabbiteye), *Vaccinium angustifolium* (Lowbush), and *Vaccinium myrtillus* (Bilberry)] berries studied ranged from a low of 13.9 to 45.9 μmol Trolox equivalents (TE)/g of fresh berry (63.2–282.3 μmol TE/g of dry matter) (Prior et al. 1998). Increased maturity at harvest enhanced the ORAC, the anthocyanin, and the total phenolic content. A linear relationship existed between ORAC and anthocyanin or total phenolic content.

Phenolic acids (gallic acid, p-hydroxybenzoic acid, caffeic acid, ferulic acid, and ellagic acid) in blueberries and blackberries were found to range from 0.19 to 258.90 mg/100 g fresh weight (FW) (Sellappan et al. 2002). Flavonoids (catechin, epicatechin, myricetin, quercetin, and kaempferol) ranged from 2.50 to 387.48 mg/100 g FW. Total polyphenols ranged from 261.95 to 929.62 mg/100 g FW, and total anthocyanins ranged from 12.70 to 197.34 mg/100 g FW. Trolox equivalent antioxidant capacity (TEAC) values varied from 8.11 to a maximum of 38.29 μM/g FW. A linear relationship was observed between TEAC values and total polyphenols or total anthocyanins. The data indicated blueberries and blackberries to be rich sources of antioxidants.

Total anthocyanins found in fresh blueberries (*Vaccinium corymbosum*) were 7.2 mg/g dry matter, expressed as cyanidin 3-rutinoside equivalents. In comparison with fresh blueberries, total anthocyanins in untreated and pretreated dried blueberries were significantly lowered to 4.3 mg/g solid content, 41% loss, and 3.7 mg/g solid content, 49% loss, respectively (Lohachoompol et al. 2004). Osmotic treatment followed by a thermal treatment had a greater effect on anthocyanin loss than the thermal treatment alone. In contrast, the frozen samples did not show any significant reduction in anthocyanin content during 3 months of storage at −20°C. Measurement of the antioxidant activity of anthocyanin extracts from blueberries showed there was no significant difference between fresh, dried, and frozen blueberries.

Anthocyanins were found to be the main components in the antioxidant activity of phenolics in fruits of blueberry (*Vaccinium corymbosum* cv. Sierra), cranberry (*Vaccinium macrocarpon* cv. Ben Lear), wild chokeberry (*Aronia melanocarpa*), and lingonberry (*Vaccinium vitis-idaea* cv. Amberland) (Zhen and Wang 2003) Chlorogenic acid was the most important antioxidant in blueberry. Phenolics such as quercetin and cyanidin, with 3′,4′-dihydroxy substituents in the B ring and conjugation between the A and B rings, imparted highly effective radical scavenging capacity in blueberries, cranberries, chokeberries, and lingonberries. Phenolic acids such as caffeic acid also showed high antioxidant activity, probably due to its dihydroxylation in the 3, 4 positions as hydrogen donors.

A total of 15 glycosylated anthocyanins, catechin, galactoside, glucoside, and rhamnoside quercetin 3-derivatives, and main benzoic and cinnamic acids were identified in steam-blanched highbush blueberry (*Vaccinium corymbosum*) (Brambilla et al. 2008). The total content and relative distribution in anthocyanins, chlorogenic acid, and quercetin of each juice were dependent upon cultivar, and the total content was highly correlated to the antioxidant capacity. Anthocyanins of all varieties of blueberries (*V. corymbosum*) increased during successive harvest stages; concomintantly flavonols and hydroxycinnamic acids decreased from unripe green to ripe blue stage of berry ripening (Castrejano et la. 2008). Blueberry antioxidant activity, as well as total phenolic content tended to decrease during ripening.

Fifteen anthocyanins were detected in blueberries, many of which exhibited substantial antioxidant activity using the FRAP (ferric reducing antioxidant power) assay (Borges et al. 2010). These phenolic compounds included: delphinidin-3-O-galactoside, delphinidin-3-O-glucoside, cyanidin-3-O-galactoside delphinidin-3-O-arabinoside, petunidin-3-O-galactoside, cyanidin-3-O-arabinoside, petunidin-3-O-arabinoside peonidin-3-O-galactoside, malvidin-3-O-galactoside, malvidin-3-O-glucoside delphinidin-3-O-(6″-O-acetyl) glucoside, peonidin-3-O-arabinoside, malvidin-3-O-arabinoside, petunidin-3-O-(6″-O-acetyl) glucoside, myricetin-3-O-galactoside, quercetin-O-diglucoside

5-O-feruloylquinic acid, malvidin-3-O-(6″-O-acetyl) glucoside, quercetin-3-O-rutinoside, quercetin-3-O-galactoside, quercetin-3-O-glucoside and quercetin-3-O-arabinoside quercetin-3-O-(6″-O-acetyl) glucoside. Most antioxidant activity was attributed to delphinidin-3-Ogalactoside, cyanidin-3-O-galactoside, delphinidin-3-O-arabinoside, petunidin-3-O-galactoside, malvidin-3-O-galactoside and malvidin-3-O-arabinoside. Compounds quercetin-O-diglucoside 5-O-feruloylquinic acid, quercetin-3-O-glactoside and traces of a quercetin-O-diglucoside, also contributed to antioxidant capacity. The low vitamin C content of the blueberries did not contribute to their antioxidant capacity.

Results from studies by Wang et al. (2008a) showed that highbush blueberries var. Bluecrop fruit grown from organic culture yielded significantly higher sugars (fructose and glucose), malic acid, total phenolics, total anthocyanins, and ORAC (oxygen radical absorbance capacity) antioxidant activity than fruit from the conventional culture. In organically cultured fruit, the average values for the ORAC, total anthocyanins, and total phenolic content were 46.14 μmol of Trolox (TE)/g of fresh weight (FW), 131.2 mg/100 g FW, and 319.3 mg/100 g FW, respectively. In conventionally cultured fruit, the average values for the ORAC, total anthocyanin, and total phenol content were 30.8 μmol of TE/g FW, 82.4 mg/100 g FW, and 190.3 mg/100 g FW, respectively. The organic culture also produced fruit with higher levels of myricetin 3-arabinoside, quercetin 3-glucoside, delphinidin 3-galactoside, delphinidin 3-glucoside, delphinidin 3-arabinoside, petunidin 3-galactoside, petunidin 3-glucoside, and malvidin 3-arabinoside than conventional culture. There was a significant correlation between the ORAC values and total phenolics and total anthocyanins.

The levels of flavonoids in blueberries (*Vaccinium corymbosum*) were found to increase after illumination with UV-C (Wang and Jiao 2000) Phytochemicals affected included resveratrol, myricetin-3-arabinoside, quercetin-3-galactoside, quercetin-3-glucoside, kaempferol-3-glucuronide, delphinidin-3-galactoside, cyanidin-3-galactoside, delphinidin-3-arabinoside, petunidin-3-galactoside, petunidin-3-glucoside, petunidin-3-arabinoside, malvidin-3-galactoside, malvidin-3-arabinoside, and chlorogenic acid. Significantly higher antioxidant capacity was detected in fruit treated with 2.15, 4.30, or 6.45 kJm^{-2} compared to the control fruit. UV-C dosage of 0.43 kJm^{-2} also increased phenolics and anthocyanins, but to a lesser extent. The optimum doses of UV-C for enhancing phytochemical content in blueberries were 2.15 and 4.30 kJm^{-2}. These data suggest that proper use of UV-C illumination is capable of modifying the phytochemical content of blueberries. Time course measurements of the effects of UV-C revealed that the strongest responses of fruit to UV-C treatment occurred immediately after the illumination and the effects diminished with time. Therefore, even though residual effects were evident following UV-C exposure, the best results were obtained immediately after the treatment.

Blueberries (*Vaccinium corymbosum*) were dried combining microwave-vacuum, hot-air drying (HA) and freeze drying (FD) technologies to retain their nutritional value (Mejie-Meza et al. 2008). Glycoside compounds such as ellagic acid, quercetin, and kaempferol exhibited a higher retention than phloridzin, and R- and S-naringin in dried blueberries following dehydration. Freeze and hot-air and microwave-vacuum combination drying (HA-MIVAC)® dried blueberries had a higher retention of total polyphenols and anthocyanins. Freeze dried blueberries had higher antioxidant activity, followed by the combination of HA-MIVAC®, MIVAC® and HA drying methods. FD, HA-MIVAC® and MIVAC® treated blueberries had a higher retention of individual polyphenols than HA treated blueberries, indicating that the nutritional properties of berries may be retained to a greater extent when these processes are employed.

Several naturally occurring essential oils including carvacrol, anethole, cinnamaldehyde, cinnamic acid, perillaldehyde, linalool, and p-cymene were found to be effective in reducing decay and increasing antioxidant levels and activities in ‘Duke’ blueberries (*Vaccinium corymbosum*) (Wang et al. 2008a). Carvacrol, anethole, and perillaldehyde showed the capability to promote total anthocyanins and total phenolics and

to enhance antioxidant activity in fruit tissues expressed as oxygen radical absorbance capacity (ORAC) and hydroxyl radical scavenging capacity. All of the essential oils tested in this study were able to inhibit fruit decay development to some degree compared to controls. The most effective compound for mould retardation was p-cymene, followed by linalool, carvacrol, anethole, and perillaldehyde. Cinnamic acid and cinnamaldehyde also suppressed mould growth, but to a lesser extent. Treatment with carvacrol, anethole, or perillaldehyde also significantly increased the levels of fructose, glucose, and citric acid. Individual flavonoids were variably affected by the essential oils. Levels of chlorogenic acid, which was the major phenolic compound in blueberry fruit, were enhanced by all of the essential oils in this study. Increased amounts of quercetin 3-galactoside and quercetin 3-arabinoside were also found in all treated fruit except samples treated with linalool or p-cymene. The major anthocyanin, malvidin 3-galactoside, was enhanced by all essential oils tested except linalool and p-cymene. The levels of other individual anthocyanins including petunidin 3-galactoside, delphinidin 3-galactoside, petunidin 3-glucoside, petunidin 3-arabinoside, delphinidin 3-arabinoside, and cyanidin 3-galactoside were higher in treated fruit compared to controls.

Studies showed that water soluble compounds obtained by enzymatic hydrolysis of blueberry were found to possess good in-vitro antioxidant activity against H_2O_2-induced cell damage in Chinese hamster lung fibroblast cell line (V79-4) (Senevirathne et al. 2010). Among the commercial food grade enzymes tested, AMG (a carbohydrase) and alcalase (a protease) hydrolysates exhibited higher total phenolic content as well as higher cell viability and ROS scavenging activities. Both AMG and alcalase hydrolysates also showed higher protective effects against lipid peroxidation, DNA damage and apoptotic body formation in a dose-dependent fashion.

Wang and Chen (2010) found that allyl isothiocyanate was effective in maintaining higher amounts of sugars and lower acids in blueberries compared to untreated fruit during storage at 10°C. However, allyl isothiocyanate reduced antioxidant enzyme activities [superoxide dismutase (SOD), guaiacol peroxidase (G-POD), glutathione-peroxidase (GSH-POD), ascorbate peroxidase (AsA-POD), dehydroascorbate reductase (DHAR), monodehydroascorbate reductase (MDAR) and glutathione reductase (GR)] and nonenzyme components, ascorbate and glutathione (GSH). Allyl isothiocyanate treatments also reduced the amount of phenolic acids (chlorogenic acid, myricetin 3- arabinoside, quercetin 3-galactoside, quercetin 3-arabinoside, and kaempferol 3-glucoside) and anthocyanins (delphinidin 3-galactoside, delphinidon 3-glucoside, delphinidin 3-arabinoside, petunidin 3-galactoside, petunidin 3-glucoside, petunidin 3-arabinoside, malvidin 3-galactoside, and malvidin 3-arabinoside) during storage at 10°C. The results from this study indicated that allyl isothiocyanate did not promote antioxidant property or scavenge constitutive reactive oxygen species (ROS), but maintained blueberry fruit quality and shelf life through other mechanisms.

Average values for oxygen radical absorbance capacity (ORAC), phenolics, and anthocyanins in 87 highbush blueberry (*Vaccinium corymbosum*) fruit were 15.9 ORAC units, 1.79 mg/g (gallic acid equivalents), and 0.95 mg/g (cyanidin-3-glucoside equivalents), respectively (Ehlenfeldt and Prior 2001). Cv. Rubel had the highest ORAC per gram of fresh weight values, at 31.1 units, and cv. Elliott had the highest values on the basis of ORAC per cm^2 surface area. In leaf tissue, values for both ORAC and phenolics were significantly higher than in fruit tissue, with mean values of 490 ORAC units and 44.80 mg/g (gallic acid equivalents), respectively. Leaf ORAC had a low, but significant, correlation with fruit phenolics and anthocyanins, but not with fruit ORAC.

The 30 minutes infusions of blueberry leaves exhibited the highest total phenol content and antioxidant capacity according to all three assays ferric reducing antioxidant power (FRAP) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2′-azinobis(3-ethylbenzthiazoline −6-sulfonic acid) (ABTS) radical scavenging assays

(Piljac-Žegarac et al. 2009). Wild blueberry infusion had the highest total phenol content (1,879 mg/L gallic acid equivalents [GAE]) and FRAP values (20,050 μM). The range of total phenol values for 30-minute infusions was 394–1,879 mg/l GAE with a mean of 986 mg/l GAE across cultivars; FRAP values fell between 3,015 and 20,050 μM with a mean of 11,234 μM across cultivars. All 30-minute infusions exhibited significant scavenging capacity for DPPH and ABTS + radicals, comparable to different concentrations of catechin, gallic acid, and 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid. Overall, tested leaf infusions showed significant reducing capacity as well as radical scavenging potential, which placed blueberry leaf tea high on the list of dietary sources of antioxidants. Blueberry (*V. corymbosum*) leaves were found to contain large quantities of chlorogenic acid (5-caffeoylquinic acid, 5-CQA), a strong antioxidant compound (Kim et al. 2010). The total amount of chlorogenic acid isolated by centrifugal partition chromatography from 0.5 g of a water fraction was 52.9 mg, corresponding to 10.6% of the water fraction.

Antimicrobial cum Antioxidant Activity

Investigations revealed that the highest amount of total anthocyanins was observed in fruits skins of blueberry (*V. corymbosum*) cultivars (Burdalis et al. 2009). Malvidin was the dominant anthocyanidin in blueberry. Extracts of "Herbert", "Coville", "Toro" blueberry cultivars fruits revealed antimicrobial properties. *Citrobacter freundii* and *Enterococcus faecalis* were the most sensitive among eight tested Gram-negative and Gram-positive bacteria. Blueberry cultivar "Berkeley" (82.13%) had the strongest antioxidant activity and the lowest antioxidant activity was estimated in blueberry cultivar "Coville". Accordingly, the strongest antiradical properties were estimated in blueberry cultivar "Ama" fruit skins.

Anticancer Activity

The main antioxidative and cytotoxic components in highbush blueberry fruits were triterpenoids and phenolic acids (Wang et al. 1999). The seven main components were ursolic acid, 3β, 19α-dihydro-urs-12-en-28-oic acid, β-sitosterol-β-D-glucoside, gallic acid, syringic acid and protocatechuic acid. Ursolic acid and 3β, 19α-dihydro-urs-12-en-28-oic acid effectively inhibited DNA synthesis in human leukaemia HL-60 cells with IC_{50} of 1.5 and 1 ppm respectively. Ursolic acid was found to have significant cytoxicity in lymphocytic leukaemia cells p-388 and L-120 as well as in the human lung cancer cell A-549. It also demonstrated marginal cytoxicity in the KB and human colon (HCT-8) and mammary (MCF-7) tumour cells. 3β, 19α-dihydro-urs-12-en-28-oic acid, a 19α-OH derivative of ursolic acid, showed even better antitumour activity than ursolic acid.

Blueberry (*V. corymbosum* cv Bluecrop) leaf extract displayed antileukaemic activity (Skupień et al. 2006). It was found that the blueberry extract was the most efficient against sensitive promyelocytic HL60 cell line (about 2-fold more active than strawberry and raspberry extracts) but presented much lower activity towards resistant cells. In contrast, strawberry and raspberry extracts exhibited the high cytotoxic activity against sensitive leukaemia HL60 cell line as well as its multidrug resistant sublines.

Cultivated highbush (*Vaccinium corymbosum* L.) and wild lowbush (*Vaccinium angustifolium* Ait.) blueberries were found to have excellent sources of phytochemicals with significant biological activity (Schmidt et al. 2005) For both cultivated highbush (*Vaccinium corymbosum* L.) and wild lowbush (*Vaccinium angustifolium* Ait.) blueberries, fresh and individually quick frozen berries were found to have the highest total phenols, antioxidant activity, and antiproliferation activity. Products that were heat-processed retained most of the antioxidant activity and total phenolics found in unprocessed whole fruit. However, the heat-treated products lacked or had diminished antiproliferation activity, suggesting

that although products may be high in phenolic compounds and antioxidant activity, some forms of bioactivity may be compromised by severe processing methods.

Antiviral Activity

Studies suggested that proanthocyanidin isolated from blueberry leaves may have potential usefulness as an anti-hepatitis C (HCV) compound by inhibiting viral RNA replication (Takeshita et al. 2009). Hepatitis C virus infection is a major cause of chronic liver disease such as chronic hepatitis, cirrhosis, and hepatocellular carcinoma. Proanthocyanidin with a polymerization degree of 8–9 showed the greatest potency at inhibiting the expression of subgenomic HCV RNA. Purified proanthocyanidin showed dose-dependent inhibition of expression of the neomycin-resistant gene and the NS-3 protein gene in the HCV subgenome in replicon cells.

Antiinflammatory and Antinociceptive Activities

The crude extract from *Vaccinium corymbosum* fruit exhibited antiinflammatory and antinociceptive activities (Torri et al. 2007). In the carrageenan test, the crude hydroalcoholic extract at doses of 100, 200 or 300 mg/kg reduced rat paw oedema by 9.8, 28.5 and 65.9%, respectively. For the histamine assay, the reductions of oedema were 70.1, 71.7 and 81.9%, respectively. In the myeloperoxidase (MPO) assay, 300 mg/kg crude extract produced a significant inhibition of the MPO activity, at 6 and 24 h after injection of carrageenan, by 42.8 and 46.2%, respectively. With the granulomatous tissue assay, dexamethasone displayed significant activity, whereas the blueberry extract was inactive. For the abdominal constriction test, inhibitions of 49.0, 54.5, 53.5%, respectively, were observed for the crude extract, and 61.4% for indometacin. In the formalin test, the crude blueberry extract (200 and 300 mg/kg) and indometacin inhibited only the second phase by 36.2, 35.3 and 45.8%, respectively. Considering that the crude extract of blueberry displayed antinociceptive and antiinflammatory activity, its consumption may be helpful for the treatment of inflammatory disorders.

Antihyperglycemia/Antihyperlipidaemic Activity

Results of studies suggested that cytoprotective and antiinflammatory actions of dietary blueberry powder (1:1 *Vaccinium ashei* and *V. corymbosum*) could provide metabolic benefits to combat obesity-associated pathology (DeFuria et al. 2009). Dietary blueberry was found to attenuate whole-body insulin resistance and hyperglycemia in high fat-fed mice by reducing adipocyte death and its inflammatory sequelae. Adipose tissue (AT) inflammation promotes insulin resistance and other obesity complications. AT inflammation and insulin resistance are associated with oxidative stress, adipocyte death, and the scavenging of dead adipocytes by proinflammatory CD11c+ AT macrophages (ATMPhi). ATMPhi gene expression was postulated to reflect the ability of blueberry anthocyanins to alter mitogen-activated protein kinase and nuclear factor-kappaB stress signaling pathways, which regulate cell fate and inflammatory genes.

Kalt et al. (2008) found that blueberry supplementation lowered plasma lipid levels and had cardiovascular benefit in animal studies. In the first trial, where basal diets contained a high level of plant-based components (70% soya, oats and barley), supplementation with 1, 2 and 4% blueberries resulted in a decrease in total cholesterol, LDL- and HDL-cholesterol. The greatest reduction was observed in the 2% blueberry-fed pigs, where total, LDL- and HDL-cholesterol were reduced 11.7, 15.1 and 8.3%, respectively. In the second trial where basal diets contained only 20% (w/w) of soya, oats and barley, the lipid-modulating effect of blueberries was attenuated, so that supplementation with 1.5% blueberries reduced total cholesterol by 8%, which occurred only in pigs whose diets had been supplemented with cholesterol (0.08%), NaCl (0.11%) and fructose (9%).

CNS/Neuroprotective Activity

Blueberry extracts were found to ameliorate age-related declines in neuronal and cognitive function, common in disorders such as Alzheimer disease (Youdim et al. 2000). Following an 8 week blueberry supplementation regime, age-related declines in several behavioral parameters such as balance, coordination, working memory and reference memory were prevented. Similarly, blueberry extracts also potentiated oxotremorine enhancement of K+-evoked release of dopamine from striatal slices. Decline in the dopaminergic system was found to have a profound effect on cognitive functions. Separate studies suggested that the polyphenols in blueberries and cranberries had the ability to improve muscle tone, strength and balance in aging rats, whereas polyphenols in blueberries, cranberries and blackcurrants enhanced neuronal functioning and restored the brain's ability to generate a neuroprotective response to stress (Shukitt-Hale et al. 2005). In further studies, the scientists suggested that a short-term blueberry intervention may result in improved heat shock protein 70 (HSP70)-mediated protection against a number of neurodegenerative processes in the brain. Results were discussed in terms of the multiplicity of the effects of the blueberry supplementation which appeared to range from antioxidant/anti inflammatory activity to signalling (Galli et al. 2006).

Fruits of *Vaccinium* species including *V. corymbosum* were found to have antioxidant phytochemicals that imparted many biological activities including protection against neurogenerative disorders. Anthocyanin-rich preparations of *Vaccinium* species (*Vaccinium myrtillus, Vaccinium corymbosum,* and *Vaccinium oxycoccus*) were found to have most potent inhibition of cytochrome c-enhanced 6-hydroxy dopamine oxidation that generated hydrogen peroxide and other reactive species (ROS) (Yao and Vieira 2007). ROS promoted oxidative stress and had been implicated in dopaminergic neurodegeneration, e.g., Parkinson's disease. Loss of mitochondrial membrane integrity, a pathological situation of relevance to several aging-related neurodegenerative disorders including Parkinson's disease, contributed to release of cytochrome c; and the level of such release is known to be indicative of the extent of mitochondrial dysfunction. The antioxidant activity was correlated strongly with reported *Vaccinium* content of anthocyanins and total cyanidins, but not quercetin or myricetin. The results provided evidence for the high potency of anthocyanins towards a potentially neurotoxic reaction, and provided a basis for in-vivo testing of these flavonoids and their physiological metabolites in the context of neuro-protective and mitochondrio-protective effects.

Preliminary studies by Krikorian et al. (2010) found that supplementation with wild blueberry juice enhanced memory and learning in older adults, while reducing blood sugar and symptoms of depression. The findings of this preliminary study suggested that moderate-term blueberry supplementation could confer neurocognitive benefit.

Bioavailability of Blueberry Anthocyanins

Studies by Mazza et al. (2002) reported that anthocyanins could be absorbed in their intact glycosylated and possibly acylated forms in human subjects and that consumption of blueberries, a food source with high in-vitro antioxidant properties, was associated with a diet-induced increase in ex-vivo serum antioxidant status. Nineteen of the 25 anthocyanins present in the blueberries were detected in human blood serum after the consumption of a high-fat meal with a freeze-dried blueberry powder containing 25 individual anthocyanins including 6 acylated structures. Further, the appearance of total anthocyanins in the serum was directly correlated with an increase in serum antioxidant capacity (ORAC (acetone)).

The results of studies by Yi et al. (2006) showed that anthocyanins from blueberries could be transported through the Caco-2 cell monolayers although the transport/absorption efficiency was relatively low compared to other aglycone polyphenols. The transport efficiency of

anthocyanins averaged approximately 3–4% [less than 1% in delphinidin glucoside]. Delphinidin glucoside exhibited the lowest transport/absorption efficiency, and malvidin glucoside exhibited the highest transport/absorption efficiency. The results indicated that more free hydroxyl groups and less OCH(3) groups could decrease the bioavailability of anthocyanins. Further, cyanindin glucoside exhibited significantly higher transport efficiency than cyanidin galactoside, and peonidin glucoside exerted significantly higher transport efficiency than peonidin galactoside, indicating that glucose-based anthocyanins had higher bioavailability than galactose-based anthocyanins.

Other Uses

Native Americans also used the plant and its fruit for medicines and food. Wildlife and birds also love the fruit, providing an important source of food for numerous species in the summer and early fall. Highbush blueberries is used in breeding tetraploid blueberries with high vigour, upright growth and disease resistance.

Volatiles identified from the aerial parts of *V. corymbosum* plant included green leaf volatiles, aromatic compounds, and terpenes (Parra et al. 2009). Five compounds: 2-nonanone, eucalyptol, R- and S-limonene, and 4-ethyl benzaldehyde elicited an attractant behavioral response from the raspberry weevil *Aegorhinus superciliosus*. These compounds have potential to be developed into a lure for the principal pest of blueberry in southern Chile.

Comments

Among the most productive growing regions in the world, British Columbia is the largest Canadian producer of highbush blueberries. Michigan is the leading state in the production of highbush blueberry in USA. Bluberry farms in Michigan account for 32% of the small, round berries eaten in the United States. Significant areas of highbush blueberries are cultivated in the southern states of Florida, Georgia and North Carolina. In the Southern hemisphere, Chile, Argentina, Uruguay, South Africa, New Zealand, and Australia also export blueberries.

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Aleurites moluccanus

Scientific Name

***Aleurites moluccanus* (L.) Willd.**

Family

Euphorbiaceae

Synonyms

Aleurites ambinux Pers., *Aleurites angustifolius* Vieill., *Aleurites angustifolius* Vieill. ex *Guillaumin, Aleurites commutatus Geiseler, Aleurites cordifolius* (Gaertn.) *Steud., Aleurites integrifolius* Vieill., *Aleurites integrifolius* Vieill. ex *Guillaumin, Aleurites javanicus* Gand., *Aleurites lanceolatus* Blanco, *Aleurites lobatus* Blanco, *Aleurites moluccanus* var. *aulanii* O.Deg. & I.Deg., *Aleurites moluccanus* var. *floccosus* Airy Shaw, *Aleurites moluccanus* var. katoi O.Deg., I.Deg. & Stone, *Aleurites moluccanus* var. remyi (Sherff) *Stone, Aleurites moluccanus* var. serotinus O.Deg. & Sherff, *Aleurites pentaphyllus* Wall. nom. nud., *Aleurites remyi* Sherff, *Aleurites trilobus* J.R.Forst. & G.Forst., *Camerium moluccanum* (L.) *Kuntze, Camirium cordifolium* Gaertn., *Camirium oleosum* Reinw. ex Blume, *Dryandra oleifera* Lam., *Jatropha moluccana* L., *Manihot moluccana* (L.) Crantz, *Mallotus moluccanus* (L.) Müll.Arg., *Mallotus moluccanus* var. *genuinus* Müll.Arg. nom. inval., *Ricinus dicoccus* Roxb., *Rottlera moluccana* (L.) Scheff., *Telopea perspicua* Sol. ex Seem.

English/Common Names

Balucanat, Belgaum Walnut, Candleberry, Candle-Nut, Candle Nut Oil Tree, Indian Walnut, Kukui Nut, Lumbang Oil, Otaheite Walnut, Tung Nut, Varnish Tree

Vernacular Names

Arabic: Khasife-Hindi, Jouzebarri;
Australia: Tiairi, Tiairi (Abor.);
Borneo: Bunsangil, Buah Keras, Kameri, Kami, Kemiri, Kemiting;
Brazil: Nogueira-Da-I´Ndia;
Carolinian: Raguar;
Creole: Lèrit, Nwa, Nwazèt;
Chamorro: Lumbang, Raguar;
Chinese: Shi Li;
Cook Islands: Tuitui (Mangaia), Tuti (Maori);
Czech: Tungovník Molucký;
Eastonian: Moluki Tungpuu;
Fijian: Balucanat, Kubui, Lauci, Lauthe, Lauthi, Nggerenggere, Qereqere, Sikeci, Sikeli, Sikethi, Toto, Tuitui, Tutui, Waiwai;

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French: Nois Des Indes, Noix De Bancoul, Noix De Moluques, Noyer De Bancoul, Noyer Des Moluques, Bancoulier, Aleurites, Noisette, Noix, Noyer, Noyer Des Indes;
French Polynesia: Tahii, Tahiri, Tiairi, Ti'A'Iri, Tutui (Moorea);
Futuna: Tutui;
German: Kerzennussbaum, Lichtnussbaum;
Guam: Lumbang;
Hawaiian: Kukui, Kuikui;
India: Akhrot, Akola, Akrot, Jangli Akrot, Jangli-Akhrot (Hindu), Akroda, Arkod, Akrotu, Jaiphala, Naadu Akrotu, Naati Akrotu, Natakrodu, Naadu Aakrotu, Natuakrodu, (Kannada), Akrottu, Akshotam, Karankolam, Vadam (Malayalam), Akhod, Akrut, Japhala, Ramakrot, Ranakot (Marathi), Akshota (Oriya), Akharota, Akhota, Akshota, Asphotaka, Gudashaya, Kandarala, Karparala, Kaureshta, Madanabhaphala, Parvatiya, Phalasneha, Pritakchhada, Rekhaphala, Svadumajja, Vrittaphala (Sanskrit), Katakrote, Nattakkarottu, Nattkkarotu, Nattu Akrottu, Woodooga, (Tamil), Naattakrotu, Natakrotu, Natu Akrotu, Uduga (Telugu);
Indonesia: Kemiri, Miri, Muncang;
Laos: Kok Namz Man;
Makatea: Tutui;
Malaysia: Buah Keras, Kemiri, Kembiri;
Mangareva: Rama;
Marquesan: 'Ama, Ama;
New Caledonia: Tai;
Niuean: Tuitui;
Palaun: Sakan;
Papua New Guinea: Tutui, Kemiri, Kurup;
Persian: Girdagane-Hindi, Chahar-Maghze-Hindi;
Philippines: Biau (Bagio), Rumbang (Bisaya), Biau (Cebu Bisaya), Kami (Sulu), Kalumban, Kapili, Lumbang, Lumbang-Bato (Tagalog);
Pohnpeian: Sakan, Shakan;
Polish: Tung;
Portuguese: Calumbàn, Noz Da India;
Rapan: Tiairi;
Rimatara: Tutui;
Rurutu: Tutui;
Samoan: Lama, Lama;
Society Island: Tutu'I, Ti'A'Iri;
Spanish: Arbol Llorón, Avellano, Avellano Criollo, Calumbán, Camirio, Lumbán, Nogal De La India, Nuez;
Tahitian: Ahama, 'Ama, Tahii Tairi, Tahiri, Ti'A'Iri, Tiairi, Tuitui, Tutui;
Thai: Photisat, Kue-Ra, Purat, Mayao;
Tongan: Tuitui;
Tubuai: Tutui;
Uvea: Tutui;
Vanuatu: Kandel, Kandeltri (Bislama);
Vietnamese: Lai.

Origin/Distribution

The species is indigenous to the Indo-Malaysia region and was introduced in ancient times throughout the Pacific islands and also elsewhere in the warm tropics and subtropics from India and China to the Australia, New Zealand and the Pacific.

Agroecology

As in its native range, candlenut thrives best in a warm, humid tropical environment with mean annual temperature of 20–30°C and annual rainfall of >1,500 – 4,000 mm distributed fairly uniformly throughout the year from near sea-level to 1,500 m altitude. It is common in wet secondary forest at the margins or along stream and along the seashore. It thrives in full sun to light shade. It will also thrive in a semi dry to wet subtropical forest climate and in areas with mean annual rainfall from 640 to 1,500 mm. Mature trees are moderately drought tolerant. It is frost intolerant and sensitive to low temperatures below 10°C. It is fairly tolerant to salt spray. It is adaptable to a wide range of soil types from acidic to alkaline, calcareous soils with pH from 5 to 8. It does best in well-drained, light- and medium-textured soils such as sands, sandy loams, loams and clayey loams.

Edible Plant Parts and Uses

Candle nut is an important spice in Indonesian and Malaysian cuisine. Kernels are eaten when thoroughly dry or after roasting to destroy mild toxins. Kernels are commonly used in curries;

nut is also roasted and eaten as a snack or added to desserts, cakes, and pies. In Java, it is used to make a thick spicy sauce that is eaten with rice and vegetables. The residual oil cake is processed into a snack food called '*dage kemiri'* in Indonesia. In Hawaii, the roasted kernels are mixed into a paste with salt, seaweed or chilli pepper to make the condiment *inamona,* a key ingredient in traditional Hawaiian *poke.*

Botany

A perennial, evergreen, upper-canopy tree, 10–47 m tall with a light spreading crown and grey-brown to blackish bark. Leaves are arranged alternately in a spiral along the stem and branches. Leaves are green above and paler green on the underside, simple, entire, pubescent, petiolate, ovate-oblong or deltoid or shallowly 3-lobed, 24 cm long by 12 cm wide, apex acuminate, base rounded or slightly cordate (Plates 1–3). Juvenile leaves especially on younger trees are larger and more deeply lobed. Flowers are borne on axillary inflorescences, male and female parts occurring in separate flowers on the same tree (Plates 1 and 2). Flowers are pale yellow or greenish white, 5–10 mm long and 5–8 mm across with distinct sepal whorl and pubescent elliptic-spathulate petals, stamens of unequal lengths and a pubescent ovary. The fruit is a fleshy, indehiscent, round to ovoid berry, 30–40 mm long green or brown (Plates 3 and 4). The outer skin rots away exposing the hard, ridged, woody-shelled or stony-shelled, sub-globose seed, 2.5 cm diameter (Plate 5). Within the seed is a white, oily, fleshy kernel consisting of a very thin embryo surrounded by a large endosperm (Plate 6).

Plate 1 Inflorescences and foliage of candlenut

Plate 2 Flowering shoot

Plate 3 Immature candlenut fruits

Plate 4 Mature candlenut fruit

Plate 5 Dried candlenut kernels with the hard, stony seed coat removed

Plate 6 Candlenut seeds in a plastic bag on sale in the local Indonesian market

Nutritive/Medicinal Properties

The food nutrient composition of raw candlenut kernel per 100 g edible portion had been reported by Dignan et al. (1994) as: moisture 5 g, energy 647 kcal (2,670 kJ), protein 18.2 g, total fat 62.3 g, available carbohydrate 3 g, dietary fibre 5.2 g, Na 26 mg, K 440 mg, Ca 154 mg, Mg 200 mg, Fe 3.4 mg, Zn 3 mg, thiamin 0.08 mg, riboflavin 0.06 mg, niacin traces and vitamin E 6 mg.

Phytochemical studies on *Aleurites moluccana* reported the presence of triterpenes, steroids, coumarins, phytsterol and flavonoid glycosides such moretenone, moretenol, acetil aleuritic acid, moluccanin, swertisin, 2 -O-rhamnosylswertisin, α and β-amyrin, stigmasterol, β-sitosterol and campesterol, a phorbol diester, 13-O-myristyl-20-O-acetyl-12-deoxyphorbol, hentriacontane (hydrocarbon), 6,7-dimethoxycoumarin, 5,6,7-trimethoxycoumarin and β-sitostenone (phytosterol) in the plant (Hui and Ho 1968; Shamsuddin et al. 1988; Girardi et al. 2003; Meyre-Silva et al. 1997; Satyanarayana et al. 2001).

Lignin from candlenut shells was found to contain predominantly guaiacyl units, and both the total hydroxyl group content and phenolic hydroxyl group content were high (Klein et al. 2010).

The flavonoids swertisin and 2″-O-rhamnosylswertisin from *Aleurites moluccana* was separated using using chitin and full N-acetylated chitin (Morsch et al. 2002). Further studies showed that the amount of 2″-O-rhamnosylswertisin isolated (30.0 mg) was approximately twice as high as swertisin (17.5 mg) using heptaldehyde-modified chitosan (heptyl-chitosan, CH-Hp) as adsorbent for chromatographic separation (Morsch et al. 2004). More studies by Morsch et al. (2006) reported the use of chitosan modified with glutaraldehyde and glyoxal as chromatographic support for the separation of flavonoids, swertisin and 2″-O-rhamnosylswertisin from *Aleurites moluccana.*

Reported pharmacological properties reported include the following:

Cytotoxicity Activity

Four new podocarpane-type trinorditerpenenes, (5β,10α)-12,13-dihydroxypodocarpa-8,11,13-trien-3-one (1), (5β,10α)-12-hydroxy-13-methoxypodocarpa-8,11,13-trien-3-one (2), (5β,10α)-13-hydroxy-12-methoxypodocarpa-8,11,13-trien-3-one (3), and (3α,5β,10α)-13-methoxypodocarpa-8,11,13-triene-3,12-diol (4), together with four known diterpenes, 12-hydroxy-13-methylpodocarpa-8,11,13-trien-3-one (5), spruceanol (6), e nt-3α-hydroxypimara-8(14),15-dien-12-one (7), and ent-3β,14α-hydroxypimara-7,9(11),15-triene-12-one (8), were isolated from the twigs and leaves of *Aleurites moluccana* (Liu et al. 2007). Except 8, all compounds were evaluated for their cytotoxicity; compound 4 exhibited moderate inhibitory activity against Raji cells with an IC_{50} value of 4.24 μg/ml.

Opthalmic Uses

Recent studies showed that *Aleurites moluccana* nut oil could replace castor oil (*Ricinus communis)* as the commonly used lipophilic vector in eye drops as castor oil exerted cytotoxic effects on conjunctival cells (Said et al. 2007). Castor oil was shown to induce significant necrosis and P2X7 cell death receptor and caspase 3 activation and to enhance intracellular reactive oxygen species production. *Aleurites moluccana* and camelina (*Camelina sativa*) oils were not cytotoxic and increased cell membrane omega-3 fatty acid content. None of the five tested oils showed any in-vivo ocular irritation. The results demonstrated that the four other oils, *Aleurites, Camelin*a, maize, and olive devoid of cytotoxic effects, may have potential to replace castor oil in ophthalmic formulations. Further studies in rabbits reported that irrigation with marine solution followed by treatment with a mixture of *Calophyllum inophyllum* and *A. moluccana* oils was a promising treatment for ocular burns (Said et al. 2009). The association of a controlled ionization marine solution with 10% *C. inophyllum* oil and 90% *A. moluccana* oil induced regeneration of the corneal epithelium and a decrease in inflammatory cells.

Antihypercholesterolaemic Activity

Methanol extract of the leaves of the *Aleurites moluccana* (300 mg/kg, body weight) decreased the serum lipids (total cholesterol, LDL- and HDL-cholesterol and triglycerides) and body weight in rats with Triton W-1339 -induced hypercholesterolaemia and on a hyperlipaemic diet (Pedrosa et al. 2002). The results suggested that the lipid lowering action of this natural extract was mediated through inhibition of hepatic cholesterol biosynthesis and reduction of lipid absorption in the intestine.

Antiinflammatory Activity

The methanolic extract of dried leaves of *Aleurites moluccana* (AMME) was found to exhibit anti-inflammatory and antipyretic activities (Niazi et al. 2010). Pre-treatment with the methanol extract (100–300 mg/kg, p.o.) significantly prevented increase in volume of paw oedema in dose dependent manner. A maximal effect was observed at 300 mg/kg which was comparable to diclofenac (20 mg/kg, orally). Aleurites methanol extract in dose of 300 mg/kg caused significant decrease in body temperature of rats.

Antinociceptive Activity

Pharmacological studies reported that the hydroalcoholic extract and some fractions obtained from *A. moluccana* leaves exhibited a potent antinociceptive action on mice, which was related to the presence of α and β-amyrin and 2 -O-rhamnosylswertisin (Meyre-Silva et al. 1997, 1998). The findings lend support for the popular use of *A. moluccana* for treatment of headache.

Antimicrobial Activity

Aleurites moluccana extracts also showed antibacterial activity against *Staphylococcus aureus* and *Pseudomonas aeruginosa* (Locher et al. 1995) and antiviral activity against human immunodeficiency virus type-1 (HIV-1) (Locher et al. 1996).

Traditional Medicinal Uses

Aleurites moluccanus has been extensively used in folk medicine for the treatment of ulcers, headache, fevers, diarrhea and hypocholesterolemia (Niazi et al. 2010). In traditional medicine in south and southeast Asia, the kernel has been used as a laxative and in poultices for headache, fevers, ulcers, swollen joints and constipation. In Sumatra, pulverised kernels, burnt with charcoal, were applied around the navel for costiveness. In the Celebes, it is used for stomach-ache. In Malaysia, the pulverized kernel were use as poultices for headache, fevers, ulcers and swollen

joints. The bark has been used for dysentery and decoction of leaves for treating scrophulosis and boiled leaves used externally for headache and gonorrhoea. In Java, the bark was used as a remedy for dysentery (diarrhea with blood). In Japan, the bark has been used on tumours. In Hawai´i, the flowers and the sap at the top of the husk (when just removed from the branch) were used to treat *e´a* (oral candidiasis) in children. Reported candlenut oil uses include as a mild purgative, as embrocation for sciatica and treatment against hair loss. Javanese used the oil to stimulate hair growth. Candle nut oil has also been used as a remedy for worms and piles. The oil has a mild aperient action like castor oil. In India, the oil has been used as a dressing for ulcers. The seeds were also used as a mild purgative in the Philippines.

Other Uses

Pacific Islanders, namely Fijians, Hawaiians, Tahitians and others have been reported to use the acrid juice of the fruit wall and charred nuts for tattooing. Tongan used pulverized kernels in a paste as soap and shampoo. The nuts have been used as toys such as marbles and tops. The crushed kernels have been used mixed with other ingredients as fish bait. The shells, which can be polished to a high lustre, are fashioned into earrings and other costume jewellery. The shells of the nuts, flowers and leaves have been used for leis in Hawaii.

In Malaysia, the nut in association with an iron nail and cockle shells have been used in social ceremonies when the new rice was dried. In Malaysia, candle nut, leaves of *Bryophyllum*, cockle shells and iron nail were put into water for bathing an infant suffering from fever.

Candlenut oil has been used for various purposes, such as for the preparation of paints, varnishes, wood polish and linoleum, for illumination, soap manufacture, cosmetics and wood preservation, preservation of fishing nets and in the batik industry. Candlenut oil used in combination with coconut oil has been used for skin and hair treatment. After removal of the oil, the remaining seed cake has been used for cattle fodder and as fertilisers. The roots provide a red dye for tapa cloth, *kapa* and *aho* cordage in Polynesia.

The wood is also made into light furniture, small boats, canoes, small utensils, fuel-wood and matches and is also suitable for paper pulp. The likeness of a pig's head carved from the wood is placed on an altar for the Hawaiian festival of *Makahiki.*

Recent laboratory studies with the Formosan termite (*Coptotermes formosanus*) showed that kukui oil (*Aleurites moluccana*)-treated yellow-pine wood was resistant to termite damage when the wood contained >27% kukui oil by weight (Nakayama and Osbrink 2010). Results also indicated that the oil acted primarily as a feeding deterrent and not a toxic agent.

Comments

Raw candlenuts can be toxic as they contain saponins and phorbol

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Elateriospermum tapos

Scientific Name

***Elateriospermum tapos* Blume**.

Synonyms

Elateriospermum rhizophorum Boerl. & Koord.

Family

Euphorbiaceae

Common/English Names

Parah Tree, Perah Tree

Vernacular Names

Borneo: Rampeh, Rapi (Bidayuh), Kelampai (Iban, Sarawak), Perah, Perah Ikan (Malay), Layang Laying, Paha, Bramban;
Indonesia: Asiloem (Karo, Sumatra), Daun Tepoes, Kajoe Si Marsang-Sang, Kedoei, Tapoes (Sumatra), Tapos (Sundanese, Java);
Peninsular Malaysia: Buah Perah, Perah, Perah Kokong, Pogoh (Malay), Gua Pra, Ple Prah (Sakai); Piah, Suing (Semang);
Thailand: Kra, Pra (Thai), Pi-Ra (Malay).

Origin/Distribution

The tree is native to south Peninsular Thailand, Malay Peninsula, Brunei, Sumatra, Java and Borneo.

Agroecology

Perah occurs wild in hilly primary (mixed dipterocarp) and secondary forest, kerangas forest, forest edges, along logging roads from sea level to 600 m elevation in its native range. It occurs in soil usually deep and yellow-coloured, mainly clay, clay-loam, sandy clay, loam, sometimes sandstone or (silty) laterite. This species is abundant on the very friable, relatively nutrient rich soil of the Sega neat series. It flowers and fruits throughout the year. The flowers are pollinated by dammar bees.

Edible Plant Parts and Uses

The seeds can be eaten cooked or roasted however, excessive consumption may cause dizziness. Seeds of Perah are normally fermented and eaten by local villagers in Southern Thailand, especially in Nakhon Si, Thammarat province. In Sumatra, the seeds are pounded with water to make a paste and used to flavour some kinds of sambal. In Peninsular Malaysia, the jungle tribes (Sakai) would bury the paste packed in a bag or in bamboo in wet earth for a month or more, resulting in a fermented paste with a strong flavour, which is highly relished with meals.

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The seeds yield a pale yellow, nearly odourless edible oil with a nice taste, which can be used for cooking.

Botany

A monoecious, semi-deciduous, medium to large tree 27–50 m high with a bole up to 10 m sometimes shortly fluted or with buttresses up to 2 m high, and a trunk diameter of 56 cm (Plate 3) and a deeply conical to hemispherical, multilayered, monopodial, crown. The bark is pale brown to grey, smooth to finely fissured and slightly flaky. A white sticky, latex is present in the bark, leaves and fruit stalk. Stipules are triangular, 2–3 mm long. Leaves are simple, spiral, long petiolate, 1–8 cm long, flat or somewhat hollow adaxially. Leaf lamina is elliptic to obovate lamina, 5–24 by 2–7.5 cm, obtuse to cuneate base, acuminate to cuspidate apes, entire margin, glabrous, dark green above and paler green beneath and with 7–17 lateral nerves per side of midrib (Plates 1 and 2). Young leaves are bright red. Inflorescences are cymose and terminal, clustered at the tips of twigs. Flowers are white to pale yellow, musty-odorous. Male flowers are 2.4–3.5 mm across on pedicel 2–7 mm long, hairy, sepals are ovate, 2.5–6 by 2.2–5 mm, apex rounded, puberulous outside, glabrescent; disc is 0.8–1.3 mm high; stamens yellow, filaments are 0.3–2 mm long and orange-colour at the base. Female flowers are larger, 3.2–5.3 mm across, on 1.3–4.2 mm long pedicel, sepals ovate; disc 1–1.3 mm high; ovary is ovoid, 2.5–4 by 2–2.6 mm, densely hairy, light green; style and stigma thick, 0.3–0.5 mm long. Fruit is oblong-ellipsoid, longitudinally 3-grooved, 3.2–5.3 by 2.2–4.5 cm, glabrous, pendant, turning from green to red to dark brown (to black), when ripe with a yellowish endocarp and containing up to 3 seeds. Seeds are oblong 3.2–3.6 by 1.4–2.2 cm, shining, brown-grey to dark brown and smooth (Plates 3–5).

Nutritive/Medicinal Properties

Pra seed flour was found to contain high amounts of protein (16.10%), carbohydrate (25.36%) and fat (36.49%) (Choohahirun 2010). The protein content was found to be relatively high when compared to those reported for hazelnut (14%), pecan (9%) and walnut (6%) but lower than the value reported for almond (21%). Pra seed flour contained 6.66% saturated fatty acids, 29.83% unsaturated fatty acids but trans fat was not detected. Palmitic acid (4.85%) was the major saturated fatty acid, while oleic acid (12.54%) followed by linoleic acid (12.01%) were the major

Plate 1 Perah foliage

Plate 2 Close-up of perah leaves

Plate 3 Perah trunk

Plate 4 Close-up of perah seeds

unsaturated fatty acid. Additionally, the flour had considerable amount of α-linolenic acid (3.44%), the principal omega-3 essential fatty acid, which was higher than that of other nuts such as hazelnut (0.09%), macadamia (0.21%) and almond (none) but comparatively lower than walnut (9.08%). the ideal intake ratio of omega-6/omega-3 was between 1:1 and 4:1. The value of omega-6/omega-3 ratio for pra seed flour was approxi-

Plate 5 Perah seeds with hard testa removed

mately 3.5:1;. The nutritive value especially the high protein content of pra seed flour suggested that it may find use in food formulations.

Both oleic acid (34.55%) and linoleic acid (31.76%) were detected as the dominant fatty acids while palmitic acid and stearic acid were the saturated fatty acids in the perah seed oil (Yong and Salimon 2006). Unlike most seed oils, perah seed oil appeared to be containing α-linoleneic acid (16.10%) as part of five major fatty acids in the lipid fraction. Monounsaturated triacylglycerol (TAG), palmitodilinolein (PPL) and polyunsaturated TAGs of α-linolenoyl-dioleoylglycerols (LnOO) and PLL were the major TAGs found in perah seed oil. Outcome from analyses showed the prospective potential of perah seed oil as a nutritive seed oil to be developed in the future.

The seeds were reported to contain cyanogenic glycosides such as amygdalin which was also found in leaves. Fresh leaves contained 30 ppm of amygdalin, while fresh seeds contained much more amygdalin, 660 ppm, equivalent to a small amount of HCN, 0.005 ppm (Ngamriabsakul and Kommen 2009). Cooked and later fermented seeds had considerably less amygdalin than the fresh ones, 100 ppm and 25 ppm, respectively. The results showed that heat (boiling) and fermentation could reduce the amount of amygdalin in the seeds. The leaves were found to contain other cyanogenic glycosides: linamarin and lotaustralin (Ling et al. 2006).

The following compounds were isolated from the leaves of *Elateriospermum tapos*: two taraxerane triterpenes, 2,3-seco-taraxer-14-ene-2,3,28-trioic acid 2,3-dimethyl ester (1) and 2,

3-seco-taraxer-14-ene-2,3,28-trioic acid 3-methyl ester (2), triterpenes, hopenol B and aleuritolic acid, and five flavonoids, putraflavone, kaempferol, sequoiaflavone, amentoflavone, and ginkgetin, were isolated from the leaves (Pattamadilok and Suttisri 2008). The stem extract yielded a cleistanthane diterpene, 2,3-seco-sonderianol (3), three triterpenes, lupeol, lupeol acetate, and 3-acetylaleuritolic acid, and three diterpenes, yucalexin B-22, yucalexin P-15, and yucalexin P-17. Compound 1 was cytotoxic against NCI-H187 and BC cell lines and also showed in-vitro antimycobacterial activity against *Mycobacterium tuberculosis.*

The acetates and palmitates of β-amyrin and germanicol and the acetates of ψ-taraxasterol and lupeol were isolated from *Elateriospermum tapos* bark (Chow and Quon 1970).

In Sumatra, the latex is used to cover dirty wounds, because it dries quickly. In Sarawak, the Bidayuh apply fresh latex once daily to crack wounds on the soles of their bare feet.

Other Uses

A tree of ornamental value. The tree is cultivated as an ornamental plant because of its reddish pink foliage during a leaf flush. Its flowering indicates the start of the rice season. The fermented seed paste is also used as fish bait. The seed oil is also used as lamp oil. The seeds make nice toys for children; they are used as toy beetles or threaded together in a game called 'conquerors'. The latex is also used to polish blowpipes to a glossy dark sheen. The timber is usually considered as excellent. It is very hard and heavy with straight or shallowly interlocked grain and moderately fine and even texture. The sapwood is white, the heartwood is dark brown with a red tinge and paler stripes and not very durable but easily impregnated with preservative. The wood is used for making handles of rubber tapping knives and for medium to heavy construction that is not in contact with the ground or exposed to termite attack unless treated with preservatives. The wood is also used as firewood.

Comments

E. tapos is the sole member of its genus *Elateriospermum* and tribe Elateriospermeae.

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Hevea brasiliensis

Scientific Name

***Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg.**

Synonyms

Hevea brasiliensis f. *acreana* (Ule) Ducke, *Hevea brasiliensis* f. *angustifolia* (Ule ex Huber) Ule, *Hevea brasiliensis* f. *latifolia* (Ule ex Huber) Ule, *Hevea brasiliensis* f. *randiana* (Huber) Ducke, *Hevea brasiliensis* monstr. *granthamii* Barth, *Hevea brasiliensis* var. *acreana* Ule, *Hevea brasiliensis* var. *angustifolia* Ule ex Huber, *Hevea brasiliensis* var. *janeirensis* (Müll. Arg.) Pax, *Hevea brasiliensis* var. *latifolia* Ule ex Huber, *Hevea brasiliensis* var. *randiana* (Huber) Pax, *Hevea brasiliensis* var. *stylosa* Huber, *Hevea camargoana* Pires, *Hevea granthamii* Bartlett, *Hevea janeirensis* Müll. Arg., *Hevea randiana* Huber, *Hevea sieberi* Warb., *Siphonia brasiliensis* Willd. ex A. Juss. (basionym), *Siphonia janeirensis* (Müll. Arg.) O.F. Cook, *Siphonia ridleyana* O.F. Cook

Family

Euphorbiaceae

Common/English Names

Brazilian Rubber Tree, Caoutchouc Tree, Hevea, Para Rubber, Pará Rubber Tree, Parawood, Rubber, Rubber Tree

Vernacular Names

Amharic: Yegoma Zaf;
Brazil: Cau-Chu, Hévea, Seringa, Seringueira;
Burmese: Kyetpaung;
Central America: Caucho Do Para;
Chinese: Guo Yang, Xiang Jiao Shu;
Czech: Kaučukovník Brazilský;
Danish: Paragummitræ;
Dutch: Kaoutchoucboom;
Fiji: Rapa;
French: Arbre De Para, Arbre Du Para, Caoutchouc, Hévéa, Hévéa Du Brasil, Hévé Du Brasil;
German: Brasilianischer Federharzbaum, Hevea, Kautschukbaum Von Javita, Parakautschukbaum;
Indonesia: Karet (Punan Malinau, East Kalimantan), Kayu Para', Fara (Lundaye, East Kalimantan), Kayo Tepee, Kata'ang (Merap, East Kalimantan), Tegei Fei (Kunyak Uma', East Kalimantan), Para (Sumatra), Karet Kipia, Cautchu (Java); Getah (Malay);
Italian: Evea;

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Khmer: Kausuu;
Laotian: Jaang;
Malaysia: Fatok Para (Bidayuh, Sabah), Getah, Getah Para, Katoh;
Peru: Caucho, Jebe, Siringa;
Philippines: Jaang Phara (Tagalog);
Portuguese: Seringueira;
Slovaščina: Kavčuk;
Spanish: Árbol Del Caucho, Caucho, Cauchotero De Pará, Hule, Jebe, Siringa;
Sri Lanka: Rubber (Sinhala), Irappar (Tamil);
Swahili: Mpira;
Thai: Katoh, Yang Phara;
Vietnamese: Cao Sau;

Origin/Distribution

Hevea brasiliensis is native to Brazil (parts of the Amazon Basin and Matto Grosso) and the Guianas. It is widely distributed on the southern side of the Amazon basin from Para state, Brazil, across Amazonas, Mato Grosso, Rondonia- and Acre states into Bolivia and Peru. There is also a small area west of Manaus in Brazil where it occurs to the north of the River Amazon. Efforts to cultivate the tree commercially on an wide scale in South America were unsatisfactory, because of the fungal disease known as South American leaf blight. Thus, most of the world's rubber comes from plantations in Indonesia, Thailand, Vietnam, Sri Lanka and Malaysia. Rubber is also grown in China, India and Papua New Guinea in Asia, as well as in Nigeria, Côte d'Ivoire, Cameroon, Liberia and Gabon in Africa.

Agroecology

Hevea brasiliensis is a crop of the humid lowland tropics between 6ºN and 6ºS from sea level to 200 m altitude. Rubber grows well at altitudes up to 1,000 m but will not fruit at 1,000 m. It forms part of the mixed canopy of the humid tropical rainforest, usually occurring at densities of 1–2 trees/ha but approaching 5 trees/ha in some areas of Acre and south-western Amazonas states (FAO 1986). Its native, natural habitat is characterised by humid and wet tropical rainforests. Rubber tree thrives in tropical areas with a well distributed annual rainfall of 2,000–4,000 mm without any marked dry season and with at least 100 rainy days per year, a temperature range of about 20–34°C with a monthly mean of 25–28°C, high atmospheric humidity of around 80%, bright sunshine amounting to about 2,000 h/year at the rate of 6 h/day throughout the year and absence of strong winds. However, as a result of intensive breeding programmes, rubber clones can be grown in locations with an annual rainfall of as little as 1,500 mm/year and a dry season of up to 3 months.

Although the rubber tree can be grown on a wide range of soil, it does best in areas with well-drained, deep, weathered soil consisting of light textured clay loams to loam soils with good nutrient levels, clay soils (oxisols and ultisols) with low nutrient levels, laterite, lateritic types, sedimentary types, non-lateritic red or alluvial soils with pH 4.0–5.5.

Edible Plant Parts and Uses

The endosperm of rubber seeds are edible after dehiscence from the fruit and detoxication by prolonged cooking or boiling (Schultes 1977; FAO 1986). Boiled and drained rubber seeds are eaten by indigenous people in the Amazon basin of South America (Schultes 1977; Njwe et al. 1990) without adverse effects. it is only the Indians of north-western Amazonia who value these seeds. In other parts of the region they are only consumed in emergencies. The boiled seeds are also eaten in East Kalimantan, Indonesia. After preparation the endosperm may be somewhat sweetish and has an agreeable flavour and odour. According to Schultes (1977) it may be eaten with fish, dried and conserved for later use or made into bread. It is also used as a meal eaten with meat or poultry.

Botany

Hevea brasiliensis is a deciduous, monoecious tree, typically 15–30 m tall in cultivation (Plate 1), with a leafy crown and smooth, greyish-brown, cylindrical trunk which yields a white latex when wounded (Plate 2). The leaves are formed in spirals on 3–23 cm long petioles and with three distinct, glabrous, elliptic or obovate leaflets 5–23.5 by 2.2–8.8 cm (Plate 3), reclinate with acuminate to cuspidate apex and tapering base and 14–27 nerves. Leaflets are brownish- bronze when young turning green with age and are borne on 5–10 mm long petiolules. The flowers are small, apetalous, greenish-yellow, sweetly-scented and formed in open, branched axillary panicles with bracts, 5–8 mm by 2.4 mm and peduncle 1–4.6 cm long. Staminate flowers are 4.5–5 mm across, with 5-lobed tomentose calyx, 5–7.5 mm high, 10 stamens in 2 layers and a short pistillode. Pistillate flowers are 5–5.6 mm in diameter with similar 5-lobed calyx and a hairy ovary and short 0.2 mm stigma. Fruit is a subglobose, 3-lobed, exploding dehiscent capsule (Plate 4), green unripe and brown when ripe, 4–5 by 3.2–4.8 cm, wall 3–4 mm thick, with 0.6–2.5 cm long pedicel and 25–32 mm long column. Seeds are oblong, mottled brown, 2.3–2.6 cm long by 1.9–2.1 cm wide by 1.4–1.6 cm thick (Plates 3–6).

Plate 1 Tree habit in a plantation

Plate 2 Tapping of rubber latex

Plate 3 Juvenile, brownish-bronze juvenile and young leaves with 3 obovate leaflets

Plate 4 Rubber seeds

Plate 5 Woody fruit capsule and seeds

Plate 6 Rubber seeds and processed, corrugated rubber sheet

Nutritive/Medicinal Properties

Numerous studies have shown that rubber seeds have potential as unconventional human food and as animal feed. Achinewhu, (1986) reported that rubber seeds had a protein content of 182 g/kg (dry weight basis (dwb); and in comparison to soya bean protein rubber seeds were lower in lysine, but higher in cystine and methionine. The fat content (ether extract) was 218 g/kg dwb; 81% of the fatty acids were unsaturated. Total carbohydrate content was 494 g/kg dwb while the methanol-soluble carbohydrate content was 136·8 g/kg dwb with sucrose (65%) predominant. In addition, in descending concentration, galactose, an unknown sugar, fructose, two other unknown sugars, maltose and glucose were present.

The average composition of the seed kernel was determined to be (dry matter basis) 21.5% crude protein, 50.2% crude fat, 6.5% crude fibre, 3.6% ash and 18.2% carbohydrates (Ravindran and Ravindran 1988). The amino acid profile, when compared with the NAS/NRC (National Academy of Science/ National Research Council, USA) reference protein pattern, revealed deficiencies of lysine, isoleucine and threonine. The seed kernels contained reasonable amounts of trace minerals, but were poor sources of Ca and P. In a more recent study, the proximate nutrient analysis of rubber seeds per 100 g showed moisture content of 3.99%, protein content of 17.41 g, fat content of 68.53 g and ash content of 3.08 g, calcium 85 mg, iron 1 mg, magnesium 0.93 mg, free fatty acid 4.4% (Eka et al. 2010). Amino acid profile of rubber seed was found to be characterised by the following expressed in g/100 g protein: essential amino acids – threonine 3.72, valine 7.08 g, methionine 1.37 g, lysine 4.26 g, isoleucine 3.28 g, leucine 6.81 g, phenyalanine 4.88 g; non-essential amino acids – aspartic acid 11.18 g, serine 5.89 g, glutamic acid 16.13 g, glycine 5.14 g, histidine 2.95 g, arginine 12.45 g, alanine 4.71 g, proline 6.77 g, cysteine 0.78 g, tyrosine 2.88 g (Eka et al. 2010). Amino acid in rubber seed was found to be high in glutamic acid (16.13%) and low in cysteine (0.78%), both being non-essential acids. The fatty acid composition of Malaysian rubber seed oil was found to be characterised by oleic acid (22.95) and linoleic acid (37.28) as the dominant fatty acids while palmitic acid and stearic acid were the saturated fatty acids found in the oil (Abdullah and Salimon 2009). It appeared to have linolenic acid (19.22) as one of the five major fatty acids in the lipid fraction. Monounsaturated triacylglycerol, PPL and polyunsaturated triacylglycerols of LnLnL and LnOO were the major triacylglycerols found.

Crude protein content of rubber seed and its products varied from 11.5% in rubber seeds to 27.4% in commercial decorticated rubber seed oil meal (Narahi and Kothandaraman 1984). The oil content of the rubber seeds and kernels was 24.0 and 40.1%, respectively. The available carbohydrate content of rubber seed and its products

ranged from 6.3% in rubber seeds to 15.9% in commercial decorticated rubber seed oil meal; these values may be compared with the value of 59.0% for yellow maize. Both undecorticated and decorticated rubber seed oil meals appeared to be deficient in sulphur-containing amino acids and lysine. The gross protein value of undecorticated and decorticated rubber seed oil meals and peanut oil meal was estimated to be 43.6, 47.0 and 49.7, respectively. Both undecorticated and decorticated rubber seed oils were rich in oleic and stearic acids, but relatively poor in poly-unsaturated fatty acids, compared with peanut oil.

Despite its potential as a source of protein, fresh rubber seed was found to contain a toxic factor, cyanogenetic glucoside (186 mg/kg). There had also been reports that fresh rubber seeds and its kernel contained about 63.8–74.9 mg of hydrogen cyanide (HCN) per 100 g (George et al. 2000). Fresh seed kernel samples was reported to contain toxic levels of HCN (164 mg/100 g dry weight), but most of the cyanide was eliminated by storage and cooking (Ravindran and Ravindran 1988). Storage at room temperature for a minimum period of 2 months was shown to be effective in reducing the hydrogen cyanide (HCN) content of rubber seeds (Narahari and Kothandaraman 1983). Studies by Ukpebor et al. (2007) determined that treating the rubber seed cake (RSC) with *Pleurotus tuberregium* mushroom mycelium yielded about 81% reduction in the total cyanogens content after 96 h at room temperature. The initial cyanide concentration of 500 ppm in the freshly obtained rubber seed cake was reduced to a level of 5 ppm for the undefatted RSC and from 300 ppm to 4 ppm for the defatted RSC. The values obtained for the treated RSC were found to be below the limit of 10 ppm as set by FAO/WHO regulatory bodies. The proximate analysis after fermentation with the mushroom mycelium revealed that the protein content of the RSC was enhanced significantly from 29.36% to a value of 39.27% further indicating its use as feed for livestock. However, the relatively high content of phytate P (37.5% of total P) in the seed kernel may be expected to further aggravate the problem of low P and to cause severe Ca/P imbalance (Ravindran and Ravindran 1988). No antitryptic activity or tannins could be detected in the samples studied. Boiled and drained rubber seeds were reported to be eaten by Indians in the Amazon Valley of South America (Njwe et al. 1988) without adverse effects. They were also reported to be eaten in east Kalimantan, Indonesia (Munawaroh and Purwanto 2009).

FAME analysis indicated that rubber seed oil to be high in oleic, linoleic and linolenic acid (Eka et al. 2010). The fuel potential of rubber seed (585.41 kJ/kg) was found to be in reasonable accord with ASTM. According to chemical composition of rubber seed, it could be considered as good sources for human food, animal feed and biofuel (Eka et al. 2010).

In *Hevea* leaves only one β-glucosidase was detectable (Selmar et al. 1987). As it is responsible for the cleavage of all β-glucosides and β-galactosides in *Hevea* leaf tissue, including the cyanogenic glucoside linamarin, the enzyme is therefore referred to as a β-glycosidase instead of the term β-glucosidase. This β-glycosidase was found to have a broad substrate spectrum and to occur in multiple forms. *Hevea* species was found to contain high amounts of cyanogenic glucosides from which cyanide is released when the plant is damaged (Kongsawadworakul et al. 2009). In *H. brasiliensis,* the cyanogenic glucosides mainly consisted of the monoglucoside linamarin (synthesized in the leaves), and its diglucoside transport-form, linustatin. The latex possessed all the enzymes (β-D-diglucosidase, linamarase and β-cyanoalanine synthase) necessary to metabolize cyanogenic glucosides to generate non-cyanogenic compounds, such as asparagine.

Published information on the few pharmacological properties of *Hevea brasiliensis* latex include:

Wound Healing Activity

The serum fraction of natural latex of the rubber tree was found to show distinct angiogenic effect and it was effective in enhancing vascular permeability (Mendonça et al. 2010). In dermal ulcers, this latex serum material significantly accelerated wound healing. This activity was lost when the serum fraction was boiled and treated with

proteases. The results obtained were in accordance with the enhancement of wound healing observed in clinical trials conducted with a biomembrane prepared with the same natural rubber latex. Increases in vascular permeability and angiogenesis are crucial events to wound repair, tumoral growth and revascularization of tissues submitted to ischemia. An increased vascular permeability allows a variety of cytokines and growth factors to reach the damaged tissue.

Osteogenic Effect

Issa et al. (2010) evaluated the osteogenic potential of two proteins, recombinant human bone morphogenetic protein-2 (rhBMP-2) and a protein, P-1, extracted from natural latex (*Hevea brasiliensis*) in wistar rats, and compared their effects on bone defects when combined with a carrier or a collagen gelatin. They found that rhBMP-2 allowed greater new bone formation than the natural latex P-1 protein and this process was more effective when the bone defect was covered with collagen gelatin.

Allergy Problem

Allergy to natural rubber latex (NRL) results from exposure to proteins derived from *Hevea brasiliensis.* Such allergy had been reported in certain occupational and other high-risk groups with frequent exposure to NRL products that included health care workers (HCWs), workers in the latex industry, children with spina bifida, and atopic individuals (Sussman et al. 2002). Thirteen proteins of natural rubber latex (*Hevea brasiliensis*) known to bind human IgE had been isolated and characterized as Hev b allergens (Bernstein et al. 2003).

Other Uses

Hevea brasiliensis is most important as the principal source of natural rubber. Natural rubber is derived from the white latex present in the bark and has an infinite range of uses. Because of its elasticity, resilience, water resistance, durability and toughness, natural rubber from rubber latex is the basic constituent of more than a thousand products used in the transportation, industrial, consumer, hygienic and medical sectors (UNCTAD Secretariat 2007). The latex is a renewable resource that can be sustainably tapped without harming the tree. Of the major end-use markets for rubber, transportation is by far the largest single sector, with tyres and tyre products (such as inner tubes, automotive belts, etc.) accounting alone for over 50% of natural rubber utilisation. Truck and bus tires would represent the largest single outlet for natural rubber, followed by automobile tires. General rubber goods for commercial and industrial use account for the balance. These non-tyre rubber items include industrial products (for example, transmission and elevator belts, castors, hoses and tubes, industrial lining, packing and sealing devices, automotive mats, plates, automotive door linings, bridge bearings, and seismic materials for buildings); consumer products (like golf or football balls and other recreational and sports goods, boots, balloons, erasers, footwear, mats, rubber foam mattresses and pillows and other apparel); and articles for use in the medical and health sector (notably, condoms, intra-uterine devices, blood bags, syringes, implantable devices, catheters and surgical gloves). Latex articles (typically condoms, gloves, threads, adhesives, and moulded foams) could be included in different categories in terms of end-use. Natural rubber is more suitable than synthetic rubber for the tyres of aircraft and space shuttles.

The wood from this tree, referred to as parawood or rubberwood, is used in the manufacture of furniture, wooden toys, wooden boxes, etc. It is valued for its dense grain, minimal shrinkage, attractive color and acceptance of different finishes. It is also prized as an "environmentally friendly" wood, as it makes use of trees that have been cut at the end of their latex-producing cycle. When processed for cellulose it has characteristics similar to those of *Eucalyptus* spp.

Rubber seeds yield an oil that can be used in making paints and soaps. Rubber seed oil (RSO)

and its derivatives, heated rubber seed oil (HRSO) and alkyd resins were found to have potential to be used as binders in air drying solvent and water-borne coatings (Aigbodion and Pillai 2000).

Various studies supports the production of biodiesel from unrefined rubber seed oil as a viable alternative to the diesel fuel (Ikwuagwu et al. 2000; Ramadhas et al. 2005; Eka et al. 2010). Eka et al. (2010) reported that the derived fuel potential of rubber seed oil is 585.41 kJ/kg. Almost all vegetable oils can be directly mixed with diesel oil. Ramadhas et al. (2005) found rubber seed oil to be a promising alternative fuel source for compression ignition engines. The tested properties of methyl esters of rubber seed oil are found to be in reasonable accord with ASTM (American Society for Testing and Material) 6,751 (36,500 kJ/kg) (Ramadhas et al. 2004). According to Ikwuagwu, et al. (2000), the methyl ester of rubber seed oil has relatively closer fuel properties to diesel fuel compared to other oil seeds which include soybean, linseed and sunflower oils.

Numerous studies have shown that rubber seed meal has potential as animal feed. The press cake residues after oil extraction serves as feed for animals or is used as fertilizer.

The press cake residues after oil extraction serves as feed for animals or is used as fertilizer. This could be attributed to its the chemical composition and nutritive content of rubber seed kernels. Since it is well known that protein sources are the main constraint for the improvement of animal production in many tropical regions of the world, the seed with 11–25% crude protein is a potential protein supplement for live stock (Eka et al. 2010). Rubber seed is an important by-product of rubber cultivation in many tropical countries, and is often included as a component of supplements fed to ruminants. It has a high content of semidrying oil which may be used in the paint industry, leaving the press cake as a potential source of high-protein food for cattle or sheep, but heat treatment and storage are required to reduce the level of hydrocyanic acid (HCN). Earlier workers used rubber seed as a feed supplements for pig (Babatunde et al. 1990), for sheep in Cameroon (Njwe et al. 1990) and as a diet for broilers in Malaysia (Yeong and Syed 1979). Although rubber seed meal protein is of poorer quality than soybean meal protein for growing pigs, at least 10% of dietary protein can be provided by rubber seed meal without adversely affecting growth and N utilization (Babatunde et al. 1990). Although rubber seed has higher lysine, phenylalanine and valine than maize; both rubber seed meal or maize could not provide the total amino acids required by poultry chicken and may be used only up to a certain percentage of the feed (Eka et al. 2010). Ong and Yeong (1977) reported a reduction in growth when pigs were fed diets containing more than 20% of the meal. Devendra (1983) also considered 20% as optimum.

Comments

Rubber clones are usually propagated by bud-grafting onto seedling rootstocks grown from seeds.

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Ricinus communis

Scientific Name

***Ricinus communis* L.**

Synonyms

Cataputia major Ludw., Cataputia minor Ludw., *Croton spinosus* L., *Ricinus africanus* Willd., *Ricinus angulatus* Thunb., *Ricinus armatus* Andr., *Ricinus atropurpureus* Pax & K. Hoffm., *Ricinus badius* Rchb., *Ricinus borboniensis* Pax & K. Hoffm., *Ricinus cambodgensis* Benary, *Ricinus communis* f. *americanus* Müll.Arg., *Ricinus communis* f. *argentatus* T. Carvalho, *Ricinus communis* f. *argyratus* T. Carvalho, *Ricinus communis* f. *atratus* T. Carvalho, *Ricinus communis* f. *atrobrunneatus* T. Carvalho, *Ricinus communis* f. *atrofulvatus* T. Carvalho, *Ricinus communis* f. *atrofuscatus* T. Carvalho, *Ricinus communis* f. *atrophoeniceus* T. Carvalho, *Ricinus communis* f. *atropunicatus* T. Carvalho, *Ricinus communis* f. *atropurpureatus* T. Carvalho, *Ricinus communis* f. *avellanatus* T. Carvalho, *Ricinus communis* f. *blumeanus* Müll.Arg., *Ricinus communis* f. *canatus* T. Carvalho, *Ricinus communis* f. *canescens* T. Carvalho, *Ricinus communis* f. *carneatus* T. Carvalho, *Ricinus communis* f. *cervatus* T. Carvalho, *Ricinus communis* f. *cinerascens* T. Carvalho, *Ricinus communis* f. *cinereatus* T. Carvalho, *Ricinus communis* f. *denudatus* Müll.Arg., *Ricinus communis* f. *epiglaucus* Müll.Arg., *Ricinus communis* f. *erythrocladus* Müll.Arg., *Ricinus communis* f. *exiguus* T. Carvalho, *Ricinus communis* f. *fulvatus* T. Carvalho, *Ricinus communis* f. *fumatus* T. Carvalho, *Ricinus communis* f. *fuscatus* T. Carvalho, *Ricinus communis* f. *gilvus* T. Carvalho, *Ricinus communis* f. *glaucus* (Hoffmanns.) Müll. Arg., *Ricinus communis* f. *gracilis* Müll. Arg., *Ricinus communis* f. *guttatus* T. Carvalho, *Ricinus communis* f. *hybridus* (Besser) Müll. Arg., *Ricinus communis* f. *incarnatus* T. Carvalho, *Ricinus communis* f. *inermis* (Mill.) Müll. Arg., *Ricinus communis* f. *intermedius* Müll. Arg., *Ricinus communis* f. *laevis* (DC.) Müll. Arg., *Ricinus communis* f. *macrophyllus* Müll. Arg., *Ricinus communis* f. *maculatus* T. Carvalho, *Ricinus communis* f. *marmoreatus* T. Carvalho, *Ricinus communis* f. *murinatus* T. Carvalho, *Ricinus communis* f. *nigellus* T. Carvalho, *Ricinus communis* f. *nigrescens* T. Carvalho, *Ricinus communis* f. *niveatus* T. Carvalho, *Ricinus communis* f. *oblongus* T. Carvalho, *Ricinus communis* f. *obscurus* T. Carvalho, *Ricinus communis* f. *oligacanthus* Müll.Arg., *Ricinus communis* f. *ostrinatus* T. Carvalho, *Ricinus communis* f. *pardalinus* T. Carvalho, *Ricinus communis* f. *picturatus* T. Carvalho, *Ricinus communis* f. *plumbeatus* T. Carvalho, *Ricinus communis* f. *pruinosus* Müll. Arg., *Ricinus communis* f. *purpurascens* (Bertol.) Pax, *Ricinus communis* f. *pullatus* T. Carvalho, *Ricinus communis* f. *punctatus* T. Carvalho, *Ricinus communis* f. *punctulatus* T. Carvalho, *Ricinus communis* f. *punicans* T. Carvalho, *Ricinus communis* f. *radiatus* T. Carvalho, *Ricinus communis* f. *rufescens* T. Carvalho, *Ricinus*

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communis f. *russatus* T. Carvalho, *Ricinus communis* f. *scaber* (Bertol. ex Moris) Müll.Arg., *Ricinus communis* f. *scriptus* T. Carvalho, *Ricinus communis* f. *sordidus* T. Carvalho, *Ricinus communis* f. *stigmosus* T. Carvalho, *Ricinus communis* f. *striatus* T. Carvalho, *Ricinus communis* f. *subpurpurascens* Müll.Arg., *Ricinus communis* f. *subrotundus* T. Carvalho, *Ricinus communis* f. *subviridus* Müll.Arg., *Ricinus communis* f. *sulcatus* T. Carvalho, *Ricinus communis* f. *tigrinus* T. Carvalho, *Ricinus communis* f. *umbrinus* T. Carvalho, *Ricinus communis* f. *venosus* T. Carvalho, *Ricinus communis* f. *vinatus* T. Carvalho, *Ricinus communis* f. *viridis* (Willd.) Müll.Arg., *Ricinus communis* f. *zebrinus* T. Carvalho, *Ricinus communis* f. *zollingeri* Müll. Arg., *Ricinus communis* f. *zonatus* T. Carvalho, *Ricinus communis* proles *persicus* Popova, *Ricinus communis* subsp. *africanus* (Mill.) Nyman, *Ricinus communis* subsp. *indicus* Popova & Moshkin, *Ricinus communis* subsp. *manshuricus* V.Bork., *Ricinus communis* subsp. *mexicanus* Popova, *Ricinus communis* subsp. *persicus* Popova, *Ricinus communis* subsp. *ruderalis* Popova & Moshkin, *Ricinus communis* subsp. *sanguineus* Popova, *Ricinus communis* subsp. *scaber* (Bertol. ex Moris) Nyman, *Ricinus communis* subsp. *sinensis* Hiltebr., *Ricinus communis* subsp. *sinensis* Popova & Moshkin, *Ricinus communis* subsp. *zanzibarinus* Popova, *Ricinus communis* subvar. *almeidae* T. Carvalho, *Ricinus communis* subvar. *americanus* (Müll.Arg.) T. Carvalho, *Ricinus communis* subvar. *blumeanus* (Müll.Arg.) T. Carvalho, *Ricinus communis* subvar. *epruinosus* T. Carvalho, *Ricinus communis* subvar. *erythrocladus* (Müll. Arg.) T. Carvalho, *Ricinus communis* subvar. *glauceus* T. Carvalho, *Ricinus communis* subvar. *gracilis* (Müll.Arg.) T. Carvalho, *Ricinus communis* subvar. *griseus* T. Carvalho, *Ricinus communis* subvar. *macrophyllus* (Müll.Arg.) T. Carvalho, *Ricinus communis* subvar. *pruinosus* (Müll.Arg.) T. Carvalho, *Ricinus communis* subvar. *purpurascens* (Bertol.) T. Carvalho, *Ricinus communis* subvar. *roseus* T. Carvalho, *Ricinus communis* subvar. *rutilans* (Müll.Arg.) T. Carvalho, *Ricinus communis* subvar. *subviridus* (Müll.Arg.) T. Carvalho, *Ricinus communis* subvar. *violaceus* T. Carvalho, *Ricinus communis* subvar. *violeus* T. Carvalho, *Ricinus communis* subvar. *viridus* (Willd.) T. Carvalho, *Ricinus communis* var. *aegyptiaceus* (Popova) Moshkin, *Ricinus communis* var. *africanus* Müll.Arg., *Ricinus communis* var. *amblyocalyx* Müll.Arg., *Ricinus communis* var. *americanus* Müll.Arg., *Ricinus communis* var. *armatus* (Andr.) Müll. Arg., *Ricinus communis* var. *badius* (Rchb.) Müll. Arg., *Ricinus communis* var. *bailundensis* J.M. Coult., *Ricinus communis* var. *benguelensis* Müll. Arg., *Ricinus communis* var. *brasiliensis* Müll. Arg., *Ricinus communis* var. *brevinodis* Moshkin, *Ricinus communis* var. *caesius* Popova, *Ricinus communis* var. *genuinus* Müll.Arg nom. inval., *Ricinus communis* var. *glaucus* Popova & Moshkin, *Ricinus communis* var. *griseofolius* Moshkin, *Ricinus communis* var. *hybridus* (Besser) Müll.Arg., *Ricinus communis* var. *indehiscens* Moshkin, *Ricinus communis* var. *inermis* (Mill.) Pax & K. Hoffm., *Ricinus communis* var. *japonicus* Popova & Moshkin, *Ricinus communis* var. *leucocarpus* (Bertol.) Müll.Arg., *Ricinus communis* var. *lividus* (Jacq.) Müll.Arg., *Ricinus communis* var. *macrocarpus* T. Carvalho, *Ricinus communis* var. *macrophyllus* Müll.Arg., *Ricinus communis* var. *megalospermus* (Delile) Müll. Arg., *Ricinus communis* var. *mexicanus* (Popova) Moshkin, *Ricinus communis* var. *microcarpus* Müll.Arg., *Ricinus communis* var. *microspermus* Moshkin, *Ricinus communis* var. *minor* Steud., *Ricinus communis* var. *nanus* Moshkin, *Ricinus communis* var. *purpurascens* (Bertol.) Müll.Arg., *Ricinus communis* var. *reichenbachianus* Müll. Arg., *Ricinus communis* var. *rheedianus* Müll. Arg., *Ricinus communis* var. *roseus* Popova & Moshkin, *Ricinus communis* var. *rugosus* Müll. Arg., *Ricinus communis* f. *rutilans* Müll.Arg., *Ricinus communis* var. *sanguineus* Baill., *Ricinus communis* var. *speciosus* (Burm.f.) Müll. Arg., *Ricinus communis* var. *spontaneus* Popova & Moshkin, *Ricinus communis* var. *subpurpurascens* Müll.Arg., *Ricinus communis var. typicus* Fiori. nom. inval., *Ricinus communis* var. *vasconcellosii* T. Carvalho, *Ricinus communis* var. *violaceocaulis* Moshkin, *Ricinus communis* var. *virens* Popova, *Ricinus communis* var. *viridis* Popova & Moshkin, *Ricinus communis* var. *undulatus* (Besser) Müll.Arg., *Ricinus compactus* Huber, *Ricinus digitatus* Noronha, *Ricinus europaeus* T.

Nees, *Ricinus gibsonii* auct., *Ricinus giganteus* Pax & K. Hoffm., *Ricinus glaucus* Hoffmanns., *Ricinus hybridus* Besser, *Ricinus inermis* Mill., *Ricinus japonicus* Thunb., *Ricinus krappa* Steud., *Ricinus laevis* DC., *Ricinus leucocarpus* Bertol., *Ricinus lividus* Jacq., *Ricinus macrocarpus* Popova, *Ricinus macrocarpus* proles *indicus* Popova, *Ricinus macrocarpus* proles *japonicus* Popova, *Ricinus macrocarpus* proles *sanguineus* Popova, *Ricinus macrocarpus* var. *nudus* Popova, *Ricinus macrophyllus* Bertol., *Ricinus medicus* Forssk., *Ricinus medius* J.F. Gmel., *Ricinus megalosperma* Delile, *Ricinus messeniacus* Heldr., *Ricinus metallicus* Pax & K. Hoffm., *Ricinus microcarpus* Popova, *Ricinus microcarpus* proles *aegypticus* Popova, *Ricinus microcarpus* proles *indostanicus* Popova, *Ricinus microcarpus* var. *atrovirens* Popova, *Ricinus microcarpus* var. *spontaneus* Popova, *Ricinus minor* Mill., *Ricinus nanus* Bald., *Ricinus obermannii* Groenl., *Ricinus peltatus* Noronha, *Ricinus perennis* Steud., *Ricinus persicus* Popova, *Ricinus purpurascens* Bertol., *Ricinus ruber* Miq., *Ricinus rugosus* Mill., *Ricinus rutilans* Müll.Arg., *Ricinus sanguineus* Groenl., *Ricinus scaber* Bertol. ex Moris, *Ricinus speciosus* Burm.f., *Ricinus spectabilis* Blume, *Ricinus tunisensis* Desf., *Ricinus undulatus* Besser, *Ricinus urens* Mill., *Ricinus viridis* Willd., *Ricinus vulgaris* Mill., *Ricinus zanzibarensis* auct., *Ricinus zanzibaricus* Popova.

Family

Euphorbiaceae

Common/English Names

Castor, Castor Bean, Castorbean, Castor-Bean Tree, Castor Oil Plant, Palma Christi

Vernacular Names

Afrikaans: Kaster Boon, Kasterolieboom;
Arabic: Bazrul-Khirvaa, Bazrul-Khirvaaaus-Saghir, Khirva, Khirvaa, Khirvaaaus-Saghir, Khirwa', Shajratul-Khirvaa, Shajratul-Khirvaaaus-Saghir;
Aragonese: Mosquitera, Rezino;
Australia: Tiarili (Abor.);
Bangladesh: Erando, Veranda;
Brazil: Carrapateira, Carrapateiro, Mamona, Mamoneira, Palma Christi, Rícino;
Burmese: Kesu, Kyekesu;
Canada: Févé Castor (French);
Catalan: Enfiter, Enfiter, Fesolera De Llum, Figuera Borda, Figuera De Ricí, Figuera Del Diable, Figuera Dels Talps, Figuera Infernal, Herba De Les Talpes, Herba De Talpas, Herba De Talpes, Herba De Talpos, Llagasta, Mugera, Mutxera, Renege, Ricí, Riciner, Rícino, Rissino;
Chamorro: Agaliya;
Chinese: Bi Ma, Bi Ma Zi, Ma Hong Liang;
Columbia: Catapucia Mayor, Higuerilla;
Cook Islands: Pākarāna, Pākarāni, Tuitui, Tuitui Papa'Ā, Tuitui Papa'Ā (Maori);
Costa Rica: Higuerilla;
Cuba: Higuereta;
Czech: Skočec Obecný;
Danish: Amerikansk Olieplante, Kristpalme, Oliepalme, Olieplante, Riccinus, Rizinus;
Dhivehi: Aamanaka;
Dutch: Wonderboom, Wonderolieboon;
Eastonian: Riitsinus;
El Salvador: Higuerillo;
Ethiopia: Gulo;
Euskera: Akain-Belar, Errizino, Errizinu;
Fijian: Belenivavalagi, Mbele Ni Vavalagi, Toto Ni Vavalagi, Totonivavalagi, Utouto;
Finnish: Risiini;
French: Grand Ricin, Ricin, Ricin Commun;
Galician: Bafureira, Carrapateira, Carrapateiro, Catapúcia, Catapúcia-Figueira-Do-Inferno, Erva Dos Carrapatos, Figueira Do Inferno, Mamona, Mamoneiro, Ricino;
German: Christuspalme, Gemeiner Wunderbaum, Hundsbaum, Kreuzbaum, Läusebaum, Palma Christi, Ricinusstrauch, Rizinus, Rizinusstaude, Rizinuspflanze, Rizinusstrauch, Wunderbaum;
Greece: Retsinoladia;
Hawaiian: Ka'Apehā, Kamakou, Koli, Lā'Au 'Aila, Pa'Aila;
Hebrew: Kikayon;
Hungarian: Csodafa, Ricinus;
India: Era-Gach, Eragoch (Assamese), Bheranda, Eradom, Eranda, Rerhi, Reri (Bengali), Kharanda (Garo), Aerand, Andi, Arand, Arand-Ke-Binj,

Arandi, Arandi-Ka-Per, Arandi-Ke-Binj, Arandka-Per, Arend, Chhoti-Arand, Chhoti-Arand-Ka-Per, Chhoti-Arand-Ke-Binj, Chhoti-Arandi, Chhoti-Arandi-Ka-Per, Chhoti-Arandi-Ke-Binj, Endi, Erand, Erandi, Erend, Ind, Irandia, Naudi, Rand (Hindu), Alambuda, Aralu, Arudalu, Audla, Avudala, Avudalu, Biliga Ondale, Chitta Haralu, Chittaralu, Chittuharalu, Cittuharalu, Eeranda, Eranda, Haralu, Haralenne, Karala, Manda, Oudla, Panchangula, Vardhamana (Kannada), Amandam, Avanacu, Avanak, Avanakka, Avanakkinkuru, Avanakku, Chittamanakku, Chittavanaku, Citavanakoo, Cittamanakku, Erandam, Gandharvahastakam, Gandharvvahastakam, Kotta, Pancangulam, Pandiavanak, Pandiyavanakku, Panjanagulam, Pantiyavanakku, Varddhamanam (Malayalam), Kege (Manipuri), Aerandi, Erand, Erandi, Erendi, Vhadli-Eramdo, Yarandicha (Marathi), Mutih (Mizoram), Mutih, Tindoko (Oriya), Amanda, Amangala, Bhanda, Chankuka, Chitrabija, Chitraka, Citra, Citrabija, Citraka, Dirghadantaka, Eranda, Erandah, Gandharavahasthah, Gandharvahasta, Gandharvahastaka, Gandharvahastakah, Hastikarna, Hastiparnaka, Ishta, Kanta, Ndataila, Oancangulah, Pancangula, Pancangulah, Pancangulavatari, Panchangula, Panchangulam, Panjangula, Raktaeranda, Rubu, Ruvuka, Shukla, Shulashatru, Suklah, Svehaprada, Taruna, Triputi, Triputiphala, Tuchhadru, Urubaka, Urubu, Urubuka, Usravuka, Uttanapatraka, Vardhamana, Vardhamanaka, Vatari, Vuka, Vyadambaka, Vyadatvaka, Vyaghradala, Vyaghrapuccha, Vyaghrapuchha, Yeranda (Sanskrit), Aamanakku, Aimmuki, Aimugi, Amanakkam Ceti, Amanakkam Chedi, Amanakkam-Chedi, Amanakkan-Kottai, Amanakkilai, Amanakku, Amanakku Ennai, Amanakku Ver, Amanakkuilai, Amanaku, Amankalam, Amantakam, Amantalam, Amantam, Amanukku-Muttu, Amirtam, Andagam, Antakam, Aratticceti, Arattitam, Aruvarulimuli, Asaram, Atalai, Atam, Atamanakku, Atamatakku, Ati, Attagam, Attakacceti, Attakam, Attamanam, Attikkarani, Attimanam, Attugam, Attukam, Attukamanakku, Attukameticceti, Cacamapari, Cacampari, Cancu, Caruci, Catticatamuli, Cattitarumuli, Cemmanakkati, Cemmanakkaticceti, Cempaimalinicceti, Centulamanakku, Centulamanakkucceti, Cevvali, Cevvamanakku, Chittamanakkan-Chedi, Chittmani, Cikanti, Cikanticceti, Cikantitam, Cirramanakkenney, Cirramanakku, Cirrerantam, Cirreranticceti, Cirunalikacceti, Cittaman, Cittamanam, Cittiram, Cittiramanakkucceti, Civappamanakku, Civappatalai, Civappatalaicceti, Civappi, Culaiccatturu, Culatavirutti, Cunnu, Curiyakanatavamanakku, Cutacenturi, Ekkalatevi, Eranam, Erandam, Erantam, Ilinkapentakatti, Iraiyamanakku, Irataverantam, Irattakam, Irenukamuli, Istam, Istayitacceti, Istayitam, Itimpam, Ittam, Itticam, Kanaipputu, Kanalakkini, Kanalakkinikari, Kantaruva, Kapanilatipanam, Katalam, Kentacatakam, Kottai, Kottaimuttu, Kumparittam, Makapattiri, Manam, Mantaki, Mantakicceti, Mantalam, Mantam, Matuvantapputu, Motanankamuli, Muttukkottaicceti, Nakakarnam, Narikamanakku, Narikamanakkucceti, Nattamanakku, Orantam, Pancamilevavatam, Pancankam, Pancankulam, Parankiyatalai, Parpatikacceti, Parpatikam, Peritaiyal, Sitta-Manakku, Sittamanaku, Taccattaru, Taittiyakikacceti, Taittiyakikam, Talarupakam, Talarupam, Tamincam, Tampincam, Tapincam, Tarunakamati, Tarunakamaticceti, Tarunam, Tatimantaram, Timitakutalacceti, Timitakutalam, Tipataili, Tiriputipalam, Tirkkapattirakam, Tirkkatantam, Tiruvalamuli, Tiruvalipputu, Tiruvatiraimuli, Tuccataru, Tuccattaru, Tuccatturu, Tuccitacceti, Tuccitam, Tutturam, Ucakam, Urppulam, Urucakam, Urupukam, Uruttirapattiram, Usapam, Vacanimuli, Valaippen, Varantalu, Varantaru, Varttamanam, Vataivari, Vataivaricceti, Vatanacanam, Vatari, Vatavairi, Vatavari, Vattamacceti, Vattamam, Viyakkiramam, Viyakkirapuccam, Viyakkiratalam, Viyatampakam, Vullak Unnay, Yatutaiyanputu (Tamil), Aamudamu, Aamudamu Chettu, Amadum, Amdi, Amidam, Amidamu, Amidapu, Amidum, Amuda, Amudala, Amudam, Amudamu, Amudapu, Amudapu Chettu, Amudapu-Vittulu, Chittaamudamu, Chittaamudapu Chettu, Chittamudamu, Chittamudapu, Cittamudamu, Eramudapu, Erandam, Erandamu, Erandthailam,

Erramuda,Erramudamu,Erramudapu,Malachintha Manakku, Peraamudamu, Peramudamu, Sittamindi, U, Yerramudapu (Telugu), Bedanjir, Bedanjir Arand, Bikh Erandi, Hab-Ul-As, Maghze Tukhm Arandi, Roghan Baid, Roghan Baid Anjir, Roghan Erand, Roghan Erandi, Roghan-I-Nilofer, Sharbat Hab-Ul-As (Urdu);

Indonesia: Padu Goa, Tai Bara Toko Lakai (Flores), Labu, Sebluk (Irian Jaya), Jarak, Jarak Kepjar, Jarak Leutik, Jrark Putih (Java), Jarak Cina (Kalimantan), Kaliki, Kalikiberitah (Madurese), Jarak (Malay), Dulang, Dluang Bajora, Gloah, Kaliki (Sumatra), Jarak, Jarak Jitun, Jarak Kaliki, Kaliki (Sundanese);

Iran: Karchak;

Italian: Fico D'inferno, Ricino;

Japanese: Casutaa Biin, Hima, Rikinusu, Rishin, Tougoma;

Korean: Ajukari, Pimaja;

Kurdish: Gerchek;

Majorcan: Caga Mutxo, Cagamuja, Cagamutxo, Herba Taupera, Ricí, Riciner;

Malagasy: Kimanga, Kinamena, Tanatanamanga;

Malaysia: Jarak, Jarak Besar (Peninsular), Dowar, Katimah (Sabah);

Maltese: Żejt Ir-Riegnu;

Marquesan: Pititu;

Mexico: Higuera Del Diablo, Higuera Infernal, Higuerilla, Higuerillo;

Nepalese: Aderi, Andel, Ander, Anderii, Andir;

Nicaragua: Higuera, Higueria;

Niuean: Tuitui, Tuitui Fua Ikiiki;

Norwegian: Oljeplante;

Palauan: Gelug, Maskerekur, Uluchula Skoki;

Papiamento: Karpata;

Papua New Guinea: Fayita (Okapa), Itumpa (Tairora), Ovomasuro (Biagi), Palawa-Palawa-I(L) (Gododala);

Paraguay: Higuera Del Diablo, Higuera Infernal;

Persian: Bedanjir, Bedanjire-Khurd, Darakhte-Bedanjir, Darakhte-Bedanjire-Khurd, Khirwa, Khora, Tukhme Bedanjir, Tukhme-Bedanjire-Khurd;

Peru: Higuierilla, Higuerillo Blanco, Higuerillo Rojo;

Philippines: Tangan-Tangan (Bikol), Katana (Bontok), Gatlaoua, Gatlawa (Ifugao), Katana (Ivatan), Taca-Taca, Taoa-Taoa, Taua-Taua, Taua-Taua Sina, Tawa-Tawa, Tawa-Tawa Sina (Iloko), Tañgan-Tañgan-Hawa (Sulu), Lansina, Liñgang-Sina, Tangan-Tangan, (Tagalog);

Poland: Rącznik, Rącznik Pospolity;

Portuguese: Bafureira,Carrapateira,Carrapateiro, Catapúcia, Catapucia Maior, Catapúcia-Figueira-Do-Inferno, Catapúcia-Maior, Erva Dos Carrapatos, Erva-Dos-Carrapatos, Figueira Do Diabo, Figueira Do Inferno, Herva Dos Carrapatos, Mammona, Mamona, Mamoneiro, Palma-Christi, Rícino, Ricino Mamona, Ricino Menor, Ricino Ordinario, Rizin, Tártago;

Puerto Rico: Higuereta;

Russian: Kastorka, Kleshchevina, Kleshchevina Obiknovennaia, Kotoroi Kastorka, Ritsin;

Samoan: Lama Pālagi, Lama Papalagi;

Slovaščina: Kloščevec, Ricinus;

Slovencina: Ricín Obyčajný;

Spanish: Alcherva, Árbol Del Demonio, Bafureura, Castaño De La India, Catapucia, Catapucia Mayor Catapucía Mayor, Catapúcia Mayor, Cataputia Mayor, Cherva, Croton, Grano Mayor De Reyes, Hiera Del Demonio, Higuera De Infierno, Higuera Del Demonio, Higuera Del Diablo, Higuera Del Infierno, Higuera Infernal, Higuereta, Higuereta Infernal, Higuerilla, Higuerillo, Kerva, Mamona, Mosquitera, Palma, Palma De Cristo, Palma-Christi, Palmacristi, Querva, Recino, Rejalgar, Ricino Rizno, Tártago De Venezuela (Castillian);

Sri Lanka: Endaru, Thel-Endaru (Sinhalese);

Swahili: Mbarika, Mbono Mdogo, Mnyonyo;

Swedish: Ricin, Ricinbuske;

Switzerland: Römische Bohne (German);

Tahitian: Tiairi Papa'A, Tiairi Popa'A;

Thailand: Lahung, Mahung;

Tibetan: Dur Byid, E Ra Nda, E Ra Nda Dmar Po, E Ram Nda, E Ram Nda, E-Ran;

Tongan: Lepo, Lepo Hina, Lepo Kula;

Tuamotuan: Tiairi;

Turkish: Hint Yağı Bitkisi;

Uruguay: Tártago Ricino;

Valencian: Figuera Borda, Figuera De Diable, Figuera Del Diable, Figuera Racinera, Figuera Resinera, Mochera, Mugera, Mugera Comun, Mugera Comuna, Muguera, Mutxera, Ricí;

Venezuela: Ricino, Tártago;

Vietnam: Thầu Dầu, Đu Đủ Tía;
Wallisian: Lepo.

Origin/Distribution

Castor bean is native to north-east tropical Africa. It was cultivated in Egypt some 6000 years ago and spread through the Mediterranean, the Middle East and India at an early date. It is now widely cultivated in most drier areas of the tropics and subtropics and in many warm sub-temperate areas.

Agroecology

Castor bean thrives in the tropical and warm temperate regions from 40°S to 52°N 40, from sea level to 1,500 m to a maximum of 2,000 m altitude at the equator. Mean day temperatures of 20–26°C with a minimum of 15°C and a maximum of 38°C are suitable for the plant. Temperatures of 40°C or higher are detrimental to seed production and frost are also detrimental. Suitable soil temperatures for germination reported are 10–18°C. The plant requires 140–180 days of warm temperatures in the growing season in order to produce good crops of seed. Being a long-day plant, castor s adaptable to a fairly wide photoperiodic range. A day length of 12–18 h is optimal and growth and development are reduced at a day length of 9 h. It prefers clear, sunny days with low humidity. Castor is drought tolerant because of its deep root system and can withstand dry arid climates, but also heavy rains and short flooding. The plant is reported to tolerate an annual precipitation in the range of 200–4,290 mm.

Castor bean is a hardy and fast growing, reaching heights of 12 m in the wild. In the wild, it is found in thickets and waste places, disturbed sites, river bed, sand banks, in flood outs associated with watercourses and along roadsides. It is much smaller and shorter when cultivated commercially or in villages or home gardens.

Castor bean prefers a sunny position and thrives best on well-drained, deep sandy loams with pH 5–6.5, although it will grow on almost any soil type from pH 4.5–8.3, as long as it is well drained and reasonably fertile. It is quite tolerant to salinity or alkalinity.

Edible Plant Parts and Uses

In Indonesia, the inflorescence and very young fruits are boiled and relished as lalab with rice (Ochse and Bakhuizen van den Brink 1980). The ripe seeds are also eaten after roasting. The Igbo in Nigeria prepare a traditional soup, *ogiri egusi,* from the fermented seeds. Mature leaves are dried and stored until winter when they are eaten as a vegetable in Korea; in Bengal, India, the young fruits are eaten (Maroyi 2007). However, some caution should be noted here as the fruits and seeds are extremely toxic and should not be eaten raw.

Castor seed can be processed to yield castor oil (35–55%) which is edible and can be used for cooking. Castor oil is processed by esterification of condensed castor oil fatty acids with polyglycerol to form polyglycerol polyricinoleate - or PGPR a powerful water-in-oil emulsifier which is used by the food industry in tin-greasing emulsions and as an emulsifier with lecithin in chocolate couverture and block chocolate (Wilson et al. 1998; James 1999), and in bakery and confectionery industry (James 1999). PGPR adds functionality to chocolate, bakery products, spreads, oils and fats by optimising flow properties, stabilising and improving emulsion, and reducing fat content of manufactured food products.

Botany

An erect, branching, evergreen, soft-woody shrub or small tree (2–5(−10)m tall with a deep tap root. Shoots glaucous, variously green , reddish or purplish. Stipules 1–3 cm long, connate. Leaves spirally arranged on 5–40 cm long petioles, lamina palmately 5–11-lobed, 30–50(−100) × 30–50(−100) cm, lobes sharply acuminate with serrate margins (Plates 1–3). Inflorescence erect terminal panicle to 40 cm.

Plate 1 Young green fruits from erect terminal inflorescence

Plate 2 Leaf with palmate lobes

Plate 3 Mature red fruits

Flowers unisexual, regular, short-pedicelled, calyx lobes 3–5, apetalous, yellowish green or shades of red. Male flowers towards the base of inflorescence, stamens numerous in fascicles, creamy, 7–8 mm long. Female flowers towards the apex of inflorescence, ovary, siperio-3-locules, styles 3 red or green with bifid stigmas. Fruit an ellipsoid to globose capsule, softly spiny, sometimes smooth, roughly 3-lobed, 1.5–2.5 cm long, green turning to red or purplish red and drying to brown, dehiscent (Plates 1–3). Seeds ellipsoid, 7–17 mm long, compressed, with a brittle, greyish, silvery or beige with mottled markings, shining seed coat and with distinct depressed-conical caruncle at the base.

Nutritive/Medicinal Properties

The nutrient composition of castor oil seeds used as a fermented product in the traditional soup in Nigeria was reported as follows per 100 g edible portion (CINE 2007): moisture 37.9 g, energy 337 kcal, protein 27.4 g, fat 18.9 g, carbohydrate 14.3 g, fibre 10.8 g, ash 1.2 g, Ca 833 mg, P 725 mg, Fe 24.6 mg and Zn 6.8 mg.

Castor bean seed and oil characteristics of castor varieties grown in different parts of India have been reported by Lakshminarayana et al. (1984) as follows: 100-seed weight, 15.2–30.2 g; 100-seed volume, 15.0–32.5 ml; kernel, 64–75%; oil, 46.0–51.8%; protein, 17.1–24.4%; crude fiber, 18.2–26.5%, and ash, 2.1–3.4%. Oil characteristics were: acid value, 1.0–2.9; saponification value, 176.2–183.7; iodine value, 81.4–88.1, and hydroxyl value, 159.2–167.1. Ricinoleic acid content varied from 87.4% to 90.4%. Lakshminarayana et al. (1982) reported the composition (wt %) of the fatty acids obtained by decomposition of castor oil fatty acid estolides and distillation to be: 16:0, 2.7%; 18:0, 2.6%%; 18:1, 5.2%; conjugated cis, trans (trans, cis)-18:2, 34.4%; conjugated cis, cis-18:2, 9.7%; conjugated trans ,trans-18:2, 3.9%; 9-cis,12-trans-18:2, 20.8%; 9-trans,12-cis-18:2, 2.3%; and 9-cis,-18:2, 18.4%.

The fatty acid composition of castor oil was reported to be: palmitic 0.8–1.1%, stearic 0.7–1.0%,

oleic acid 2–3.3%, linoleic 4.1–4.7%, linolenic 0.5–0.7%, C20 (mainly eicosenoic acid) 0.3–0.8%, ricinoleic acid (12-hydroxy-9-octadecenoic acid) 87.8–90.4% and dihydroxy stearic 0.6–1.1% (Binder et al. 1962). An acylglycerol containing four acyl chains, (12-ricinoleoylricinoleoyl) diricinoleoylglycerol (RRRR), was positively identified in castor oil using electrospray ionization tandem mass spectrometry (ESI-MS/MS) (Lin et al. 2006).

Other Phytochemicals – in Seeds and Leaves

Five low-molecular weight phenolic compounds namely p-coumaric acid, ferulic acid, o-coumaric acids, syringic, and cinnamic acids, were isolated from defatted castor seed powder (Chakravartula and Guttarla 2007). A glycoprotein lectin from *R. communis* immobilized using concanavalin A was found to retains its sugar binding properties (Surolia et al. 1974) The authors suggested that the immobilzation technique where the functional group of a glycoprotein lectin remained available for its biological activity could prove an important tool for the study of receptor hormone and antibody-antigen interactions.

Four new compounds named (3*E*,7*Z*,11*E*)-19-hydroxycasba-3,7,11-trien-5-one (1), 6α-hydroxy-10β-methoxy-7α,8α-epoxy-5-oxocasbane-20,10-olide (2), 15α-hydroxylup-20(29)-en-3-one (3), and (2*R*,4a*R*, 8a*R*)-3,4,4a,8a-tetrahydro-4a-hydroxy-2,6,7,8a-tetramethyl-2-(4,8,12-trimethyltridecyl)-2*H*-chromene-5,8-dione (4) were isolated from the methanol extracts of the aerial parts of *Ricinus communis* (Tan et al. 2009). The gallic acid, quercetin, gentisic acid, rutin, epicatechin and ellagic acid were the major phenolic compounds isolated from leaves (Singh et al. 2009). Flavonoids kaempferol-3-O-β-d-rutinoside and kaempferol-3-O-β-d-xylopyranoid were isolated from the leaves (Khafagy et al. 1979; Kang et al. 1985). Quercetin and keampferol were isolated from the hydrolyzed aqueous leaf extract of *R. communis* and quercetin was found to be to be the major flavonoid present (Upasani et al. 2003). Chen et al. (2009) isolated rutin, gentistic acid, quercetin, and gallic acid from the leaves of *Ricinus communis* using capillary electrophoresis with amperometric detection. Three monoterpenoids: 1,8-cineole, camphor and α-pinene, and a sesquiterpenoid: β-caryophyllene were identified in castor bean leaves (Darmanin et al. 2009).

Polyglycerol Polyricin-Oleate – Byproduct of Castor Oil

Polyglycerol polyricin-oleate (PGPR), a potent water-in-oil emulsifier which is used by the food industry is formed by esterification of condensed castor oil fatty acids with polyglycerol (Wilson et al. 1998). Since the late 1959- early 60s a safety evaluation programme was undertaken to assess the health safety aspects of the emulsifier, polyglycerol polyricin-oleate (PGPR), (Quest International trade name ADMUL WOL). The programme included acute toxicity tests, subacute rat and chicken toxicity studies, a rat chronic toxicity /multigeneration reproduction study, rodent metabolism, carcinogenicity testing in rat and mouse and a human clinical evaluation (Howes et al. 1998; Wilson et al. 1998; Wilson and Smith 1998a, b). Toxicological studies showed that rats fed 1.5% (w/w) PGPR showed no evidence of a cumulative effect on breeding performance over three generations. PGPR was found to be 98% digested by rats and utilized as a source of energy superior to starch and nearly equivalent to groundnut oil. There was no interference with normal fat metabolism in rats or in the utilization of fat-soluble vitamins. No adverse effects on such vital processes as growth, reproduction, longevity and maintenance of tissue homeostasis were found. PGPR was found not carcinogenic in either 2-year rat or 80-week mouse feeding studies. The human studies showed no adverse effects on tolerance, liver and kidney function, and fat balance at levels up to 10 g/day PGPR which corresponded to approximately 63 times the estimated maximum per capita mean daily intake by man of 2.64 mg/kg body weight/day. The acceptable daily intake for PGPR which was set by JECFA (Joint FAO/WHO

Expert Committee on Food Additives) in 1974 and the EC/SCF (European Commission, Scientific Committee on Food) in 1979 was 7.5 mg/kg body weight/day (Wilson et al. 1998). The UK FAC (United Kingdom - Food Advisory Committee) in 1992 estimated that the maximum per capita mean daily intake of PGPR was 2.64 mg/kg body weight/day. Wilson et al (1998) concluded that the use of ADMUL WOL brand of PGPR in tin-greasing emulsions or in chocolate couverture did not constitute a human health hazard.

Undecylenic Acid – Byproduct of Castor Oil

Undecylenic acid (10-undecenoic acid) is a fatty acid derived from castor oil that is a valuable and physiologically active renewable building block from castor oil (Van der Steen and Stevens (2009). It is a natural fungicide and is approved by USA FDA in over-the counter medications for skin disorders such as skin infections, itching, burning, and irritation. It is effective against infections caused by *Candida albicans* as it inhibits morphogenesis of the fungus (McLain et al. 2000). It is used in the therapy for psoriasis (Ereaux and Craig 1949). It also possesses antiviral properties and is effective on skin infections such as herpes simplex (Shafran et al. 1997; Bourne et al. 1999).

Some of the pharmacological properties of various castor plant parts and castor oil are elaborated below.

Antioxidant Activity

The methanol:water (8:2) extract of castor leaves showed strong DPPH radical-scavenging activity, and gallic acid, quercetin, gentisic acid, rutin, epicatechin and ellagic acid were isolated as active components (Singh et al. 2009). The methanolic extract of castor root exhibited significant free radical scavenging activity by inhibiting lipid peroxidation initiated by carbon tetrachloride and ferrous sulphate in rat liver and kidney homogenates (Ilavarasan et al. 2006). The extract increased free radical scavenging activity of stable radical 2,2-diphenyl-1-picryl-hydrazyl (DPPH), nitric oxide and hydroxyl radical in in-vitro assay methods.

Antiinflammatory Activity

Petroleum ether extract of *Ricinus communis* exhibited significant antiinflammatory activity against formaldehyde and adjuvant induced rat's paw arthritis (Banerjee et al. 1991). At 150 mg/kg p.o. the extract exhibited no significant analgesic activity. *R. communis* was safe up to a dose of 1 g/kg p.o. in rats. The methanol extract of castor root showed anti-inflammatory in Wistar albino rats (and free radical scavenging activity (Ilavarasan et al. 2006). The extract exhibited significant antiinflammatory activity at doses 250 and 500 mg/kg p.o. in the carrageenan-induced hind paw edema model and at the dose of 500 mg/kg p.o. in the cotton pellet granuloma model. Ricinoleic acid (RA), the main active principle of castor oil, was found to have pro- and anti-inflammatory activities (Vieira et al. 2001). In an experimental model of blepharitis induced by intradermal injection of carrageenan in the guinea-pig, topical treatment with RA (10–100 mg) or capsaicin (1–10 mg) caused eyelid reddening and oedema. At lower doses 0.3–3 mg and 0.009–0.09 mg for RA and capsaicin, respectively, both drugs significantly potentiated the eyelid oedema induced by carrageenan. However, repeated (8 days) topical application of RA (0.9 mg) or capsaicin (0.09 mg/guinea-pig) inhibited the carrageenan-induced eyelid oedema. This antiinflammatory effect was accompanied by a reduction in tachykinin content of the eyelids. Thus, RA possessed capsaicin-like dual pro-inflammatory and antiinflammatory properties which are observed upon acute and repeated application, respectively. However, unlike capsaicin, RA did not induce inward current in dorsal root ganglia neurons and was devoid of analgesic properties in-vivo. Ethanolic extracts of *Ricinus communis* and *Solanum nigrum* were found to have antihistamine and antiinflammatory

properties (Lomash et al. 2010). Both exhibited significant decrease in permeability response at an early stage (0–2 minutes) of histamine as well as in carrageenan induced inflammatory lesions. There was a significant suppression in the emigration of heterophils, monocytoid cells, basophils and total leukocytosis in *Solanum nigrum* and *Ricinus communis* pretreated chicken skin lesions as compared to the control.

Hepatoprotective Activity

Ethanol leaf extract of castor was found to show significant protection against galactosamine-induced hepatic damage in albino rats (Visen et al. 1992). It also showed dose-dependent choleretic and anti cholestatic activity, and hepatoprotective activity as evidenced by hepatocytes isolated from paracetamol-treated rats. fractionation of the ethanol extract yielded of two active fractions which in turn yielded two pure compounds: ricinine and N-demethyl-ricinine. N-Demethyl-ricinine was found to be more active and it reversed the biochemical changes produced by galactosamine. It possessed marked choleretic activity and demonstrated an anticholestatic effect against paracetamol-induced cholestasis. Sabina et al. (2009) found that an increase in the activities of serum transaminases and the concentration of liver lipid peroxidation, protein, glycogen and the activities of acid and alkaline phosphatase in liver induced by CCl_4 were significantly suppressed by treatment with *Ricinus communis* ethanol leaf extract (250/500 mg/kg/b.wt). In addition, the depletion of glutathione level and adenosine triphosphatase activity observed in the CCl4-induced rat liver were effectively obviated by treatment with the extract (250/500 mg/kg b.wt). Histopathological examination further confirmed the hepatoprotective activity of *Ricinus communis* ethanol leaf extract when compared with the carbon tretrachloride-induced control rats.

Antidiabetic Activity

Castor bean roots was found to have a promising value for the development of a potent phytomedicine for diabetes (Shokeen et al. 2008). Five-hundred milligram per kilogram body weight of castorbean root extract appeared to be the effective dose as it caused the maximum lowering of the fasting blood glucose, both in normal as well as type 1 diabetic animals. Administration of the effective dose of the extract to the diabetic rats for 20 days showed favorable effects not only on fasting blood glucose, but also on total lipid profile and liver and kidney functions on 10th and 20th day. Out of several different fractions tested, only one fraction (R-18) showed significant antihyperglycemic activity. The extract appeared to have a high margin of safety as no mortality and no statistically significant difference in alkaline phosphatase, serum bilirubin, creatinine, serum glutamate oxaloacetate transaminase, serum glutamate pyruvate transaminase and total protein was observed even after the administration of the extract at a dose of 10 g/kg body weight.

Antinociceptive Activity

Methanol extract of castor leaves exhibited considerable antinociceptive activity using acetic acid induced writhing test, formalin induced paw licking and tail immersion method in mice. (Taur et al. 2011). Its antinociceptive property was postulated to be due to the presence of saponins, steroids and alkaloids.

Central Nervous System Activity

Castor bean pericarp extract exhibited some typical central nervous system stimulant effects when administered to mice (Ferraz et al. 1999). The animals became exophthalmic, displayed tremors and clonic seizures and died a few minutes after receiving larger doses of the extract. At lower doses the extract improved memory consolidation and showed some neuroleptic-like properties, such as a decrease in exploratory behavior and catalepsy. The memory-improving effect and the seizure-eliciting properties of the extract but not neuroleptic effects were also observed with

the administration of ricinine, a neutral alkaloid isolated from the extract. As the therapeutic index of ricinine is of the order of 200, the compound may be considered as a promising cognition-enhancing drug that may be used for the treatment of human amnesias.

Anticancer Activity

Ricin A, a newly isolated lectin from castor seeds exhibited a strong inhibitory effect on the growth of tumour cells (Lin and Liu 1986). By using cell cultures, it was demonstrated that the tumour cells were more sensitive to lectin than non-transformed cells, and that this could be caused by the higher binding affinity of lectin to tumour cells than to non-transformed cells. A conjugate toxin containing transforming growth factor (TGF-alpha) and ricin A was found to specifically inhibit human epidermoid cancer cells A431 but not other NSCLC (human non-small cell lung cancer) cells studied and normal human lung cells (Fang 1998). The toxic ricin A had been reported to bind to ribosome and inhibit protein synthesis of target cells. The cytotoxicity of the conjugate was studied within the range of 10^{-12} and 10^{-8} M and IC_{50} was found to be 10^{-10} M for human A431 epidermoid cells that over-express epidermal growth factor receptor (EGFR). The castor bean leaf extract was found to be cytotoxic to several human tumour cell lines in a dose-dependent manner, with IC_{50} values ranging between 10 and 40 μ/ml (Darmanin et al. 2009). Apoptosis was shown to be induced in SK-MEL-28 human melanoma cells at a concentration of 20 μg/ml. Three monoterpenoids: 1,8-cineole, camphor and α-pinene, and a sesquiterpenoid: β-caryophyllene, were identified as the main constituents in the leaf extract. You et al. (2010) found that *Ricinus communis* agglutinin I (RCA I), a galactose-binding lectin from castor beans, preferentially bound to and was internalized by tumour endothelial cells. This led to down-regulation of vascular endothelial growth factor receptor-2 (VEGFR-2), endothelial cell apoptosis, and tumour blood vessel regression. Taken together, the results illustrated the selective impact of RCA I on VEGF signalling in tumour blood vessels.

Antibacterial Activity

Jombo and Enenebeaku (2008) found that *Klebsiella pneumoniae, Escherichia coli, Proteus vulgaris,* and *Staphylococcus aureus* were highly susceptible to both the methanol and water extracts of the fermented castor seed while *Pseudomonas aeruginosa* showed reduced susceptibility. *Enterococcus faecalis* was resistant to all the preparations tested. *Ricinus communis* leaf extract showed good activity against dermatophytic and pathogenic bacterial strains *Streptococcus progenies, Staphylococcus aureus, Klebsiella pneumoniae* and *Escherichia coli*. (Islam et al., The petroleum ether and acetone extracts showed higher antibacterial activity than the ethanolic extract.

Bone Regeneration Activity

Studies by Beloti et al. (2003) showed that *Ricinus communis* polyurethane blended with calcium carbonate or calcium phosphate, favoured events that promoted matrix mineralization and were more biocompatible materials. Subsequent studies in animals found that a polyurethane resin derived from castor bean, being an inexhaustible source of biomaterial has potential application for use in bone regeneration after demineralized bone matrix and castor oil polyurethane implantation (Laureano Filho et al. 2007; Leite and Ramalho 2008). Laureano Filho et al. (2007) found that human demineralized bone matrix and polyurethane resin derived from the *Ricinus communis* proved to be biologically compatible, however polyurethane was more slowly resorbed presented considerable better results when compared with demineralized bone matrix. Leite and Ramalho (2008) found that bovine bone matrix and a polyurethane resin derived from castor bean were biocompatible providing an alternative in bone reconstruction. Animals treated with both materials showed good stability and osteogenic connective tissue with blood vessels into the surgical area. The polyurethane derived from castor oil was implanted in the nasal dorsum of Apella monkeys with favourable biocompatible outcome

with progressive bone formation and maturation (Dias et al. 2009).

Larvicidal Activity

Studies revealed that the crude extract of *R. communis* leaves possessed remarkable larvicidal, adult emergence inhibition and oviposition deterrent properties against *Anopheles arabiensis* and *Culex quinquefasciatus* and could be used as biological control of mosquitoes (Elimam et al. 2009). The larval mortality was observed after 24 hours. The LC50 values calculated were 403.65, 445.66 and 498.88 ppm against 2nd, 3rd and 4th instar larvae of *An. arabiensis* and 1091.44, 1364.58 and 1445.44 ppm against 2nd, 3rd and 4th larval instars of *Cx. quinquefasciatus*. 50% of adult emergence inhibition (EI50) were 374.97 and 1180.32 ppm against 3rd instar larvae of *An. arabiensis* and *Cx. quinquefasciatus.*

Antifertility Effects

The 50% ethanol extract of *Ricinus communis* was found to have antifertility effects in male rats (Sandhyakumary et al. 2003). There was a drastic reduction in the epididymal sperm counts was observed accompanied by alteration in the motility, mode of movement and morphology of the sperms. Reductions in the fructose and testosterone levels were suggestive of reduced reproductive performance. Reversibility tests showed that the antifertility effect of *Ricinus communis* was completely reversible on withdrawal of the drug. The ethanol extracts did not cause any hepatotoxicity since the hepatic GOT and GPT levels were unaltered. In another study, male rats treated with the methanol castor seed extract registered a significant decrease in the weight of the reproductive organs, sperm functions and serum levels of testosterone (Raji et al. 2006). There was disorganization in the cytoarchitecture of the testes, disruption of the seminiferous tubules and erosion of the germinal epithelium. The number and weight of litters produced by untreated female rats that cohabited with extract treated males decreased significantly. The extract caused no changes in liver, kidney, heart or body weights in male rats. The extract was found to have a reversible negative impact on male reproductive functions, which appeared to be mediated via gonadal disruption in testosterone secretion.

The crude castor bean seed extract which possessed antifertility activity and contraceptive efficacy in female and male rodents was also found to exhibit in-vitro inhibitory activity in the primary cultured rat decidual stromal cells (Zhang et al. 2007). The bioactive components were found to be four phytosterols which were ergost-5-en-3-ol (6.10%), stigmasterol (35.80%), γ-sitosterol (44.77%), and fucosterol (8.40%); and one probucol analog (4.93%). It was presumed that γ-sitosterol may be the main component contributing to inhibit the viability of decidual stromal cells. Studies showed that Rp, a 62 kDa protein isolated from 50% ethanolic extract of castor bean root impaired spermatogenesis in mice by suppressing the production of testosterone (Nithya et al. 2011). The fertility index of the Rp treated groups was reduced by 100%. Sperm motility and count were decreased significantly in the Rp treated group as compared to the control. The testicular activities of 3βHSD, 17βHSD, glucose 6-phosphate dehydrogenase and malic enzyme and the level of serum testosterone were decreased significantly in the Rp treated group. The activity of HMG Co A reductase and cholesterol were increased significantly in the Rp treated group.

Toxicity Studies and Reviews

In the acute oral toxicity study, the aqueous (AE) and methanol (ME) extracts of castor roots did not produce any toxic symptoms or mortality at the dose level of 2,000 mg/kg in rats (Ilavarasan et al. 2011). In the sub-chronic (1,000 mg/kg for 90 days) toxicity study both extracts demonstrated no significant changes in body weight, food, and water intake. The hematology parameters (RBC,

WBC, DLC, Hb, blood clotting time), biochemical parameters (glucose, blood urea nitrogen, creatinine, total cholesterol, total protein, total bilirubin AST, ALT, and ALP) and histopathology evaluations did not show any adverse effects in any of the organs (liver, kidney, heart, spleen, lungs, ovary, testis, and brain) tested. These results demonstrated the non-toxic nature of the root extracts aqueous and methanol could be used for long-term usage in clinical practice. Various plant parts have been reported to be used as carminative, asthma, bronchitis, leprosy, antiinflammatory, cathartic, and aphrodisiac.

The Cosmetic Ingredient Review (CIR) Expert Panel in their review report on the Safety Assessment of *Ricinus communis* (castor) seed oil, hydrogenated castor oil, glyceryl ricinoleate, glyceryl ricinoleate, ricinoleic acid, potassium ricinoleate, sodium ricinoleate, zinc ricinoleate, cetyl ricinoleate, ethyl ricinoleate, glycol ricinoleate, isopropyl ricinoleate, methyl ricinoleate, and octyldodecyl ricinoleate, concluded these cosmetic ingredients to be safe in the practices of use and concentrations as described in the safety assessment (Anonymous 2007).

Adverse Effect

Castor oil (2 ml orally) produced diarrhoea in rats 1–7 hours after challenge, which was associated with gross damage to the duodenal and jejunal mucosa (Capasso et al. 1994). The injury was accompanied by release of acid phosphatase into the gut lumen, indicating cellular injury. Intraperitoneal injection of the nitric oxide (NO) synthase inhibitor NG-nitro-L-arginine methyl ester(L-NAME), prevented the diarrhoea. The dose of L-NAME (50 mg/kg) completely halted the diarrhoea but increased the release of acid phosphatase and worsened the gross damage. The apparent dissociation of the diarrhoeal and intestinal mucosal damaging effects of castor oil suggested that NO had a protective effect on the rat duodenal and jejunal mucosa, but that NO mediated, in part, the diarrhoeic effect of this laxative. Smith et al. (2009) reported a case of multisystem organ failure after large volume (500 ml) subcutaneous injection of castor oil for cosmetic enhancement. Symptoms observed included immediate local pain and erythema followed by abdominal and chest pain, emesis, headache, hematuria, jaundice, and tinnitus. The patient was admitted to an emergency department 12 hours postinjection but deteriorated rapidly despite treatment and developed fever, tachycardia, hemolysis, thrombocytopenia, hepatitis, respiratory distress, and anuric renal failure. After intensive supportive care, including mechanical ventilation and hemodialysis, she was discharged 11 days later, requiring dialysis for an additional 1.5 months.

Castor Bean Seed Toxins

Two ricin toxins and two agglutinins were purified from castor seeds by an improved procedure based on ion-exchange chromatography and gel filtration (Lin and Li 1980). Three toxic proteins and one agglutinin were purified from the seeds of *Ricinus communis* (Lin and Liu 1986). Molecular weights of ricins A, B, and C were about 62,000 and that of ricinus agglutinin was 120,000. They all possessed two non-identical subunits: A and B chains linked by one disulfide bond. Their LD_{50} values were 4, 28, 14 and 112 μg per kg body weight of mice for ricins A, B and C and ricinus agglutinin, respectively. The amino acid compositions of the three toxins and their A and B subunits were very similar, but not identical, while ricinus agglutinin showed a different composition.

The castor seed contains the toxin ricin, one of the most poisonous naturally occurring toxins (Sehgal et al. 2010). The whole of the plant is poisonous, however the seeds are considered the major source of ricin. Sehgal et al. (2010) found that ricin existed in different forms in castor beans of different origin. Ricin I, II and III were found to be highly cytotoxic against Vero cell line with IC_{50} values of 60, 30 and 8 ng/ml respectively. Difference in cytotoxicity of isoforms was confirmed through hemagglutination assay, ricin III caused high degree of hemolysis. The preliminary in-vivo toxicity studies showed ricin III to be highly toxic. Immunological studies revealed that

anti-ricin I and II antibodies were cross reactive with all the ricin variants, whereas the anti-ricin III antibody was highly specific. The present study showed that anti-ricin I and II antibodies could be used for detection of entire ricin isoforms. The a toxic lectin (ricin) isolated from the castor bean seeds was found to have a broad range of affinity for the beta-anomer of Ga of 31 glycoproteins and pneumococcus type XIV capsular polysaccharide tested (Wu et al. 2005). Galbeta was found to be the major combining site of the lectin and the hydrophobic interaction imparted a significant contribution for binding. This information should facilitate future usage of this lectin in glycobiological research and medical applications.

Ricin, with a molecular weight of 65,750 Da was found to be different from the two phyto-hemagglutinins or lectins which were also present in the seeds (Lugnier et al. 1980). The symptoms of ricin's intoxication were established on animals which died from a dramatic hepatonephritic injury, but always after a lag. Ricin exerted a cytostatic, and then a cytotoxic effect on cells in culture. It inhibited protein synthesis in-vivo as well as in-vitro, by acting on ribosomes whether cytoplasmic, mitochondrial or chloroplastic. A case of ricin poisoning following ingestion of castor bean was reported in Korea; symptoms observed included nausea and vomiting (Lim et al 2009). Symptoms after ingestion (onset within 12 h) of ricin are nonspecific and may include nausea, vomiting, diarrhea, and abdominal pain and may progress to hypotension, liver failure, renal dysfunction, and death due to multiorgan failure or cardiovascular collapse (Audi et al. 2005). Ricin is one of the most potent and lethal substances known, particularly when inhaled. Inhalation (onset of symptoms is likely within 8 hours) of ricin is expected to produce cough, dyspnea, arthralgias, and fever and may progress to respiratory distress and death, with few other organ system manifestations.

Traditional Medicinal Uses

Various parts of castor bean plant and castor bean oil is used in traditional medicine in Asia and Africa.

Castor seed is rubbed on the temples to treat headache. In the Philippines, roasted seeds are pounded, and applied to affected area for haemorrhoids. Area with facial paralysis is treated with poultice of pounded dehulled seeds. Seed paste is applied to wounds caused by piercing with pointed objects (nails, bamboo slats, bullet wound) and itch for 4–5 days. The seed is used in Tibetan medicine, where it is considered to have an acrid, bitter and sweet taste with a heating potency. Castor seed and its oil have also been used in China for centuries, mainly prescribed in local medicine for internal use or in dressings. Castor seed oil is used as anthelmintic, cathartic, emollient, laxative, purgative in Unani, Ayurvedic and other ethnomedical systems. Traditional Ayurvedic medicine considers castor oil the king of medicinals for curing arthritic diseases. In Ayurveda, the leaf, root and seed oil are used for inflammation and liver disorders. Castor oil is rubbed on the body, for chest pains and skin affections. The oil from the seed is a very well-known laxative that has been widely used for over 2,000 years. Castor oil has been used as an abortifacient and is given orally, alone or with quinine sulphate, to induce labour in pregnancy at term. Castor oil also used as ear drops to hardened cerumen. Castor oil is used as a vermicide and for warts.

The leaves are used as a poultice to relieve headaches and treat boils. Pounded leaves are used for difficult labour (partus) - the non-lowering of the fetus. In Indonesia, heated leaves are applied to body to relive gout pains, for sprains and swelling and pulp leaves for rashes. Pounded leaves are applied as a poultice on breast as a galactogue but castor oil is l applied to breast as a galactifuge. Boil pounded leaves are use as wash for skin ulcers. Leaf sap is applied for ear-ache. A decoction of the leaves and roots is regarded as antitussive, discutient and expectorant. Pulverised bark of castor plant is used as dressing for ulcers and sores. In the Philippines, root decoction is drunk for rheumatic arthritis, paralysis, epilepsy, distension of the uterus and prolapsus ani.

Current Medicinal Uses

Castor oil is widely used as a laxative. It is considered to be fast, safe and gentle, prompting a bowel movement in 3–5 h, and is recommended for both the very young and the aged. The oil is now sometimes given as a sweetened aromatized emulsion or as capsules. It is so effective that it is regularly used to clear the digestive tract in cases of poisoning. Castor oil is classified by the FDA as GRAS (generally recognized as safe) and effective as a stimulant laxative in medicine. The oil has a remarkable anti-dandruff property. Castor oil gel is useful in the treatment of non-inflammatory skin diseases and is a good protective in cases of occupational eczema and dermatitis. Castor is also applied as an emollient in the treatment of sores and as a solvent for antibiotic eye-drops. Neutral sulphated castor oil can replace soap in certain cases of contact dermatitis. Ricinoleic acid derive from castor oil is a component of contraceptive creams and jellies. The seed oil and its primary constituent, ricinoleic acid are used in the manufacture of skin-conditioning agents, as emulsion stabilizers and surfactants in cosmetics.

Other Uses

Castor plant is often cultivated as an ornamental plant and used for landscape purposes in parks, gardens and other public areas. It is also planted as a hedge plant in India, as a shade plant in Costa Rica or for sand dune stabilization in Libya. In Brazil castor plant is planted for biodiesel production. The leaves are utilized as fodder for silkworms in Korea and in India for the Eri silkworm, *Philosamia ricini*. When grown in the garden it is said to rid it of moles and nibbling insects. The leaves have insecticidal properties. The major *Ricinus communis* allergens, 2S albumins, Ric c 1 and Ric c 3 proteins were found to have a trypsin/α-amylase inhibitor family domain, suggesting that they have a role in insect resistance (Nascimento et al. 2011). Studies by the researchers confirmed that Ric c 1 and Ric c 3, as well as mammalian α-amylase, inhibited the α-amylase activity of *Callosobruchus maculatus, Zabrotes subfasciatus* and *Tenebrio molitor* larvae. The results revealed that Ric c 1 and Ric c 3 represented a new class of α-amylase inhibitors and could potentially be used to help design inhibitors that would be useful in diverse fields, ranging from diabetes treatment to crop protection. Leaf methanol of *R. communis*, was found to have acaricidal and insecticidal activities against the adult of the mite, *Haemaphysalis bispinosa* (Acarina: Ixodidae) and hematophagous fly, *Hippobosca maculata* (Zahir et al. 2010). It has potential to be used as an ideal eco-friendly approach for the control of both pests. A fibre for making ropes is obtained from the stems. Cellulose from the stems is used for making cardboard, paper. In rural areas in many countries, the abundant seeds are used by children for slingshot balls. The attractive castor seeds are used in jewelry, mainly necklaces and bracelets.

In rural areas, castor oil on its own or mixed with kerosene used for illumination. It imparts cooler and brighter light, burns more steadily and generate little soot. A preparation of slaked lime, resin and castor oil is used for caulking boats. Castor oil is primarily used as a high-quality lubricant and a versatile raw material in the chemical industry beside being widely used in Medicine. Its high lubricity, high viscosity over a wide range of temperatures coupled with its insolubility in aliphatic petrochemical fuels and solvents, makes it suitable for use in equipment operating under extreme conditions such as in arctic zones and in aviation. Castor oil is used in crumb-rubber manufacturing, where it prevents rubber crumbs from coagulating. Highly purified, food-grade castor oil is employed as an anti-stick agent for candy moulds and as a lubricant for industrial food processing machinery. In the textile industry, castor oil is used for moisturizing and removal of grease in fabrics, and for the manufacturing of waterproof fabrics. In the steel industry, it is utilised in cutting oils and lubricants for steel lamination at high temperatures and it is also used in other liquids that are necessary for steel work.

Transesterification of castor oil with methanol yields biodiesel (Barajas Forero 2005). The castor biodiesel has very interesting properties (very

low cloud and pour points) that make this fuel very suitable for using in extreme winter temperatures. Partial oxidation and polymerization of castor oil by bubbling finely dispersed air through it at 80–130°C yields 'blown oil', which is a major component of hydraulic and brake fluids and is used as a plasticizer for inks, lacquers and leather. Dehydration of castor oil yields a very pale, odourless, quick-drying oil used in manufacturing alkyd resins, epoxy resins and acryl resins used in heavy-duty paints and varnishes e.g. for refrigerators and other kitchen equipment. Hydrogenated castor oil yields a hard and brittle, odourless wax, mainly applied to modify the qualities of other waxes. The hydrogenated oil is utilized in the manufacture of waxes, polishes, carbon paper, candles and crayons. Its main component, hydroxystearic acid, is used in lubricants, insulators and surfactants and in the production of non-drip paints. Treating castor oil with sulphuric acid yields 'Turkey red oil' which is used as a wetting agent in dyeing textiles, cotton and linen fabrics, as a defoaming agent in the sugar industry, and in leather and fur manufacturing. Saponification of castor oil yields a clear, transparent soap, water solube but with inferior detergent qualities.

Cracking of ricinoleic acid generates s a number of compounds, particularly suitable for the manufacture of high quality lubricants and synthetic polymers such as the polyamides nylon 11, nylon 6.10 and more recently developed polyurethanes. Castor oil based polyurethane (PU)-polyester nonwoven fabric composites can be fabricated by impregnating the polyester nonwoven fabric in a composition containing castor oil and diisocyanate (Kumar et al. 2007). The seed oil and its primary constituent, ricinoleic acid are used in the manufacture of skin-conditioning agents, as emulsion stabilizers and surfactants in cosmetics. In lipstick, castor oil is used at 81% concentration. Other components derived from cracked ricinoleic acid include aroma chemicals, sebacic acid used in manufacturing jet-engine lubricants, synthetic detergents and additives for insecticides. Castor oil is so important in chemistry that the United States has declared it a 'strategic material' of which adequate stocks have to be maintained at all time. Castor oil is classified by the FDA as GRAS (generally recognized as safe) and effective as a stimulant laxative in medicine.

Comments

Leading castor bean producing countries are India (with over 60% of the global yield), China and Brazil. The crop is also widely cultivate in Ethiopia.

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Acacia cyclops

Scientific Name

***Acacia cyclops* A.Cunn. ex G.Don**

Synonyms

Acacia cyclopis Cunn. ex Loudon, *Acacia cyclopis* G. Don., *Acacia cyclopis* J. Mackay ex Loudon nom. nud., *Acacia eglandulosa* DC., *Acacia mirbelii* Dehnh.

Family

Fabaceace or Leguminosae, also placed in Mimosaceae

Common/English Names

Red-Eyed Wattle, Western Coastal Wattle (Australia), Cyclops Acacia (USA)

Vernacular Name

Afrikaans: Rooikrans.

Origin/Distribution

The species is indigenous to Australia. It is found along the west coast of Western Australia as far north as Jurien Bay, and along the south coast into South Australia. The species is widespread in coastal and near-coastal areas mainly between Denmark and Israelite Bay in south-western W.A., ranging north to Leeman in W.A. and east to near Yorketown and Yorke Peninsula in South Australia. It has been introduced and is being cultivated for dune stabilization in North Africa (Morocco, Tunisia), in Cyprus and in South Africa. It has also been introduced to USA, Portugal and elsewhere.

Agroecology

In its native range, *Acacia cyclops* occurs in full sun in coastal heath, coastal dunes or scrubland in loam or sand, often over limestone, in locations exposed to coastal winds and at altitude below 300 m. Its native habitat is characterized by mean annual rainfall of 300–800 mm per annum, winter temperature of 5°C and summer temperature of 31°C. It is slightly frost resistant and drought resistant.

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Edible Plant Parts and Uses

Australian aborigines have been reported to collect the seeds, ground them to produce a chalky white powder which was mixed with water and baked into cakes. A gum exudates from the stem is also edible. Insect larvae boring into the trunk are nutritious and are sought after food.

Botany

Acacia cyclops is a bushy shrub to small tree 1–6 m high with dark brown fissured bark and often crooked main stem. Branchlets are compressed apically and glabrous. Young leaves are first pinnate then developed into phyllodes. Phyllodes are green, ascending, narrowly oblong to elliptic or obovate, inequilateral, slightly recurved, mostly 3–8 cm long, 5–15 mm wide, obtuse or acute, apiculate, coriaceous, glabrous, with 3 or 4 t main nerves occasionally anastomosing with secondary nerves (Plate 2). Flowers are clustered in globular 60–75-flowered glomerules, 5–7 mm in diameter, yellow in colour, either single or grouped in clusters (Plate 1). Flowers pentamerous, bisexual and yellow; sepals more than half united. Pods are linear, slightly raised over seeds, strongly arcuate before dehiscence, to 15 cm long, 7–15 mm wide, thick-coriaceous, glabrous, persistent after seed-fall.

Plate 1 Yellow, globular flower-heads

Plate 2 Phyllodes of *A. cyclops*

Plate 3 Strongly arcuate pods with black seed encircled by scarlet funicle

Seeds are longitudinal, elliptic, 5–7 mm long, glossy, dark brown to black encircled by orange to scarlet, enlarged funicle (Plate 3).

Nutritive/Medicinal Properties

No information is available on the nutrient composition of the edible seeds.

Bark was reported to yield 6.5% tannin, or in Natal, up to 12.1%. Seed was found to contain 10% of fixed oil, the aril or funicle 40% (Duke 1983). With its high tannin content, the species could serve as an astringent.

Other Uses

The green seed pods may be used as a natural soap, by crushing them and using the pods with water to wash with. Pods and bark (tannin content up to 12%) are used in tannery. The wood is used as fuelwood. For fuelwood purposes a harvestable size plant may be reached in around 7–10 years. At a sheltered site, trees with a 10 cm basal diameter yield about 12 kg dry mass, and at 15 cm basal diameter can yield up to 60 kg dry mass (National Academy of Sciences 1980).

The species have been introduced to many countries for sand dune stabilization especially close to the sea-shore.

Comments

Under Conservation code, the species is not regarded as a threatened species.

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Adenanthera pavonina

Scientific Name

***Adenanthera pavonina* L.**

Synonyms

Adenanthera gersenii Scheff., *Adenanthera polita* Miq., *Corallaria parvifolia* Rumph.

Family

Fabaceae or Leguminosae also placed in Mimosaceae

Common/English Names

Barbados Pride, Bead Tree, Crab's Eyes, Circassian Bean, Circassian Seed, Condori Wood, Coral Bean Tree, Coral-Wood, Coralwood, Crab's Eyes, False Sandalwood, False Wiliwili, Jumbi Bead, Jumble-Bead, Peacock Flower Fence, Polynesian Peanut, Red Bead, Red Beadtree, Red Bean Tree, Red Sandalwood, Red Wood, Saga Tree, Sandalwood Tree

Vernacular Names

Brazil: Carolina;
Burmese: Mai-Chek;
Caribbean: Coralitos, Peronias, Jumble-Bead;
Chamorro: Colales, Culalis, Kolales, Kolales, Kulales, Kulalis;
Chinese: Hai Hong Dou;
Cook Islands: Kōviriviri, Mata Kōviriviri, Pitipiti'Ō (Maori);
Creole: Legliz, Reglisse;
Cuba: Mato Colorado;
Fijian: Lera, Lere Ndamu, Pomea, Vaivai, Vaivai Ni Vavalangi;
French: Bois De Condori, Bois De Corail, Bois Noir De Bourbon, Bois Noir Rouge, Crete-De-Paon, Église, Reglisse;
German: Condoribaum, Indischer Korallenbaum, Rotes Sandelholz;
India: Chandan, Rakta Chandan (Assamese), Bir Mungara, Rakta Kambal, Raktakanchan, Raktakambal, Ranjana, (Bengali), Badigunchi (Gujerati), Badi Gumchi, Baragunci, Barighumchi Baragunci, Barigumchi, Rakt Chandan, Raktachandana, Rakta Chandan, Raktachandana, Ranjana (Hindi), Aane Gulaganji, Aanegulaganji, Ane Golaganji, Dodda Gulaganji, Manjaadi, Doddagulaganji, Mancatige, Mancatti, Manchataga, Manchatige, Manda Theeya, Mandatiya, Manjadi, Manjati, Manjatti, Manjatthi, Manjetti, Manjitte, Manjuti, Manjutti, Munjuti (Kannada), Dieng Thing (Khasi), Odlygunji (Konkani), Adhangi, Cem, Chem, Mancati, Mandsjadi, Manjati, Manjeti, Sem, Manchadi, Manchati, Mandsjati, Manjadi, Manjatti, Manjetti, Munjatie (Malayalam), Thorla-Gunj, Thorlagunj, Thorligunj, Thorlaguni, Thorligunji, Val, Vhadli-Gunj (Marathi),

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Sokakainjo, Tamraka (Oriya), Kamboji, Ksharaka, Kucandanah, Kuchandana, Kusandana, Ranjaka, Tamraka, Tamrakah, Tilakah (Sanskrit), Aanaikundrimani, Anai-Kondumani, Anaik-Kunri, Anaikkunri, Anaik-Kunrimani, Anaikundimani, Anai Kundumani, Anaikunrimani, Anaikkunrimani, Anaikkuntumani, Anegundumani, Ani Kundamani, Attipotikam, Calakai, Cem, Cemmaram, Cuvetakolam, Kulirkirakam, Mancali, Mancat, Mancati, Mancatikkuntumani, Mancittam, Manjadi, Mileccakamani, Muvutamani, Periyakuntumani, Perunkunri, Peunkunrimani, Potaikkancanamani, Sem, Tilagam, Tilam, Tamirakam, Tampulovalli, Vikacam, Vanakam, Varnakam, Yanaikuntumani, Yanaikkunrimani (Tamil), Bandi Gurvina, Bandi Gurivenda, Bandigurivenda, Bandiguruginja, Enugaguruginji, Enugagurunginji, Gurivenda, Mansenikottae, Mensenikotta, Peddaguriginja (Telugu);
Indonesia: Segawé Sabrang (Java), Kitoke Laut (Sundanese), Kendiri Batang, Saga Hutan, Saga Telik, (Malay);
Khmer: Chan'trèi;
Kosraean: Metekam, Metkam, Metkem, Mwetkwem;
Kwara'Ae: Tatarabebe;
Laotian: Lam;
Madagascar: Bonaramena, Conori, Kafe Bonara, Oeil De Paon (Malagasy);
Malaysia: Saga, Saga Hutan, Saga Daun Tumpul, Saga Tumpul;
Niuean: Pomea;
Pakistan: Ratangunj;
Palauan: Telengtúngd, Telentundalel;
Philippines: Saga (Tagalog), Malatingli;
Pohnpeian: Kaikes;
Portuguese: Carolina;
Samoan: Lopa;
Spanish: Árbol Del Coral, Caralillo, Caralín, Carolina, Coral, Coralitos Peonía, Peronía, Peronías;
Sri Lanka: Madatiya, Mas-Moca;
Tahitian: La'Au Paina, Lopa, Paina, Pitipitio Papa'A;
Thailand: Pai, Maklam Ta Chang, Hok Daeng, Ma Klam Ta Chang, Maklamton; Tongan: Lopa;
Vietnamese: Trachquach.

Origin/Distribution

The species is endemic to tropical Southeast China, India and Myanmar. The tree has been introduced throughout the humid tropics. It has become naturalized in Malaysia, Western and Eastern Africa and most island nations of both the Pacific and the Caribbean.

Agroecology

Adenanthera pavonina is common throughout the secondary lowland forests in the tropics in areas with annual precipitation ranging between 3,000 and 5,000 mm for optimal growth and at elevations up to 300–600 m. The species has thoroughly naturalized along roads, in dry forest, and occasionally in dense forest. It grows on a variety of soils from deep, well-drained to shallow and rocky, this tree prefers neutral to slightly acidic soils. Initial seedling growth is slow, but rapid height and diameter increment occur from the second year onward. The tree is susceptible to breakage in strong winds, with the majority of damage occurring in the crown.

Edible Plant Parts and Uses

In Melanesia and Polynesia, the seeds of this tree are roasted over a fire and eaten by children and adults alike. In Java, roasted seeds are eaten with rice. The seeds are rich in oil (oil content of 25–30%) and provide valuable food. The young leaves are also cooked and eaten.

Botany

A medium- to large-sized, erect deciduous tree, reaching 15 m or more high, with trunk diameters up to 45 cm, dark brown to greyish bark and a spreading irregular crown (Plate 1). The leaves are bipinnate up to 24 cm long with 2–6 opposite pairs of pinnae, each having 8–21

Plate 1 Ripe pods and seeds

Plate 2 Trunk and foliage

small leaflets on short stalks. The alternate leaflets, 2.0–2.5 cm wide and 3 cm long, are sessile, obovate with an asymmetric base, blunt apex, glabrous, being a dull green colour on top and a blue-green beneath. Flowers are small, pedicellate, creamy-yellow, fragrant and borne in narrow spike-like racemes, 12–15 cm long, at branch ends. Each flower is star-shaped, with 5-toothed gamosepalous calyx, five petals 2.5–3 mm long connate at the base, and 8–10 prominent stamens bearing anthers tipped with minute glands. The curved pods are long and narrow, 15–22 cm by 2 cm, with slight constrictions between seeds, and dark brown in colour turning black upon ripening. The leathery pods curve and twist upon dehiscence to expose the 8–12 showy, red seeds (Plate 2). The seeds, 7.5–9.0 mm in diameter, are lenticular, biconvex, hard, smooth and glossy red.

Nutritive/Medicinal Properties

Analysis showed the seeds of *Adenanthera pavonina* contained per 100 g portion, appreciable amounts of proteins 29.44 g, crude fat 17.99 g and minerals, comparable to commonly consumed staples (Ezeagu et al. 2004). Total sugar was low (8.2 g/100 g) while starch (41.95 g/100 g) constituted the major carbohydrates. Low levels of antinutrients were reported and methionine and cystine were the most deficient amino acids. Linoleic and oleic acids comprised 70.7 % of the total fatty acids. Free fatty acid levels were relatively high but peroxide and saponification values of 29.6 mEq/kg and 164.1 mg KOH/g respectively indicated resemblance to oils processed for food. It was concluded that *A. pavonina* seeds represented a potential source of oil and protein that could alleviate shortages.

The oil of *Adenanthera pavonina* seeds was found to be rich in neutral lipids (86.2%), and low in polar lipids (13.8%) (Zarnowski et al. 2004). The neutral lipids consisted mainly of triacylglycerols (64.2%). Unsaturated fatty acids were found as high as 71%, while the percentage of saturated fatty acids was only 29%. Linoleic, oleic and lignocerotic acid predominated among all fatty acids in the *A. pavonina* oil, whereas stigmasterol was the major steroid. The oil was used for preparation of submicron oil-in-water (o/w) lipid emulsions. Lipid emulsions were formulated

by using soybean lecithin to investigate their particle size, Zeta potential and stability at the different oil and soybean lecithin ratios. The results obtained indicated possible applications of the tested oil in pharmaceutical and medical fields as drug and cosmetic active ingredient carriers.

A new five-membered lactone named pavonin with an *exo*-cyclic double bond was isolated from the methanol soluble part of *Adenanthera pavonina* (Ali et al. 2005).

In a recent study on the optimal composition of edible coatings in view of their application to extend the shelf life of several tropical fruits, coatings constituted by galactomannans from different sources (*Caesalpinia pulcherrima* and *Adenanthera pavonina*) and glycerol were characterized as coatings for five tropical fruits: acerola (*Malpighia emarginata*), cajá (*Spondias lutea*), mango (*Mangifera indica*), pitanga (*Eugenia uniflora*) and seriguela (*Spondias purpurea*) (Cerqueira et al. 2009). Taking into account the surface and permeability properties of the obtained films, four compositions were selected as the best coatings to the studied fruits: acerola – 0.5% of *A. pavonina* galactomannan and 1.0% of glycerol; cajá – 1.0% of *A. pavonina* galactomannan and 1.0% of glycerol; mango and pitanga – 1.5% of *A. pavonina* galactomannan and 1.0% of glycerol; and seriguela – 0.5% of *C. pulcherrima* galactomannan and 1.5% of glycerol.

Some pharmacological properties of the various plant parts are discussed below.

Antiinflammatory and Analgesic Activity

Studies in Nigeria demonstrated that *A. pavonina* seed extract exhibited the antiinflammatory and analgesic effects using animal models (Olajide et al. 2004). The extract (50–200 mg/kg) produced statistically significant inhibition of the carrageenan-induced paw oedema in the rat, and the acetic-acid-induced vascular permeability in mice. The extract at concentrations of 100 and 200 mg/kg, inhibited pleurisy induced with carrageenan. At doses of 50–200 mg/kg, it exhibited a concentration-dependent and significant analgesic activity in the acetic-induced writhing in mice. Further, both early and late phases of the formalin-induced paw licking in mice was inhibited by the extract. Acute toxicity studies revealed that the extract produced reduced motor activity. The LD_{50} value of the extract was found to be 1.36 g/kg. In a separate study, the ethanolic extract from the leaves of *Adenanthera pavonina* was found to have antiinflammatory property (Mayuren and Ilavarasan 2009). At concentrations of 250 and 500 mg/kg, the extract exerted inhibitory effects on the acute phase of inflammation as seen in carrageenan-induced hind paw edema as well as in a subacute study of cotton pellet-induced granuloma formation. The anti-inflammatory activity elicited by the leaf extracts may be due to the influence of the active constituents such as β-sitosterol and stigmasterol.

Using the carrageenan-induced rat hind paw oedema assay, the methanol dried bark extract (400 mg/kg) of *A. pavonina* exhibited 37.10% inhibition of inflammation at the first hour of the study and, the dichloromethane extract (400 mg/kg) showed 33.11% inhibition of inflammation at the third hour of the study which was comparable with that of reference standard drug dichlofenac sodium (Ara et al. 2010). The results of this study supported some of the traditional medicinal uses of this plant.

Antihypertensive Activity

Studies in Nigeria showed that *Adenanthera pavonina* seed extract had the potential to cause a blood pressure lowering effect (Adedapo et al. 2009). The mean arterial blood pressure of the normal saline treated rats was 60 mmHg, those of propranolol treated rats was 23 mmHg while the 200 mg/kg seed extract treated group was 30 mmHg. Phytochemical screening showed that the extract contained cardiac glycosides, tannins, saponins, alkaloids and flavonoids. The total bilirubin, total protein and the globulin fraction were significantly higher in the extract treated rats compared to the control rats. Histopathological examination showed that the extract did not cause any significant lesion changes in the liver, kidney and even the testes.

Antimicrobial Activity

Studies in Sri Lanka reported that extracts of *A. pavonina* exhibited antibacterial activity against methicillin-sensitive and resistant strains of *Staphylococcus aureus*, *Enterococcus faecalis* and *Pseudomonas aeruginosa* (Jayasinghe et al. 2006). Further studies reported the bark of *Adenanthera pavonina* contains antioxidant compound(s) presumably more active than α-tocopherol while the roots showed moderate activity (Rodrigo et al. 2007). The root and stem-bark extracts of *A. pavonina* showed cytotoxicity against brine shrimp *Artemia salina.* The results of this and previous studies corroborated with the use of these plants in traditional medicine.

Anthelmintic Activity

The ethanolic extract of *A. pavonina* bark demonstrated invitro anthelmintic activity against *Pheretima posthuma* and *Ascardia galli* (Dash et al. 2010). The extract caused paralysis as well as death of worms in a comparable time as compared to piperazine citrate especially at higher concentration of 100 mg/ml. Preliminary phytochemical screening revealed the presence of anthraquinone glycosides, phenolic compounds and steroids.

Trypsin Inhibition Activity

ApKTI, an *Adenanthera pavonina* Kunitz trypsin inhibitor was isolated from the seeds (Migliolo et al. 2010). Purified ApTKI showed a molecular mass of 22 kDa and higher affinity against trypsin in comparison to papain, while the bifunctional inhibitor presented lower inhibitory activity.

Traditional Medicinal Uses

Various parts of tree have been used for traditional medicines in Asia and Africa. According to Ayurvedic Pharmacopoeia, *Acronychia pedunculata* (Rutaceae) and *Adenanthera pavonina* are widely used in various ayurvedic herbal preparations for treating diseases such as diarrhoea, tussis, asthma, tumours, ulcers, itchy skin, scales, sores, rheumatism, cold and cough (*A. pedunculata*) and boils, inflammations and gout (*A. pavonina*) (Jayasinghe et al. 2006; Ara et al. 2010).

In India, a decoction of leaves are used against rheumatism and gout and wood for making a tonic. A red dye for cosmetic purposes is produced from the wood in India and South Africa. Bark is used in Billiton for washing hair and clothes. Powdered seeds made in to plasters to hasten ripening of boils and for headache, rheumatism in India. In Africa, the ground seeds are used to treat boils and inflammatory reactions. Decoction of leaves is used to treat gout and rheumatism. The seeds have been found to be effective in treating cardiovascular diseases in pregnancy.

Other Uses

Adenanthera pavonina is cultivated mainly as shade tree for field vegetables, spices like nutmeg, in coffee and cocoa plantations in tropical Africa, Central and South America, as well as in tropical countries of Asia. It is also planted as ornamental avenue trees in East Asia. The rapid growth and spreading crown of light, feathery foliage makes it an attractive shade tree. It is also a valuable agroforestry species. The species is esteemed for fuel-wood in the Pacific Islands, often being sold in local markets. It provides valuable timber which is hard and durable having red-coloured heartwood with light-grey sapwood. The wood is close- and even-grained, making it useful for constructing furniture, cabinets, and decorative wood products and house building. Additionally, it is useful for nitrogen fixation, and is often cultivated as a forage crop. The small leaves breakdown easily making it useful as a green manure. As a supplemental source of fodder, the leaves are fairly high in digestible crude protein (17–22%), but low in mineral content (Rajaguru 1990).

During former times, the seeds were used as weight measures for jewellery and gold smithing

due to their small variation in weight. The bright scarlet seeds are still used today in making necklaces and decorative ornaments.

Adenanthera pavonina seeds also have insecticidal activity. A trypsin inhibitor (ApTI) isolated from seeds was highly effective against digestive proteinases from *Callosobruchus maculatus* (cowpea weevil), *Acanthoscelides obtectus* (bean weevil), and *Zabrotes subfasciatus* (Mexican bean weevil) and moderately active against midgut proteinases from the boll weevil *Anthonomus grandis* and the mealworm, *Tenebrio molitor (*Rodrigues Macedo. et al. 2004). *Adenanthera pavonina* trypsin inhibitor purified from seeds was found to retard growth of *Anagasta kuehniella* a polyphagous storage pest (Macedo et al. 2010). The trypsin inhibitor (ApTI) when ingested by *Anagasta kuehniella* significantly reduced larval survival and weight. The ApTI diet emergence rate was only 28% while the emergence rate of control larvae was 80%. The percentage of surviving adults decreased to 62%. The fourth instar larvae reared on a diet containing 1% ApTI showed a reduction in tryptic activity of gut and no new proteolytic form resistant to ApTI was induced. The results suggested that ApTI had a potential antimetabolic effect when ingested by *A. kuehniella.*

Comments

Raw seeds are toxic and may cause intoxication.

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Arachis hypogaea

Scientific Name

***Arachis hypogaea* L.**

Synonyms

Arachidna hypogaea (L.) Moench, *Arachis africana* Lour., *Arachis americana* Ten., *Arachis asiatica* Lour., *Arachis hypogaea* L. forma *communis* (A. Chev.) F. J. Herm., *Arachis hypogaea* L. forma *macrocarpa* (A. Chev.) Hoehne, *Arachis hypogaea* L. forma *microcarpa* (A. Chev.) Hoehne, *Arachis hypogaea* L. forma *nambyquarae* (Hoehne) F. J. Herm., *Arachis hypogaea* L. forma *typica* Hoehne, *Arachis hypogaea* L. subsp. *fastigiata* Waldron, *Arachis hypogaea* L. subsp. *nambyquarae* (Hoehne) A. Chev., *Arachis hypogaea* L. subsp. *oleifera* A. Chev., *Arachis hypogaea* L. var. *communis* A. Chev., *Arachis hypogaea* L. var. *gigantea* Patel & Narayana, *Arachis hypogaea* L. var. *hirsuta* Kohler, *Arachis hypogaea* L. var. *macrocarpa* A. Chev., *Arachis hypogaea* L. var. *microcarpa* A. Chev., *Arachis hypogaea* L. var. *nambyquarae* (Hoehne) Burkart, *Arachis hypogaea* L. var. *stenocarpa* A. Chev., *Arachis hypogaea* L. var. *vulgaris* Harz, *Arachis nambyquarae* Hoehne, *Arachis procumbens* Berneaud., *Arachis rasteiro* A. Chev., *Lathyrus esquirolii* H. Léveillé.

Family

Fabaceae or Leguminosae, also placed in Papilionaceae

Common/English Names

Earth Nut, Goober Pea, Groundnut, Mani, Monkey Nut, Peanut, Runner Peanut, Spanish Peanut, Valencia Peanut, Virginia Peanut

Vernacular Names

Afrikaans: Apeneutjie, Grondboontjie;
Arabic: Fûl Sûdânî;
Aragonese: Cascagüet;
Aymara: Chuqupa;
Azeri: Araxis;
Bolivia: Chikopa (Aymara);
Bosnian: Kikiriki;
Brazil: Amendoim, Amendoim Verdadeiro, Aráquida, Jinguba, Mancarra, Mendoim, Mendubi, Mondubim, Mudubim (Portuguese);
Catalan: Cacauet;
Chinese: Chang Sheng Guo, Fan Dou, Hua Sheng, Luo Hua Sheng;
Czech: Podzemnice Olejná;
Danish: Jordnød, Jordnødder, Jordnoedder;

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Dutch: Aardnoot, Grondnoot, Pindaplant;
Eastonian: Harilik Maapähkel;
Ecuador: Zaruma (Spanish);
Esperanto: Ternukso;
Fiji: Pinati (Fijian), Maungafali (Indian);
Finnish: Maapähkinä;
French: Arachide, Arachide Du Cayor, Cacahuète, Cacahouète, Pistache De Terre, Pistachier De Terre, Rufisque;
Galician: Cacahuete;
German: Erdnuß, Echte Erdnuss, Erdmandel;
Greek: Arahida, Arapico Fistiki;
Hungarian: Amerikaimogyoró, Földimogyoró;
Icelandic: Jarðhnetur;
India: China Badam (Bengali), Bhoising (Gujarati), Moong Phali, Muungaphalii (Hindu), Kadale Kayi (Kannada), Moong Phalli (Kashmiri), Nellakkadalai, Nilakkadalai (Malayalam), Bhui Mug (Marathi), China Badam (Oriya), Moong Phalli (Punjabi), Nilakkadalai, Verikaddalai, Verusanaga (Tamil), Mugphalii (Urdu);
Italian: Arachide, Mandorla Di Terra, Nocciolina, Pistacchio Di Terra;
Indonesia: Kacang Jawa, Kacang Manila, Kacang Tanah;
Khmer: Sanndaek Dei;
Japanese: Nankinmame, Piinatsu, Piinattsu, Rakkasei;
Korean: Ttang Kong;
Laotian: Thwax Din, Thwax Ho;
Lithuanian: Valgomasis Arachis;
Luxembourgish: Kakuett;
Malaysia: Kacang Goreng, Kacang Jawa, Kacang Tanah;
Mexico: Cacahueta;
Nahuatl: Tlālcacahuatl;
Nepal: Badam, Mungphalii;
Norwegian: Peanøtt, Jordnøtt;
Pakistan: Mung Phali;
Papua New Guinea: Galip Bilong Giraun, Kasang;
Paraguay: Manduvi (Guarani);
Peru: Inchik, Inchis (Quechua);
Philipines: Batung–China (Sulu), Mani (Tagalog);
Polish: Orzech Ziemny, Orzacha Podziemna;
Portuguese: Amendoim, Caranga, Mandobi;
Russian: Arakhis;
Senegal: Mankoli (Badyara), Mangara, Su U, Suk Su (Balanta), O-Tika (Basari), Ma-, E -, Ba-Bɛ́tér (Bedik), Mâkara, Mãnkara (Crioulo), Badâgot (Diola);
Slovaščina: Arašid, Kikiriki;
Spanish: Alcagüeses, Aráquido, Avellana Americana, Cacahuate, Huasquillo, Mandovi, Maní, Manî, Pistacho De Tierra;
Swahili: Mjugu Nyasa, Mnjugu Nyasa;
Swedish: Jordnöt;
Thai: Thùa Lísong;
Tongan: Pīnati;
Turkish: Yer Fıstığı;
Vietnamese: Lac, Dâu Phong.

Origin/Distribution

Peanut is native to South America. Archaeological records indicated its cultivation in the Peruvian desert oases between 300 and 2500 BC (Kaprovickas 1969; Weiss 1983). The domesticated *Arachis hypogaea* is a natural, well-established allotetraploid (AABB) with $2n = 40$. Genetic evidence reveals that it possesses two sets of chromosomes from *Arachis duranensis* (A genome) and *Arachis ipaensis* (B genome) which naturally hybridised to form the tetraploid, *Arachis monticola,* the immediate wild antecessor of *A. hypogaea* (Guillermo et al. 2000). It is likely that this domestication occurred in Paraguay or Bolivia which have the greatest diversity of wild varieties of *Arachis* species. Peanut is now widely cultivated throughout the tropics, subtropics and warm temperate areas.

Agroecology

Peanut is grown in the warm tropical, subtropical and subtemperate areas from 40°S to 40°N latitude in areas with annual mean temperature of 10.5–30°C, annual precipitation of 500–600 mm uniformly distributed through the growing season. It is frost sensitive and growth ceases below 15°C. It prefers light, friable, well-drained sandy loams enriched with gypsum or lime to prenet

'pops' empty shells, basaltic red or grey soils, but will grow in heavier soils in the pH range of 4.3–8.7 with optimum range of 5.5–6.5. Many farmers use irrigation by overhead or flood sprinklers. By keeping the soil moist, the peanut disease aflatoxin is minimised. The peanut crop is usually rotated with other crops to retain soil fertility and to conserve minerals – potassium, phosphorus and calcium in the soil and also to reduce problems with soil-borne diseases.

Edible Plant Parts and Uses

Young leaves, tender shoot tips, young pods and seeds are edible. Young pods may be consumed as a vegetable. Young leaves and tender shoot tips are consumed as cooked green vegetable. Javanese use the shoot tips for lablab, and germinating seeds to make *toge* or *tauge* (sprouts). Raw, unshelled green peanuts are boiled in brine and typically eaten as a snack in southern United States. Matured, unshelled peanuts are popularly eaten as snacks after boiling. Matured unshelled peanuts are salted and sundried or air dried to prepare salted shelled peanuts which are packed in sealed plastic bags and popularly eaten as snacks or appetizers in South East Asia or boiled. Whole unshelled peanuts are also fried and eaten as snacks.

Seeds are use as pulses, dessert nuts or for processing into edible cooking oil. Seeds are eaten raw, cooked, whole roasted and salted, or chopped in confectioneries, ice-cream or into powder or ground into peanut butter. The largest demand for peanuts is in snack foods – packaged salted, roasted or raw where whole peanut seeds are salted and roasted in oil and packed in retail size, plastic bags or hermetically sealed cans. Dry roasted, salted peanuts are also marketed in significant quantities. Lower yielding peanuts have their skins removed and are ground to make peanut butter, peanut oil and also are a common ingredient in confectionary like chocolate and in biscuits. Ninety percent of all peanut butter is peanuts, the other 10% being salt, vegetable oil and a sweetener dextrose. Peanut butter is widely consumed in the home, but large quantities are also used in the commercial manufacture of sandwiches, candy, and bakery products. Shelled peanuts are also fried in oil and salted and are popularly eaten as snacks in Asia. Peanuts are also commonly used in a variety of food dishes such as stews, porridge, curries, and soups. Peanuts can be used like other legumes and grains to make a lactose-free milk-like beverage, peanut milk. Scorched seeds may serve as a coffee substitute.

Peanuts yield a non-drying, edible oil, used in cooking, margarines, ice cream, salads, canning, for deep-frying, for shortening in pastry and bread, salads. Ground nut oil is one of the most commonly used edible cooking oils in the world. It has a mild flavor and a relatively high smoke point. Its high monounsaturated content makes it heart-healthy and resistant to rancidity. There are several types of peanut oil including: aromatic roasted peanut oil, refined peanut oil, extra virgin or cold pressed peanut oil and peanut extract. Studies have shown that refined peanut oil but not crude peanut oil is safe for peanut allergic individuals because the allergen is destroyed during the processing (Hourihane et al. 1997).

Peanuts are employed in many sauces for South American meat dishes, especially rabbit meat. Peanuts are common ingredients in Peruvian Creole cuisine. Popular and well-known dishes include papas *con ocopa* prepared by roasting peanuts, hot peppers and blending with roasted onions, garlic, and oil to make a smooth sauce poured over boiled potatoes. Another popular dish generally called *Aji de Pollo* or *Aji de Mariscos* comprise a similar mixture with sautéed seafood or boiled and shredded chicken in the form of a fricassee. Peanuts are also used in the Mali meat stew called *maafe*. Peanuts are also widely used in South-East Asian cuisine, particularly Malaysia, Singapore and Indonesia, where it is typically made into a spicy sauce. Common Malaysian/Indonesian peanut-based dishes include *gado-gado*, *pecel*, *karedok* and *ketopak* and the famous peanut-based dipping, spicy sauce for satay.

Peanuts are also ground into a powder or flour which can be used as a flavour enhancer with cereals to greatly improve the protein content of

breads, cakes, biscuits etc. Peanut flour is also used as a gluten-free solution and is lower in fat than peanut butter.

The processed cake meal prepared from expeller pressed peanuts could be blended with wheat flour to the extent of 10% (w/w) to prepare acceptable cookies with improved protein and mineral contents (Tate et al. 1990). Expeller pressed partially defatted peanut cake obtained from skin-free kernels could be used as graded supplements in the preparation of breads, sweet buns, cupcakes and yeast-raised doughnuts (Chavan et al. 1991). Incorporation of cake meal lowered the specific volume and sensory properties, but improved the fresh weight, water holding capacity and protein content of the products. The products containing 10% peanut cake meal were found to be acceptable.

Research performed to find new uses for peanut skins demonstrated that up to 35% of the oil in the skins could be recovered (Sobolev and Cole 2004). In some cases the oil could be used as a new potential source of behenic and lignoceric acids, used in body-building formulations and as ingredients in shampoos. After removal of the oil, the skins were useful for making brandy, liqueur and tea.

Plate 1 Four foliolate leaves and yellow flowers

Plate 2 Peanut plant with young pods

Botany

Annual, erect, decumbent or prostrate herb, (6)-30-80 cm tall with much-branched, nodulated tap root (Plates 1 and 2). Stipules pilose, 2–4 cm long. Leaves pinnate with two opposite pairs of leaflets (four-foliolate); petiole 1.5–7 cm long. Leaflets obovate or elliptic, 1–7 cm long, 0.7–3.2 cm wide, rounded or emarginate and mucronate at the apex, glabrous or sparsely pilose beneath (Plates 1 and 2). Flowers solitary axillary, papilionaceous, bisexual, yellow, sessile to shortly pedicellate (Plate 2); primary bracts ovate-lanceolate, 1–1.4 cm long, 4–5 mm wide, biapiculate; secondary bracts similar but bifid. Hypanthium 2–4 mm long, pubescent. Calyx tube 4–6 mm. Corolla yellow to golden yellow; standard spreading, apex emarginate; wings distinct, oblong to obliquely ovate, slender; keels distinct, long ovate, shorter than wings, inflexed, apex acuminate to beaked. Stamens 8–9. Ovary oblong; style longer than calyx; stigma terminal, small, sparsely pubescent. The tip of the ovary, bearing from 1 to 5 ovules, grows out from between the floral bracts, bearing with it the dried petals, calyx lobes and hypanthium; creating a unique floral structure – the peg (gynophore) becoming

Plate 3 Mature peanut pods

Plate 4 Peanut kernels minus the testa

1–20 cm long. The peg quickly turns down toward the soil and thrusts its tip with its ovules into the soil where the tip turns horizontally and develops into the pod (Plates 2 and 3). Fruit, an indehiscent, geocarpic, oblong, inflated legume, 2–5 × 1–1.3 cm, thick-walled, reticulate veined, with 1–4(–6) seeds (Plates 2 and 3). Seed oval to subovoid, 1–2 cm long, by 0.5–1 cm wide, with thin, smooth testa in variable colours – pink, red, purple, tan, brown, yellow, white or red and white, pink and white, brown and white, purple and white, or marked with small purple dashes or splashes on a base colour. Testa envelops the off-white kernel which comprises two off-white halves (Plate 4).

Nutritive/Medicinal Properties

Analyses carried out in the United States (2010) reported raw peanut to have the following nutrient composition (per 100 g edible portion): water 6.50 g, energy 567 kcal (2,374 kJ), protein 25.80, total lipid 49.24 g, ash 2.33 g, carbohydrates 16.13 g, total dietary fibre 8.5 g, total sugars 3.97 g, Ca 92 mg, Fe 4.58 mg, Mg 168 mg, P 376 mg, K 705 mg, Na 18 mg, Zn 3.27 mg, Cu 1.144 mg, Mn 1.934 mg, Se 7.2 μg, vitamin C 0 mg, thiamine 0.640 mg, riboflavin 0.135 mg, niacin 12.066 mg, pantothenic acid 1.767 mg, vitamin B-6 0.348 mg, total folate 240 μg, choline 52.5 mg, betaine 0.6 mg, vitamin A 0 IU, vitamin E (α-tocopherol) 8.33 mg, total saturated fatty acids 6.834 g, 14:0 myristic acid 0.025 g, 16:0 palmitic acid 5.154 g, 18:0 stearic acid 1.1 g; total monounsaturated fatty acids 24.429 g, 16:1 undifferentiated palmitoleic acid 0.009 g, 18:1 undifferentiated oleic acid 23.756 g, 20:1 gadoleic acid 0.661 g; total polyunsaturated fatty acids 15.559 g, 18:2 undifferentiated linoleic acid 15.555 g, 18:3 undifferentiated linolenic acid 0.003 g; phytosterols 220 mg, tryptophan 0.250 g, threonine 0.883 g, isoleucine 0.907 g, leucine 1.672, lysine 0.926 g, methionine 0.317 g, cystine 0.331 g, phenylalanine 1.337 g, tyrosine 1.049 g, valine 1.082 g, arginine 3.085 g, histidine 0.652 g, alanine 1.025 g, aspartic acid 3.146 g, glutamic acid 5.390 g, glycine 1.554 g, proline 1.138 g, serine 1.271 g.

From the above, it can be seen that peanut is very rich in protein and fatty acids (oil), niacin, folate, phytosterols, amino acids (especially arginine, aspartic acid and glutamic acid), minerals like calcium, phosphorus, iron, magnesium, potassium and also contains vitamins, especially the B complex, pantothenic acid and Vitamin E (α-tocopherol).

Other Phytochemicals

Peanuts are also rich in co-enzyme 10 and phytosterols. Peanuts, sesame seeds, and pistachio were reported as the richest ubiquone or co-enzyme 10 (UQ10, Q10 or CoQ10) representatives within nuts and seeds, with levels over

20 mg/kg (Pravst et al. 2010). UQ10 is an essential nutrient in the human body. It is a component of the electron transport chain and participates in aerobic cellular respiration, generating energy in the form of ATP. The following phytosterols: β-sitosterol, δ(5)-avenasterol, campesterol, and stigmasterol were identified in peanut lipid extracts of some commercial peanut cultivars in the United States (Shin et al. 2010). Clerosterol, δ(5,24(25))-stigmastadienol, δ(7)-sitosterol + cycloartenol, and one unidentified sterol were also present but at low amounts. Free and esterified phytosterols accounted for approximately 80% of the total sterols determined; the remainder was attributed to steryl glucosides. The total sterol content in Spanish market type peanuts (144.1 mg/100 g) was significantly higher than both Runners (127.5 mg/100 g) and Virginias (129.3 mg/100 g). Tamspan 90 (146.9 mg/100 g) followed by OLIN (138.5 mg/100 g) showed the highest total sterol content among the cultivars studied. Total phytosterol contents were significantly higher than those reported in the existing literature for Runner and Virginia type peanuts, partially attributed to the inclusion of steryl glucosides in the analysis. Another study reported that 4-desmethylsterols, the main component of the phytosterol fraction, were found during the development of Tunisian peanut kernels: Trabelsia (AraT) and Chounfakhi (AraC), both monocultivar species, and Arbi (AraA) a wild species (Cherif et al. 2010). Immature wild peanut (AraA) had the highest levels of β-sitosterol (554.8 mg/100 g of oil), campesterol (228.6 mg/100 g of oil), and δ(5)-avenasterol (39.0 mg/100 g of oil) followed by peanut cultivar AraC with β-sitosterol, campesterol, and δ(5)-avenasterol averages of 267.7, 92.1, and 28.6 mg/100 g of oil, respectively, and similarly for AraT 309.1, 108.4, and 27.4 mg/100 g of oil, respectively. These results suggested that, in immature stages, phytosterol contents could be important modulating factors for the functional quality of peanut oil for the agro-industry chain from plant to nutraceuticals.

Studies by Awad et al. (2000), suggested a protective role of phytosterols, especially β-sitosterol, for colon, prostate, and breast cancer. Roasted peanuts were found to contain 61–114 mg phytosterols/100 g depending on the peanut variety, 78–83% of in the form of β-sitosterol. Unrefined peanut oil contained 207 mg phytosterols/100 g, a value higher than that of unrefined olive oil. Refining these oils resulted in loss in phytosterols contents in the oil. This loss was greater in the case of olive oil than peanut oil. Further refining, such as deodorization, resulted in significant loss in phytosterols, but hydrogenation after refining had a minimal effect on phytosterols loss. Peanut butter, which accounted for 50% of the peanuts consumed in the United States, was found to contain 144–157 mg phytosterols/100 g. Peanut flour, resulting from partial removal of oil from peanuts, was found to contain 55–60 mg phytosterols/100 g. The data indicated peanuts and its products, such as peanut oil, peanut butter, and peanut flour, to be good sources of phytosterols.

Peanuts were reported to contain bioactive phytochemicals, particularly isoflavones (genistein, daidzein, and biochanin A) and trans-resveratrol (Chukwumah et al. 2007a). Of four methods of extraction [stirring, sonication, Soxtec, and microwave-assisted sonication (MAS)] for runner peanuts, MAS and Soxtec methods extracted significantly greater quantities of the phytochemicals. Also, defatted peanuts gave significantly higher amounts of the phytochemicals compared to the nondefatted peanuts.

The phytoestrogen, resveratrol, is found in grapes, mulberries and peanuts, all of which are consumed regularly by humans. Resveratrol has been associated with reduced cardiovascular disease, aging and reduced cancer risk. Peanut plant was found to have not only resveratrol but also piceatannol which compared with the renowned resveratrol, was a better anticancer agent and a superior agent with other biological activities (Lin et al. 2007). Both resveratrol and piceatannol are recognized as important ingredients in functional foods due to their beneficial health effects. However, unlike resveratrol, the piceatannol concentration in plants is very low (Ku et al. 2005). To induce resveratrol and piceatannol,

calluses were exposed to the ultraviolet (UV) irradiation. Significant quantities of resveratrol and piceatannol were produced by calluses upon UV irradiation in both static and suspension culture conditions. The amounts of piceatannol and resveratrol produced in 1 g of calluses ranged from 2.17 to 5.31 μg and from 0.25 to 11.97 μg, respectively, in static culture. In suspension culture, the amounts of induced piceatannol and resveratrol were somewhat lower.

Sanders et al. (2000) found that peanuts from each market type, Virginia, runner, and Spanish, produced in four different locations contained from 0.03 to 0.14 μg of resveratrol/g. Seed coats from runner and Virginia types contained about 0.65 μg/g of seed coat, which is equivalent to <0.04 μg/seed. Quantitative analysis of 15 cultivars representing 3 peanut market types, which had been cold stored for up to 3 years, indicated a range of 0.02 – 1.79 μg/g of peanut compared to 0.6 – 8.0 μg/ml in red wines.

The phytoalexin, trans-resveratrol was found in six peanut varieties, five pistachio varieties, and four market samples ranging between 0.03 and 1.92 μg/g (Tokuşoglu et al. 2005). The Cerezlik 5025 peanut (1.92 μg/g) and Ohadi pistachio genotype (1.67 μg/g) had significantly higher trans-resveratrol contents. Peanuts contained 0.03–1.92 μg/g (mean = 0.84 μg/g) of trans-resveratrol, whereas pistachio contained 0.09–1.67 μg/g (mean = 1.15 μg/g). With exposure to UV light for 1 minute, trans-resveratrol concentrations of samples ranged from 0.02 to 1.47 μg/g and those of cis-resveratrol from 0.008 to 0.32 μg/g. Formation of the cis-isomer in pistachios was higher than in peanuts. Boiling had a significant effect on the phytochemical composition of peanuts compared to oil- and dry-roasting (Chukwumah et al. 2007b). Boiled peanuts had the highest total flavonoid and polyphenol content. The biochanin A and genistein content of boiled peanut extracts were two- and fourfold higher, respectively. Trans-resveratrol was detected only in the boiled peanuts, with the commercial product having a significantly higher concentration.

Germination of peanut kernels was found to enhance resveratrol biosynthesis and germinated sprouts could served as a functional vegetable (Wang et al. 2005). When the rehydrated kernels of three peanut cultivars were germinated at 25°C and 95% relative humidity in the dark for 9 days, resveratrol contents increased significantly from the range of 2.3 to 4.5 μg/g up to the range of 11.7–25.7 μg/g depending upon peanut cultivar. In comparison with the sprout components, resveratrol contents were highest in the cotyledons, slightly lower in the roots, and not found in the stems. Methanol extracts of the freeze-dried sprouts exhibited potent 1,1-diphenyl-2-picryl-hydrazyl scavenging activity and antioxidative potency against linoleic acid oxidation. These activities increased with an increase of germination time. After 9 days of germination, total free amino acid, sucrose, and glucose contents increased significantly while crude protein contents decreased. Peanut roots were found to have resveratrol and to have potent antioxidative activity (Chen et al. 2002). The highest and lowest resveratrol contents in the peanut roots of 2000 fall and 2001 spring crops were 1.330 and 0.130 mg/g and 0.063 and 0.015 mg/g, respectively. When the dehydrated peanut root powders of spring and fall crops were combined and cooked with pork-fat patties (1%, w/w) and the separated oils were stored at 60°C, conjugated diene hydroperoxide (CDHP) contents of the control oils increased after 3 days of storage, whereas the contents in the peanut root-treated oils of spring and fall crops did not increase after 9 and 15 days of storage, respectively.

From the seed coat of two compounds were isolated and identified as the dimer of proanthocyanidin-A type (I) and D-(+)-catechin (II) (Zhang et al. 1990). Five proanthocyanidins found in peanut skins were identified as epicatechin-(2β→O→7, 4β→6)-[epicatechin-(4β→8)]-catechin, epicatechin-(2β→O→7, 4β→8) epicatechin-(4β→8)-catechin-(4α→8)-epicatechin, procyanidin B2, procyanidin B3 and procyanidin B4 (Lou et al. 2004). Free vanillin was found in two commercial brands of boiled peanuts at low ppm levels (Sobolev 2001). Both the kernels and the hulls contained vanillin, which was formed during hydrolysis of lignin, one of the major constituents of the peanut hulls. Since

vanillin had a low flavour threshold, it could be considered as one of the major ingredients that determined the flavour of boiled peanuts.

Eight flavonoids including two new ones and two novel indole alkaloids were isolated from the water-soluble fraction of peanut skins (Lou et al. 2001). Two new flavonoid glycosides were identified as isorhamnetin 3-O-[2-O-β-glucopyranosyl-6-O-α-rhamnopyranosyl]-β-glucopyranoside and 3′,5,7-trihydroxyisoflavone-4′-methoxy-3′-O-β-glucopyranoside. Two alkaloids were identified as 2-methoxyl-3-(3-indolyl)-propionic acid and 2-hydroxyl-3-[3-(1-N-methyl)-indolyl]-propionic acid. These isolated flavonoids were evaluated for their free radical scavenging activity and protein glycation inhibitory effects.

Groundnut oil was found to contain 47.00% fat, 38.61% protein, 5.80% moisture, 1.81% carbohydrate, 3.70% crude fibre and 3.08% ash (Atasie et al. 2009). Minerals (mg/100 g) included: Na (42.00), K (705.11), Mg (3.98), Ca (2.28), Fe (6.97), Zn (3.20), P (10.55). The physico-chemical characteristics showed; saponification value, 193.20 mgKOH/g, iodine value 38.71 (g/100 g), acid value 5.99 (mgKOH/g), free fatty acid (mgKOH/g) 3.01 peroxide value 1.50 (meq/kg) and refractive index 1.449. The predominant fatty acid was found to be oleic acid (41.11%). The oil yields from peanut kernels were found to vary from 32.7% to 45.4% (Ozcan 2010). The content of protein varied from 25.9% to 32.4%, with a mean value of 28.93%. The contents of Na varied from 867.7 to 1186.1 mg/kg, with a mean value of 1004.7 mg/kg. The phosphorus contents of kernels ranged between 2769.7 and 3784.9 mg/kg, with a mean value of 3433.91 mg/kg. The oil had a refractive index between 1.451 and 1.461 and a saponifiable value between 165.3 and 187.6. The main fatty acids in peanut kernel oils were found to be oleic, linoleic and palmitic. Peanut oil contained glycerides of palmitic, oleic, stearic, lignoceric, linolic, and arachidic acids (Jamieson et al. 1921). The nut-meal and the kernel contained sugar, starch, nitrogenous matter, fatty matter, moisture, fibre and ash (Nadkarni and Nadkarni 1982). The oilseed cake was said to be a good source of arginine and glutamic acid, used in treating mental deficiencies.

Peanut protein concentrate (PPC) isolated from fermented and unfermented defatted peanut flour contained over 85% protein versus 50% protein in the defatted peanut flour used as raw material for PPC production (Yu et al. 2007). PPC had a solubility profile similar to that of peanut flour, with minimum solubility observed at pH 3.5–4.5 and maximum solubility at pH 10 and higher. Roasting of peanut reduced all functional properties of defatted peanut flour while fermentation had the reverse effect. The type of drying significantly affected the functional properties of PPC. Spray dried PPCs exhibited better functional properties, particularly emulsifying capacity and foaming capacity, than vacuum oven dried PPC. Spray dried PPCs also showed comparable oil binding and foaming capacity to commercially available soy protein isolate (SPC). At equivalent concentrations and room temperature, PPC suspension exhibited lower viscosity than soy protein isolate (SPI) suspensions. However, upon heating to 90°C for 30 min, the viscosity of PPC suspension increased sharply. Results obtained suggested that the PPC could be used in food formulations requiring high emulsifying capacity, but would not be suitable for applications requiring high water retention and foaming capacity. PPC could be a good source of protein fortification for a variety of food products for protein deficient consumers in developing countries as well as a functional ingredient for the peanut industry. The production of PPC could also add value to defatted peanut flour, a low value by-product of peanut oil production.

Cooking was found to enhance the amino acid levels of asparagine, serine, glutamic acid, proline, arginine, alanine, cysteine, valine, leucine and phenylalanine in peanut. (Adeyeye 2010). The following essential amino acids were reduced by both cooking and roasting: lysine (15.9–27.6%), histidine (4.23–16.5%), threonine (40.1–60.6%), methionine (38.0–63.4%) and isoleucine (13.3–31.8%). Total amino acid was as follows: (g/100 g crude protein): 83.5 (raw seeds, Rs), 85.9 (cooked seeds) and 66.8 (roasted seeds) with corresponding essential amino acids as: 39.4 or 47.2% (raw seeds), 38.3 or 44.6% (cooked seeds) and 30.0 or 44.9% (roasted seeds).

Predicted protein efficiency ratios were 2.55 (raw seeds), 3.00 (cooked seeds) and 2.31 (roasted seeds) and essential amino acid index of 1.18 (raw seeds), 1.08 (cooked seeds) and 0.83 (roasted seeds).

Groundnut leaves artificially infected with foliar phytopathogens were found to accumulate isoflavonoid phytoalexins (Edwards et al. 1995). Major compounds included medicarpin, formononetin, demethylmedicarpin, three isoflavanones and the isoflavone, daidzein.

Peanuts, Health and Coronary Heart Disease (CHD)

Peanut has been recognized recently as a functional food, its evaluation for its role in a heart-healthy diet has received tremendous attention (Francisco and Resurreccion 2008). Functional compounds have been isolated, identified, quantified, and even enhanced to maximize the amount for adequate health benefits. The peanut industry's byproducts such as peanut hulls and shells, skins, and even leaves and roots have also been identified as possible sources of bioactive compounds. King et al. (2008) reported that about one-third of Americans consumed nuts (tree nuts or peanuts) on any one day. Seven percent of Europeans were reported to eat nuts, but the amount eaten by European nut consumers (31 g/day) was higher than that of Americans (21 g/day). Nuts are an excellent source of vitamin E and magnesium. Individuals consuming nuts were also found to have higher intakes of folate, β-carotene, vitamin K, lutein + zeaxanthin, phosphorus, copper, selenium, potassium, and zinc per 1,000 kcal. Regular nut consumption increased total energy intake by 250 kcal/day (1.05 MJ/d), but the body weight of nut consumers was not greater than that of nonconsumers (King et al. 2008). Nuts were also found to be an excellent source of phytochemicals (phytosterols, phenolic acids, flavonoids, stilbenes, and carotenoids). The total phenolic constituents probably contributed to the total antioxidant capacity of nuts, which was comparable to broccoli and tomatoes.

Hu and Stampfer (1999) reported that five large prospective cohort studies (the Adventist Health Study, the Iowa Women Health Study, the Nurses' Health Study, the Physicians' Health Study, and the CARE Study) had examined the relation between nut consumption and the risk of coronary heart disease (CHD) and all have found an inverse association. Further, several clinical studies had observed beneficial effects of diets high in nuts (including walnuts, peanuts, almonds, and other nuts) on blood lipids (Hu et al. 1998). Most fats in nuts were found to be mono- and polyunsaturated fats that decreased low-density lipoprotein cholesterol level. Based on the data from the Nurses' Health Study, they estimated that substitution of the fat from 1 oz of nuts for equivalent energy from carbohydrate in an average diet was associated with a 30% reduction in CHD risk and the substitution of nut fat for saturated fat was associated with 45% reduction in risk. Ellsworth et al. (2001) reported that frequent nut consumption may offer postmenopausal women modest protection against the risk of death from all causes and CHD. Their observation was based on a 12 years of follow-up study started in 1986 involving 34,111 post-menopausal women. After adjustment for multiple risk factors for CHD and dietary variables, there was an inverse but not statistically significant association between frequent nut consumption (two or more 28.5 g servings per week compared with less than one serving per month) and death from CHD. In separate studies, Li et al. (2009) reported that frequent nut and peanut butter consumption was inversely associated with total CVD risk in age-adjusted analyses of women with type 2 diabetes. After adjustment for conventional CVD risk factors, consumption of at least 5 servings/week of nuts or peanut butter [serving size, 28 g (1 oz) for nuts and 16 g (1 tablespoon) for peanut butter] was significantly associated with a lower risk of CVD (relative risk = 0.56).

Nuts, including peanuts, are now recognized as having the potential to improve the blood lipid profile and, in cohort studies, nut consumption had been associated with a reduced risk of coronary heart disease (CHD). Epidemiologic and clinical trial evidence had demonstrated consistent

benefits of nut and peanut consumption on coronary heart disease (CHD) risk and associated risk factors (Kris-Etherton et al. 2008). A pooled analysis of four U.S. epidemiologic studies showed that subjects in the highest intake group for nut consumption had about 35% reduced risk of CHD incidence. The reduction in total CHD death was due primarily to a decrease in sudden cardiac death. Evidence from these studies consistently showed a beneficial effect on these CHD risk factors. The LDL cholesterol-lowering response of nut and peanut studies was greater than expected on the basis of blood cholesterol-lowering equations that were derived from changes in the fatty acid profile of the diet. Thus, in addition to a favourable fatty acid profile, nuts and peanuts contained other bioactive compounds that explain their multiple cardiovascular benefits (Kris-Etherton et al. 2008). Other macronutrients included plant protein and fibre; micronutrients including potassium, calcium, magnesium, and tocopherols; and phytochemicals such as phytosterols, phenolic compounds, resveratrol, and arginine. Nuts and peanuts are food sources possessing a composite of numerous cardioprotective nutrients and if routinely incorporated in a healthy diet, population risk of CHD would therefore be expected to decrease considerably. The scientists concluded that there was justification to consider the inclusion of nuts in the diets of individuals with diabetes in view of their potential to reduce CHD risk, even though their ability to influence overall glycemic control remained to be established.

Peanut Resveratrol and Anticancer Activity

The phytoestrogen, resveratrol (3,5,4′-trihydroxy-trans-stilbene), is a stilbene phytoalexin found in grapes, mulberries, turmeric and peanuts, all of which are consumed regularly by humans. Peanut plant was found to have not only resveratrol but also piceatannol which compared with the renowned resveratrol, was a better anticancer agent and a superior agent with other biological activities (Lin et al. 2007). Resveratrol content in commercial peanut products was similar to the resveratrol content of the raw peanut fractions routinely used for making them (Sobolev and Cole 1999). Roasted peanuts had the lowest content of resveratrol of 0.055 μg/g, while in peanut butter its concentration was significantly higher, 0.324 μg/g, and boiled peanuts had the highest level of 5.138 μg/g. Ibern-Gómez et al. (2000) identified and quantified trans-resveratrol and trans-piceid (3-β-glucose of trans-resveratrol) in peanut butter. Trans piceid form could be more easily absorbed by the intestinal gut; in this way trans-piceid would exercise its beneficial function more efficiently than trans-resveratrol. Resveratrol and piceid contents in natural peanut butters were found to be significantly higher than those in blended peanut butters. Resveratrol was purified and shown to have cancer chemopreventive activity in assays representing three major stages of carcinogenesis (Jang et al. 1997). Resveratrol was found to act as an antioxidant and antimutagen and to induce phase II drug-metabolizing enzymes (anti-initiation activity); it mediated antiinflammatory effects and inhibited cyclooxygenase and hydroperoxidase functions (antipromotion activity); and it induced human promyelocytic leukemia cell differentiation (antiprogression activity). In addition, it inhibited the development of preneoplastic lesions in carcinogen-treated mouse mammary glands in culture and inhibited tumorigenesis in a mouse skin cancer model. Resveratrol was also reported to be used in chemotherapy against cancer and aging and as a cardioprotectant (Supornilchai et al. 2005). The reservatrol had an effect on adrenal steroidogenesis (Supornilchai et al. 2005). Studies in rats showed that resveratrol suppressed corticosterone production by primary rat adrenocortical cell cultures in vitro and ex vivo by inhibiting cytochrome P450 c21-hydroxylase. Corticosterone production was inhibited 47% by 50 μM resveratrol in-vitro and 20% ex-vivo, while progesterone production was elevated to 400% of the control value in in-vitro experiments. Resveratrol treatment decreased adrenal cytochrome P450 c21-hydroxylase expression in-vivo and cell culture conditions.

Reservatrol was also reported to be associated with reduced risk of cardiovascular disease by

inhibiting or altering platelet aggregation and coagulation, or modulating lipoprotein metabolism (Sobolev and Cole 1999).

Peanut Reservatrol and Antiinflammatory Activity

One of the possible mechanisms for reservatrol biological activities was postulated to be down-regulation of the inflammatory response through inhibition of synthesis and release of pro-inflammatory mediators, modification of eicosanoid synthesis, inhibition of activated immune cells, or inhibition of inducible nitric oxide synthase (iNOS) and cyclooxygenase-2 (COX-2) via its inhibitory effects on nuclear factor (kappa)B (NF-(kappa)B) or the activator protein-1 (AP-1) (de la Lastra and Villegas 2005). More recent data provided interesting insights into the effect of this compound on the lifespan of yeast and flies, implicating the potential of resveratrol as an anti-aging agent in treating age-related human diseases. Djoko et al. (2007) reported that productions of prostaglandin E2 (PGE2) and NO were inhibited by the test stilbenoids, resveratrol, arachidin-1 and piceatannol in a concentration-dependent fashion while gene and protein expressions of COX-2 and iNOS were not inhibited. As shown by NF-kappaB-driven luciferase assay, lipopolysaccharide (LPS)-induced NF-kappaB activities were also decreased by the stilbenoids. Further, these stilbenoids inhibited the LPS-induced transcription expression of the transcription factor CCAAT/enhancer binding protein delta (C/EBPdelta) but not C/EBPbeta. Thus, these stilbenoids were effective in inhibition of PGE2- or NO-mediated inflammation and NF-kappaB- or C/EBPdelta-mediated inflammatory gene expression. The highest inhibitory activity on LPS-induced PGE2/NO production, C/EBPdelta gene expression, and NF-kappaB activation was provided by piceatannol was followed in order by arachidin-1 and resveratrol. The observed antiinflammatory activities of these peanut stilbenoids suggested that they may have merit for nutraceutical applications.

Udenigwe et al. (2008) reported that resveratrol had been reported to exhibit several physiological activities including anticancer and antiinflammatory activities in-vitro and in experimental animal models, as well as in humans. Resveratrol exhibited antiinflammatory activity through modulation of enzymes and pathways that produced mediators of inflammation and also induction of programmed cell death in activated immune cells. Resveratrol had been shown to produce no adverse effects, even when consumed at high concentrations. Hence, resveratrol possesses good potential to be used as an adjunctive or alternative therapy for cancer and inflammatory diseases in humans.

Antioxidant Activity

Peanuts, in addition to having healthy fatty acid profiles and being good sources of fibre and protein, contain phytochemicals that are capable of directly scavenging free radicals such as various polyphenolics (coumaric acid, ferulic acid, resveratrol, etc.), tocopherols, flavonoids (procyanidins, catechin, etc.) and folate (Blomhoff et al. 2006; Isanga and Zhang 2007). New research showed peanuts to rival the antioxidant content of many fruits. Peanut kernels were found to contain bioactive stilbenes identified as trans-resveratrol (Res), trans-arachidin-1 (Ara-1), trans-arachidin-3 (Ara-3), and trans-isopentadienylresveratrol (IPD) (Chang et al. 2006). During incubation of the peanut slices, contents of Res, Ara-1, and Ara-3 increased notably from initially trace or not detectable amounts up to 147.3, 495.7, and 2414.8 μg/g, corresponding to 20, 16, and 24 h of incubation, while IPD contents continued to increase up to 28 h (4474.4 μg/g). When the four stilbenoids and butylated hydroxytoluene (BHT) were subjected to antioxidant characterization by various measures, all exhibited varied potencies of antioxidant activity. When the media were supplemented with Res, Ara-1, Ara-3, and IPD at 15 μM for cultivation of mouse macrophage RAW 264.7 cells activated by lipopolysaccharide (LPS), the LPS-induced extracellular production of prosta-

glandin E2 (PGE2) and nitric oxide (NO) was significantly inhibited by Ara-1, Res, Ara-3, and IPD. Results showed that all test stilbenoids exhibited potent antioxidant and anti-inflammatory activities. This potency was governed by the number of hydroxyl groups and isopentenyl or isopentadienyl moiety. Antioxidant stilbenoids, such as resveratrol, arachidin-1, and arachidin-3, had demonstrated beneficial effects on human health. Recently, *Arachis hypogaea* hairy root cultures (produced via *Agrobacterium rhizogenes*-mediated transformation) were reported to secrete stilbenoids into liquid growth media upon elicitation in quantities sufficient for commercial production (Abbott et al. 2010). In a single run of centrifugal partition chromatography (CPC), resveratrol, arachidin-1, and arachidin-3 were separated to a purity of 97.1%, 97.0%, and 91.8%, respectively from *A. hypogaea* hairy root cultures. Lipid oxidation using the thiobarbituric acid reactive substances (TBARS) assay was inhibited by a 27 and 7 μM dose for reference standards of resveratrol and arachidin-1, respectively, while oxidation was not inhibited up to a 27 μM dose for reference standard of arachidin-3. Oxidation was inhibited at a 14, 7, and 14 μM doses for CPC-purified resveratrol, arachidin-1, and arachidin-3, respectively. Arachidin-1 and arachidin-3 demonstrated cytotoxicity at 27 and 55 μM in RAW 264.7 and HeLa cell lines, respectively; while resveratrol exhibited no cytotoxicity to either cell line.

Peanuts were found to be rich in phenolic antioxidants such as coumaric acid (Francisco and Resurreccion 2008; Craft et al. 2010) and ferulic acid, a free radical scavenger (Anouar et al. 2009). Roasting was found to increase the courmaric acid content. Five predominant compounds were found in methanolic extracts of dry, oil-roasted skinless kernel from several peanut cultivars comprising free *p*-coumaric acid and potential *p*-coumaric acid derivatives (Craft et al. 2010). A Spanish high-oleic peanut possessed the greatest naturally-occurring level of *p*-coumaric acid and its derivatives, followed by a high-oleic Runner, a normal Runner, and a Virginia peanut. Upon thermal processing, *p*-coumaric acid was liberated at the expense of its derivatives according to the sequence: oil roasting > dry roasting > raw. A high-oleic Runner exhibited the greatest increase (approximately 785%) in free *p*-coumaric acid levels after oil roasting. For many of the samples, processing increased the total phenol content (TPC) and antioxidant capacities were in the order of raw < dry roast < oil roast, but results were cultivar dependent. Oil-roasted peanuts were more effective at scavenging O(2) than their dry-roasted counterparts. The findings indicated that although thermal processing altered the composition of peanut kernel antioxidants, TPC values and radical-scavenging activities were preserved.

Methanolic extract from peanut hulls (MEPH) was found to have good thermal stability and antioxidative properties (Yen and Dur 1993). It exhibited 85.2% inhibition of peroxidation of linoleic acid when heated at 185°C for 2 h. Only a slight decrease in antioxidative activity of MEPH occurred when the extract was stored at different temperatures (−20°C, 5°C and 30°C) under air or nitrogen (30°C) for 70 days. Antioxidative activity of MEPH decreased with an increase of pH from 3 to 9. No synergistic effect of ascorbic acid, citric acid, cysteine or α-tocopherol was observed on the inhibitory effect of MEPH. The reducing power of MEPH increased with an increase in concentration and was significantly correlated with antioxidative activity. MEPH also showed good inhibitory activity in lard oxidation when compared with butylated hydroxyanisole (BHA). Duh et al. (1992) found that the methanol extract of peanut hulls produced a higher yield of a component having stronger antioxidant activity (AOA) than other organic solvents. The antioxidant activity of methanolic extracts from peanut hulls was equal to butylated hydroxyanisole and stronger than α-tocopherol. High antioxidant activity was found in subfractions with Rfs of 0.20, 0.25, 0.28, 0.31 and 0.37 at 95.6%, 93.8%, 94.7%, 92.0% and 81.6% inhibition of peroxidation of linoleic acid, respectively. Further purification of the subfraction yielded a compound identified as luteolin with antioxidant activity of 94.8%. Methanolic extracts of peanut hulls (MEPH) from three peanut cultivars showed similar and

strong antioxidant activity as a result of a high content of total phenolic compounds (Yen and Dur 1995). The luteolin content in MEPH for Spanish, Valencia, Runner, and Virginia was 3.16, 2.47, 0.95, and 0.75 mg/g of hulls, and the total phenolic content was 10.2, 10.1, 6.6, and 4.2 mg/g of hulls, respectively.

Rehman (2003) found that the methanolic extract from peanut hulls (MEPH) at various concentrations, exhibited very strong antioxidant activity which was almost equal to synthetic antioxidants (BHA and BHT). Subjective evaluation studies also showed that potato chips treated with 1,200–1,600 ppm MEPH after 6 months storage at 45°C, were organoleptically acceptable. MEPH treated potato chips had lower free fatty acids and peroxide values than the control samples. Duh and Yen (1997) found that soybean and peanut oils with 0.12%, 0.48%, and 1.20% MEPH had significantly lower peroxide values and acid values than the control after storage at 60°C. Further, oils with 0.48% and 1.20% MEPH were significantly superior to 0.02% BHA in reducing oxidation of both oils. An antioxidant, ethyl protocatechuate was isolated from peanut seed testa (Huang et al. 2003). It was found to be effective in preventing oxidation of linoleic acid.

Peanut skin was found to contain high content of antioxidants such as phenolics (Yu et al. 2005). Peanut skin contained potent antioxidants and could provide an inexpensive source of antioxidants for use as functional ingredients in foods or dietary supplements. One gram dry peanut skin contained 90–125 mg total phenolics. Total antioxidant activity of water and ethanol extracts of peanut skin were 3.39 and 4.10 mM Trolox Equivalent/mM of total phenolics compared with 1.91 and 2.46, respectively, for green tea. Three classes of phenolics (phenolic acids, flavonoids, and stilbene) were found in peanut skin extracts. Yu et al. (2006) found that peanut skin processing methods significantly affected total extractable phenolics and their composition. Roasting had limited effects on concentration of TPs while blanching caused 89% loss of TPs. TPs in directly peeled, roasted, and blanched peanut skins were 130, 124, and 14.4 mg/g dry skin, respectively. Total catechins, procyanidin dimers, trimers and tetramers in directly peeled peanut skin were 16.1, 111.3, 221.3 and 296.1 mg/100 g, respectively, versus 8.8, 143.5, 157.5 and 203.9 mg/100 g, respectively, in roasted dry skin. TAAs and free radical scavenging capacities of peanut skin extracts were all higher than those of Trolox and Vitamin C at equivalent concentration.

Ethanolic extract prepared from defatted peanut skins contained 0.932 g/g of total phenolic compound and exhibited 31.5% of radical scavenging activity (Nepote et al. 2004). The resveratrol concentration was 91.4 μg/g in ethanolic extract and 9.07 μg/g in peanut skins. Roasted peanut and hazelnut skins exhibited similar total phenolic contents, much higher than that of almond skins, but their flavan-3-ol profiles differed appreciably (Monagas et al. 2009). Peanut skins were low in monomeric flavan-3-ols (19%) compared to hazelnut (90%) and almond (89%) skins. However, polymeric flavan-3-ols in peanut and almond skins occurred as both A- and B-type proanthocyanidins, but in peanuts the A forms (up to degree of polymerization, DP12) were predominant, whereas in almonds the B forms (up to DP8) were more abundant. In contrast, hazelnuts were mainly constituted by B-type proanthocyanidins (up to DP9). The antioxidant capacity as determined by various methods (i.e., total antioxidant capacity, ORAC, DPPH test, and reducing power) was higher for whole extracts from roasted hazelnut and peanut skins than for almond skins; however, the antioxidant capacities of the high molecular weight fraction of the three types of nut skins were equivalent despite their different compositions and degree of polymerization. The huge dissimilarities in flavan-3-ol concentration, structural composition, type of interflavan linkage, and degree of polymerization found among the three types of nut skins suggested considerable difference in their expected in-vivo biological activities.

Roasting of peanuts was found to increase its antioxidant activity (Hwang et al. 2001; Talcott et al. 2005b; Davis et al. 2010). Peanut kernels roasted at 180°C for 60 minutes displayed the most notable antioxidative activity on linoleic acid, determined by the ferric-thiocyanate method (Hwang et al. 2001). In reducing power,

the absorbance at 700 nm of enzymatic hydrolysates(1mg/ml)preparedfroma60-minutes-roasted sample with Esperase and with Neutrase was 1.24 and 0.81, respectively. The scavenging activity of Esperase and Neutrase hydrolysates on DPPH (α, α′- diphenyl-β-picryldrazyl) radicals was 93% and 89%, respectively, while their chelating activity on Fe^{+2} was 69% and 52%, respectively. Besides, in vitro, Esperase hydrolysates (≥100 μg/ml) exhibited considerable antioxidative effect on the oxidation of low-density lipoprotein (LDL) induced by copper by showing a lag time of longer than 6 hours. Roasting whole peanuts at 175°C for 10 minutes to a Hunter L-value of approximately 50 was found to increase hydrophilic oxygen radical absorbance capacity (H-ORAC) approximately 22% (Talcott et al. 2005b). Davis et al., (2010) characterised the hydrophilic and lipophilic oxygen radical antioxidant capacity (H&L-ORAC) of peanut flours, blanched peanut seed, and peanut skins across a range of roast intensities. H-ORAC ranged from 5,910 to 7,990, 3,040 to 3,700 and 152,290 to 209,710 μmol Trolox/100 g for the flours, seed, and skins, respectively. H-ORAC increased linearly with darker seed colour after roasting at 166°C from 0 to 77 min, whereas skin H-ORAC peaked after roasting for 7 min. Linear correlations with H-ORAC and total phenolic content were observed. For defatted peanut seed solubilised in water, H-ORAC decreased with roast intensity which correlated with soluble protein. Lipophilic-ORAC varied from 620 to 1,120, 150 to 730 and 2,150 to 6,320 μmol Trolox/100 g for peanut flours, seed, and skins, respectively. L-ORAC increased linearly with both darker seed colour and skin colour across the 77 min range.

The quality of dry roasted peanuts was found to be highly dependent on storage conditions for preventing oxidation of fatty acids (Talcott et al. 2005a). The normal oleic acid peanuts sustained up to 2.6-times and mid-oleic acid peanuts 2-times more lipid oxidation than the high-oleic acid peanuts stored at 35°C. Alterations in total soluble phenolics were initially similar among cultivars, but antioxidant capacity was found to decrease by 62%, on average, during storage at 35°C, independently of rates of lipid oxidation. Free *p*-coumaric acid, three esterified derivatives of *p*-coumaric, and two esterified derivatives of hydroxybenzoic acid were the predominant polyphenolics detected and their rates of change were similar among cultivars and independent of storage time or temperature. The high-oleic acid content was essential for prevention of lipid oxidation, but data indicated that co-oxidative reactions, influencing polyphenolic content during storage, were not large enough to significantly change antioxidant capacity.

Antidiabetic Activity

Jenkins et al. (2008) reported that data from the Nurses Health Study indicated that frequent nut consumption was associated with a reduced risk of developing diabetes and cardiovascular disease. Randomized controlled trials of patients with type 2 diabetes had confirmed the beneficial effects of nuts on blood lipids also observed in non-diabetic subjects. Acute feeding studies demonstrated the ability of nuts, when eaten with carbohydrate (bread), to depress postprandial glycemia. Moreover, there was evidence of reduced postprandial oxidative stress associated with nut consumption. The aqueous extract of *Arachis hypogaea* exhibited hypoglycemic and hypolipidemic effect (Bilbis et al. 2002).

Findings from a study by Jiang et al. (2002) involving the documentation of 3,206 new cases of type 2 diabetes suggested potential benefits of higher nut and peanut butter consumption in lowering risk of type 2 diabetes in women. Nut consumption was inversely associated with risk of type 2 diabetes after adjustment for age, body mass index (BMI), family history of diabetes, physical activity, smoking, alcohol use, and total energy intake. Further adjustment for intakes of dietary fats, cereal fibre, and other dietary factors did not appreciably change the results. Consumption of peanut butter was also inversely associated with type 2 diabetes. To avoid increasing caloric intake, regular nut consumption could be recommended as a replacement for consumption of refined grain products or red or processed meats. The extract caused a significant

fall of fasting blood glucose in both normal and alloxan-induced diabetic rats. The extract also caused a significant decline in serum triglyceride, total cholesterol, HDL-cholesterol and LDL-cholesterol in both normal and alloxan-induced diabetic rats. Li et al. (2009) observed that increasing nut consumption was significantly associated with a more favourable plasma lipid profile, including lower LDL cholesterol, non-HDL cholesterol, total cholesterol, and apolipoprotein-B-100 concentrations. Their data suggested that frequent nut and peanut butter consumption was associated with a significantly lower CVD risk in women with type 2 diabetes. Animal studies showed that supplementation with peanut in the streptozotocin (STZ) induced diabetic group led to significantly higher HDL-C levels and lower atherogenic index levels compared to STZ-induced diabetic group (Emekli-Alturfan et al. 2008). In the STZ-induced diabetic rat group TG (triglyceride), TC (total cholesterol), LDL-C (LDL-cholesterol) levels and atherogenic indexes increased significantly whereas HDL-C (HDL-cholesterol) level decreased significantly compared to the control group. Peanut consumption increased GSH levels significantly both in control and diabetic groups. The study showed that peanut consumption may improve oxidant-antioxidant status in healthy and diabetic status without increasing blood lipids. Moreover, increased HDL-C levels and decreased AI levels in diabetic rats indicating that, peanut consumption may have protective effects against cardiovascular complications of diabetes.

Antiobesity, Antihypercholesterolemic Activity

A lipid which inhibited pancreatic lipase was isolated from an acetone extract of peanut seeds (Hochstrasser et al. 1972). The inhibitor was a triglyceride or a mixture of triglycerides in which myristic, palmitic and oleic and linoleic acids were detectable. Alkaline hydrolysis destroyed the inhibitory activity while hydrogenation had no effect. Luteolin, a flavonoid present in the ethanolic extract of the nutshells (Duh et al. 1992), was also reported as a weak inhibitor of lipase (Yamamoto et al. 2000). Animal studies showed that peanut consumption ameliorated blood glutathione (GSH), and HDL-cholesterol levels and lowered thiobarbituric acid reactive substances (TBARS), without elevating other blood lipids in experimental hyperlipidemia (Emekli-Alturfan et al. 2007). The addition of peanut to the diet did not alter blood lipids, prothrombin time, activated partial thromboplastin time or fibrinogen levels significantly both in the control and hyperlipidemic groups. It affected tissue factors (TF) activities differently in both groups. It decreased brain and aorta TF activity but increased spleen and kidney TF activity in the control group. It led to significant increases in the TF activity of kidney, spleen and aorta and a significant decrease in the TF activity of brain in the hyperlipidemic group. Tissue factor (TF), the major regulator of normal haemostasis and thrombosis, plays a critical role in haemostasis in all tissues. The results of a 30 week, randomised cross-over study by Lokko et al. (2007) suggested that regular consumption of peanuts decreased the total cholesterol and triacylglycerol concentrations among healthy Ghanaians. However, individually, high-density lipoprotein-cholesterol and low-density lipoprotein-cholesterol levels did not alter significantly. Peanut skin was found to exclusively consist of polyphenols and fibre (Shimizu-Ibuka et al. 2009). Peanut skin was fractionated into a water-soluble fraction (WSF) and water-insoluble fraction (WIF), and WSF was further fractionated into a soluble dietary fibre fraction (DF) and dietary fibre-free, water-soluble fraction (DFF-WSF). Peanut skin, WSF, and DFF-WSF decreased the serum lipid and cholesterol levels and increased those in faeces of male Sprague-Dawley rats fed on high-cholesterol diets supplemented with peanut skin and its fractions. This effect was probably due to the polyphenols that inhibited intestinal cholesterol absorption.

Peanut hull extract was found to have antiobesity activity (Moreno et al. 2006). PSE (peanut shell extract) was found to inhibit a number of lipases, including pancreatic lipase (PL) and lipoprotein lipase (LPL), and possibly, hormone sensitive lipase (HSL). PSE-treated Wistar rats

showed increased faecal lipid excretion respect to the control group. Body weight and body weight gain, and liver size, were significantly lower in rats fed the high-fat diet with 1% of PSE than in those fed the high-fat diet alone. The rats treated with PSE showed reduced triacylglycerol content in the liver, as well as the serum glucose and insulin. The inhibitory activity of PSE on the lipid metabolic enzymes and the increase in faecal fat excretion suggested that PSE might be useful as a treatment to reduce the dietary fat absorption. The observed reduction in intracellular lipolytic activity of cultured 3 T3-L1 adipocytes may reduce the levels of circulating free fatty acids. The observed effects were likely induced by more than one bioactive component of PSE. The PSE actions may partially be attributed to the inhibition of fat absorption in the digestive tract and the reduction of the adipocyte lipolysis.

Data reported in the Continuing Survey of Food Intake by Individuals and Diet and Health Knowledge Survey (CSFII/DHKS) from 1994 to 1996 revealed that peanut users (24% of CSFII/DHKS) had higher intakes of protein, total fat, polyunsaturated fat (PUFA), monounsaturated fat, (MUFA), fibre, vitamin A, vitamin E, folate, calcium, magnesium, zinc, and iron (Griel et al. 2004). Percent of energy from saturated fat was not significantly different for men, women or girls and was slightly lower for boys. Dietary cholesterol of peanut users was lower for all population groups; this decrease was significant for both men and children. The HEI (Health eating index) calculated as a measure of overall nutrient profile of the diets was significantly higher for peanut users (men 61.4, women, 65.1, children 66.8) compared to nonusers (men 59.9, women 64.1, children 64.7) for men and children. Energy intake was significantly higher in all population groups of peanut users; however mean BMI (body mass index) for peanut users was lower for all gender/age categories. These results demonstrated improved diet quality of peanut users, indicated by the higher intake of the micronutrients vitamin A, vitamin E, folate, calcium, magnesium, zinc, and iron and dietary fibre, and by the lower intake of saturated fat and cholesterol. Despite a higher energy intake over a 2-day period, peanut consumption was not associated with a higher BMI.

In a prospective study, Bes-Rastrollo et al. (2009) reported that higher nut consumption was not associated with greater body weight gain during 8 years of follow-up in healthy middle-aged women. Instead, it was associated with a slightly lower risk of weight gain and obesity. Women who reported eating nuts 2 or more times/week had slightly less mean weight gain (5.04 kg) than did women who rarely ate nuts (5.55 kg). For the same comparison, when total nut consumption was subdivided into peanuts and tree nuts, the results were similar (i.e., less weight gain in women eating either peanuts or tree nuts > or =2 times/week). The results were similar in normal-weight, overweight, and obese participants. The results of this study suggested that incorporating nuts into diets did not lead to greater weight gain and may help weight control. Mattes et al. (2008) reported that epidemiological studies documented an inverse association between the frequency of nut consumption (peanuts and tree nuts) and BMI (Body Mass Index). Clinical trials revealed little or no weight change with inclusion of various types of nuts in the diet over 1–6 months. Mechanistic studies indicated this was largely attributable to the high satiety property of nuts, leading to compensatory responses that accounted for 65–75% of the energy they provide. Additionally, due to poor bioaccessibility, there was limited efficiency of energy absorption from nuts. Collectively, these mechanisms off-setted much of the energy provided by nuts. The few trials contrasting weight loss through regimens that included or excluded nuts indicated improved compliance and greater weight loss when nuts were permitted. This consistent literature suggests nuts may be included in the diet, in moderation, to enhance palatability and nutrient quality without posing a threat for weight gain.

Antihypertensive and Cardiovascular Disease Activity

Angiotensin I converting enzyme (ACE) inhibitory peptides were isolated from alcalase hydro-

lysate of peanut flour (Guang and Phillips 2009). Peptide mass for the most potent fraction was determined to be Lys-Ala-Phe-Arg. An enzymatic digest of arachin, the major storage globulin of peanut was found to have angiotensin I-converting enzyme (ACE) activity (Jimsheena and Gowda 2010). The ACE inhibitory activity of a tripeptide (IEY) isolated from these digests was characterized. Five synthetic structural analogs of this peptide (IEW, IKY, IKW, IEP and IKP) were assembled. Among these, the tripeptide IKP was found to be a potent competitive inhibitor with an IC_{50} of 7×10^{-6}M similar to that of the potent whey peptides IPP and VPP. These studies illustrated that these peptides, like lisinopril, behaved as transition state analog inhibitors and could be useful in therapeutic intervention for blood pressure management.

Results of a 30-week cross-over intervention study revealed that regular peanut consumption lowered serum triglycerol (TAG), augmented consumption of nutrients associated with reduced cardiovascular disease (CVD) risk and elevated serum magnesium concentration. Energy intake from fat was increased through greater intake of monounsaturated fatty acids and polyunsaturated fatty acids, while saturated fatty acid intake remained relatively stable under all conditions. TAG was reduced by 24% during a 3-week addition (ADD), by 17% during an 8-week substitution (SUB) and by 14% during 4-weeks of free feeding, but then rebounded to baseline by week 8. Dietary fibre, magnesium, folate, α-tocopherol, copper and arginine increased during all treatments. Serum magnesium increased in 13 of 15 subjects during free feeding. No changes were found in total plasma homocysteine concentration.

Antimutagenic and Anticancer Activity

Studies showed that peanut oil preparations could inhibit chemically-induced skin carcinogenesis in mice (Lasne et al. 1991). When the peanut oil excipient was used as a solvent, a complete inhibition of BaP (benzo[a]pyrene) and TPA (phorbol 12-myristate 13 acetate) activities was observed in short-term skin tests, as well as a complete inhibition of BaP, DMBA (7, 12-dimethylbenz[α]anthracene) and TPA carcinogenicity in long-term tests. TPA-induced ornithine decarboxylase (ODC) activity was suppressed by the peanut oil mixture while BaP binding to nucleic acids and proteins of epidermal cells was only slightly inhibited. These results indicated that the excipient possessed anti-carcinogenic potentials for epidermal cells. In another study, methanolic extracts of peanut hulls (MEPH) was found to inhibit the mutagenicity of 4-nitroquinoline-N-oxide (NQNO), a direct-acting mutagen (Yen and Duh 1996). MEPH also inhibited the mutagenicity of some indirect-acting mutagens and in decreasing order of 2-amino-3-methyl-imidazo(4,5-f)quinoline (IQ) > aflatoxin B1 (AFB1) > 2-amino-6-methyldipyrido(1,2-a:3′,2′-d)imidazole (Glu-P-1) > 3 amino-1,4-dimethyl-5 H-pyridol(4,3-b) indole (Trp-P-1) > benzo(a)pyrene (B(a)P for *S. typhimurium* TA98, and IQ > Trp-P-1 > Glu-P-1 > AFB1 > B(a)P for *S. typhimurium* TA100.

Roasted and defatted peanut dregs exhibited antimutagenic and antiproliferative effects on human leukemic U937 and HL-60 cells (Hwang et al. 2008). Studies showed that the antimutagenic effects on the *Salmonella typhimurium* TA98 and TA100 strains were found to follow a diminishing order: roasted and defatted peanut dregs (RDPD) > roasted and defatted peanut dregs enzyme hydrolysate (RDPDEH) >> peanut protein isolate (PPI) = peanut protein isolate enzyme hydrolysate (PPIEH) in a dose-dependent manner. Antiproliferative effects on leukemia cells U937 and HL-60 were also detected. RDPD was found to be the most effective of all the peanut preparations. At 100 μg/ml concentration, RDPD inhibited the proliferation of U937 and HL-60 cells by 56% and 52%, respectively. The researchers proposed that RDPD and RDPDEH could be used in the development of natural chemotherapeutic or chemopreventive dietary supplements against leukemia and to upgrade the utilization of these by-products in peanut oil production.

A prospective cohort study started in 1990–1992 with a 10 year follow-on involving 12,026 men and 11,917 women aged 30–65 years in

seven townships, Taiwan, suggested that frequent intake of peanut and its products may reduce colorectal cancer risk in women, demonstrating the anti-proliferating effect of peanut intake (Yeh et al. 2006). During the study period, 107 new colorectal cancer cases (68 men and 39 women) were confirmed. The multivariate Cox's proportional hazard model showed that the relative risk (RR) of peanut consumption was 0.73 for men and 0.42 for women. However, frequent intake of pickled foodstuffs was harmful for women. The risk of colorectal cancer was also elevated among cigarette smokers but not significantly.

Gallstone Disease and Peanuts

Tsai et al. (2004b) studied nut (peanuts, other nuts, and peanut butter) consumption in relation to the risk of cholecystectomy (surgical removal of gallbladder) in the Nurses' Health Study that was started in 1980 involving a cohort of 80,718 women aged 30–55 years with no history of gallstone disease. During 1,393,256 person-years of follow-up from 1980 to 2000, they documented 7,831 cholecystectomies and found that women who consumed 5 units of nuts or more (1 unit = 1 oz or 28.6 g nuts)/week (frequent consumption) had a significantly lower risk of cholecystectomy than did women who never ate nuts or who ate <1 unit/month (rare consumption). Findings in a Health Professionals Follow-up study by Tsai et al. (2004a) that began in 1986 suggest that frequent nut consumption was associated with a reduced risk of gallstone disease in men. During 457,305 person-years of follow-up, 1,833 participants reported gallstone disease. After adjustment for age and other known or suspected risk factors, men consuming 5 or more units of nuts per week (frequent consumption) had a significantly lower risk of gallstone disease than did men who never ate or who ate less than 1 unit per month (rare consumption) (1 unit = 1 oz (0.028 kg) of nuts). Further adjustment for fat consumption (saturated fat, trans-fat, polyunsaturated fat, and monounsaturated fat) did not materially change the relation.

Cataract Inhibition Activity

A new coumestan, 3, 9-dihydroxy-4, 8-dimethoxycoumestan (1) was isolated from *Arachis hypogaea* together with two known compounds: 3, 9-dihydroxy-4-methoxycoumestan (2) and 3, 9-dihydroxy-8-methoxycoumestan (3) (Fu et al. 2005). The 3 coumestans exhibited inhibitory effect on lens aldose reductase from rat lens with IC_{50} values of 2.6×10^{-8} and 3.6×10^{-8} mol/l. The inhibitions (%) were for (1) : 38%, 10^{-5} mol/l, 0%, 10^{-6} mol/l, 0%, 10^{-7} mol/l, (2): 28%, 10^{-5} mol/l, 0%, 10^{-6} mol/l, 0%, 10^{-7} mol/l, (3): 32%, 10^{-5} mol/l, 0%, 10^{-6} mol/l, 0%, 10^{-7} mol/l respectively. Lens aldose reductase was postulated to participate in the initiation of cataract in diabetes.

Sedative Activity

Studies showed that the brain lactate was significantly elevated in rat cerebrums after peanut leaf aqueous extract (PLAE) administrations, compared with control and peanut stem aqueous extracts (PSAE) groups (Zu et al. 2010). Significant decreases of the brain adenosine triphosphate (ATP) and adenosine monophosphate (AMP) were observed in the brainstems and even the whole brains of rats after PLAE treatments. Additionally, brain γ-aminobutyric acid (GABA), and glutamate also decreased significantly in corresponding brain areas. Results indicated that PLAE could influence the target neurotransmitters that related to the rat circadian rhythms in the specific brain regions, possessing the potential as a sedative or sleep-aid for hypnic therapy purposes. PLAE has been reputed to be a type of sleep-aid in China.

Immunochemical and Agglutination Activity

Fourteen antigenic constituents were detected in *Arachis hypogaea* seeds (Daussant et al. 1969). The major proteins of the classic arachin and conarachin fractions were identified. Arachin contained 4 antigens (the major one called

α-arachin) and conarachin contained 2 called α1, and α2-conarachin. Structural differences between α-arachin, α1 and α2-conarachin were indicated by their different antigenic specificities. α-Arachin precipitated as a separate entity at low temperature. The action of trypsin on this protein induced an increase in electrophoretic mobility and prevented precipitation at low temperature. Trypsin had no detectable effect on α1 and α2-conarachin. Immunoelectrophoretic analysis of subcellular preparations from cotyledons confirmed t α-arachin to be an aleurin and that α1-conarachin to be a typical cytoplasmic protein. Peanut seed lectin (PNA) was reported to be widely used to identify tumour-specific antigens on the eukaryotic cell surface (Ortíz et al. 2000). The affinity-purified PNA and its isoforms consisted of four equal subunits of 24.5 kDa each, all of which agglutinated human sialidase-treated erythrocytes equally well; however, differences in their relative thermostabilities and sugar specificities for lactose were observed.

Antimicrobial/Antifungal (Phtyoalexin) Activity

An arabinogalactan protein (AGP) a highly water-soluble glyco-conjugate was isolated from groundnut (*Arachis hypogaea*) seedling (Parveen et al. 2007). When conjugated with amphotericin-B (AmB), AGP did not reduced the antifungal activity against several *Candida albicans* isolates. The results suggested that AGP could be a potent carrier in AmB formulation, which may result in effective treatment of fungal infections. Seven prenylated stilbenes were identified in the mucilage isolated from peanut root tips (Sobolev et al. 2006b). The principal constituent 4-(3-methyl-but-1-enyl)-3,5-dimethoxy-4′-hydroxy-trans-stilbene was designated mucilagin A. Its concentration in the mucilage was estimated at 250 μg/g (wet weight basis). The large body of literature on the antimicrobial properties of plant-derived stilbenes suggested that compounds detected in peanut mucilage may play a role in regulating root-soil pathogen interactions. A new pigmented, optically active, low molecular weight metabolite, designated SB-1 was isolated from peanut kernels challenged by four species of *Aspergillus* (Sobolev et al. 2006a). The new metabolite was accumulated in different peanut genotypes challenged by five *Aspergillus* species and may be an important representative of a new class of peanut phytoalexins. SB-1 production often exceeds production of major known stilbenes. Four new stilbene derivatives, termed arahypins, were isolated from peanut seeds challenged by an *Aspergillus caelatus* strain, along with two known stilbenoids that had not been previously reported in peanuts (Sobolev et al. 2009). Two new prenylated stilbene dimers named arahypin-6 (3) and arahypin-7 (4) were isolated from wounded peanut seeds challenged by an *Aspergillus caelatus* strain (Sobolev et al. 2010). These new phyoalexins may play a defensive role against invasive fungi. The peanut plant can prevent fungal attacks by producing stilbene-derived phytoalexins. Once understood, such a natural phytoalexin-based mechanism of peanut resistance could be potentially manipulated to obtain fungal-resistant peanut breeding lines.

An antifungal protein designated hypogin, with excellent inhibitory action on the growth of the fungi *Mycosphaerella arachidicola, Fusarium oxysporum* and *Coprinus comatus*, was isolated from seeds of the peanut (Ye and Ng 2001). The protein suppressed human immunodeficiency virus (HIV) reverse transcriptase and enzymes associated with HIV infection including αglucosidase and β-glucosidase. The proliferative response of mouse splenocytes was attenuated in the presence of the protein. The protein exhibited a molecular mass of 7.2 kDa and an N-terminal sequence resembling peanut allergen Ara H1. Another peanut antifungal protein from peanut seed was characterized by a high inhibitory activity against HIV-1 integrase and an intermediate potency in inhibiting HIV- I reverse transcriptase and HIV- I protease (Ng et al. 2002). A protein designated hypotin, with both antifungal and antibacterial activity, was isolated from peanut seeds (Wang et al. 2007). The protein exhibited a molecular mass of

30.4 kDa and is a monomeric protein. Its N-terminal sequence was highly homologous to those of chitinases and chitinase precursors from plants. It exerted potent antifungal action toward a variety of fungal species, including *Pythium aphanidermatum, Fusarium solani, Physalospora piricola, Alternaria alternata, Botrytis cinerea,* and *Fusarium oxysporum*. In addition, this novel protein exhibited antiproliferative activity against tumour cells.

Peanut Lectins and Uses

Within the past few years, lectins including peanut lectins (PNA) have become a well-established means for understanding varied aspects of cancer and metastasis. Evidence is now emerging that lectins are dynamic contributors to tumour cell recognition (surface markers), cell adhesion and localization, signal transduction across membranes, mitogenic stimulation, and augmentation of host immune defence, cytotoxicity, and apoptosis. (Mody et al. 1995). PNA can be used for diagnostic differentiation between neoplastic and non-neoplastic diseases (Calderó et al. 1989); diagnosis of squamous cell carcinoma and keratoacanthoma (Kannon and Park 1990) and for other purposes in histopathologic investigations (in particular, to gain a better understanding of the pathogenesis of various infectious, toxic and neoplastic diseases such as human breast and mammary carcinomas (Böcker et al. 1984; Walker et al. 1985); histogenesis of renal cysts (Faraggiana et al. 1985) and for identification of mono-, oligo- and polysaccharides in histochemistry (Klein et al. 1982). The use of peanut lectins will probably be useful in investigating other types of cystic kidneys, such as dysplastic kidneys and experimental models (Faraggiana et al. 1985). Lectins are also used as therapeutic tools (Mody et al. 1995). To advance understanding of these lectin-dependent processes, attempts are being made to discover new lectins that have one or more of these functions and to develop lectin- (or glycoconjugate-) based tools that could be used to target tumour cells.

Safety Assessment of Peanut Oil, Its Derivatives and Peanut Flour

A final report had been published in the *International Journal of Toxicology* volume 20 Supplement 2 on the on the safety assessment of peanut oil, hydrogenated peanut oil, peanut acid, peanut glycerides, and peanut flour (Anonymous 2001). Peanut oil is the refined fixed oil obtained from the seed kernels and hydrogenated peanut oil, peanut acid, and peanut glycerides are all derived from peanut oil. Peanut flour is a powder obtained by the grinding of peanuts. The oils and glycerides are used in cosmetic formulations as skin-conditioning agents. The acid is used as a surfactant-cleansing agent, and the flour is used as an abrasive, bulking agent and/or viscosity-increasing agent. When applied to the skin, peanut oil can enhance the absorption of other compounds. United States Pharmacopeia (USP)-grade peanut oil was considered relatively non-irritating when injected into guinea pigs and monkeys. Technical-grade peanut oil was found to be moderately irritating to rabbits and guinea pigs and mildly irritating to rats following dermal exposure. This same oil produced reactions in < or = 10% of 50 human males. Peanut oil was not an ocular irritant in rabbits. Studies found that peanut oil, either "laboratory expressed" or extracted using a food-grade solvent, was not carcinogenic to mice. Peanut oil was found to exert anti-carcinogenic activity when tested against known carcinogens. Peanuts are the food most likely to produce allergic and anaphylactic reactions. The major allergen is a protein that does not partition into peanut oil, hydrogenated peanut oil, peanut acid, and peanut glycerides. Aflatoxins can be produced in stored agricultural crops such as peanuts, but do not partition into the oils, acids, or glycerides. The available studies on peanut oil supported the conclusion that peanut oil, hydrogenated peanut oil, peanut acid, and peanut glycerides are safe for use in cosmetic formulations. However, available data are insufficient to support the safety of peanut flour for use in cosmetic products.

On the downside some adverse effects of peanuts includes its anti-nutritional factors, lectins

and atherogenicity of peanut oil, these are elaborated below.

Mitogenic Activity

Studies by Ryder et al. (1992, 1994) reported that the dietary protein peanut agglutinin (PNA) a galactose-binding lectin which bind to the Thomsen-Friedenreich (TF) antigen, promoted cell proliferation and thus cancerous growth, while galactose-containing vegetable fibre would inhibit this effect by competing for binding by these lectins. Peanut lectin extracted from faeces showed hemagglutinating activity toward desialylated red blood cells similar to that of a lectin preparation extracted from raw peanuts. Evaluation of biopsy specimens of normal colonic mucosa demonstrated that PNA at a concentration of 25 μg/ml caused statistically significant increases in crypt cell production (31%) and mucus synthesis (77%). At 7.5–100 μg/ml, PNA was mitogenic for the HT29 colorectal cancer cell line. At 25 μg/ml, PNA alone produced a statistically significant increase in thymidine incorporation. Unstimulated crypt cell proliferation rate (CCPR) was greater in patients with ulcerative colitis than in patients with histologically normal colon. PNA (25 μg/ml) produced a 25% average increase in CCPR in tissues from patients with ulcerative colitis, Crohn's disease, and colonic polyps. In ulcerative colitic biopsy specimens incubated with PNA, CCPR increased to more than double that of unstimulated normal colonic epithelium. In controls, the response to PNA was greater when adjacent specimens were positive for PNA (avidin-biotin) histochemistry than when they were negative. Mucus synthesis was increased by an average 75% over 24 hours by PNA. They further concluded that increased TF expression by premalignant epithelia may allow stimulation of proliferation by dietary galactose N-acetylgalactosamine-binding lectins.

Atherogenic Activity

Kritchevsky et al. (1994) found that rabbits fed olive oil exhibited higher levels of serum and liver lipids than did the two peanut oil-fed groups but significantly lower levels of aortic atherosclerosis. The findings confirmed earlier observations that the structure of a fat could have an affect on its atherosclerogenic potential that was independent of its level of unsaturation. In further studies, Kritchevsky et al. (1998) reported that randomization of peanut oil reduced significantly its atherogenic properties, but native and randomized peanut oils had similar rates of lipolysis, and rats fed the two oils absorbed and transported lipids in a similar fashion. Peanut oil differed from other oils in having a relatively high lectin content, and the randomization process markedly reduced the lectin content as well. The biologically active lectin of peanut oil was found to have an affinity for glycoproteins found specifically on arterial smooth muscle cells. Peanut lectin had been shown to stimulate growth of smooth muscle and pulmonary arterial cells. Vigorous washing of peanut oil reduced its lectin content by 46%. Compared to rabbits fed cholesterol and peanut oil, rabbits fed cholesterol and washed peanut oil exhibited less severe atherosclerosis in the aortic arch (by 9%) and in the thoracic aorta (by 31%). The data suggested that peanut oils' endogenous lectin may contribute significantly to its atherogenic properties.

Skeletal Muscle Reduction

In a recent study, Jacques et al. (2010) found that rats fed with the low-quality protein, dietary peanut protein (PP) had lower body weight gain, body protein mass, soleus mass and liver weight than those fed with the high-quality dietary animal proteins, casein (C) and cod protein (CP). PP also evoked a deficit in contractile properties in soleus. Likewise, PP increased plasma cholesterol and body fat mass compared with CP. However, these elevations were accompanied with increased hepatic TAG concentrations and lowered intestinal fat excretion. These results indicated that peanut protein intake altered body composition by reducing skeletal muscle mass and liver weight as well as muscle contractility and lipid metabolism. Adding a complete protein

such as casein might partially counteract these adverse effects.

Anti-nutritional Factors

Peanut was found to contain flatus producing factors such as raffinose oligosaccharides and α-galactosidase. Raffinose and stachyose contents (%) ranged from 0.05 to 0.12 and 0.31 to 0.61, respectively in 33 peanut cultivars examined (Bryant et al. 2003). The specific activity (μmol product/min/mg protein) of crude preparation of α-galactosidase for the 33 cultivars ranged from 1.096 to 2.784 for the non-germinated seeds and nil in some samples up to 2.432 for the germinated seeds; the mean values for non-germinated and germinated seeds were: 1.781 and 1.410, respectively. The specific activity of β-galactosidase ranged from 0.101 to 1.727 in the non-germinated seeds and nil in some samples up to 0.898 in the germinated seeds. Germination decreased the activity of both galactosidases significantly. A basic trypsin and chymotrypsin inhibitor was isolated from peanut (Tur-Sinai et al. 1972). Five protease inhibitors were isolated from peanut seeds and named A-I, A-II, B-I, B-II, and B-III (Norioka et al. 1982). These inhibitors appeared to be Bowman-Birk type inhibitors judging from their low molecular weights and high cystine contents. All the inhibitors inhibited both bovine trypsin and chymotrypsin at ratios of 1:2 and 1:1, respectively, but not simultaneously. Trypsin inhibitors are pathogenesis-related (PR) proteins, which play an important role in the plant defence mechanism against insects and pathogens. Peanut trypsin inhibitors are low molecular mass seed storage proteins. Like peanut allergens, they are stable to acid and heat, resistant to digestion, and can have a negative impact on human health. Dodo et al. (2004) isolated five Bowman-Birk trypsin inhibitors (BBTI) in peanuts. A trypsin inhibitor assay revealed that peanut allergen Ara h 3 had a trypsin inhibitory activity of 11,238 TIA/mg protein. It was concluded that peanut allergen Ara h 3 may also function as a trypsin inhibitor.

Peanut Allergy

Peanut allergy is acute and severe with immediate hypersensitivity. Peanut allergy is the most serious of the hypersensitivity reactions to foods due to its persistence and high risk of severe anaphylaxis (Scurlock and Burks 2004). Severe allergy can result in anaphylactic shock requiring immediate treatment. Peanut (groundnut) allergy is the most common cause of deaths related to food allergy. It is very common, affecting 1% of preschoolers (Pham and Rudner 2000). Diagnosis is via history, skin prick test, and serum IgE level. The mainstay of therapy is avoidance. Treatment of anaphylaxis includes epinephrine and antihistamines. Children usually will not outgrow this food allergy. In a double blind, crossover food challenge with crude peanut oil and refined peanut oil, none of the 60 subjects with proven peanut allergy reacted to the refined oil; six (10%) reacted to the crude oil (Hourihane et al. 1997). Crude peanut oil caused allergic reactions in 10% of allergic subjects studied and should continue to be avoided. If refined peanut oil is used properly and is not reused after cooking peanuts, it seems to be safe for most people with peanut allergy; crude oil represents a risk.

Three major peanut allergens were recognized by more than 50% of peanut allergic individuals: Ara h 1 (vicilin), Ara h 2 (conglutin- homologue protein), and Ara h 3/Ara h 4 (glycinin) (Bannon et al. 2000). These allergens were found to be seed storage proteins and their primary structure and major IgE-binding epitopes had been characterized. More recently three additional minor allergens Ara h 6 and Ara h 7 (both conglutin-homologue proteins) as well as the plant pan-allergen profilin (Ara h 5) were described.

Peanut lectin PNA and other legume lectins had been characterized as potential allergens for patients allergic to edible legume seeds (Rougé et al. 2010). Their IgE-binding cross-reactivity most probably depended on the occurrence of structurally related epitopes that had been identified on the molecular surface of PNA and other legume lectins. These epitopes differed from those responsible for the allerge-

nicity of the major allergens Ara h 1, Ara h 2 and Ara h 3.

Aflatoxin Contamination

Contamination of peanuts with carcinogenic mycotoxins, particularly aflatoxin, is a worldwide problem that affects both food safety and agricultural economies (Talcott et al. 2005a). Most countries have adopted regulations that limit the quantity of aflatoxins in food and feed to 20 μg/kg or less; however, environmental conditions in most of the world where peanuts are produced and stored often make it difficult or impossible to attain such low concentrations. In addition to aflatoxins, peanuts are often contaminated with cyclopiazonic acid (CPA) (Dorner 2008). Both mycotoxins are produced by *Aspergillus flavus* and *Aspergillus parasiticus*, ubiquitous fungi that can infect and grow in peanuts under both pre- and post-harvest conditions (Dorner 2008; Pitt and Hocking 2006). Management of mycotoxin contamination in peanuts generally involves good farm management practice, removal of high-risk components from shelled lots or the removal of individual, highly contaminated nuts, segregation into grades on aflatoxin content at intake to shelling facilities, colour sorting, aflatoxin assays and high temperature treatments. Recently, biological control technology has been developed that prevents much of the contamination that might otherwise occur. Biocontrol is based on competitive exclusion whereby a dominant population of a non-toxigenic strain of *A. flavus* is established in the soil before peanuts are subjected to conditions favouring contamination.

Traditional Medicinal Uses

Peanuts have been reported in various folk pharmacopoeias. The seeds have been used in folk medicine as an anti-inflammatory, aphrodisiac, decoagulant and for nephritis, cholecystosis. Haemostatic and vasoconstrictor activity are reported. In China the seeds are considered demulcent, pectoral, and peptic; the oil aperient and emollient, taken internally in milk for gonorrhoea, externally for rheumatism. The whole plant of *Arachis hypogaea* has been used as traditional Chinese medicine for the treatment of insomnia (Fu et al. 2005). In Zimbabwe the nut is used in folk remedies for plantar warts.

The oil from the seed is aperient, demulcent, emollient and pectoral. It is used as a basis for liniments and ointments. Peanut oil is also employed in catarrh of the bladder. The alcoholic lipoid fraction of the seed is said to prevent haemophiliac tendencies and for the treatment of some blood disorders (mucorrhagia and arthritic haemorrhages) in haemophilia. A teaspoonful of the oil in milk has been used for treating gonorrhoea.

Other Uses

Peanut oil is used for pharmaceuticals, soaps, cold creams, cosmetics, nitro-glycerine, plastics, dyes, paints, pomades and lubricants, liniments, oilments, dyes, massage oil, paints, leather dressings, furniture polish, emulsions for insect control, and fuel for diesel engines. Soap is made from saponified oil and many cosmetics contain peanut oil and its derivatives. The protein portion of the oil is used in the manufacture of some textile fibers. Low grade peanuts are also widely sold as a garden bird feed Peanut hulls are used for furfural, garden mulch, fuel, as a filler for fertilizers, and for livestock feed, or sweeping compound, abrasives, fuel, and in the manufacture of plastic, wallboard, abrasives, fuel, cellulose (used in rayon and paper) and mucilage (glue). Foliage provides silage, forage and makes good fodder and hay for livestock. The oil cake provides a high-protein livestock feed.

Peanut by-products fed to cattle include peanuts and peanut meal, peanut skins, peanut hulls, peanut hay, and silages (Hill 1952). Residual peanut hay is by far the most widely used peanut by-product fed to beef cattle, and if it is properly harvested with minimal leaf shatter, it is comparable to good-quality grass hays in nutrient con-

tent. Peanut skins are often included in small quantities in cattle and pet foods, supplying both protein and energy. High tannin content of peanut skins can cause severe performance depressions in beef cattle if peanut skins are included at levels higher than 10% of the diet, unless diets contain relatively high crude protein (CP) (above 15% CP), or additional N sources are added such as ammonia or urea. Because dairy cattle diets are often above 16% CP in the total dietary DM, peanut skins may increase milk production when added at levels up to 16% of the dry matter. Peanut hulls are effectively used as a roughage source at levels up to 20% of beef finishing diets, for bedding in dairy cattle loafing sheds (if tested and found to contain low aflatoxin levels), and in a variety of manufactured products. Peanut hulls are economically priced because of their quantity, their inherent high fibre, and low CP content, and they should not be fed as primary feedstuffs for beef cattle. Peanut by-products are generally priced below other by-products, and they can be incorporated into a variety of supplements and diets for cow herds, growing-finishing cattle, and dairy cattle.

Peanut hull, an agricultural waste can be used for the production of activated carbons to remove phenol from aqueous solutions (Mohanty et al. 2008). The activated carbon developed by chemical activation with zinc chloride under four different activation atmospheres showed substantial capability to adsorb phenol from aqueous solutions. Sawdust and modified peanut husk were found to be good adsorbents to remove Pb(II), Cr(III) and Cu(II) from aqueous solution (Li et al. 2007). Peanut husk can be used in the manufacture of medium-density fibreboards (Akgül and Tozluoğlu 2008). Studies indicated that panels could be produced utilizing up to 30% peanut husk without affecting the usability of the panels. Peanut hull mixed with pine wood chips in different ratios can be used in the manufacture of particleboards (Guler et al. 2008). Studies showed that increase in peanut hull in the mixture resulted in a decrease in mechanical and physical properties of produced panels and panel including 25% hull in the mixture solely met the standard required by TS-EN 312 standard.

Peanut testa (skins, seed coats) are an extremely low value by-product of peanut-blanching operations. Their commercial value is reported as $12–20 per ton and their limited use is only as a minor component of cattle feed (Sobolev and Cole 2004). Peanut skin oil extraction followed by tannin extraction also produces a protein-enriched product that could find application in mixed feeds for cattle consumption at higher concentrations relative to existing practice. A simple technique was also offered to use the skins in finishing decorative panels.

Comments

China leads in production of peanuts having a share of about 32.95% of overall world production, followed by India (18%) and the United States of America (6.8%).

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Archidendron bubalinum

Scientific Name

***Archidendron bubalinum* (Jack) I.C. Nielsen**

Synonyms

Albizia acradena Miq., *Cylindrokelupha bubalina* (Jack) Kosterm., *Feuilleea bubalina* (Jack) Kuntze, *Inga bubalina* Jack, *Ortholobium bubalinum* (Jack) Kosterm., *Pithecellobium bigeminum* (L.) Mart. var. *bubalinum* (Jack) Benth., *Pithecellobium bubalinum* (Jack) Benth., *Pithecellobium ellipticum* sensu auct., *Pithecellobium lobatum* sensu Ridley.

Family

Fabaceae or Leguminosae, also placed in Mimosaceae

Common/English Names

Kerdas, Nieng-nok

Vernacular Names

Indonesia: Kabau, Kabau Tupai;
Malaysia: Kerdas, Keredas, Keredas Antan, Keredas Padi, Geredas Padi, Buah Pelong;
Thailand: Nieng-Nok.

Origin/Distribution

The species is indigenous to Peninsular Malaysia, Thailand, and Sumatra in Indonesia.

Agroecology

This species occurs naturally in the secondary tropical rainforests in the lowlands and hills. It thrives in well-drained soil and occurs on sandy or in chutney. lateritic or sandy clay soils.

Edible Plant Parts and Uses

The strong pungent smelling seeds have an odour like jering (*Archidendron jiringa*) and petai (*Parkia speciosa*) but the odour disappears on cooking. Seeds have the flavour of jering and are similarly used to flavour food. Young seeds can be eaten raw in ulam (traditional vegetable salad). or in chutney Excessive consumption can lead to kidney problem.

Botany

An evergreen, unarmed small tree 15 high, bole straight to rather crooked, bark surface greyish-brown and closely fissured. Leaves arranged spirally, bipinnate; rachis and pinnae with extrafloral nectaries. Leaflets 1–2 pairs per pinna, lanceolate to elliptic-lanceolate to oblong, 8–16 cm by

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4–6 cm, opposite and papery, glabrous, violet red when young. Inflorescence terminal and axillary, paniculate, 20 cm long with 4–7 sessile flowers in a pseudo-umbel. Flowers – pentamerous, bisexual, white with a cup shaped calyx and tubular corolla and numerous stamens. Fruit a plump, straight to slightly curved, woody pod, 5–8 cm long by 1.5–2.5 cm wide, with rounded apex, green turning purplish-brown (Plates 1–3), dehiscing along 1 or both sutures, containing 6–8 angled, ellipsoid to ovoid, laterally flattened seeds which are creamy-white turning brown to reddish brown and shining when mature (Plates 3–5).

Plate 1 Bundle of kerdas pods on sale in the local market in Kelatan, Malaysia

Nutritive/Medicinal Properties

Kerdas seeds were found to have high moisture content, low fat content, a high crude protein content of 6–10% FW but a poor chemical score of 32% being limited in valine, methionine and tyrosine contents (Suhaila et al. 1987). Keredas contained significant levels of anti-nutrients: tannin, trypsin inhibitors and hemagglutinin. The use of moist heat to reduce the amount of trypsin inhibitor and hemagglutinin was more effective than dry heat, and germination of seeds was more effective than fermentation with *Rhizopus oligosporus*. The magnitude of reduction in trypsin inhibitor activity and hemagglutinin depended on the time and temperature of treatment.

Studies in Thailand reported that crude extracts of seeds of *A. jiringa* (Nieng) and *A. bubalinaum* (Nieng-nok) had superoxide scavenging activities (Kittiponkul and Ratanachaiyavong 1998).

The bark of *A. bubalinum* is used as a febrifuge. Seeds are used traditionally as a diuretic, but are poisonous when eaten in large amounts.

Plate 2 Close up of kerdas pods

Other Uses

The tree provides hard, durable timber which is used for planking, construction, interior joinery, furniture and cabinet work, canoes, paddles, fencing, household utensils, knife handles, weapon sheaths, boxes and coffins. It is also used as fuel.

Plate 3 Kerdas pod sliced to show arrangement of seeds

Plate 4 Unripe seeds and shell of kerdas pod

Plate 5 Ripe kerdas seeds on sale in the local market in Kelantan, Malaysia

Comments

The species is deemed to be critically endangered.

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Archidendron jiringa

Scientific Name

***Archidendron jiringa* (Jack) Nielsen**

Synonyms

Abarema jiringa Kosterm, *Albizzia jiringa* (Jack) Kurz, *Albizia lucida* sensu auct., *Archidendron pauciflorum* (Benth.) I. C. Nielsen, *Feuilleea jiringa* Kuntze, *Inga bigemina* sensu auct., *Inga jiringa* (Jack) DC., *Inga kaeringa* (Roxb.) Voigt, *Inga lobata* Grah., *Mimosa jiringa* Jack, *Mimosa kaeringa* Roxb., *Pithecellobium bigeminum* sensu auct., *Pithecellobium jiringa* (Jack.) Mansf., *Pithecellobium jiringa* (Jack) Prain, *Pithecellobium lobatum* Benth., *Zygia jiringa* (Jack) Kosterm.

Family

Fabaceae or Leguminosae, also placed in Mimosaceae

Common/English Names

Blackbead, Dog Fruit, Djenkol Tree, Luk Nieng Tree, Ngapi Nut

Vernacular Names

Burmese: Danyin, Danyin –Wek, Dog Fruit, Tangyin, Taujin, Tanyeng-Pen;
French: Jengkol;
Indonesia: Jengkol, Jingkol, Jering (Java), Jarring, Jaring-Jaring, Jengkol Hutan, Jering Altut, Tutung (Kalimantan), Lubi (Sulawesi), Jarung (Sumatra);
Malaysia: Jering, Jiring;
Nepalese : Dhinyindi;
Thailand: Cha Niang, Khang Daeng, Luk Nieng, Niang, Pha Niang.

Origin/Distribution

The species is indigenous to the old world tropics – Southeast Asia – Bangladesh, Myanmar, South Thailand, Malaysia, Indonesia (Sumatra, Sulawesi, Kalimantan).

Agroecology

A tropical species, occurs naturally in the primary and secondary forests of humid, high rainfall and mountainous areas, as well as undulating hills, lowland flats and along river banks from sea-level to 1,600 m. It prefers a well-drained soil and occurs on sandy, lateritic or sandy clay soils.

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Edible Plant Parts and Uses

The seeds are used to flavour food and are relished in Thailand, Indonesia and Malaysia. Immature seeds are eaten raw as *ulam*. Mature seeds are prepared in several ways: boiled and consumed with salt and grated coconut; steeped for hours in salt water before frying in oil; processed into chips *emping* or *kripik jenkol*, after cooking the cotyledons are pounded into small cakes and sun-dried – these are then deep fried in oil before consumption. Germinated seeds are eaten after removal of the sprouts. The wine-red, tender leaves and shoots are also consumed raw as *ulam* or vegetable. Seeds are also pounded with ginger and boiled before consumption. The seeds are also eaten with *sambel kimiri* (a paste made of pounded roasted candlenut, green chillies and dried shrimps) in Java.

In southern Thailand, *luk-nieng* is always eaten with curry or with any hot food. To use *luk-nieng* as a dessert fruit, a special method for preparation is followed. Djenkolic acid, a toxic substance, is extracted several times in a mixture of water, wood ash, bamboo leaves and pieces of steel or nails. Local people have used this method for centuries, although it is difficult to explain the function of each substance. The maturing seeds are boiled and the extracts are discarded several times. The seeds are then free from djenkolic acid and can be eaten. The taste of luk-nieng after this extraction is similar to that of beans and it has a high nutritive value. A mixture of fresh coconut endosperm and sugar is added to the cooked luk-nieng for consumption. Cooked luk-nieng in a solution of coconut milk and sugar is also popular in southern Thailand.

Botany

A medium-sized tree about 18–25 m tall with a spreading crown and multi-branched (Plate 4). It has a grey glabrous bark and bipinnate leaves up to 25 cm long. Leaflets 2–3 pairs per pinna, ovate-elliptical to oblong, 8–16 cm by 4–5 cm, opposite and papery, glabrous, violet red when young (Plate 5). Inflorescence axillary, paniculate, 20 cm long with 4–7 sessile flowers in a pseudo-umbel. Flowers – pentamerous, bisexual, white with a cup shaped calyx and tubular corolla and numerous yellowish-white stamens. Fruit a compressed, falcate, twisted, glabrous, woody legume, deep purple, deeply lobed along the lower suture, 20–25 cm by 4–5 cm wide and easily broken by hand (Plates 1–3, 6–7). There are 3–6 seeds per pod. The seed is 3–5 cm across with yellow testa when young, which turns brown at maturity. Seed is compressed orbicular 2.5–3 cm across and 1.5 cm thick, with yellowish-white testa (Plate 8).

Plate 1 Twisted, purplish-black, mature pods of jering

Plate 2 Jering seeds intact and with seed coat removed

Plate 3 Jering seeds with intact orange-brown seed coats

Plate 6 Intact Jering pod segments and one segment sliced to show the yellowish-white orbicular seed kernel

Plate 4 Tree canopy with clusters of brown pods amongst the dense foliage

Plate 7 Detached jering pod segments commonly sold in the local market

Plate 5 Young, wine-red, tender leaves are used as vegetable

Plate 8 Jering kernels on sale in Kuching market

Nutritive/Medicinal Properties

It has been reported by the Thai Department of Health that 100 g of edible luk-nieng seed contained: moisture 76.3 g, calorie 92 units, fat 0.2 g; carbohydrate 16.9 g, fibre 1.3 g, protein 6.2 g, calcium 23 mg, phosphorous 38 mg, iron 0.7 mg, vitamin A 658 IU, vitamin B_1 0.14 mg, vitamin B_2 0.01 mg, niacin 0.4 mg, and vitamin C 8.0 mg (Subhadrabandhu 2001). Jering seeds were found to be high in moisture and low in fat (Suhaila et al. 1987). The crude protein content of jering was about 5% on fresh weight basis (FW) but it contained 47.8% essential amino acid (excluding tryptophan) and a fairly high chemical score of 59%. Although jering had low methionine content, it contained an exceptionally high concentration of cysteine. Mature jering had a lower tannin and trypsin inhibitor content compared to immature jering. Most of these antinutrients were located in the testa. The percentage of reduction in trypsin inhibitor activity and hemagglutinin depended on the time and temperature of treatment. The use of moist heat to reduce the amount of trypsin inhibitor and hemagglutinin was more effective than dry heat, and germination of seeds was more effective than fermentation with *Rhizopus oligosporus.*

Antioxidant Activity

The shoots and fruits of *Pithecellobium jiringa* were found to have high polyphenolic contents (>150 μg gallic acid equivalents/mg dried basis) and antioxidant activities when measured using the ferric reducing antioxidant power (FRAP) (>1.2 mM) and Trolox equivalent antioxidant capacity (TEAC) assays (>2.4 mM) (Razab and Abdul-Aziz 2010). A strong correlation was observed between the two antioxidant assays (FRAP versus TEAC) implying that the plant could both scavenge free radicals and reduce oxidants. There was also a strong correlation between the antioxidant activities and polyphenolic content suggesting the observed antioxidant activities were contributed mainly by polyphenolics in the plant.

Hypoglycaemic and Anti-urolithiasis Activities

Ingested the seeds acts as a diuretic. Studies revealed that aqueous extracts of jering induced a hypoglycaemic effect in fasted cats (Thevathasan 1972). Studies conducted in Malaysia showed that *A. jiringa* had an effect of reducing urinary stones or urolithiasis (Zakaria et al. 2001). Male Sprague Dawley rats treated weekly with intraperitoneal injection of methanol extract of *P. jiringa* (60 mg/kg × 3 doses) in addition to 1.0% ethylene glycol in their drinking water to induce calcium oxalate crystal, showed significant reduction in the size of calcium oxalate crystals (dihydrate and monohydrate types) after 6 weeks compared to positive control group receiving 1.0% ethylene glycol in their drinking water. Biochemical tests showed significant reduction in the excretion of magnesium in the treatment group compared to the control group fed rat chow and water *ad libitum* but no significant differences in the levels of calcium, inorganic phosphate, creatinine and uric acid between the treatment and control group. Histological examination of kidneys of the positive control group showed greater extent of glomerular damage and tubular necrosis.

Toxicity Problems

Excessive consumption can lead to the Jering poisoning or djenkolism also referred to as kejengkolan disease caused by crystallisation of jenkolic acid in the kidneys and bladder (H'ng et al. 1991). This is characterised by renal hyperemia, oliguria, urinary obstruction and spasmodic pain when urinating. Djenkol bean consumption was also identified as one of the probable causes of hematuria in children in the areas where the djenkol tree grows in southern Thailand (Vachvanichsanong and Lebel 1997). Two cases of jering poisoning were reported in Singapore which resulted in acute renal failure (Wong et al. 2007). Clinical symptoms included bilateral loin pain, fever, nausea, nausea, vomiting, oligo-anuria, haematuria and sandy particles in the urine. Remedial therapy consisted of dehydration with

normal saline and alkalinisation of urine with sodium bicarbonate.

Traditional Medicinal Uses

In Malaysia, jering leaves have been used as a poultice for skin complaints and for pains in the chest in traditional medicine. The bark has been employed also for chest pains and to make a gargle for tooth-ache. Old leaves are burnt and the ashes are applied for itch in Java. Powder of scorched young leaves has been applied to cuts and to wounds of circumcision.

Other Uses

Methanolic extracts of *Pithecellobium jiringa* demonstrated moderate antinematodal activity against *Bursaphelenchus xylophilus*, the pine wood nematode (Mackeen et al. 1997).

Jering pods provide a purple dye on silk and have been used by dyers in Pekan, Pahang, Malaysia. In Borneo, the bark is used for dyeing matting black. The leaves can also be similarly used. The pods have been used for washing hair. The soft wood of the timber have been used for building coffins and as firewood.

Comments

The species is propagated from seeds.

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Cajanus cajan

Scientific Name

***Cajanus cajan* (L.) Millisp.**

Synonyms

Cajan cajan (L.) Huth, *Cajan inodorum* Medik., *Cajanum thora* Raf., *Cajanus bicolor* DC., *Cajanus cajan* var. *bicolor* (DC.) Purseglove, *Cajanus cajan* var. *flavus* (DC.) Purseglove, *Cajanus flavus* DC., *Cajanus indicus* Spreng., *Cajanus indicus* var. *bicolor* (DC.) Kuntze, *Cajanus indicus* var. *flavus* (DC.) Kuntze, *Cajanus indicus* var. *maculatus* Kuntze, *Cajanus luteus* Bello, *Cajanus obcordifolia* Singh, *Cajanus pseudocajan* (Jacq.) Schinz & Guillaumin, *Cajanus striatus* Boj., *Cytisus cajan* L., *Cytisus pseudocajan* Jacq.

Family

Fabaceae or Leguminosae, also placed in Papilionaceae

Common/English Names

Angola Pea, Congo-Pea, Gungo Pea, No Eye Pea, Pigeon-Pea, Red Gram, Puerto Rico Pea, Yellow Dhal

Vernacular Names

Arabic: Bisillah Hindîyah, Lûbyâ Sûdânî;
Argentina: Guando, Guandu, Guandú, Guandul, Guisante De Angola, Guisante De Paloma, Guisante Gunga, Guisante Gungo, Planta De Guandú (Spanish);
Brazil: Feijão-Guandu, Guandu (Portuguese);
Chamorro: Lenteha Franchesa, Lenteja Francesa;
Chinese: Mu Dou, Huang Dou Shu, Chieh Tu, Chieh Tu Tzu, Shan Tou Ken;
Cuba: Gandua, Gandul;
Czech: Kajan, Mestelice;
Danish: Ærtebønne, Ærteboenne;
Dutch: Struikerwt, Katjang Goedé;
Eastonian: Harilik Tuvihernes;
Ecuador: Gandú;
Finnish: Kyyhkynherne;
Ethiopia: Yewof Ater;
Fijian: Nggiringgiri, Pi;
French: Ambrévade, Ambrevade, Pois Cajan, Pois D'angole;
German: Straucherbse, Strauchbohne, Taubenerbse;
Hawaiian: Pī Nūnū, Pī Pokoliko;
India: Rahar Dal (Assamese), Arhar (Bengali), Arhar, Toor, Tur, Tuvar, Tuver Dahl, Dhal, Tuvar, Tuur, Tor, Tur, Tuar (Hindu), Kariuddu, Thogari Bele, Thurukara Thogari, Togari, Thugari Bele, Athaki, Baele, Byale, Dhaal, Kari Uddu (Kannada), Thora-Paerou, Thuvarappayar, Tuvara,

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Tuvarapparippu (Malayalam), Mairongbi (Manipuri), Tuur, Thoora, Thoori, Thoovar (Marathi), Arhar (Oriya), Adhaki, Tuvari, Tuvarika (Sanskrit), Tuvarai, Atakam, Ataki, Curattam, Kacci, Miruttalakam, Miruttanam Yarai, Torai, Thuvarai, Kattu-Thovarai, Duvarai, Malaittuvarai, Amakam, Amam, Atacai, Impurupali, Irumpali, Iruppappuli, Iruppuli, Iruppulikam, Iruppulikamaram, Iyavu, Iyavucceti, Kaccikacceti, Kaccikam, Kalvayam, Kalvayamaram, Kanti, Karaviram, Karkai, Karkaicceti, Kaycci, Kecapukacceti, Kecapukam, Kuvalam, Kuvalamaram, Malikaittuvarai, Malur, Pataippeyan, Pataippeyanmaram, Torai, Miruttalakam, Miruttanam, Muluttuvarai, Naiciravam, Naiciravamaram, Nattuttuvarai, Tuvaraippayaru, Tuvarankay1, Tuvari, Tuvarikam (Tamil), Kandi, Kandulu, Aadhaki, Errakandulu, Kondakandi, Peddakandi, Peddakondakandi, Polukandi, Potujandalu, Sinnakandi, Kandul (Telugu);
Indonesia: Kacang Bali, Kacang Gude, Kacang Kayu;
Italian: Pisello D'angola, Pisello Del Tropico, Caiano;
Jamaica: Congo Pea, Gungo Pea;
Japanese: Pijonpii, Ki-Mame;
Khmer: Sândaèk Dai, Sândaèk Kroëb Sâ, Sândaèk Klöng;
Laotian: Thwàx H'ê;
Malaysia: Kacang Dhal, Dhal, Kacang Hiris;
Nepalese: Rahar;
Nigeria: waken turawa (Hausa), otili (Yoruba);
Papiamento: Wandu;
Peru: Frijol De Palo;
Philippines: Tabois (Bikol), Kidis (Bontok), Tabois (Cebu Bisaya), Kardis (Ibanag), Kusia (Ifugao), Kaldis, Kardis, Kusia (Igorot), Kaldis, Kardis, Kidis (Iloko), Kadios (Mangyang), Kadios (Panay Bisaya), Gablos, Kadios, Kagyos, Kagyus, Kalios (Tagalog);
Portuguese: Feijão-Guandu, Guandú, Guisante-De-Angola , Ervilha De Angola, Ervilha Do Congo;
Puerto Rico: Gandule;
Spanish: Cachito, Frejol De Palo, Frijol Del Monte, Gandul, Guando, Fríjol De Árbol, Frijol De La India, Frijol Guandul, Frijol Quinchancho, Vaina Del Guandú (Pods);
Sudan: Lubia Addassy;
Swedish: Duwärt;
Taiwan: Shu Dou;
Thailand: Thua Rae, Thua Maetaai, Ma Hae;
Tibetan: Tu Ba Ri, Tu Pa Ri;
Uganda: Lapena (Acholi), Lapena, Apena (Langi), Enkuuku (Runyankore), Enkuuku (Runyoro), Enkuuku (Rutooro), Ekilimite (Teso),
Venezuela: Quinchocho, Quinchoncho (Spanish);
Vietnamese: Cay Dau Chieu, Dau Sang, Dau Thong.

Origin/Distribution

Pigeon pea probably evolved in south Asia and appeared around 2000 BC in west Africa which is considered a second major centre of origin. It is widely cultivated in the tropical and subtropical regions in Asia, Africa, the Pacific and the Atlantic. Pigeon peas are an important grain legume crop of rain-fed agriculture in the semi-arid tropics. The world's three main pigeon pea producing regions are the Indian subcontinent, Eastern Africa and Central America, in decreasing order.

Agroecology

Pigeon pea is hardy, widely adaptable, and more tolerant of drought and high temperatures than most other crops. The crop is cultivated and occasionally escaping, apparently naturalized in open, disturbed areas such as roadsides, pastures and waste-lands. Various cultivars are grown from sea level to 2,500 m. The crop thrives in areas with temperatures ranging from 18°C to 38°C and mean annual rainfall of 600–1,000 mm/year in elevations below 2,000 m. Pigeon pea is very drought resistant and can be grown in areas with less than 650 mm annual rainfall. It is less suited to the hot wet tropics and areas with frequent inundations. It is frost sensitive and abhors water-logging. It prefers well drained, fertile soil with pH 5–7 and can tolerate some salinity from 0.6 to 1.2 S/m electrical

conductivity. Pigeon pea is adaptable on a wide range of soil types provided they are free draining, from sands to clays. It grows best in full sun.

Edible Plant Parts and Uses

Young pods, shoots, leaves and seeds are edible. The seeds are used as dried peas, flour or green vegetable peas. In India, the seeds are mainly used as pulses (dhal – split pea) and the young pods are used as vegetables in dishes like *sambhar*. The fresh pods, young shoots and seeds are used as vegetables in *sayor*, spicy soups and other side-dishes in southeast Asia and the Pacific. In Indonesia, the young pods and leaves are cooked and eaten in various dishes. In Ethiopia, the pods, young shoots and leaves are cooked and consumed. Ripe seeds are eaten roasted too. Pigeon pea may replace soya beans to make *tempeh* and *tahu* (fermented soya products). The dried peas may be sprouted briefly, and then cooked, for a flavor different from the green or dried peas. Green pigeon pea and rice together are considered the main traditional food, served as a representative of Puerto Rican cuisine called *Arroz con gandules*. Pigeon pea is also cooked as a stew with plantain balls. In Hawaii and the Dominican Republic, pigeon peas are cultivated for canning. In the latter, pigeon pea with rice is eaten in the traditional dish called *Moro de Guandules*.

Bean pastes from the black eyed bean (*Vigna unguiculata*), pigeon pea (*Cajanus cajan*) and Ife brown (*V. unguiculata*) were processed into a popular West African snack moi-moi, cooked in open aluminium cups and in sealed, thin, transparent cellophane bags (Okolie and Omoigberale 1999). Cooking of moi-moi in cellophane bags was found to reduce the risks of cyanide exposure from legumes.

Studies showed that the pigeon pea flour mixed with rice had high protein quality and were similar when mixed in ratios of 80:20 to 40:60 (Mueses et al. 1993). All pigeon pea flour mixtures with rice gave similar protein quality values. Testing of three products developed gave the following results. The gruel "atole" and the fruit flavoured thick drink had high acceptability based on a sensory evaluation test. Cookies with 100% pigeon pea flour were unacceptable; however, mixtures of 75% wheat flour and 25% pigeon pea flour gave cookies of attractive appearance and good taste. Pigeon pea flour can be blended with millet flour to make biscuits (Eneche 1999). They all contained high proportions of protein (7.5–15.2%), fat (17.1–18.1%) and digestible carbohydrate (60.2–66.5%). The moisture content was in the range 5.0–6.6%, ash 1.5–2.3% and crude fibre 0–0.1%. Sensory evaluation results indicated that all the biscuits had high sensory ratings for all the selected attributes evaluated. The recipe with the 65% MF/35% PPF blend resulted in the highest scores for flavour, texture and general acceptability. There was no significant difference between all the biscuits and the familiar Nasco short cake biscuit in flavour, colour, texture and general acceptability.

Flavoured snacks can be made from extruded cassava flour (CF)/pigeon pea flour (PF) (Rampersad et al. 2003). Extrudate with 95% CF/5% PF had a suitable crisp to hard texture. All enrobed products were liked moderately to very much in overall acceptability. Chocolate extrudates were most liked for flavour and colour over paprika, hickory, and cheese/onion.

Studies by Singh et al. (1989) found that pigeon pea starch of dhal (decorticated dry split cotyledons) was as good for noodle preparation as mung bean dhal starch. No large differences in size and shape of respective starch granules were observed. The degree of syneresis of pigeon pea starch was nearly three times that of mung bean starch. Swelling power of pigeon pea starch was considerably lower at 60°C and 70°C but it did not differ markedly at 80°C and 90°C. The Brabender viscosity patterns of 6% starch pastes of pigeon pea and mung bean indicated no pasting peak during heating to 95°C; neither showed breakdown of the hot paste. Pigeon pea can also be blended with sorghum to make tempe by soaking the mixture and using *Rhizopus oligosporus* to ferment the mixture (Mugula and Lyimo 2000). Tempe processing reduced the tannin content. The developed tempe had protein quality and energy recommended for weaning foods. The deep-fried snacks were acceptable.

Germinated pigeon pea flour was found to be an excellent ingredient to increase the nutritional value of semolina pasta without affecting the sensory properties (Torres et al. 2007). Germination brought about a sharp reduction of α-galactosides, phytic acid and trypsin inhibitor activity (83%, 61% and 36%, respectively) and an increment of vitamin B2 (145%), vitamin C (from negligible amounts to 14 mg/100 g d.m.), vitamin E (108%) and total antioxidant capacity (28%). These flours when used as ingredients to produce pasta products in a proportion of 5%, 8% and 10% had shorter cooking time and higher water absorption. From sensory evaluation, fortified pasta generally had acceptability similar to control pasta. Cooked pasta with the highest level of substitution (semolina:germinated pigeon pea flour at 10%) showed that protein, fat, dietary fibre and mineral contents were improved. Fortified pasta provided more vitamin B1, B2, E and antioxidant capacity than did control pasta. Biological assessment of fortified, cooked pasta indicated that true TD and PER value increased by 12% and 64%, respectively, in comparison with control.

Plate 1 Leaves, flowers and pods of pigeon pea

Plate 2 Red-podded variety of pigeon pea

Plate 3 Green-podded variety of pigeon pea

Botany

An erect, glandular-pubescent, branched, short-lived perennial shrub, 0.5–3 m high usually 1–2 m high, with thin, nodulated roots up to 2 m deep. Stems ribbed and up to 15 cm in diameter and with many slender pubescent branches. Leaves alternate, trifoliolate (Plates 1–3), glandular punctuate on 1.5–5 cm long petioles. Leaflets elliptical to lanceolate, 3–13 cm × 1.5–6 cm, upper surface glabrous, lower pilose, papery, apex acute, acuminate or mucronate. Flowers in axillary pseudo-racemes, papilionaceous, calyx yellow, tomentose, corolla yellow or cream, standard suborbicular, dorsally red, orange or purple; keel yellowish green tinged orange to purple (Plate 1), apex obtuse and slightly inflexed, wings slightly obovate with short auricle, ovary hairy, style long, linear and glabrous with capitate stigma. Fruit a straight or sickle-shaped, green or red depending on variety, linear-oblong legume (Plates 1–3), 2–13 cm long by 0.5–1.7 cm wide with subglobose to ellipsoid or squarish seeds. Seeds white, cream, brown, purplish to almost black, plain or speckled, 5 mm in diameter.

Nutritive/Medicinal Properties

The proximate value per 100 g edible portion of raw mature pigeon pea seeds based on USDA National Nutrient Database for Standard Reference (2010) was reported as: water 10.59 g, energy 343 kcal (1,435 kJ), protein 21.7 g, total lipid 1.49 g, ash 3.45 g, carbohydrate 62.78 g, total dietary fibre 15 g, minerals – Ca 130 mg, Fe 5.23 mg, Mg 183 mg, P 367 mg, K 1,392 mg, Na 17 g, Zn 2.76 mg, Cu 1.057 mg, Mn 1.791 mg, Se 8.2 μg, vitamins – vitamin C 0 mg, thiamine 0.643 mg, riboflavin 0.187 mg, niacin 2.965 mg, pantothenic acid 1.266 mg, vitamin B-6 0.283 mg, total folate 456 μg, vitamin A 28 IU, total saturated fatty acids 0.330 g, total monounsaturated fatty acids 0.012 g, total polyunsaturated fatty acids 0.814 g, tryptophan 0.212 g, threonine 0.767 g, Isoleucine 0.785 g, leucine 1.549 g, lysine 1.521 g, methionine 0.243 g, cystine 0.250 g, phenylalanine 1.858 g, tyrosine 0.538 g, valine 0.937 g, arginine 1.299 g, histidine 0.0.774 g, alanine 0.972 g, aspartic acid 2.146 g, glutamic acid 5.031 g, glycine 0.802 g, proline 0.955 g and serine 1.028 g.

The range of nutrient contents obtained for six varieties of pigeon pea were: dry matter 86.6–88.0%, crude protein 19.0–21.7%, crude fat 1.2–1.3%, crude fibre 9.8–13.0%, and ash 3.9–4.3%. Minerals ranges (mg/100 g dry matter) were: K 1845–1941, P 163–293, Ca 120–167, Mg 113–127, Na 11.3–12.0, Zn 7.2–8.2, Fe 2.5–4.7 and Cu 1.6–1.8. (Amarteifio et al. 2002). In general, the composition of pigeon peas compared favourably with those of other legumes such as Bambara groundnut (*Vigna subterranea*). The levels of crude protein, crude fibre, K, Ca, P and Mg indicated that pigeon peas could be valuable in the diet of the people of Botswana.

Some of the important factors affecting the protein quality of pigeon pea were reviewed by Singh and Eggum (1984). Among important food legumes, pigeon pea contained the lowest levels of limiting sulphur amino acids, methionine and cystine implicating the importance of these amino acids in protein quality improvement program. Large variation existed in the contents of protease inhibitors of pigeon pea varieties. The amounts of these inhibitors were significantly higher in some of the wild relatives of pigeon pea. Protein digestibility of cooked pigeon pea meal remained low and this could be attributable to the presence of certain compounds besides trypsin inhibitors. Pigeonpea polyphenolic compounds adversely affected the activity of digestive enzymes and this would affect the protein quality of pigeon pea. The protein quality of pigeon pea was also largely influenced by storage and processing practices.

The average protein content of the high-protein genotypes of pigeon peas was higher by nearly 20% but their starch content, the principal constituent of the seed, was lower by about 8% (Singh et al. 1990). The higher fraction (about 7%) of globulin, the dominant storage protein, was associated with a lower glutelin fraction in the high-protein genotypes. The amino acid composition (g per 100 g protein) of the high-protein genotypes was similar to those of the normal-protein genotypes. However, the sulphur-containing amino acids methionine and cystine were distinctly higher (about 25%) in high-protein genotypes when results were expressed in g per 100 g sample. No large differences in true protein digestibility, biological value and net protein utilisation were found between high and normal protein genotypes. True protein digestibility was significantly increased by cooking in both whole-seed and dhal samples. The values for utilisable protein were considerably higher in high-protein genotypes, suggesting their superiority from the nutritional aspects.

From the above, it can be seen that pigeon pea seeds are very rich sources of proteins, amino acids (methionine, lysine and tryptophan), minerals like K, P, Mg and Fe, and fair in vitamin B complex and calcium and very low in lipids.

The oil of *Cajanus cajan* was found to comprise of sesquiterpenes (92.5%, 81.2% and 94.3% respectively in the leaves, stem and seeds) (Ogunbinu et al. 2009). The dominant compounds identified were α-himachalene (9.0–11.5%), β-himachalene (8.0–11.0%), γ-himachalene (6.9–8.1%), α-humulene (7.1–8.7%) and α-copaene (4.5–5.6%).

Obizoba (1991) found that sprouting pigeon peas for 48 h offered greater nutritional advantage

over 96 hours. After 48 and 96 hours of pigeon pea sprouting, there were increases in percent moisture, crude protein, ash except during the 96 hours; total nitrogen, total non-protein nitrogen, protein nitrogen and true protein nitrogen. Sprouting caused increases in mineral contents except for phosphorus.

The solubility of pigeon pea flour and protein concentrate was greater than 70% at pH above 6.7 and below 3.5 (Mizubuti et al. 2000). The water and oil absorption were 1.2 and 1.07 ml/g for the flour concentrate and 0.87 and 1.73 ml/g for the protein concentrate, respectively. The minimum concentration of flour and protein concentrate required for gelation was 20% and 12%, respectively. The emulsifying capacity of flour and protein concentrate was 129.35 g and 191.66 g oil/g of protein and the emulsion stability 87.50% and 97.97%, respectively, after 780 min. The foam capacity and stability of flour foam were 36.0% and 18.61%, while of the protein concentrate were 44.70% and 78.97% after 90 min. These properties indicated that the pigeon pea flour as well as the protein concentrate could have application in various food systems.

Okpala and Mamah (2001) investigated and compared the emulsification capacity, foam capacity, foam stability, fat and water absorption of raw and processed pigeon pea flour with those of raw soy flour. The processing methods included soaking in water, soaking and blanching in water and soaking and blanching with trona, a sodium sesquicarbonate salt. Soaking in water was found to lower the water absorption capacity of pigeon pea flour while soy flour had a slightly higher water absorption capacity than the other processed flours. All the processing treatments enhanced the fat absorption capacity of pigeon pea flour and the values were also higher than that for raw soy flour. The trona-treated pigeon pea flour had the highest emulsification capacity and was even higher than that of raw soy flour. Soy flour was found to have higher foaming capacity than all the pigeon pea flour samples. Refined wheat flour can be partially substituted with 30% whole *Cajanus cajan* flour for the preparation of brownies and foodstuffs traditionally consumed by school age children in Venezuela (Granito et al. 2010). The protein content was 10–11%, in-vitro protein digestibilities 87% and calorie value was 246 kcal.

Jayadeep et al. (2009) found a decrease in fat and crude fibre was observed when dehusked whole grains (*gota*) of pigeon pea was converted to dehusked splits (dhal). The lipid profile of *gota* and dhal from red and white husk pigeon pea types indicated that essential fatty acids were greater in gota than in their respective dhals. *Gota* from white husk variety contained more tocopherols than the red variety. *Gota* contained more tocopherols than dhal. A decrease in the content of γ- and α tocopherols, vitamin E activity and total antioxidant activity indicated loss of bioactive components on splitting *gota* into dhal. Cooking time and dispersed solids on cooking indicated good cooking quality of *gota*. The results indicated the nutritional superiority of *gota* over dhal and its similarity with dhal in cooking characteristics.

Leaf, root and seed extracts of *Cajanus cajan* have been reported to display various pharmacological activities that included potent antioxidant, anti-cancerous, hypoglycaemic, microbial, hypocholesterolemic, hepatoprotective and nephroprotective activities.

Antioxidant Activity

Cajanus cajan leaf extracts are valuable natural antioxidant sources and may have potential application in both medicine and the health food industry. In the DPPH radical scavenging assay, the antioxidant activity of the ethanol extracts was found to be superior to that of the aqueous extracts, with IC_{50} values of 242.01 and 404.91 μg/ml, respectively (Wu et al. 2009). Of the four fractions i.e. petroleum ether, ethyl acetate, n-butanol and water fractions, the ethyl acetate faction showed the highest scavenging activity, with an IC_{50} value of 194.98 μg/ml. Among the four main compounds separated from the ethanol extract, i.e. cajaninstilbene acid (3-hydroxy-4-prenylmethoxystilbene-2-carboxylic acid), pinostrobin, vitexin and orientin, cajaninstilbene acid (302.12 μg/ml) and orientin

(316.21 μg/ml) exhibited greater radical-scavenging abilities than pinostrobin and vitexin. In the β-carotene-linoleic acid test, the inhibition ratio (%) of the ethyl acetate fraction (94.13%) was found to be the highest, almost equivalent to the inhibition activity of the positive control BHT (93.89%) at 4 mg/ml. Pinostrobin (>500 μg/ml) and vitexin (>500 μg/ml) showed insignificant antioxidant activities compared with cajaninstilbene (321.53 μg/ml) and orientin (444.61 μg/ml). The antioxidant activities of all the tested samples were dose-dependent.

Cajaninstilbene acid (CSA) derived from pigeon pea leaves exhibited stronger antioxidant properties, DNA damage protective activity, and xanthine oxidase (XOD) inhibitory compared with resveratrol (Wu et al. 2011). The IC_{50} values of CSA were 19.03 μM for superoxide radical scavenging, 6.36 μM for hydroxyl radical scavenging, 39.65 μM for nitric oxide scavenging, 20.41 μM for reducing power, 20.58 μM for lipid peroxidation, and 3.62 μM for XOD inhibition. CSA possessed good protective activity from oxidative DNA damage. In addition, molecular docking indicated that CSA was more potent than resveratrol or allopurinol in interacting with the active site of XOD. Thus it was conclude that CSA represented a valuable natural antioxidant source and may potentially be applicable in health food industry.

Hypoglycaemic and Hypolipidemic Activity

Amalraj and Ignacimuthu (1998) reported that single doses of unroasted pigeon pea seeds (60% and 80%) on administration to normal as well as alloxanized mice showed significant decrease in the serum glucose levels after 1–2 h and a significant rise at 3 h. In case of roasted seeds, there was a significant elevation in serum glucose levels during the 3 h experimental period. It was concluded that roasting of seeds at high temperature for an half hour period resulted in the total loss of hypoglycemic principle but not the hyperglycemic principle present in the seeds. Separate studies demonstrated that the aqueous fraction of the leaves and stems of *C. cajan* did not produce any hypo blood sugar effect in normoglycemic mice; instead, it elicited a hyperglycemia at concentrations of 500 mg/kg and 1,000 mg/kg (Esposito et al. 1991). A short lived reduction in glycemia was observed after 1 hour only at the concentration of 300 mg/kg. In the glucose tolerance test, the aqueous fraction of *C. cajan* produced a significant and short lived decrease with the dose of 300 mg/kg, while the dose of 500 mg/kg did so at 0.25, 0.5 and 1 hour. The 1,000 mg/kg dose produced a significant increase in glucose tolerance at 1 and 2 hours.

Leaf extracts like those of the seeds were reported to show hypoglycemic activity occasionally caused by excess of insulin and other hypoglycemic drugs. Stilbene extract from *C. cajan* leaves exhibited hypocholesterolemic effect on hepatic cholesterol metabolism in diet-induced hyperlipidemic mice (Luo et al. 2008a, b). After 4 weeks pretreatment with the stilbenes containing extract-fraction from *Cajanus cajan* (sECC) the atherogenic properties of dietary cholesterol in mice were reduced compared with the model group, the elevated serum and hepatic total cholesterol were markedly attenuated by sECC (200 mg/kg) by 31.4% and 22.7%, respectively, the triglyceride levels of serum and liver were also reduced by 22.98% and 14.39%, respectively. Concomitantly, serum LDL cholesterol fell by 52.8% and the activities of serum superoxide dismutase rose by 20.98%. Atherogenic index and body weight were also markedly lowered. Its hypocholesterolemic effect may involve enhancement of the hepatic LDL-receptor and cholesterol 7α-hydroxylase expression levels and bile acid synthesis. The mRNA expressions of hepatic 3-hydroxy-3-methylglutaryl-CoA reductase (HMG-CoA reductase), cholesterol 7α-hydroxylase (CYP7A1), and low density lipoprotein receptor (LDL receptor) were significantly enhanced in the mice administered with sECC (200 mg/kg/day), whereas those expressions were inhibited by the hypercholesterolemic diet.

Studies in the Philippines on five legumes including chick pea (*Cicer arietinum*), pigeon pea (*Cajanus cajan*), black bean (*Phaseolus vulgaris*), mung bean (*Phaseolus areus*) and white bean

(*Phaseolus vulgaris*) showed that the blood glucose response to all legumes was significantly lower compared to bread (Panlasigui et al. 1995). The glycaemic response to chick pea was significantly lower than that to black bean, pigeon pea and mung bean. The glycaemic index of chick pea (13.87) was significantly lower than those of black bean (27.91), pigeon pea (30.99) and mung bean (44.38) but was not different from that of white bean (19.48). The differences in the glycaemic responses among the legumes could be due to the dissimilarities in quantity and type of dietary fibre, amylose content and the presence of antinutrients. The scientists concluded that legumes could therefore be added to the list of foods for diabetics and hyperlipidaemics and continuous consumption in larger amounts should be recommended to the general Filipino population.

The methanol fraction of *C. cajan* seeds was found to significantly lower fasting blood glucose, and lipid profiles on streptozotocin-induced mice compared to control (Habib et al. 2010). The bioactive compound (CCA1) was found to be a substituted cyclopentene with glucose and was shown to possess notable hypolipidemic activity.

Hepatoprotective and Nephroprotective Activities

Administration of a protein fraction isolated from the leaves of *C. indicus* counteracted the action of carbon tetrachloride on transaminase and phosphatase, thus showing hepatoprotection (Datta et al. 1998). Treatment with carbon tetrachloride hepatotoxin at 0.1 ml/100 g of body weight, twice a week induced acute hepatic necrosis in Swiss albino mice, with significant changes in the activities of glutamic oxaloacetic transaminase (GOT), glutamic pyruvic transaminase (GPT), alkaline phosphatase (AP) and serum bilirubin. Daily treatment with a purified protein fraction 'X' from the above plant (0.5 mouse ml i.p; 50–60 μg/ml) for a period of 7, 14, 21 days respectively showed decreased activities of serum transaminases alkaline phosphatase and decreased levels of serum bilirubin. These findings were further confirmed by histopathological study of the liver.

Treatment with CI-1, the herbal protein isolated from pigeon pea inhibited the pathogenesis of a majority of lesions produced by the hepatotoxins: carbon tetrachloride (0.1 ml/100 g); β-galactosamine (500 mg/kg); paracetamol (300–500 mg/kg) and 40% ethanol (2 ml/100 g) (Datta and Bhattacharyya 2001). Ethanol treated mouse hepatocytes manifested giant mitochondria and presence of balloon cells. Carbon tetrachloride and paracetamol treated mouse hepatocytes showed increase in nuclear size and striking anisonucleosis. Condensation of chromatin, nucleoli were fragmented and dispersed in β-galactosamine induced hepatotoxic mice. Slender mitochondria, array of granular ER, presence of binucleated cells were the salient features of CI-1 treated hepatotoxic mice. Ultrastructurally, the hepatocytes of CI-1 treated mice were near normal. Thus, the herbal protein CI-1 may be a useful approach in the treatment of liver disorders in clinical medicine. Sarkar et al. (2006) also reported that the 43 KD protein showed maximum hepatoprotective activity when administered at a dose of 2 mg/kg body weight for 5 days after carbon tetrachloride administration. Histopathological studies also supported the hepatoprotective nature of the protein.

The 43 KD protein from pigeon pea was also reported to protect liver and kidney against mercuric chloride-induced oxidative stress (Ghosh and Sil 2008) Intraperitoneal administration of $HgCl_2$ at a dose of 5 mg/kg body weight for 1 day significantly reduced the activities of antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx). It also diminished the glutathione to oxidized glutathione (GSH/GSSG) ratio. Additionally, $HgCl_2$ increased the activities of serum marker enzymes (namely, glutamate pyruvate transaminase, GPT and alkaline phosphatase, ALP), creatinine, blood urea nitrogen and serum tumour necrosis factor alpha (TNF-alpha) level along with hepatic and renal lipid peroxidation. Also, administration of $HgCl_2$ to hepatocytes enhanced reactive oxygen species production and lowered the total antioxidant activity of the treated hepatocytes. Treatment with the protein intraperitoneally at a dose of 2 mg/kg body weight before or after $HgCl_2$ administration showed that it could scavenge free

radicals in-vitro and protect the alterations of the antioxidants and the other parameters.

Separate studies showed that levels of serum glutamate pyruvate transaminase and alkaline phosphatase, which showed an elevation in chloroform induced hepatic damage, were reduced to near normal levels with the pigeon pea 43 KDa protein pretreatment (Ghosh et al. 2006). In contrast, the levels of antioxidant enzymes such as catalase, superoxide dismutase and glutathione-S-transferase that were decreased in mice orally fed with chloroform were significantly increased in protein pretreated mice. Also, chloroform induced lipid peroxidation was effectively reduced by protein treatment both in-vivo and in-vitro. In cell free system the protein effectively scavenged diphenyl picryl hydroxyl radical and superoxide radical, but it could not catalyse the breakdown of hydrogen peroxide. Post treatment with the protein for 3 days after 2 days of chloroform administration showed similar results. Histopathological studies indicated that chloroform induced extensive tissue damage was less severe in the mice livers treated with the 43 kD protein prior and after the toxin administration. Results from all these data suggested that the protein possessed both prophylactic and therapeutic role against chloroform induced hepatotoxicity and probably acted by an anti-oxidative defence mechanism.

Studies also showed that the 43 KDa protein had potent protective activity against acetaminophen induced hepato-nephrotoxicity (Ghosh and Sil 2007; Sarkar and Sil 2007). Studies showed that that incubation of hepatocytes with the protein prevented acetaminophen-induced loss in cell viability, reduction in glutathione level and enhancement of reactive oxygen species generation. Pretreatment with the 43 KDa protein inhibited the acetaminophen-induced rise of alanine amino transferase (ALT) and alkaline phosphatase (ALP) in murine sera. Further, post-treatment with the protein significantly altered most of the changes induced by acetaminophen. Treatment of mice with the protein before administration of acetaminophen also reduced serum nitrite and TNF-alpha formation. It also counteracted acetaminophen-induced loss in mitochondrial membrane potential, loss in adenosine triphosphate and elevation in intracellular calcium. The protein exerted its protective action via the activation of NF-kappaB and Akt and deactivation of STAT-1 (Ghosh and Sil 2009). The data suggested that the protein possessed cytoprotective activity against acetaminophen-induced oxidative cellular damage and prevented hepatocytes from necrotic death.

Studies in India using animal models demonstrated that methanol-aqueous fraction of *Cajanus cajan* leaf reversed the liver damage due to alcohol (Kundu et al. 2008). Simultaneous administration of methanol-aqueous fraction (MAF2) of *Cajanus cajan* leaf extract reversed the liver damage due to alcohol, decreased the activities of liver marker enzymes and augmented antioxidant enzyme activities. MAF2 co-administration normalized uridine 5′-diphospho-glucuronosyltransferase (UDP)-glucuronosyl transferase (UGT) activity and revived the expression of UGT2B with a concomitant expression and nuclear translocation of Nrf2, a transcription factor that regulates the expression of many cytoprotective genes. It decreased the activities of liver marker enzymes and augmented antioxidant enzyme activities, indicating its therapeutic use potential in alcohol induced liver dysfunction.

Studies also showed that a 43 kD protein isolated from pigeon pea leaf extract can ameliorate galactosamine-induced oxidative stress in nephrotoxicity (Manna et al. 2007b). The protein possessed hepatoprotective activity, presumably by first ameliorating galactosamine -induced liver damage and consequently reducing the renal disorders. The increased activities of serum marker enzymes, alanine aminotransferase, and alkaline phosphatase because of GalN administration, were significantly reduced by the protein treatment. The protein also normalized the altered activities of antioxidant enzymes superoxide dismutase, catalase, glutathione reductase, and glutathione-S-transferase as well as the levels of cellular metabolites, reduced glutathione, glutathione disulfide, and total thiols. Further, the increased activities of serum marker enzymes, alanine aminotransferase, and alkaline phosphatase and hepatic lipid peroxidation resulting from GalN

intoxification, were effectively reduced by the protein treatment.

Intraperitoneal administration of mice with the 43 KD protein at a dose of 2 mg/kg body weight for 7 days followed by 600 ppm sodium fluoride treatment for the next 7 days, normalized the activities of the hepato-renal antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT), glutathione-S-transferase (GST), glutathione reductase (GR) and the cellular metabolites such as reduced glutathione (GSH), oxidized glutathione (GSSG), total thiols, lipid peroxidation end products in the mice liver and kidney (Manna et al. 2007a). Post treatment with the protein for 4 days showed that it could assist tin restoring the damages after sodium fluoride administration. Time-course study suggested that the protein could stimulate the restoration of both the organs faster than natural process. Taken together, the results suggested that sodium fluoride could induce severe oxidative stress both in the liver and kidney tissues in mice and the protein possessed the ability to attenuate that hepato-renal toxic effect of sodium fluoride probably via its antioxidant activity. Sinha et al. (2007b) reported that the 43 kD protein from pigeon pea leaves exerted a protective activity against cadmium chloride induced cytotoxicity in mouse hepatocytes probably via its antioxidant property. Incubation of hepatocytes with the protein at prior to the cadmium chloride treatment normalised the activities of all the antioxidant enzymes, the levels of glutathione (GSH), total thiols, cell viability and also attenuated the elevated levels of glutamate pyruvate transaminase (GPT) and alkaline phosphatase (ALP), lipid peroxidation and oxidised glutathione (GSSG). Sarkar and Sil (2006) reported that the 43 KD protein acted as a hepatoprotector and primary antioxidant against thioacetamide-induced cytotoxicity in mouse hepatocytes. Incubation of hepatocytes with the protein prior to thioacetamide administration significantly inhibited the cell membrane damage as revealed from less lactate dehydrogenase (LDH), alanine aminotransferase (ALT) and total protein leakage. Thioacetamide depleted endogenous antioxidant glutathione (GSH) and increased membrane lipid peroxidation in hepatocytes. The protein had very remarkable effect in changing the GSH level and lipid peroxidation. The protein exhibited all these cytoprotective effects in a concentration-dependent manner. Further, measurement of DPPH radical scavenging activity indicated that the protein could scavenge free radicals. In addition, the protein resisted thioacetamide induced alterations of various effects when applied in combination with thioacetamide.

Anticancer Activity

The leaf dichloromethane extract and prenylated stilbenes from leaves of *Cajanus cajan* were shown to exhibit in-vitro cytotoxic activity against human amelanotic melanoma, C32, human breast adenocarcinoma, MCF-7, and human large cell lung carcinoma, COR-L23, cell lines (Ashidi et al. 2006, 2007, 2010). Further partitioning of the dichloromethane fraction yielded six compounds: hexadecanoic acid methyl ester, α-amyrin, β-sitosterol, pinostrobin, longistylin A and longistylin C. Pinostrobin and longistylins A and C were tested for cytotoxicity on the cancer cell lines. In addition, an adriamycin-sensitive acute T-lymphoblastic leukaemia cell line (CCRF-CEM) and its multidrug-resistant sub-line (CEM/ADR5000) were used in an XTT {2, 3-bis (2-methoxy-4-nitro-5-sulfophenyl)-5-[(phenylamino) carbonyl]-2H-tetrazolium hydroxide} assay to evaluate the activity of the pure compounds obtained. The dichloromethane fraction of *Cajanus cajan* had IC_{50} value 5–10 μg/ml, attributable primarily to the two constituent stilbenes, longistylins A and C, with IC_{50} values of 0.7–14.7 μM against the range of cancer cell lines. This confirmed the rational inclusion of *Cajanus cajan* in traditional herbal medicines used for the treatment of cancer in south-western Nigeria.

Cajanol (5-hydroxy-3-(4-hydroxy-2-methoxyphenyl)-7 -methoxychroman-4-one) an isoflavanone and phytoalexin from pigeon pea roots was found to have cytotoxic activity of towards MCF-7 human breast cancer cells (Luo et al. 2010). Cajanol inhibited the growth of MCF-7 cells in a time and concentration-dependent manner. The IC_{50} value was 54.05 μM after 72 hours treatment, 58.32 μM after 48 hours and 83.42 μM after 24 hours. Cajanol arrested the cell cycle in the

G2/M phase and produced apoptosis via a ROS-mediated mitochondria-dependent pathway. Western blot analysis showed that cajanol inhibited Bcl-2 expression and induced Bax expression to disintegrate the outer mitochondrial membrane causing cytochrome c release. Mitochondrial cytochrome c release was associated with the activation of caspase-9 and caspase-3 cascade, and active-caspase-3 was involved in PARP (poly(ADP-ribose) polymerase) cleavage. All of these signal transduction pathways were involved in initiating apoptosis.

Antimicrobial Activity

Four antifungal isoflavones [7-hydroxy-4′-methoxy; 5,7,4′-trihydroxy; 5,7,2′,4′-tetrahydroxy; and 5,2′,4′-trihydroxy-7-methoxy] and one isoflavanone [5,2′-dihydroxy-7,4′-dimethoxy] were isolated from the fungus-infected stems of *Cajanus cajan* (Ingham 1976). A sixth compound was tentatively identified as 5,2′-dihydroxy-7,4′-dimethoxyisoflavone. The structure of 5,2′-dihydroxy-7,4′-dimethoxyisoflavanone (cajanol) was confirmed by synthesis from ferreirin (5,7,2′-trihydroxy-4′-methoxyisoflavanone).

Cajanus cajan was also found to possess antibacterial activity (Okigbo and Omodamiro 2006). The organic solvent extracts of the plant were found to be inhibitory *to Escherichia coli*, *Staphylococcus aureus*, and *Salmonella typhi*; the aqueous extract was inhibitory to *Escherichia coli* and *Staphylococcus aureus*; while *Klebsiella pneumoniae* and *Proteus mirabilis* showed resistance to all the extracts. The minimum inhibitory concentration value of the extracts on the organisms varied between 0.125 and 0.25 mg/ml for *Escherichia coli*, 0.125 mg/ml for *Staphylococcus aureus* and 0.0325–0.0625 mg/ml for *Salmonella typhi*. Bactericidal or bacteristatic effect varied with type of solvent extract, leaf extract concentrations, and the organisms. The active components of the plant extract exhibited no bactericidal or bacteristatic effect on the tested yeast (*Candida albicans*). A new natural coumarin, named as cajanuslactone (1), together with two known phytoalexins, pinostrobin (2) and cajaninstilbene acid (3) were isolated from pigeon pea leaves (Kong et al. 2010). The structure of 1 was determined as 7-hydroxy-5-O-methyl-8-(3-methyl-2-butylene)-4-phenyl-9,10-dihydro-benzopyran-2-one. Cajanuslactone was found to possess good antibacterial activity against *Staphylococcus aureus*, and the minimum inhibitory concentration (MIC) and the minimum bactericidal concentration (MBC) were 0.031 and 0.125 mg/ml, respectively. The result indicated cajanuslactone to be a potential anti-bacterial agent against Gram-positive bacteria.

Supercritical fluid extraction-CO_2 extracts of *C. cajan* were found to exhibit marked inhibitory effect against *Staphylococcus epidermidis, Staphylococcus aureus* and *Bacillus subtilis* (Zu et al. 2010b). The IC_{50} of SFE- CO_2 extracts ranged from 0.0557 mg/ml to 0.0689 mg/ml for cancer (MCF-7 (0.0557 mg/ml)) as well as non-cancer (BHK-21 (0.0641 mg/ml), RAW264.7 (0.0689 mg/ml) and Vero (0.0625 mg/ml)) cells. The flavonoid compounds orientin, vitexin, isovitexin, pinostrobin and the stilbene cajaninstilbene acid were detected in the SFE-CO_2 extracts.

Cajanol extracted from the roots of *Cajanus cajan* exhibited potent antibacterial activity towards *Staphylococcus epidermidis, Staphylococcus aureus, Bacillus subtilis, Escherichia coli, Proteus vulgaris,* and *Pseudomonas aeruginosa* with minimal inhibition concentration (MIC) values ranging from 98.90 to 197.8 μM (Liu et al. 2011). Mortality rates induced by cajanol were 96.55% in *E. coli* and 97.25% in *S. aureus*, the two most susceptible species. The results showed that cajanol suppressed *E. coli* only by DNA damage, whereas *S. aureus* was suppressed by affecting both, the lecithin and phosphate groups on the cellular membrane and DNA. Results indicated that cajanol may be a promising antibacterial agent for the therapy of bacterial infections.

Antiviral Activity

Aqueous and ethanolic extracts of *Cajanus cajan* were found to exhibit high antiviral activity against cell-free HSV-1 and HSV-2 (Zu et al. 2010a). The ethanol extract was most active with IC_{50} values of 0.022 μg/ml for HSV-1 and

0.1 μg/ml for HSV-2. HSV-1 and HSV-2 were considerably inactivated when the viruses were pretreated with the extracts for 1 hour prior to cell infection. At maximum non-cytotoxic doses of the extracts, plaque formation was significantly reduced by 95–99% for HSV-1 and HSV-2. A distinct time-dependent effect was demonstrated whereby the *Cajanu*s ethanol extract revealed a much higher activity than the *Cajanu*s aqueous one. The results obtained indicated that the extracts affected HSV before cell adsorption, but were inactive on the intracellular virus replication. The scientists reported a therapeutic application of *Cajanu*s ethanolic extracts containing crème or ointment as antiviral agent in recurrent HSV infection appeared to be promising.

Anti-sickle Cell Anaemia Activity

Amino acid analysis showed that solvent extracts of *Cajanus cajan* seeds (white variety) contained, as free amino acid, as much as 26.3% phenylalanine (Ekeke and Shode 1990). The presence of free phenylalanine in the methanol (water-soluble) extract of the seeds alone could account for about 70% of the antisickling potency of *Cajanus cajan* seed extract. Sickling inhibition was observed to be efficacious with *Cajanus cajan* methanolic extract which contained a mixture of phenylalanine (0.69 mg/ml) and p-hydroxybenzoic acid (10.5 μg/ml), equivalent to those found in bean extract (Akojie and Fung 1992). The level of phenylalanine and p-hydroxybenzoic acid per gram weight of bean was 4.92 mg and 21.0 mg, respectively. The additive antisickling effect of both compounds could be therapeutically exploited for the therapy of sickle cell anaemia. The aqueous methanol extract (3:1, v/v) of the seeds of pigeon pea was found to possess significant dose-dependent antisickling activity (Ogoda Onah et al. 2002). Phytochemical screening of the extract revealed the presence of free amino acids, phenolic compounds, tannins, globulins and saponins. These results showed that the extract could potentially be used in the management of painful episodes experienced by sickle cell patients.

Antiplasmodial Activity

Two stilbenes, longistylin A and C, and betulinic acid from the leaves and roots of pigeon pea displayed moderately high in-vitro activity against the chloroquine-sensitive *Plasmodium falciparum* strain 3D7 (Duker-Eshun et al. 2004).

Cognitive Enhancement Activity

Studies in mice showed that consumption of the stilbenes containing extract-fraction from *C. cajan* (sECC) significantly ameliorated the cognitive deficits and neuron apoptosis caused by a single intracerebroventricular injection of Abeta(25–35) (Ruan et al. 2009). Concomitantly, the decreased superoxide dismutase (SOD), choline acetyl transferase activity in hippocampus and cortex were markedly increased by sECC (200 mg/kg). sECC did not affect acetylcholine esterase activity in the hippocampus and cortex. These findings suggested that sECC may be a potential candidate for the development of therapeutic agents to treat cognitive impairment associated with Alzheimer's disease (AD) through increasing the activity of choline acetyltransferase and anti-oxidative mechanism.

Antiosteoporotic Activity

Studies conducted in China reported stilbene extracts from *Cajanus cajan* to have potential action in treatment of postmenopausal osteoporosis (Zheng et al. 2007a). Rats treated with stilbene extract from pigeon pea showed no alterations in uterine weight and serum 17βa-estradiol (E2) concentration compared with OVX (ovariectomized) rats. However, the serum follicle stimulating hormone (FSH) and luteinizing hormone (LH) contents were reduced by 11.5% and 15.2% respectively. It was found that the 60% of the femur structure had been significantly improved in OVX rats treated with 200 mg/kg of the stilbene extract without affecting serum E2 level and uterine weight in OVX rats. The trabeculae were thicker and larger than that of OVX rats. The

results showed that cajanine (longistylin A-2-carboxylic acid) isolated from extracts of the plant had estrogen-like action on osteoblast and osteoclast. Further studies (Zheng et al. 2007b) showed that cajanine and *Cajanus cajan* extracts stimulated the osteoblast cells proliferation and mineralized bone-like tissue formation in HOS TE85 cell human osteoblast-like cells. All of these suggested that cajanine had the estrogen-like action on osteoblast and osteoclast, and could be developed as anti-osteoporosis drugs.

Studies by Zhang et al. (2010) indicated that the water extract of *Cajanus cajan* leaves (WECML) promoted the proliferation of mouse primary bone marrow stromal cells (BMSCs) and mouse primary osteoblasts (OBs) at most concentrations tested. WECML promoted the osteogenic differentiation and formation of mineralized matrix nodules of BMSCs at concentrations of 0.1, 1, and 10 μg/ml, but inhibited the osteogenic differentiation and formation of mineralized matrix nodules of BMSCs at concentration of 0.01 μg/ml. WECML suppressed the adipogenic differentiation of BMSCs and adipocytic transdifferentiation of OBs at concentrations of 0.001, 0.1, 1, 10, and 100 μg/ml, but had no effects at concentration of 0.01 μg/ml. The results suggested that WECML had protective effects on bone and these protective effects may be mediated by decreasing adipocytic cell formation from BMSCs, which may promote the proliferation, differentiation, and mineralization function of OBs.

Immunomodulatory Activity

The herbal protein, CI-1, purified from pigeon pea leaves was found to influence humoral and cell-mediated immune response (Datta et al. 1999). In mice, sensitized with sheep red blood cells (SRBC), CI-1 enhanced IgG level by 28% over control. Primary and secondary antibody response to SRBC and bovine serum albumin (BSA) were significantly increased in CI-1 treated group. Furthermore CI-1 facilitated the delayed type of hypersensitivity (DTH) response to SRBC in sensitized mice and also increased leucocyte and macrophage migration inhibition response in immunized mice.

Depressant Activity

Studies showed that pinostrobin, a substituted flavanone from *Cajanus cajan*, inhibited voltage-gated sodium channels of mammalian brain (IC_{50} = 23 μM) (Nicholson et al. 2010). This was based on the ability of pinostrobin to suppress the depolarizing effects of the sodium channel-selective activator veratridine in a synaptoneurosomal preparation from mouse brain. The resting membrane potential of synaptoneurosomes was unaffected by pinostrobin. The pharmacological profile of pinostrobin was found to resemble that of depressant drugs that block sodium channels.

Effect on Pregnancy

Extracts of *Acanthospermum hispidum* and *Cajanus cajan* had been used by Brazilian people in an attempt to produce abortion but scientific animal studies conducted showed that both plant extracts had no abortifacient activity (Lemonica and Alvarenga 1994). There was no significant change in the mean weight of the fetuses, and no alteration in the percentage of post implantation loss in the treated groups. However, there was a dose-related increase in the number of external malformations. No internal malformations were observed in fetuses at term, but there was a significant incidence of fetuses with visceral anomalies. The tendency of the pregnancy to continue or terminate did not change with the treatment.

Olayaki et al. (2009) reported that oral administration of aqueous *C. cajan* leaf extract increased litter size and plasma progesterone in pregnant rats. There was also reduction in litter weight and maternal weight in extract treated rats during pregnancy. Aqueous leaf extract of *Cajanus cajan* was reported to be consumed by pregnant women in Nigeria. *C. cajan* leaf extract also elicited dose-dependent reduction in uterine contraction in rats (Olatunji-Bello et al. 2002).

Anti-nutritional Factors

Protease inhibitors, amylase inhibitors, phytolectins, polyphenols, and oligosaccarides were found to be important antinutritional factors of chickpea and pigeon pea (Singh 1988). Pigeon pea seeds were found to contain the following 21–25% protein, 7.5–14.1 mg/g trypsin inhibitor (TI), 0.14–0.97 mg/g tannin, 0.14–0.97 mg/g phytate and phytic acid contributed 66–75% phosphorus (Ene-Obong 1995). In-vitro protein digestibility (IVPD) of pigeon pea seeds was 76.34%. There was a significant negative correlation between TI and IVPD ($r=-0.63$). There was no significant correlation between IVPD and phytate and tannin contents. There was a positive correlation between protein content and IVPD. The legume may pose no serious problems to populations consuming them especially when heat treatment is applied before consumption. Cooking improved the bioavailability of nutrients and also partially or wholly destroyed some of the anti-nutritional factors (Salunkhe et al. 1986).

Cajanus cajan lectin was found to contain 3% concanavalin A-reactive neutral carbohydrates (Siddiqui et al. 1995). Its amino acid composition was characterized by high contents of acidic amino acids. The number of tyrosine and tryptophan residues per mole of the lectin was determined to be 14 and 4 respectively. *C. cajan* lectin was specific for mannose and glucose.

The protease inhibitor isolated and purified from pigeon pea was found to produce a marked reduction in aflatoxin B1-induced β-galactosidase activity in *Escherichia coli* PQ37 (Osowole et al. 1992). The observed reduction was postulated to be a result of the inhibitor's activity on the RecA protease produced in response to aflatoxin B1-induced DNA damage in the bacteria. In another study, a protein proteinase inhibitor (PI) purified from pigeon pea with a molecular weight of 14 K exhibited inhibitory activity toward proteolytic enzymes belonging to the serine protease group, namely trypsin and α-chymotrypsin (Haq and Khan 2003). The inhibitory activity was stable over a wide range of pH and temperatures. N-terminal sequence homology suggested that it belonged to the Kunitz inhibitor family.

Pigeon pea seeds were found to contain a proteinase inhibitor, designated red gram proteinase inhibitor (RgPI) that belonged to the Bowman-Birk inhibitor family (Prasad et al. 2010). RgPI exhibited non-competitive type inhibitory activity against bovine pancreatic trypsin and chymotrypsin. It decreased the activity of larval midgut trypsin-like proteinases in *Manduca sexta*. Its insecticidal property was further confirmed by reduction in the growth and development of these larvae, when supplemented in the diet.

Pigeonpea seeds were found to have amylase inhibitor (AI) activity (Giri and Kachole 1998). At least four AI isoforms were identified in pigeon pea seeds. The AIs inhibited human salivary and bovine pancreatic amylase but failed to inhibit bacterial, fungal and endogenous amylase. Pigeonpea AIs were found to be active over a pH range of 4.5–9.5 and were heat labile. The isoelectric point of a major inhibitor is 6.2. The AIs were tolerant to proteolysis by trypsin, chymotrypsin, bromelain and endogenous pigeon pea proteases. Pigeonpea AIs were synthesized during late seed development and also degraded during late germination.

The application of dry heat to pigeon pea seeds and meal was not effective in inactivating the trypsin inhibitory activity (TIA) and chymotrypsin inhibitory activity (CIA) (Mulimani and Paramjyothi 1994). Soaking for 24 h followed by 20 min cooking was efficacious in destroying the TIA and CIA. Reduction in trypsin and chymotrypsin inhibitory activity was observed on soaking pigeon pea seeds in salt solutions in comparison to soaking in distilled water (Mulimani and Paramjyothi 1995). Maximum loss of trypsin and chymotrypsin inhibitory activity was observed on soaking the seeds in mixed salt solution.

The unprocessed seeds of Manak, the high yielding cultivar of pigeon pea were found to contain considerable quantities of phytic acid, 917 mg per 100 g (Duhan et al. 1999). This antinutrient was reduced significantly to varying extents (4–37%) by various domestic processing and cooking methods, viz. soaking (6, 12 and 18 hours, 30°C), soaking and dehulling, ordinary cooking, pressure cooking and germination (24, 36 and

48 hours, 30°C). Except soaking and dehulling, the remaining processing and cooking methods did not lower the contents of total calcium, phosphorus and iron. That HCl-extractability of these dietary essential minerals, an index of their bioavailability, was enhanced significantly when the pigeon pea seeds were processed and cooked. This was attributed to reduction in phytate content, which was known to chelate the minerals. A significant and negative correlation between the phytic acid and HCl-extractability of minerals further supported the findings. Soaking (6, 12, 18 hours), soaking (12 hours)-dehulling, ordinary cooking, pressure cooking and germination (24, 36, 48 hours) were found to be quite effective in reducing the content of saponins and trypsin inhibitors in all the pigeon pea cultivars (Duhan et al. 2001). Saponin content of these unprocessed cultivars ranged from 2,164 to 3,494 mg/100 g. There were significant varietal variations in trypsin inhibitor activity (TIA) (1,007–1,082 TIU/g) of these pigeon pea cultivars. Pressure cooking of soaked and dehulled seeds lowered the content of saponins to a maximum extent (28–38%) followed by ordinary cooking of soaked and dehulled seeds (28–35%), soaked dehulled raw seeds (22–27%) and 48 hours germinated seeds (15–19%). Loss of TIA was marginal due to soaking but ordinary as well as pressure cooking of unsoaked and soaked-dehulled pigeon pea seeds reduced the TIA drastically. Pressure cooking of pigeon pea seeds completely destroyed the TIA while it was reduced to the extent of 86–88% against the control in 48 hours pigeon pea sprouts. Pressure cooking of soaked-dehulled pigeon peas seeds was also found to be the most effective method in reducing the levels of polyphenols (Duhan et al. 2000). This was followed by sprouting for 48 hours, ordinary cooking of soaked-dehulled seeds, and pressure cooking of soaked whole seeds followed by sprouting for 36 hours. A decrease in the polyphenolic contents varying from 4% to 26% in different pigeon pea cultivar was achieved. Sprouting (germination) and cooking was reported to improve digestibility of pigeon pea by reducing the content of non-digestible oligosaccharides and produced an in-vitro digestibility of 99.4% (Akporhonor et al. 2006).

Fermentation of pigeon pea (*Cajanus cajan* var. *aroíto*) seeds could be used to remove antinutritional factors and to obtain functional leguminous flour for use as pasta ingredients (Torres et al. 2006). Fermentation of pigeon pea flour considerable reduction of α-galactosides (82%), phytic acid (48%), and trypsin inhibitor activity (39%). Fermented legume flours produced a notable increase of fat and total soluble available carbohydrates, a slight decrease of protein, dietary fibre, calcium, vitamin B2, vitamin E, and total antioxidant capacity, and a decrease of soluble dietary fibre, Na, K, Mg, and Zn contents. No changes were observed in the content of starch and tannins as a consequence of fermentation. The fermented flour was used as an ingredient to make pasta products in a proportion of 5, 10, and 12%. The supplemented pasta products obtained had longer cooking times, higher cooking water absorptions, higher cooking loss, and higher protein loss in water than control pasta (100% semolina). From sensory evaluations, fortified pasta with 5% and 10% fermented pigeon pea flour had an acceptability score similar to control pasta. Pasta supplemented with 10% fermented pigeon pea flour presented higher levels of protein, fat, dietary fibre, mineral, vitamin E, and Trolox equivalent antioxidant capacity than 100% semolina pasta and similar vitamins B1 and B2 contents. Protein efficiency ratios and true protein digestibility were enhanced (73% and 6%, respectively) after supplementation with 10% fermented pigeon pea flour.

Allergenic Activity

Studies in BALB/c mice sensitized with red gram (*C. cajan*) proteins confirmed the allergenicity of red gram proteins as evidenced by prominent anaphylactic symptoms, discernible histopathological responses and down regulation of IFN-gamma levels (Misra et al. 2010). Allergenic response was manifested by significant elevation in specific IgE, IgG1, histamine and Th2 cytokine levels. Five novel IgE binding proteins (namely Caj c1, Caj c2, Caj c3, Caj c4

and Caj c5) were identified as putative clinically relevant allergens in *C. cajan*. All these proteins showed homology to known allergens of soybean (different subunits of β-conglycinin), lentil (Len C1 and Len C2), peanut (Ara h1) and pea (vicilin).

Traditional Medicinal Uses

Faris and Singh (1990) reported that pigeon pea has several uses as medicine. It is used in ayurveda as volerant; a medicine that heals wounds and sores; as an astringent; a medicine that stops bleeding by constricting the tissues, and as a medicine that cures diseases of lungs and chest. It also works as anthelminthic to destroy internal parasitic worms. Pigeonpea leaves have been used to treat malaria (Aiyeloja and Bello 2006) in Nigeria. *Cajanus cajan* and *Cassia fistula*, which are used in Panamanian folk medicine for the treatment of diabetes (Esposito et al. 1991).

Some of the medicinal uses of *C. cajan* according to Morton (1976) and Duke (1981) are for the treatment of jaundice, bronchitis, cough, anthelminthic, sedative and Child delivery. According to Burkill (1966) in Malay traditional medicine a decoction or infusion of the leaves is used for coughs, diarrhoea, and abdominal troubles. Leaf juice is pressed into the ear for ea-ache and applied to sores in children. In India, the tender leaves are chewed for sores in the mouth, and in cases of aphthae and spongy gums. In Java the pulped leaves are applied to sores, herpes and itches. The expressed juice is given with a little salt in jaundice. In China the roots, are considered to possess anthelmintic, sedative, expectorant, and vulnerary properties. The roots have been reported to be used for treating their inflammation of the throat, diarrhoea and for chlorosis. The flowers have been reported to be pectoral. Seeds have been pulverized and use as a cicatrizant of the smallpox pustules. A poultice has been used to reduce swellings. In the Philippines, a decoction or infusion of the leaves is used for cough, diarrhoea and abdominal pains (Bureau of Plant Industry 2005).

Other Uses

Perennial pigeon pea is used as a multi-purpose species for agroforestry systems in India; its multiple uses include food, fodder, manure and firewood (Daniel and Ong 1990). In addition, pigeon pea improves soil fertility by nutrient cycling and biological nitrogen fixation. In Africa, tall perennial pigeon pea are often used as live fences (Phatak et al. 1993), windbreaks and in soil conservation and are also favoured for use as fuel wood, basket weaving, and thatching in African villages.

Pigeon pea is often grown as shade crops, forage crop, cover crop or windbreak, or even as support for vanilla. It improves the soil by its extensive root system, nitrogen fixation by *Rhizobium* and the mulch provided by the fallen leaves and serves as an important nitrogen-fixing intercrop or supplementary crop on sugar-cane farms in Fiji or as a green maure crop. Pigeon pea can be used as a semi-permanent perennial component in alley cropping systems. It can be grown as shade cover for establishing plantation crop such as coffee. It is also planted as a host for silkworms (Madagascar) or the lac insect (northern Bengal, Thailand).

Pigeonpea can provide high-quality forage that could be used as a primary or supplementary forage for grazing livestock at a time when other forages are less productive (Rao et al. 2002). In two dry and two wet seasons Studies by Karachi and Zengo (1998) found that forage of pigeon pea, *Leucaena* and *Sesbania* fed to growing goats as supplements to natural grazing over a 2 year period resulted in significant weight gains. Intakes of pigeon pea (63.1–91.4 g/head/day) and leucaena (52.6–93.8 g/head/day) were consistently higher ($P<0.05$) than that of sesbania (49.7–83.4 g/head/day) and this was reflected in live weight gains in both wet and dry season. Live weight gains ranged from 25.5 to 43.2, 16.7 to 37.5, 14.4 to 28.3 and 6.7 to 21.6 g/head/day for goats supplemented with pigeon pea, Leucaena, Sesbania and the control animals respectively.

Pigeonpea seed has been recommended as an alternative to maize, soybean meal or groundnut cake in the diets of broilers (Amaefule and Obioha 2001; Onu and Okongwu 2006), pullet

chicks (Amaefule and Obioha 2005), pullet growers and layers (Amaefule et al. 2006a; b) and layers (Agwunobi 2000) in Nigeria. Amaefule et al. (2006b) found that processed pigeon pea seed meal (PSM) could be a good protein source for grower pullets, which could be incorporated into the diets at 20% of the whole diet without any adverse effect on growth performance. Also they (Amaefule et al. 2006a) found that 30% raw, toasted or soaked PSM diet could be fed to point of lay pullets without adverse effect on egg production, external and internal egg quality characteristics. Studies by Onu and Okongwu (2006) found that starter broilers fed processed pigeon pea seed meal performed significantly better than those on raw pigeon pea seed meal. There was no significant difference in performance among the groups fed differently processed pigeon pea seed meals. The results of the trial indicated that the three processing methods boiling, boiling with potash and toasting were effective in reducing the anti-nutritional factors in pigeon pea seeds. The result of the study also indicated improved nutritive value of pigeon pea boiled with potash.

Comments

Pigeon pea is propagated from seeds as cuttings yield little success.

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Canavalia gladiata

Scientific Name

***Canavalia gladiata* (Jacq.) DC.**

Synonyms

Canavalia ensiformis auct. non (L.) DC., *Canavalia ensiformis* (L.) DC. var. *gladiata* (Jacq.) Kuntze, *Canavalia ensiformis* var. *alba* Makino, *Canavalia ensiformis* DC. var. *gladiata* Makino, *Canavalia gladiolata* Sauer, *Canavalia incurva* (Thunb.) DC., *Canavalia incurva* Thou., *Canavalia loureirii* G. Don, *Canavalia lunareti* Carr., *Canavalia machaeroides* (DC.) Steud., *Canavalia maxima* Thou., *Dolichos gladiatus* Jacquin, *Dolichos incurvus* Thunb., *Malocchia gladiata* (Jacq.) Savi.

Family

Fabaceae or Leguminosae, also placed in Papilionaceae

Common/English Names

Japanese Jackbean, Jamaican Horse Bean, Scimitar Bean, Sword Bean

Vernacular Names

Arabic: Fûl Hindî;
Brazil: Feijão-De-Porco (Portuguese);
Chinese: Dao Dou;
Cuba: Frijol Café, Frijol De Machete;
Danish: Sabelbønne, Svaerdbønne;
Dutch: Zwaardboon;
French: Haricot Sabre, Pois Sabre, Pois Sabre De La Jamaïque, Pois De l'Inde, Dolique Sabre, Poir Sabre Rouge;
German: Jackbohne, Schwertbohne;
India: Bara Sem, Khadsampal, Lalkudusumpal (Hindu), Shambee Avare, Thumbe Kaayi (Kannada), Bara-Mareca, Valamara, Valpayar, Valvara (Malayalam), Asisimbi, Asisimbi, Mahasimbi (Sanskrit), Araniyamutkam, Civapputtampattai, Kattavarai, Kattavaraikkoti, Kayilakakkoti, Kayilakam, Peyavarai, Segapputampattai, Segapu Thampattai (Tamil);
Indonesia: Kacang Nyonya, Kacang Prasman, Kara Wedung, Koas Pedang, Krandang (Java), Kara Bedog, Koas Bakol, Koas Bebedogan, Koas Parasman (Sundanese)
Japanese: Nata Mame;
Khmer: Tioeuhs;
Laotian: Khùa, Khao Khieo;
Malaysia: Kacang Hantu, Kacang Parang, Kacang Polong;
Philippines: Magtambokau (Bisaya), Habas (Tagalog);

T.K. Lim, *Edible Medicinal And Non-Medicinal Plants: Volume 2, Fruits*,
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Portuguese: Fava-Contra, Feijão Espada;
Spanish: Haba De Burro, Poroto Sable, Carabanz;
Swahili: Mwingasiafu, Mbwanda;
Thai: Thua-Phra;
Vietnamese: Daaju Ruwja, Dau Rua.

Origin/Distribution

Sword bean is known only in cultivation and is widely distributed in the old world probably domesticated in Eastern Asia. It is mainly cultivated in South, Southeast and East Asia, less so in Saudi Arabia, East and South Africa and Madagascar, more rarely grown in West Africa and the American tropics. It has become naturalised in some areas in the tropics.

Agroecology

C. gladiata thrives best in warm areas with temperatures of 20–30°C and well distributed annual rainfall of 900–1,500 mm from sea level to 1,500 m elevation. It grows well in full sun to light partial shade and is hardy, able to survive drought conditions as it has a deep rooted system and is fairly frost tolerant. It tolerates a wide array of soil types from pH 4.3–6.8. It will grow even on highly leached nutrient poor soils.

Edible Plant Parts and Uses

Young leaves, flowers, tender green pods and seeds are edible after cooking. The young pods are sliced and cooked or eaten raw. In Japan, the young, tender pods are processed into several kinds of pickles called "*Fukujin-zuke*", "*Nuka-zuke*" and "*Miso-zuke*". Young seeds are edible after cooking and the mature seeds also after prolonged cooking. In Java, the de-skinned and twice-boiled seeds are left in running water for 2 days, and allowed to ferment for 3–4 days and cooked before being eaten as flavouring. In Java, the young leaves and flowers are steamed and used as flavouring. In Cuba, seeds are used as substitute for coffee.

Botany

A climbing, twining, woody perennial herb several metres high with a deep root system and runners as long as 10 m. Leaves alternate, compound, ternate with caduceous stipules and on 96 mm long petiole. Leaflets are ovate, 8–20×8–12 cm, sparsely whitish or brown pubescent on surfaces, base rounded or cuneate, apex acuminate. Flowers mainly pinkish purple, in 10–20 flowered racemes with 2–3 flowers at each node, pedicellate, perianth 2 –whorled. Calyx of 5 sepals, 15–16 mm, slightly pubescent, upper lip rounded, lower lip with 3 acute teeth. Corolla with 5 white or pink petals, 3–3.5 cm, clawed and auriculate; standard petal broadly elliptic, 3–3.5×2.5 cm, emarginate; wings and keel oblong, incurved, smaller than standard. Stamens 10, free of the perianth, both opposite and alternating with the corolla parts. Ovary monomerous, superior, 1-celled with many ovules. Fruit large, linear-oblong legume, straight or slightly curved (sabre-shaped), 20–35 cm long by 3.5–6 cm wide, thickly leathery (Plates 1 and 2). Seeds 10–14, ellipsoid-oblong, 3.5×2 cm, white, mauve, mauve-brown –mottled, reddish pink to reddish-brown, with large hilum, 1.5 cm (Plate 2).

Plate 1 Swordbean pods

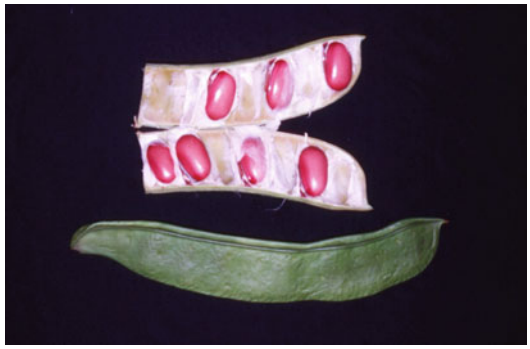

Plate 2 Swordbean seeds

Nutritive/Medicinal Properties

The nutritional composition of fresh sword bean pods per 100 g edible portion was reported as: water 83.6 g, energy 247 kJ (59 kcal), protein 4.6 g, fat 0.4 g, carbohydrate 10.7 g, dietary fibre 2.6 g, calcium 33 mg, phosphorus 66 mg, iron 1.2 mg, vitamin A 40 IU, thiamin 0.2 mg, riboflavin 0.1 mg, niacin 2 mg, ascorbic acid 32 mg. Dry seeds contain per 100 g: water 10.7 g, energy 1,453 kJ (347 kcal), protein 24.5 g, fat 2.6 g, carbohydrate 59 g, fibre 7.4 g, calcium 158 mg, phosphorus 298 mg, iron 7.0 mg, thiamin 0.8 mg, riboflavin 1.8 mg, ascorbic acid 1 mg (Rubatzky and Yamaguchi 1997).

The chemical composition of whole and cotyledon flour of mature seeds per dry matter basis (Ekanayake et al. 1999) was reported as: crude protein 26.8 and 29.2%; fat 2.8% and 3.1%; fibre 33.2% and 10.2%; ash 3.9% and 4.3%; carbohydrate 33.3% and 53.2% on respectively. The carbohydrate fractions had starch contents of 30.7% and 39.6% and 27.7 and 34.6 mg/g low molecular weight carbohydrates. The energy content of whole seed and cotyledon flour was 11,082 and 14,923 kJ/ kg. Sucrose manifested the highest fraction of low molecular weight carbohydrates with fructose being the lowest. K, Mg, Ca, P and S were present in high amounts. The essential amino acid profile was in accord with FAO/WHO recommended pattern except for sulphur containing amino acids, cysteine and methionine. The chemical composition of the raw mature seeds of *Canavalia gladiata* (kernel) indicated the bean to be a good supplement to cereal-based diets.

Seed protein content and composition of *Canavalia gladiata* and *Canavalia ensiformis* were quite similar (Rajaram and Janardhanan 1992). The seeds of *C. gladiata* were found to contain less crude protein, crude lipid and minerals like Na, K, Ca, Mg, P, Fe and Mn than does *C. ensiformis*. Both albumins and globulins together comprised the main bulk of seed proteins. In both the species, glutamic acid, aspartic acid, isoleucine, leucine, tyrosine, phenylalanine and lysine were the dominant amino acids of seed proteins. Concanavalin A (Con A) and canavalin were found to be two primary seed storage proteins of *Canavalia gladiata* (Yamamoto et al. 1995). Yamauchi and Minamikawa (1986) reported on the changes of seed protein accumulation in developing sword bean seed. They found that albumin content increased gradually after the stage of 1.8 g fresh weight per seed, attained a maximum, then declined at later stages. Seed globulins were synthesized actively after the stage of 1.8 g fresh weight per seed, and the major polypeptides of seed globulins, including the major polypeptides of canavalin, were first detected at this stage. Albumins continued to accumulate until seed maturation was completed. The synthesis of canavalin commenced earlier than that of concanavalin A and also ended earlier during seed development. The mature raw *Canavalia gladiata* seeds were found to contain 28.39% of protein, 7.84% of lipid, 8.23% of fibre, 5.63% of ash and 49.91% of carbohydrates (Vadivel et al. 2010).

Among the different species/varieties of *Canavalia*, the brown variety of *C. gladiata* was found to have the highest amount of protein (35.0%) (Siddhuraju and Becker 2001). The essential amino acid profile of total seed proteins conformed well to the FAO/WHO reference pattern established for pre-school children, except for a deficiency of sulphur containing amino acids in both varieties of *C. gladiata* and *C. ensiformis*. However, tryptophan in the red variety and lysine in the brown variety of *C. gladiata* appeared to be the second most limiting amino acids. All in all, these *Canavalia* seeds represented good source of

potassium, phosphorus and calcium. They contained low amounts of sodium. Despite the high proportion of total starch (31.8–36.9%), the percentage of digestible starch appeared to be much higher in *C. ensiformis* (70.6%) than in *C. gladiata*. The seed lipids of all the *Canavalia* samples investigated had a large proportion of unsaturated fatty acids (71–78%) with oleic acid as the dominant one (38.6–47.4%). All samples were rich in dietary fibre (17.5–23.6%), most of which was insoluble dietary fibre. The level of the toxic amino acid, canavanine, was found to be relatively low (27–42%) in *C. gladiata* and *C. ensiformis* compared to previous literature reports for the same species. The other antinutrients such as phenolics, tannins, condensed tannins, saponins, protease inhibitors, α-amylase inhibitor and haemagglutinating activity were also detected. *C. ensiformis* seeds exhibited a relatively high level (69.0%) of in-vitro protein digestibility compared to the red (67.2%) and brown (65.4%) varieties of *C. gladiata* and *C. virosa* (62.5%).

The weight gain of the male Sprague-Dawley rats fed with diets containing raw whole sword bean seed and raw cotyledon alone were significantly lower than rats fed the reference diet (Ekanayake et al. 2000). Feeding with processed cotyledons (dry-autoclaved or roasted) significantly elevated the weight gain of the rats versus weight gain of rats fed diets prepared with raw seed flour. Net protein utilisation (NPU) of raw (whole seed 13.8; cotyledon 27.6) was significantly lower than the reference diet (79.5). The NPU of processed samples was also significantly lower when dry-autoclaved (25.1) or roasted (25.1) compared to the reference diet fed group (79.5). The biological value (BV) of the processed samples (dry-autoclaved 31.1; roasted 37.7) was significantly lower than that of raw (53.6) cotyledon. In contrast TD (true protein digestibility) increased with processing (dry-autoclaved 80.9; roasted 65.9) when compared to raw cotyledon (51.4). In-vitro protein digestibility for the raw whole seed and cotyledon was 71.7% and 70.1% respectively. In-vitro starch digestibility of raw and processed cotyledon flour samples indicated dry-autoclaved sample to have the highest digestibility.

In further studies, Ekanayake et al. (2003) found that true protein digestibility (TD) of processed sword bean seed flour cooked (84.8), soaked and cooked (76.2), autoclaved (82.0), roasted grits (64.5), and roasted flour (61.2) were significantly higher than in the raw (51.4) and the soaked only grits (35.8). Soaking the grits lowered TD. Biological value of cooked grits and grits cooked after soaking were significantly greater than that of the other processed samples. However, the biological value of the diets containing cooked and soaked and cooked grits were not significantly different. The NPU (net protein utilization) of the cooked grits (39.4) and grits cooked after soaking (37.6) were significantly higher than that of the other processed samples (autoclaved grits (31.0), roasted grits (19.5), roasted flour (10.8), and soaked only grits (1.6)). The NPU of all the processed samples were significantly lower than the reference casein. The highest protein nutritional quality was obtained by either cooking the grits or by soaking and cooking the grits. In-vitro protein digestibility measurements were not well correlated to the true digestibility.

Other Phytochemicals

Pentaamines identified as aminopropyl and aminobutyl derivatives of canavalmine (PA 434), i.e. aminopropylcanavalmine and aminobutylcanavalmine were isolated from sword bean, *Canavalia gladiata* (Matsuzaki et al. 1990).

An ent-kaurane-type glycoside, canavalioside, and eight new acylated flavonol glycosides, gladiatosides A1, A2, A3, B1, B2, B3, C1, and C2, were isolated from the seed of *Canavalia gladiata* together with robinin, kaempferol 3-O-β-D-galactopyranosyl-7-O-α-L-rhamnopyranoside, and kaikasaponin III (Murakami et al. 2000). A guanidinooxyamine identified as γ-guanidinooxypropylamine was isolated from sword bean seedlings (Hamana and Matsuzaki 1985). A tertiary methylated tetraamine, N4-methylthermospermine in addition to spermidine, homospermidine, spermine, thermospermine and canavalmine were found in *C. gladiata* seed extract (Hamana et al. 1992). The unusual polyamines, sym-homospermidine

(homoSPD) and canavalmine (CAN) were found in the seed of *Canavalia* species such as *C. gladiata, C. ensiformis* and *C. brasiliensis*, but not in those of other leguminous crops (Fujihara et al. 1982, 1986). Putrescine (PUT), spermidine (SPD), and spermine (SPM) accumulated in the radicle and hypocotyls during seed germination whereas HomoSPD and CAN remained at very low levels over a 6-day period of germination. In nodulated sword bean plants, a large quantity of homoSPD was found in the root nodule. CAN was found exclusively in the senescent nodule at very low levels. These polyamines were not detected in any other organs including root, stem, leaf, vine, flower, and pod, while PUT, SPD, and SPM were always present in those organs. As plants reached the reproductive stage, homoSPD and CAN appeared in the immature seed and their concentrations increased as seed formation progressed. By contrast, the level of SPM continuously decreased during seed development. In developing seeds, considerable accumulation of canavanine, an analog of arginine and a precursor in polyamine biosynthesis, was also observed.

Pharmacological properties of sword bean that have been reported are discussed below.

Antioxidant Activity

The DPPH radical scavenging activity of the methanolic seed extracts of *Canavalia ensiformis* and *Canavalia gladiata* was found to increase with increasing dosage (Doss et al. 2010). The highest radical scavenging effect was observed in *Canavalia gladiata* with IC_{50}=59.23. Radical scavenging activity was found to be strongly correlated with total phenolic content of *Canavalia gladiata* extract.

Anticancer and AntiHIV Activity

Wong and Ng, (2005) isolated a lectin with specificity toward mannose, glucose, and rhamnose from *Canavalia gladiata*. The lectin was composed of two identical 30-kDa subunits with substantial N-terminal sequence similarity to Concanavalin A (Con A). Compared with Con A, sword bean lectin stimulated [methyl-(3)H]thymidine uptake by mouse splenocytes at a lower concentration, and more strongly suppressed proliferation of L1210 leukaemia cells. The mitogenic activity of sword bean lectin toward mouse splenocytes, but not its antiproliferative activity toward tumour cells, could be abolished by 250 mM glucose. In contrast, both mitogenic and antiproliferative activities of Con A were annulled by glucose. Sword bean lectin inhibited HIV-1 reverse transcriptase with an IC_{50} of 35 μM and cell-free translation in a rabbit reticulocyte lysate system with an IC_{50} of 2.08 μM. Sword bean lectin did not exhibit antifungal activity.

Studies reported that *Canavalia gladiata* seeds contained a bioactive compound 4-O-methylgallic acid (4-OMGA) that potently suppressed bovine endothelial cell invasion and tube formation stimulated with basic fibroblast growth factor (BFGF) at low μmolar concentrations where it showed no cytotoxicity to the cells (Jeon et al. 2005). Further, 4-OMGA inhibited vascular endothelial cell growth factor (VEGF) production under hypoxic condition and the production of reactive oxygen species (ROS) in the endothelial cells stimulated with VEGF. These results demonstrated 4-OMGA to have potential as an anti-angiogenic agent to treat angiogenesis related diseases including cancer.

Vasodilatory Activity

Studies using the rat models of paw edema and isolated aorta demonstrated important vasodilator effects of different magnitudes and in-vivo and in-vitro mechanisms of *Canavalia* lectins from *Canavalia brasiliensis, Canavalia gladiata*, and *Canavalia maritima* (Assreuy et al. 2009). In-vivo, the edematogenic activity was paralleled by plasma exudation, and in-vitro, aorta relaxation was strictly dependent on intact endothelium. All effects occurred via interaction with lectin domains and participation of nitric oxide (NO) and/or prostanoids. *C. gladiata* elicited aorta relaxation involving NO, prostacyclin and EDHF

(endothelium-derived hyperpolarizing factor). All lectin effects were inhibited by their binding sugars.

Antiosteoporosis Activity

Consumption of yellow and black soybeans, and sword beans (*Canavalia gladiata*) was found to have a distinct protective effect on bone loss in ovariectomized rats by inhibiting bone turnover and preventing bone resorption (Byun and Lee 2010). Femur and spine bone mineral density were significantly higher in the yellow soybean and sword bean groups than in the black soybean group. Femur bone mineral content was the highest in the yellow soybean group, and spine bone mineral content was not significantly different between the various bean groups. The sword bean group showed significantly lower osteocalcin (a bone formation biomarker) and deoxypyridinoline (a bone resorption biomarker) levels than the yellow and black soybean groups. There were no significant differences between the yellow and black soybean groups. TNF-alpha (a bone resorption cytokine) concentrations were not significantly different between the groups. Further, the results showed that consumption of sword beans may help prevent postmenopausal osteoporosis.

Antinutritional Factors

The presence of certain antinutritional factors (total free phenols, tannins, lectins, L-DOPA, trypsin inhibitor activity) was reported for *Canavalia gladiata* and *Canavalia ensiformis* (Rajaram and Janardhanan 1992). The seeds of *Canavalia gladiata* contained the amino acid canavanine, a structural analogue of L-arginine and a potentially toxic constituent besides other growth-inhibiting and toxic storage proteins, e.g. canavalin (vicilin), con-canavalin A and B and canatoxin. Studies showed that overnight soaking and boiling of the seeds in excess water followed by decanting gave the most drastic reduction in canavanine content (around 50%), followed by boiling and decanting excess water (34%) (Ekanayake et al. 2007). Roasting and autoclaving were less effective in reducing the canavanine content.

Autoclaving sword bean seeds was found more efficacious in reducing the maximum levels of various anti-nutritional compounds such as total free phenolics (91%), tannins (85%), L-Dopa (92%), phytic acid (83%), raffinose (84%), stachyose (66%), verbascose (83%), and also haemagglutinating activity (88%), trypsin inhibitor activity (75%) and á-amylase inhibitor activity (65%) without affecting the nutritional value when compared to soaking, cooking or roasting treatments (Vadivel et al. 2010). Rats fed with the experimental diet containing autoclaved sword bean seeds as a protein source exhibited better growth performance such as feed intake (219 g) and body weight gain (58 g). In addition, the protein quality parameters such as true digestibility, biological value, net protein utilization and utilizable proteins were higher in the experimental diet containing autoclaved sword bean seeds as a protein ingredient. Thus, autoclaving treatment could be recommended for the utilization of sword bean seeds as an alternative/additional protein source in the diets of human beings/animals.

A lectin from Japanese jack bean (*Canavalia gladiata* agglutinin, CGA) was shown to have a protein subunit with a molecular weight of 30 K (Kojima et al. 1991). CGA possessed an amino acid composition identical to that of Concanavalin A. The lectin activity of CGA could be detected by hemagglutination assay with trypsinized human erythrocytes and also by the binding assay with intact horseradish peroxidase. CGA exhibited sugar-binding specificities similar to those of concanavalin A. Three major serine proteinase inhibitors (SBI−1, −2, and −3) purified from the seeds of white sword bean (*Canavalia gladiata*) were found to be members of the Bowman-Birk proteinase inhibitor family (Park et al. 2000).

Delatorre et al. (2007) isolated a lectin from *Canavalia gladiata* seeds that was found to have a non-protein amino-acid, and α-aminobutyric acid in its structure imparting the ability of the lectin on carrying secondary metabolites. This strengthened the role of lectins in plant defence mechanism in plants.

Traditional Medicinal Uses

Traditional medicinal uses of *C. gladiata* include the treatments of vomiting, abdominal dropsy, kidney-related lumbago, asthma, obesity, stomach-ache, dysentery, coughs, headache, intercostal neuralgia, epilepsy, schizophrenia, inflammatory diseases and swellings in Korea. In Japan, it is also used for treating ozena, haemorrhoids, pyorrhea, otitis media, boils, cancers, inflammatory diseases and atopic dermatitis. In Korea, sword bean extract is used in soap for the treatment of athlete's foot and acne. In Peninsular Malaysia, the leaves were used by the Malays in treating gonorrhoea. The leaves were used with other substances in a kind of magic tonic that was squeezed into the eyes. The plant was pounded and applied to boils. The seeds were also employed medicinally.

Other Uses

It is often grown as a cover crop, green manure and forage crop. Its foliage provides a good leaf meal for use in animal feeds. In African countries the species is sometimes a fetish plant.

Comments

Sword bean is not widely consumed because of prolonged cooking required to remove toxic growth inhibiting proteins in the seed before they are edible.

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Cassia fistula

Scientific Name

***Cassia fistula* L.**

Synonyms

Bactyrilobium fistula Willd., *Cathartocarpus excelsus* G. Don, *Cathartocarpus fistula* Pers., *Cathartocarpus fistuloides* (Collad.) G. Don, *Cathartocarpus rhombifolius* G. Don,*Cassia bonplandiana* DC., *Cassia excelsa* Kunth, *Cassia fistuloides* Collad., *Cassia rhombifolia* Roxb.

Family

Fabaceae, or Leguminosae, also placed in Caesalpiniaceae

Common/English Names

Golden Shower, Golden Shower Tree, Indian Laburnum, Pudding-pine tree, Pudding-Pipe Tree, Purging Cassia

Vernacular Names

Arabic: Katha-Ul-Hind, Khiār Shambar, Khiyar-Shanbar, Khiyar-Shanbur, Maghze Khiyar-Shanbar;
Bangladesh: Amaltas, Bandar Lathi, Sonalu;
Brazil: Cana-Fístula, Cássia-Fístula, Cássia-Imperial, Chuva-De-Ouro (Portuguese);
Burmese: Mai Lum , Ngu, Ngu Sahwe, Ngusat, Pwabet;
Caribbean: Kas Dous (Creole);
Chinese: Guo Mai Long Lang, Là Cháng Shù;
Czech: Kasie Obecná;
Danish: Roerkassia, Rørkassia;
Dutch: Indishe Goude Regen, Kassie, Pijpkassie;
Eastonian: Torukassia;
French: Averse-Dorée, Bâton Casse, Canéficier, Casse, Casse Doux, Casse Espagnole, Casse Fistuleuse, Cassier, Douche D'or, Faux Caroubier;
German: Indischer Goldregen, Röhrenkassie, Roehrenkassie;
Hungarian: Csőkasszia, Esőkasszia, Mannakasszia;
India: Honalu, Honaru, Sonari, Sonaru, Sunaru, (Assamese), Amaltas, Amultas, Bandar Lathi Bandarlati, Bandarlathi, Nuruic, Sonali, Sonalu, Sundali (Bengali), Sinaru, Sonari, Soneru (Garo), Garmalo (Gujerati), Alis, Amaltas, Amaltas-Ki-Phalli, Amaltash, Amlatash, Amulthus, Bahawa, Bahawa Dhediya, Bandarlauri, Bendra Lathi, Dhanbaher, Dhanbohar, Dhediya, Dodiya, Garmale,Garmalo Karmalo, Girimala, Girmalah, Girimaloah, Karmalo, Kaniar, Kaniar Amaltas, Kirala, Kirmalo, Semara, Sonhali (Hindu), Aragina, Aragina Mara, Araghvadha, Aragvadha, Arevata, Arevata Mara, Jamba, Kaadu Konde Mara, Kake, Kakee, Kakkaayi, Kakkaemara, Kakkai, Kakke, Kakke Gida, Kakke-Kayi, Kakke

T.K. Lim, *Edible Medicinal And Non-Medicinal Plants: Volume 2, Fruits*,
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Mara, Kakki, Kakkikaayi, Kirugakke, Konde, Kodre, Kokke, Konde Mara, Kondi, Konne, Raama Danda Kaayi, Rajataru, Ramdanda, Sampaaka, Swarna Pushpi, Takke (Kannada), Caturangulam, Choonay, Conna, Kanikonna, Kanikkonna, Konna, Konnak-Kaya, Konne, Konnei, Kritamalam, Krytamalam, Saturangulam, Svarnaviram, Svarnnakam, Vishnu-Konna (Malayalam), Chahui (Manipuri), Bahava, Balo, Bawa, Bahawa, Bhawabaya, Bhawan, Bova, Boya, Chimkani, Garmala, Girimala, Gurmala (Marathi), Ngaingaw (Mizoram), Ngaingaw, Sonarli (Oriya), Amaha, Amayaghata, Antadru, Aragbadha, Aragbhada, Aragvadha, Aragvadhah, Aragwadhah, Arakvadam, Arevata, Arogyashimbi, Aruja, Caturangula, Caturangulah, Chakraparivyadha, Chaturangula, Dhirghaphala, Dirghaphala, Dirghaphalah, Drumotpala, Himapushpa, Jatharanut, Jvarantaka, Kandughna, Karnabharanaka, Karnikara, Karnikarah, Kritamala, Kritamalaka, Krtamala, Krtamalah, Krtamalaka, Kundali, Kushtaghna, Kushthasudana, Mahakarnikara, Maharajdruma, Manthana, Naktamala, Naradhipa, Narendradrma, Nripadruma, Nrpadrma, Nrpataru, Nrpavrksa, Pragraha, Pramcha, Rajadrma, Rajataru, Rajavraksha, Rajavriksha, Rajavrksa, Rajavrksah, Rasetiktah, Recanah, Rechana, Rochana, Sampaka, Samyak, Samyaka, Samyakah, Saraphala, Sauvarni, Shamyaka, Shephalika, Suvarnaka, Svarnabhusana, Svarnabhushana, Svarnadra, Svarnasthali, Svarnavriksha, Vyadhighata, Vyadhighatah, Vyadivata, Vyathantaka, Evatah (Sanskrit), Acarati, Acaratu, Akaratu, Akeru, Akkottumam, Akkotu, Akkuvatam, Anaiveni, Anaivenimaram, Ankacutam, Ankam, Annai, Apalankam, Appai, Ar, Aragoram, Arakkuvadam, Arakoram, Arakotam, Arakuvatam, Arevatam, Aricalam Idali, Aricammarikam, Aricayam 2, Aricayamanku, Ariyacam, Ariyacamaram, Ariyakam, Arkkutam, Arkoramaram, Arkotam, Atavamaram, Atipacami, Atipacamimaram, Atitam, Atitamaram, Attatatikam, Cammiyakam, Cammiyakamaram, Campikapakam, Campurakam, Campuvakku, Canipakam, Canipakamaram, Canippakam, Carakkonrai, Carakkonrai Puli, Carakkonrai Vittu, Cataimuti, Cataimutikkottu, Catakavanni, Caturankulam, Contalu, Cutareccati, Cuvarnakam, Elilai, Icalil, Icanarani, Icankoti, Icanrar, Ikali, Ikuli, Ilacatcacam, Iracavikuratam, Iracavirutcam, Iragavinnadagam, Iragaviruttam, Irakavinnakamaram, Irakavinnatakam, Irali, Irjviruttam, Iruli, Irulimaram, Isandar, Itali, Iravankam, Iyagam, Kamukam, Kavani, Kavuci, Kavuti, Kicaram, Kicaramaram, Kicaran, Kicari, Kiratamalam, Kiratamalamaram, Kiri, Kirutamalam, Kirutamalamaram, Kirutamalikai, Kiyaracampar, Konai, Konakkonrai, Kondrai Poo, Konnai, Konnaikkay, Konnaimaram, Konnei, Konnekai, Konrai, Konraik-Kay Kotaimuti, Konraikkai, Kotitikali, Kottikali, Kottitali, Kurappulikakkonnaimaram, Kurappulikam, Makaracitam, Makaracitamaram, Matalai, Matalaimaram, Mutantam, Muticaram, Mutiyiltarittan, Nallekavam, Nallekavamaram, Natamitumican, Nattukkornai, Nilaccam, Nilcataiyon, Perunkonrai, Ponkonrai, Puccarrilpasanamayini, Sara Kondrai Puli, Sarak-Konrai, Sarakonnai, Sarakonnekai, Sarakkondrai, Sarakkonnai, Sarakkonrai Kai, Sarokkonnoi, Sharak-Konraik-Kay, Taccuka, Taccukamaram, Talaiccuti, Talaiccutimaram, Talimarutam, Talimarutamaram, Tamam, Tirakari, Tirakarimaram, Tirakkiya, Tirkkamuli, Tirkkapalam, Tirukkonrai, Tunkarimantam, Vakkam, Viyatikatam, Viyatikkatam (Tamil), Aaragvadhamu, Aragvadhamu, Koelapenna, Kolapenna, Kolaponna, Konay,Kondrakayi, Raela, Rala, Raelachettu, Rela, Rela-Kayalu, Relagujju, Relangi, Rella, Rellu, Reyla, Reylu, Sampaakamu, Sampakamu, Sonnalu, Suvarnam, Suvarnamu (Telugu), Amaltas, Khayarshanbar, Maghz Amaltas, Maghz Khiyar Shambar, Mughze Amaltas (Urdu);

Indonesia: Keyol, Klohur, Klohor, Peyok, Piyok, Tangguli, Tengguli, Trengguli (Java), Bobondelan, Budulan, Bumbungdelan, Bondel, Tanggoli, Tranggoli (Sundanese)

Italian: Cassia;

Japanese: Kanji, Nanban Saikachi;

Khmer: Reachapreuk;

Laos: Khoun;

Malaysia: Bereksa, Dulang, Rajah Kayu, Tengguli;

Mexico: Canafistula;

Nepali: Amaltash, Raj Brishi, Rajbriksya;
Norwegian: Kasja;
Papiamento: Tròmustok;
Persian: Khiyar-Chambar, Khiyar-Chanbar, Khiyar-Shambar, Maghze Khiyar-Shamber;
Philippines: Ibabau, Lombayong (Bisaya), Bistula, Fistula (Cebu-Bisaya), Kaña-Pestula (Ibanag), Lapad-Lapad (Tagbanua), Fistula, Kaña-Pistula, Kanya Pistula (Tagalog);
Portuguese: Cássia;
Spanish: Cañafístula, Cañafístula Mansa, Cassia Purgante, Casia Fistula, Chácara, Guayaba, Laburno De La India, Lluvia Dorada, Lluvia De Oro;
Sri Lanka: Aehaela-Gaha, Ahalla-Gass, Ekela (Sinhalese);
Taiwan: Ā Bó Lè;
Thai: Chaiyaphruek, Dok Khuen, Khun, Ratchaphruek;
Tibetan: Dan Ka, Don Ga, Don-Ka;
Vietnam: Bò-Cap Nuóc, Krééte.

Origin/Distribution

Cassia fistula is indigenous to south Asia. It occurs in southern Pakistan east through India, Sri Lanka to Myanmar. It is the national tree of Thailand and its flower is Thailand's national flower.

Agroecology

Cassia fistula is widely grown as an ornamental plant in tropical and subtropical areas in areas with mean annual temperatures of 18–29°C and mean annual rainfall of 500–2,750 mm from sea level to 1,200 m altitude. It thrives best in full sun on well-drained soil of pH 5.5–8.7. It is relatively drought tolerant and slightly salt-tolerant and will tolerate light brief frost. It will grow well in dry climates.

Edible Plant Parts and Uses

The fruit pulp, flowers and leaves are edible (Barthakur et al. 1995; Duke 1996; King 2007; ICRAF 2009). The fruit pulp is also used in the preparation of tobacco-cakes for the hukka, in India. In Europe, the pods are also used in the preparation of tobacco for smoking. Parched leaves are eaten as a mild laxative with other foods. Flowers are consumed by Santal people of India. Pieces of the heartwood is used as masticatory in Thailand and traded under the name "*ken kun*".

Botany

Cassia fistula is a medium-sized, semi-deciduous tree growing to 10–20 m tall with grey to reddish brown bark and numerous spreading branches (Plates 1 and 2) . Leaves are alternate to sub-opposite, with 3–8 pairs of leaflets (Plates 2 and 5). Leaflets are ovate, smooth, obtuse or emarginate, 7–21 cm long and 4–9 cm wide. Flowers are large, fragrant, bright-yellow, and borne on long, slender, smooth pedicels in pendant, axillary racemes, 30–60 cm long (Plates 1–4). Flower consist of 5 smooth, oblong, obtuse sepals, 5 yellow, oval, concave and

Plate 1 Golden shower tree in bloom (Saw, L.G.)

Plate 2 Flowering inflorescences, foliage and trunk of golden shower

Plate 3 Closer view of flowering inflorescences (Saw, L.G.)

subequal spreading petals, 10 stamens – 3 with long stamens and oblong anther and 7 with clavate anthers, glabrous, filiform, cylindrical, curved, ovary (Plate 4). The fruit is an indehiscent, cylindrical pod or legume, 30–60 cm long, 1.5–2.5 cm diameter, green (Plate 5) becoming woody, dark-brown to blackish-brown when ripe; the fruit is divided into many cells by hard, transverse phragmata; the cells are 1-seeded. The seeds are oval, glossy, and somewhat flattened and are embedded in a viscid, reddish-black, sweetish pulp.

Nutritive/Medicinal Properties

The edible fruit tissue of Indian laburnum (*Cassia fistula*) fruit was found to contain 827 mg per 100 g of dry matter (Barthakur et al. 1995). The fruit was also found to be a good source of Fe and Mn, and their concentrations were considerably higher than those found in apple, apricot, peach, pear, and orange. The contents of Ca and K were also high. Na levels in pulp and seeds were relatively low. Aspartic acid, glutamic acid, and lysine constituted 15.3%, 13.0%, and 7.8% of the total amino acids respectively in the pulp. In the seeds the same amino acids constituted, 16.6%, 19.5%, and 6.6%. The relatively high energy value of the fruit at 18 kJ/g could enhance the daily energy requirement of people in need of adequate caloric intake. Vasi and Kalintha (1980) reported the protein content of the fruit as 19.94% and carbohydrate content as 26.30%. The data are indicative of the potential of the fruit to be an important source of nutrients and energy.

Extensive studies over the past four decades have been carried out on the isolation and identification of chemical constituents of various parts of the medicinal plant, *Cassia fistula* (Bahorun et al. 2005; Rizvi et al. 2009).

Plate 4 Close-up of golden shower flowers

Plate 5 Young, green pods and pinnate leaves

Phytochemicals From Fruits and Seeds

Rhein (1,8-dihydroxy-3-anthraquinone carboxylic acid) was identified as a major anthraquinone derivative in the pulp of *C. fistula* (Modi and Khorana 1952). This was also confirmed by Kapadia and Khorana (1966) when it was shown that free rhein occurred as complexes with sennidin-like compounds in *C. fistula* pods. Lal and Gupta (1976) isolated rhein, glucose, sucrose and fructose from the fruit pulp and galactomannans consisting of eight different types of sugar moieties from the seeds. Agrawal et al. (1972) isolated fistulic acid from the pods. The pod was also found to have sennosides (Asseleih et al. 1990; Chowdhury et al. 1996; Dutta and De 2002). The highest percentages of sennosides in pods were recorded at the mid-stage of fruit maturation when the pods were pale brown in colour (Asseleih et al. 1990). The pod was found to have the commercially important laxative sennoside B rhein (Dutta and De 2002). Both sennoside and rhein contents in the pods exhibited seasonal variation (Chowdhury et al. 1996).

Apolar compounds including 5-nontetra contanone, 2-hentriacontanone, triacontane, 16-hentriacontanol and sitosterol along with oil showing antibacterial activity had also been isolated in *C. fistula* pods (Misra et al. 1996). A new diterpene, 3-β-hydroxy-17-norprimar-8(9)-en-15-one was isolated from the pod (Misra et al. 1997). Proanthocyanidins containing flavan-3-ol (epiafzelechin and epicatechin) units with an abnormal 2S-configuration were also found in pods together with the common flavan-3-ols and proanthocyanidins like catechin, epicatechin, procyanidin B-2 and epiafzelechin (Kashiwada et al. 1996). Rani and Kalidhar (1998) isolated and characterised 3-formyl-1-hydroxy-8-methoxy anthraquinone from the pods. Luximon-Ramma et al. (2002)

reported that the highest levels of phenolics were contained in the pod, which coincidentally represented the harvest stage and organ recommended by the Pharmacopoeias.

The seeds are rich in glycerides with linoleic, oleic, stearic and palmitic acids as major fatty acids together with traces of caprylic and myristic acids (Abu Sayeed et al. 1999). Four new compounds, 5-(2-hydroxyphenoxymethyl)furfural, (2′S)-7-hydroxy-5-hydroxymethyl-2-(2′-hydroxypropyl) chromone, benzyl 2-hydroxy-3,6-dimethoxybenzoate, and benzyl 2β-O-D-glucopyranosyl-3,6-dimethoxybenzoate, together with four known compounds, 5-hydroxymethylfurfural, (2′S)-7-hydroxy-2-(2′-hydroxypropyl)-5-methylchromone, and two oxyanthraquinones, chrysophanol and chrysophanein, were also isolated from the seeds of *Cassia fistula* by Kuo et al. (2002).

Phytochemicals From Pod and Leaves

The ripe pods and leaves were reported to contain several anthraquinones both in the aglycone and glycoside forms such as rhein, aloe-emodin, chrysophanic acid and sennosides (Chowdhury et al. 1996; Misra et al. 1996; Rani and Kalidhar 1998 Dutta and De 2002; Bahorun et al.. 2005; Rizvi et al. 2009).

Phytochemicals From Leaves

Free rhein, rhein glucoside and sennosides A and B were found in the leaves (Kaji et al. 1968). While rhein and its glucoside could be isolated in pure state, others were obtained as mixtures. The anthraquinones chrysophanol, rhein and physcion were identified in the leaves (Mahesh et al. 1984). Morimoto et al. (1988) isolated (−) epiafzelechin 3- O-_-D-glucopyranoside, 7 biflavonoids and two triflavonoids together with (−) epiafzelechin, (−) epicatechin and procyanidin B-2 from the leaves. Sennosides were also found in the leaves (Asseleih et al. 1990). The leaves were found to contain the commercially important laxative sennoside B rhein (Dutta and De 2002). Both sennoside and rhein contents in the leaves exhibited seasonal variation (Chowdhury et al. 1996). Luximon-Ramma et al. (2002) reported that among the vegetative organs of *C. fistula*, the young and old leaves showed the highest total phenolic, flavonoid and proanthocyanidin contents. Sakulpanich and Gritsanapan (2008) found that rhein was the major anthraquinone component in leaf extracts. Sakulpanich and Gritsanapan (2009) found that decoction of leaves containing an average total anthraquinone glycosides of 1.52%w/w might be used as an alternative source of raw material for various laxative preparations.

Forty-four compounds were identified representing 92.6% and 90.7% of the flower and leaf oil, of *Cassia fistula* respectively (Tzakou et al. 2007). The composition of the leaf oil was characterized by the abundance of phytol (16.1%) together with the hydrocarbons, tetradecane (10.5%) and hexadecane (8.7%). The hydrocarbons and their derivatives (alkanes, alkenes, and ketones) were common components of leaf waxes, from which they were probably derived.

Phytochemicals From Flowers

A bianthraquinone glycoside, fistulin, together with kaempferol and rhein were isolated from ethanolic extracts of *C. fistula* flowers (Kumar et al. 1966). The presence of kaempferol and a proanthocyanidin whose structure was established as a tetramer of leucopelargonidin with a free glycol were isolated from the acetone extract of the flower (Narayanan and Seshadri 1972). A detailed biochemical analysis of the flower's pollen, suspected to play a significant allergenic role, showed a protein composition of 12% with appreciable amounts of free amino acids such as phenylalanine, methionine, glutamic acid and proline (Mondal et al. 1998). Carbohydrate, lipid and free amino acid contents were of the order of 11.75%, 12% and 1.42%, respectively.

Forty-four compounds were identified representing 92.6% and 90.7% of the flower and leaf oil, of *Cassia fistula* respectively (Tzakou et al. 2007). The flower oil was dominated by the presence of the sesquiterpene (E)-nerolidol (38.0%), followed by 2-hexadecanone (17.0%) and heptacosane (12.8%).

Phytochemicals From Bark, Stem, Roots

Fistucacidin, an optically inactive leucoanthocyanidin, 3,4,7,8,4′-pentahydroxyflavan along with barbaloin and rhein were identified from the bark and heart-wood of *Cassia fistula* (Murty et al. 1967). The stembark of *C. fistula* was also reported as a potential source of lupeol, ß-sitosterol and hexacosanol (Sen and Shukla 1968; Bahorun et al. 2005). *Cassia fistula* bark, used extensively against a wide range of ailments, had been reported to contain flavonoids, phenolic acids and xanthine glycoside (Gupta et al. 1989). Vaishnav and Gupta (1996) showed the presence of rhamnetin 3-O-gentibioside in *C. fistula* roots. The ethanolic extract of *C. fistula* bark revealed the presence of tannins, flavonoids, steroids, glycosides and carbohydrates (Malpani et al. 2009).

Different parts of the plant have various pharmacological properties as elaborated below.

Antioxidant Activity

The methanol fruit extract of *Cassia fistula* was found to inhibit the 5-lipoxygenase catalysed formation of leukotriene B4 in bovine polymorphonuclear leukocytes with an IC_{50} value of 38 µg/ml (Sunilkumar and Muller 1998). Also, lipid peroxidation in bovine brain phospholipid liposomes induced with 2,2′-azo-bis-(2-amidinopropane) dihydrochloride (AAPH) was inhibited with an IC_{50} value of 40 µg/ml. A linear correlation was obtained between the effects of the extract in the two kinds of assays suggesting a redox-based mechanism for the inhibition of the 5-lipoxygenase enzyme.

Trolox equivalent antioxidant capacity and ferric-reducing antioxidant power assays showed that the antioxidant activities of fresh vegetative and reproductive organs of *Cassia fistula* were strongly correlated with total phenols (Luximon-Ramma et al. 2002). The antioxidant activities of reproductive parts were higher than those of the vegetative organs, with the pods having highest total phenolic, proanthocyanidin, and flavonoid contents and antioxidant potentials (TEAC = 992 µmol/g dry weight; FRAP = 811 3 µmol/g dry weight). Siddhuraju et al. (2002) found the antioxidant capacity of aerial parts *of C. fistula* to decrease in the following order stem > bark > leaves > flowers > pulp. Antioxidant activity was well correlated with the total polyphenolic content of the extracts. The low antioxidant activity in the flower and pulp fractions was attributed to the presence of some prooxidants, such as chrysophanol and reducing sugars which dominated the antioxidant compounds present in the extracts. The stem bark had more antioxidant activity in terms of reducing power, inhibition of peroxidation, O_2^- and DPPH radical scavenging ability.

Cassia fistula bark extracts (aqueous and methanol) were found to possess significant antioxidant activity (Ilavarasana et al. 2005). Both extracts showed significant radical scavenging by inhibiting lipid peroxidation initiated by CCl_4 and $FeSO_4$ in Wistar rat liver and kidney homogenates. Both extracts exhibited significant antioxidant activity in DPPH, nitric oxide and hydroxyl radical induced in-vitro assays. Both extracts exhibited concentration-dependent protective effect against lipid peroxidation and free radical generation in liver and kidney homogenates.

Manonmani et al. (2005) observed an appreciable decrease in peroxidation products viz thiobarbituric acid reactive substances, conjugated dienes and hydroperoxides in heart tissues of diabetic rats treated with aqueous *Cassis fistula* flower extract (ACF). The decreased activities of key antioxidant enzymes such as superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase and glutathione in diabetic rats were normalised upon ACF treatment. These results indicated that *C. fistula* flower extract exhibited promising antioxidative activity in alloxan diabetic rats.

C. fistula fruit pulp extract was found to have high antioxidant activity as indicated by the dose-dependent increase in FRAP (ferric reducing antioxidant power) value (Bhatnagar et al. 2010). The fruit pulp was found to have high phenolic (22 mg/kg) and flavones (4 mg/kg) contents. young adult mice administered fruit pulp powder extract (100 mg/kg/BW single dose) daily for 30 days prior

to daily combination of stresses (immobilization followed by swimming type) of 2 hours for 30 days, exhibited significant elevation in superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx) and reduced glutathione (GSH) levels in the brain, gastronomies muscle, heart, kidney, lung and stomach of treated mice as compared to mice given only stress. Levels of malondialdehyde (MDA) were significantly decreased after the fruit extract treatment in all the tissues in stress group mice as compared to control.

Antiinflammatory and Antipyretic Activities

Aqueous and methanol extracts of *C. fistula* bark at concentrations of 250 and 500 mg/kg exhibited significant reduction in paw oedema volume of rats (Ilavarasana et al. 2005). Further, the acute toxicity study with the extracts showed no sign of toxicity up to a concentration level of 2,000 mg/per os.

Studies indicated *C. fistula* to have antiinflammatory and antipyretic activities (Gobianand et al. 2010). The ethanolic extract of *Cassia fistula* was found to significantly inhibit both the carrageenan-induced hind paw oedema and cotton-pellet granuloma in a concentration dependant manner. The extract at 250 and 500 mg/kg b.w., lowered TAB (typhoid-paratyphoid A and B) vaccine-induced pyrexia in rats after 60 min, whereas at 750 mg/kg b.w., it reduced the vaccine induced elevated body temperature after 30 min of its administration.

Studies found that *Cassia fistula* dried fruit extracts showed less anti-inflammatory activity than extracts of *Solanum xanthocarpum* dried fruits using the carragenan-induced paw edema model in rats (Anwikar and Bhitre 2010). Both the extracts exhibited maximum antiinflammatory activity at 500 mg/kg concentration. Among the different dose combinations of both the extracts, the 1:1 combination at the 500 mg/kg concentration showed maximum percentage inhibition of 75%, which was comparable with the positive control, diclofenac sodium, with 81% inhibition. Since both the combinations fell below the additivity line in the isobolograms, synergistic interactions between *S. xanthocarpum* and *C. fistula* extracts were indicated.

Antiulcerogenic Activity

The ethanol leaf extract (ELE) of *Cassia fistula* was found to have antiulcer activity (Karthikeyan and Gobianand 2010). The antiulcer activity of ELE was evidenced by the significant decrease of gastric volume, pH, free acidity, and total acidity in the gastric juice of pyloric-ligated rats in a concentration-dependent manner. This protective effect could be attributed to strengthening of the mucosal defence mechanism. ELE pre-treatment significantly mitigated the decline in status of sialic acid and fucose accompanied by an elevation in hexose, hexosamine, total non-amino polysaccharide, total carbohydrate, and C:P ratio in the gastric juice of pylorus-ligated rats. This effect could be attributed to protection of the mucosal barrier system. ELE pre-treatment significantly averted the increase in lipid peroxide and superoxide dismutase followed by a decrease in catalase, in the gastric juice of pyloric-ligated rats. This protective ability of ELE against pylorus ligation-induced gastric ulcer could be attributed to its free radical scavenging and antioxidant properties. Higher doses of ELE (750 mg/kg b.w.) produced maximum antiulcer activity comparable to ranitidine treatment. Taken together, the antiulcer activity of ELE could be attributed to (i) a decrease in gastric acid secretion, (ii) protection of the mucosal barrier and restoration of mucosal secretions, (iii) inhibition of free radical generation or prevention of lipid peroxidation, and (iv) free radical scavenging or antioxidant properties.

Anti-diabetic/Hypoglycemic/Hypocholesterolemic/Hypolipidemic Activities

The aqueous fraction of *C. fistula* leaves induced a significant decrease in the glycemia at 4 and 24 hours with doses of 300 and 500 mg/kg, and at 1 and 4 hours with the dose of 1,000 mg/kg in mice (Esposito Avella et al. 1991). El-Saadany

et al. (1991) reported that administration of *Cassia fistula* significantly lowered blood and liver total lipids. Similar trend was observed in the brain, spleen, kidneys and heart but to a moderate extent. Total cholesterol of the blood, liver, kidneys, spleen and heart was significantly reduced, but that of brain was not changed. The level of triglycerides was markedly improved. There was a moderate rise, however, in phospholipids content in all studied organs. Moreover, administration of *Cassia fistula* to hypercholesterolaemic male albino rats produced a significant reduction in the high activities of serum GOT, GPT, alkaline and acid phosphatase and the level nearly returned to the initial values. Values of total serum protein, albumin (A), globulin (G), A/G, free amino acids, uric acid and creatinine were also ameliorated and attained nearly the normal values of the control group. In separate studies, Bhakta et al. (1997) found that oral administration of methanol extract of leaves significantly lowered blood glucose level up to 25.2% and 45.7% at the concentration of 400 and 600 mg/kg respectively in alloxan diabetic rats. The LD_{50} of the extract was found to be 3.5 g/kg. Blood glucose level was reduced within 2 hours and the effect was maintained up to 10 hours.

Cassia fistula bark extract was found to exhibit hypocholesterolemic and hypoglycemic effects (Nirmala et al. 2008). Hexane extract of *C. fistula* bark at concentrations of 0.15, 0.30, 0.45 g/kg body weight for 30 days suppressed the elevated blood glucose levels in diabetic rats. The extract at 0.45 g/kg was found to be comparable with glibenclamide, the reference drug. The lipid profile (total cholesterol, triglyceride, HDL-cholesterol, LDL and VLDL-cholesterol) after the extract treatment at 0.45 g/kg body weight exhibited notable improvement compared to the diabetic control animals. Antioxidant and polyphenol content present in the extracts were postulated to contribute to the antihyperglycemic and antilipidemic properties. Thus the results suggested that *Cassia fistula* barks would be effective in the treatment of diabetes and in prevention and management of coronary artery disease.

Methanol extracts of *Cassia fistula* (flowers, leaves and bark) were found to have protective effects against glycated protein (GFBS) -induced toxicity in a human umbilical vein endothelial cells (HUVEC) model (Einstein et al. 2008). Results showed that HUVEC incubated with GFBS alone showed a significant elevation of lipid peroxidation accompanied by depletion of superoxide dismutase (SOD), catalase, glutathione peroxidase (GPx) and glutathione reductase (GR), in addition to decreased cytosolic GST (glutathione S-transferase). Treatment of HUVEC with *C. fistula* extracts at a concentration of 25 and 50 μg significantly lowered lipid peroxidation and normalized the activities of the antioxidant enzymes and GST levels in a concentration-dependent fashion. Further, *C. fistula* extracts increased the viability of HUVEC damaged by GFBS. The results suggested a potential beneficial effect of the extract in preventing diabetic angiopathies.

In recent studies, Gupta and Jain (2009) found that oral feeding of cholesterol (500 mg/kg b.w./day) dissolved in coconut oil (0.5 ml/rat/day) for 90 days produced a significant rise in total and LDL-cholesterol, triglycerides and phospholipid in serum of rats. Administration of *C. fistula* legume extract at concentrations of 100, 250 and 500 mg/kg b.w./day along with cholesterol significantly prevented the elevation in the serum total and LDL-cholesterol, triglycerides and phospholipid in a concentration dependent manner. The ratio of HDL-cholesterol/total cholesterol was elevated in serum of *C. fistula* extract treated groups as compared to cholesterol alone fed control rats.

Immunomodulatory Activity

Cassia fistula fruit extract was found to have an immunomodulatory effect (Ali et al. 2008). Increasing titre of haemagglutinating antibody in all animals was observed after 4, 6, 8, 10 days of immunization but amoxy-cassia (combination of amoxillin and *Cassia fistula* fruit extract) treated mice serum had the highest titre. However significant increase in haemagglutinating antibody titre was observed in and *C. fistula* (alone) treated mice. The result showed that amoxy-cassia and

water extract of fruit *C. fistula* stimulated immune system by activating large number of anti RBC producing cells in the spleen indicating its therapeutic usefulness.

Hepatoprotective Activity

The n-heptane extract of *Cassia fistula* leaves was shown to possess significant protective effect by decreasing the serum concentrations of transminases (SGOT and SGPT), bilirubin and alkaline phosphatase (ALP) in carbon tetrachloride:liquid paraffin (1:1)-induced hepatotoxic rats (Bhakta et al. 1999). The extract of *C. fistula* at a concentration of 400 mg/kg exhibited significant hepatoprotective activity which was comparable to that of a standard hepatoprotective agent. Similar results were obtained with n-heptane extract of *Cassia fistula* leaves in paracetamol-induced hepatoxicity in rats (Bhakta et al. 2001). In separate studies, administration of ethanolic leaf extract of *C. fistula* for 30 days prevented the diethylnitrosamine (DEN) induced hepatic injury and oxidative stress in wistar rats (Pradeep et al. 2007, 2010). DEN induced hepatotoxicity in all the treated animals were characterised by increased serum ALT, AST, ALP and bilirubin levels and a concomitant decline in their levels in the liver tissue after 30 days. Induction of oxidative stress in the liver was evidenced by increased lipid peroxidation and fall in the activities of SOD and CAT. Oral administration of the ethanolic leaf extract (ELE) of *Cassia fistula* for 30 days to ethanol + DEN treated rats significantly ameliorated the above alterations in the markers of hepatotoxicity and oxidative stress, resulting in the reversal of most of the parameters studied. The effects were comparable to the standard hepatoprotective drug silymarin.

Cassia fistula aqueous bark extract was found to attenuate the hepatotoxic effect of carbon tetrachloride (Parthasarathy and Prasanth 2009). The extracts exhibited concentration dependant reduction in total bilirubin, alkaline phosphatase (ALP), serum glutamate oxaloacetate transaminase (SGOT), serum glutamate pyruvate transaminase (SGPT) levels and total protein. Aspartate transaminase (AST), alanine transaminase (ALT) and elevation in total protein (serum and liver) levels. *Cassia fistula* fruit extract exhibited significant hepatoprotective effect in the murine model (Kalantari et al. 2011). Co-treatment of bromobenzene with *Cassia fistula* fruit extract, significantly and concentration-dependently decreased the serum enzyme activities of aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP) and (with exception of gamma glutamyl transpeptidase (γGT)) and serum levels of direct and total bilirubin levels, eliciting a recovery to the normal state. Bromobenzene treatment alone produced a significant increase in activities of AST, ALT, ALP but not γGT. It significantly elevated the levels of direct and total bilirubin. The protective effect of *Cassia fistula* fruit extract against liver injury evoked by bromobenzene was also confirmed by histological examination.

Studies showed that the methanolic extract of *C. fistula* bark had cardioprotective effect in doxorubicin induced myocardial damaged rats (Khatib et al. 2010). Doxorubicin at 10 mg/kg caused cardiac damage in wistar rats and elevated the levels of cardiac biomarker enzymes namely aspartate aminotransferase, alanine aminotransferase, lactate dehydrogenase, and creatine kinase-MB. Doxorubicin treated animals sustained severe degeneration of the myofibrils with focal necrosis and vacuolated cytoplasm. Pretreatment with Cassia bark extract at a dose of 400 mg/kg significantly reduced the elevated levels of serum enzymes histological disturbances and electro-cardiogram alterations to normal myocardium functioning.

Antimicrobial Activity

A new bioactive flavone glycoside 5,3′,4′-trihydroxy-6-methoxy-7-O-α-L-rhamnopyranosyl-(1 → 2)-O-β-D-galactopyranoside with antimicrobial activity was isolated from *C. fistula* seeds (Yadava and Verma 2003). The methanol extract of *Cassia fistula* seeds was found to have antimicrobial activity against medically important bacterial, yeast and fungal strains (Lachumy

et al. 2010). The extract was effective on tested microorganism and the minimum inhibitory concentration (MIC) values were found in the range of 1.563–50.00 mg/ml. The extract exhibited no significant toxicity (LC_{50} = 2.11 mg/ml) against *Artemia salina* in the brine shrimp lethality test. The *C. fistula* seed extract with high LC_{50} value signified that this plant was not toxic to human.

Hexane, chloroform, ethyl acetate, methanol and water extracts from the flower of *Cassia fistula* exhibited antibacterial activity against Gram-positive organisms with minimum inhibitory concentrations (MIC) between 0.078 and 2.5 mg/ml (Duraipandiyan and Ignacimuthu 2007). Among the Gram-negative bacteria, only *Pseudomonas aeruginosa* was susceptible to the extracts. 4-hydroxy benzoic acid hydrate was isolated from the ethyl acetate extract and found to exhibit antifungal activity against *Trichophyton mentagrophytes* (MIC 0.5 mg/ml) and *Epidermophyton floccosum* (MIC 0.5 mg/ml). Rhein (1,8-dihydroxyanthraquinone-3carboxylic acid) isolated from the ethyl acetate extract of *Cassia fistula* flower was found to have antifungal activity (Duraipandiyan and Ignacimuthu 2010). Rhein inhibited the growth of many fungi such as *Trichophyton mentagrophytes* (MIC 31.25 µg/ml), *Trichophyton simii* (MIC 125 µg/ml), *Trichophyton rubrum* (MIC 62.5 µg/ml) and *Epidermophyton floccosum* (MIC 31.25 µg/ml).

The alcoholic extract of leaves of *C. fistula* showed antimicrobial activity against *Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli* and Group A *Streptococcus*, some common human pathogens (Vasudevan et al. 2009). The MBC values ranged from 4 to 8 mg/ml and MIC values varied from 1 to 2 mg/ml. Extracts of petroleum ether, chloroform, ethanol, methanol and aqueous of *Cassia fistula* leaves showed promising antifungal activity against *Candida albicans* (12.6 mm), *Candida krusei* (13.3 mm), *Candida parapsilosis* (14.0 mm), and *Candida tropicalis* (14.3 mm) (Panda et al. 2010). Maximum activity was observed in methanol extract followed by ethanol and aqueous extracts. Petroleum ether and ethanol extracts, exhibited zone of inhibition against all the three species of *Aspergillus* (*A. niger, A. flavus* and *A. fumigatus*) with highest zone of inhibition for *Aspergillus fumigatus* (12.0 mm). MIC values for most of the extracts ranged from 0.75 to 3.0 mg/ml; while the least MFC value was observed at 6.0 mg/ml. Result of MFC (minimum fungicidal concentration) showed that at concentration 6.0 mg/ml, 75% of the test *Candid*a species were killed while 25% were inhibited at the same concentration. Phytochemical analysis showed the presence of alkaloids, flavonoids, carbohydrates, glycosides, protein and amino acids, saponins and triterpenoids in the different extracts. The results revealed the antifungal activity of *C. fistula* leaf extracts may be useful in treatment of candidiasis and aspergillosis.

Antitumour Activity

Studies showed that the methanolic extract (ME) of *Cassia fistula* had antitumour activity treatment (Gupta et al. 2000). The extract elicited an increase of life span, and a decrease in the tumour volume and viable tumour cell count in the Ehrlich ascites carcinoma tumour hosts. Cytological studies revealed a reduction in the mitotic activity, and the appearance of membrane blebbing and intra-cytoplasmic vacuoles in the treated tumour cells. Improvement in the haematological parameters, like haemoglobin content, red blood cell count and bone marrow cell count of the tumour bearing mice were also observed following the extract treatment.

Antifertility Activity

Oral administration of aqueous extract of *Cassia fistula* seeds to mated female rats from day 1–5 of pregnancy at concentrations of 100 and 200 mg/kg body weight caused 57.14% and 71.43% inhibition of pregnancy, respectively, whereas 100% pregnancy prevention was noted at 500 mg/kg body weight (Yadav and Jain 1999). In the uterine bioassay test carried out in immature bilaterally ovariectomized female rats, the extract (100 mg/kg b.w.) enhanced the uterine wet weight and luminal epithelial cell height but did not

cause premature opening of the vagina. This suggested a mild estrogenic activity of the extract. However, when the extract was administered simultaneously with estradiol valerate (EDV, 0.1 mg/kg b.w.), it significantly suppressed the estrogen-induced uterotrophic effect, thus showing an antiestrogenic nature of the extract in the presence of a strong estrogen. In separate studies, *Cassia fistula* extract was found to inhibit fertility in male rats (Chauhan and Agarwal 2010). Withdrawal of the extract restored all the altered parameters, including organ weights, fertility, circulatory level of hormones and tissue biochemistry, to control levels after 120 days.

CNS Activity

The methanol extract of *Cassia fistula* seed significantly potentiated the sedative actions of sodium pentobarbitone, diazepam, meprobamate and chlorpromazine (Mazumdar et al. 1998). The extract also potentiated significantly the analgesia induced by morphine and pethidine in a concentration dependent manner. A depressant action of the extract was also evident from the behavioral studies on mice.

Antitussive Activity

The methanol extract of *Cassia fistula* exhibited significant antitussive activity when compared with control in a dose dependent fashion using a cough model induced by sulphur dioxide gas in mice (Bhakta et al. 1998b). The antitussive activity of the extract was comparable to that of codeine phosphate, a prototype antitussive agent. The *C. fistula* extract (400, 600 mg/kg, per os) exhibited maximum inhibition of cough by 44.44% and 51.85% respectively with respect to control group.

Wound Healing Activity

The alcoholic leaf extract of *C. fistula* was found to have wound healing activity (Bhakta et al. 1998a; Senthil Kumar et al. 2006). The extract treated rats displayed better wound closure, improved tissue regeneration at the wound site, and supporting histopathological parameters pertaining to wound healing. Biochemical analysis and matrix metalloproteinases expression correlated well with the results thus confirming the efficacy of *C. fistula* in the treatment of the infected wounds.

Antiparasitic Activities

The methanolic leaf extract of *Cassia fistula* was found to have larvicidal and ovicidal activity against *Culex quinquefasciatus* and *Anopheles stephensi* (Govindarajan et al. 2008). The extract was found to be more lethal to the larvae of *A. stephensi* than *C. quinquefasciatus* with LC_{50} values of 17.97 and 20.57 mg/l, respectively. Mean percent hatchability of the ovicidal activity was observed 120 hours post treatment. The percent hatchability was inversely proportional to the concentration of extract and directly proportional to the eggs. The egg raft of *C. quinquefasciatus* was found to be more hatchable than *A. stephensi*. In another study, the crude leaf extract of *Cassia fistula* showed significant repellency against chikungunya vector, *Aedes aegypti* (Govindarajan 2009). The methanol, benzene and acetone extract exhibited concentration dependent activity and produced significant mortality. The 24 hours LC_{50} concentration of the extract against *Aedes aegypti* was observed at 10.69, 18.27 and 23.95 mg/l respectively. The percent hatchability was inversely proportional to the concentration of extract and directly proportional to the eggs.

Hexane extract from *Cassia fistula* fruits showed significant antileishmanial activity against the promastigote form of *Leishmania* (L.) *chagasi* (Sartorelli et al. 2007). The 50% inhibitory concentration (IC_{50}) was 10.03 μg/ml against promastigotes. Intracellular amastigotes demonstrated high susceptibility, with an IC_{50} of 18.10 μg/ml. The bioactive compound in the dichloromethane extract of *Cassia fistula* fruits was found to be the isoflavone biochanin A (Sartorelli et al. 2009).

This compound showed 50% effective concentration (EC_{50}) value of 18.96 μg/ml against promastigotes of *Leishmania* (L.) *chagasi*. The cytotoxicity of this substance against peritoneal macrophages resulted in an EC_{50} value of 42.58 μg/ml. Additionally, biochanin A presented an anti-*Trypanosoma cruzi* activity, resulting in an EC_{50} value of 18.32 μg/ml and a 2.4-times more effectiveness than benzindazole.

Traditional Medicinal Uses

The whole plant of *Cassia fistula* possesses medicinal properties and is used as traditional folk treatment of skin diseases, inflammatory diseases, rheumatism, anorexia, burns, cancer, constipation, convulsions, delirium, diarrhoea, dysuria, epilepsy, gravel, hematuria, pimples, jaundice and glandular tumours (Burkill 1966; Chopra et al. 1986; Duke 1996; Nadkarni and Nadkarni 1982). *Cassia fistula* is widely used in traditional medicine in many areas of India for the treatment of various diseases and ailments viz. hepatoprotective, antioxidant, antidiabetic etc. (Malpani et al. 2009). *Cassia fistula* is traditionally used in cardiopathy and heart disease (Khatib et al. 2010).

The fruit pulp is reported to be aperient, astringent, mild laxative, purgative, and vermifuge. In Ayurvedic medicine, fruit pulp is used as a mild laxative, against fevers, arthritis, *vata-vyadh*i (nervous system diseases), leprosy, all kinds of *rakta-pitta* (bleeding, such as hematemesis or hemorrhages), as well as cardiac conditions and stomach problems such as acid reflux. In Yunani medicine, the fruit is employed as antiinflammatory, antipyretic, abortifacient, demulcent, purgative, refrigerant, chest complaints, eye ailments, flu, heart and liver ailments, and rheumatism. The Konkanese in India use the juice to alleviate ringworm and blisters. In Africa, Zimbabweans use the pulp for anthrax, blood poisoning, blackwater fever, dysentery, and malaria and the Ghana natives use the pulp from as a safe and useful purgative. Throughout southeast Asia, the uncooked pulp of the pods is a popular remedy for constipation. In the West Indies, the pulp and/or leaves are poulticed onto inflamed liver.

In Ayurvedic medicine, the seed is regarded as antibilious, aperitif, carminative, and laxative. In Yunani medicine the seeds are deemed emetic.

In Ayurvedic medicine, the leaves are employed for erysipelas, malaria, rheumatism, and ulcers, the buds for biliousness, constipation, fever and leprosy. Yunani use the leaves for inflammation. In the upper Sind, leaf poultices are applied to the chilblains and also used in facial massage for brain afflictions, and applied externally for paralysis, rheumatism and gout.

In Ayurvedic medicine, the flower buds are used for biliousness, constipation, fever, leprosy, and skin disease. Yunani use the flowers for a purgative. In the West Indies, the flowers are used for fever.

The root is potently purgative and any use without medical supervision is strongly advised against in Ayurvedic texts. In Ayurvedic medicine, the root is used for adenopathy, burning sensations, leprosy, skin diseases, syphilis, and tubercular glands. In the West Indies, root is used as a diuretic, febrifuge, for gout and rheumatism. In Java, a decoction of the root bark used as lotion for wounds and ulcerations.

Other Uses

Cassia fistula is popularly planted as an ornamental or as way-side trees. It yields pollens during flowering and bees collect nectar from the extra-floral nectaries located at the base of the leaf-stalk. The wood is very hard, very heavy, grey to brick-red, difficult to work and apt to split. The wood is used for buildings, cabinetwork, inlay work, wheels, mortars carts, fence posts and agricultural implements as well as for charcoal. The bark is also used for dyeing and tanning and the pods are used in traditional medicine.

Comments

Cassia fistula is deemed an environmental weed in some countries.

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Castanospermum australe

Scientific Name

***Castanospermum australe* A. Cunn. & C. Fraser ex Hook.**

Synonyms

Castanocarpus australis Sweet

Family

Fabaceae or Leguminosae, also placed in Papilionaceae

Common/English Names

Australian Chestnut, Black Bean, Moreton Bay Chestnut

Vernacular Names

French: Châtaignier Austral;
German: Castanospermum;
Spanish: Castaño De La Bahía De Moretón.

Origin/Distribution

Moreton Bay Chestnut is native to the coastal rainforests and beaches in Australia from around Lismore, New South Wales to the Iron Range, Cape York Peninsula on the Queensland coast and 160 km west to the Bunya Mountains. It has been introduced into India, Malaysia, Papua New Guinea, Sri Lanka and the United States of America.

Agroecology

Moreton Bay Chestnut is suited for a wide range of conditions throughout Australia spanning subtropical and tropical climatic regimes. It thrives in areas with mean annual temperature of 28°C and mean annual rainfall of 1,000–3,800 mm in altitudes of 50–750 m. It thrives on well-drained, fertile, moist alluvial soils and deep loams on basalt in sunny positions but will tolerate partially shaded conditions. It will tolerate only light frost. It has nodules in its roots that harbour the *Rhizobium* bacterium that fixes nitrogen.

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Edible Plant Parts and Uses

The starchy seeds of this tree are poisonous and are eaten by the aborigines after considerable preparation. The hard seeds are cracked and soaked in water, then pounded, and made into cakes, and finally roasted. The washing in water removes some of the soluble toxins, while roasting destroys other toxins. The plant is not used in modern bush tucker preparations.

Plate 1 Flowers and foliage

Botany

A tall evergreen tree, reaching heights of 20–40 m high, with a dense rounded canopy with a spread of 4–8 m, low spreading branches, trunk diameter of 1.2 m and greyish brown bark. Leaves are alternate, imparipinnate, 20–35 cm long, with 11–17 mostly alternate leaflets (Plates 1 and 2). Leaflets have entire margins, elliptic-lanceolate to oval, about 8–17 × 3–6 cm, obtuse apex and unequal sides at base, glossy green on upper surface and pale green below and borne on 0.5–7 cm long petiolules. Flowers are borne in racemes, 15 cm long and on yellow, 2.5 cm long pedicels. Flowers are showy, attractive, papilionaceous (butterfly-like), 4–5 cm long, cauline or produced on twigs below the leaves (Plates 1 and 2). Calyx is waxy-yellow, campanulate up to 2 × 1.5 cm and 5- acute lobed at the apex, sparsely pubescent. Petals 5, coriaceous, changing from greenish-yellow to deep orange, the standard petal is 3–4 × 3 cm and lobed at the apex. Stamens are yellow, 8–10, all free, incurved, about 0.4 × 0.15 cm and can dehisce in the bud stage. Ovary on a stalk about 1.5–2 cm long, 1-celled, with 3–4 ovules. Style 1–2 cm long and red, glabrous with a small terminal stigma. Fruits large, woody, cylindrical, dehiscent pods, 15–25 × 4–5 cm, 2-valved and slightly falcate, green turning to brown to blackish brown when mature. It contains 3–5 round or compressed, brown-, 3–5 cm diameter seeds.

Plate 2 Close-up of flower clusters and imparipinnate leaves

Nutritive/Medicinal Properties

No published information is available on its nutritive composition.

Leaves have been reported to contain saponins and the seeds are rich in alkaloids with various pharmacological properties.

A new type of higher plant alkaloid, 1,6,7, 8-tetrahydroxyoctahydroindolizine, designated castanospermine, was isolated from the toxic seeds of the Australian legume *Castanospermum austral* (Hohenschutz et al. 1981). The sapogenin mixture prepared from the extract of the wood of *Castanospermum australe* was found to contain

the known triterpenes 2β,3β-dihydroxyolean-12-en-28-oic acid and 3β-hydroxyolean-12-ene-23,28-dioic acid; the latter also occurs as the free triterpene (Bannon et al. 1973).

Three new triterpenoid saponins, their methyl esters designated as castaralesides F (1), G (2) and H (3), were isolated from the fresh leaves of *Castanospermum australe* (Ahmed et al. 1994). The structures of these three saponins were elucidated as 3 β-O-[β-galactopyranosyl-(1→4)-β-glucuronopyranosyl]-2 β,23-dihydroxyolean-12-en-28-oic acid; 3 β-O-[α-rhamnopyranosyl-(1→4)-β-galactopyranosyl-(1→2)-β-glucuronopyranosyl]-2 β,28-dihydroxyolean-12-ene; and 3 β-O-[α-rhamnopyranosyl-(1→4)-β-xylopyranosyl-(1→2)-β-glucuronopyranosyl]-2β,28-dihydroxyolean-12-ene.

Some of the reported pharmacological properties of the plant include:

Glucosidase Inhibition Activity

Castanospermine (1,6,7,8-tetrahydroxyoctahydroindolizine) an indolizidine alkaloid that was isolated from *Castanospermum australe* seed, was found to be a potent inhibitor of lysosomal α- and β-glucosidases (Saul et al. 1984). Castanospermine proved to be a competitive inhibitor of amyloglucosidase at both pH 4.5 and 6.0 when assayed with the p-nitrophenyl-α-D-glucoside. It was also a competitive inhibitor of almond emulsin β-glucosidase at pH 6.5. Castanospermine was a more efficient inhibitor at pH 6.0–6.5 than it was at lower pH values. The pK for castanospermine was found to be 6.09, indicating that the alkaloid was probably more active in the unprotonated form. These results probably elucidated why castanospermine was a good inhibitor of the glycoprotein processing enzyme, glucosidase I, a neutral enzyme. Saul et al. (1983) found castanospermine (1,6,7,8-tetrahydroxyoctahydroindolizine) to be a potent inhibitor of almond emulsin β-glucosidase, and also to inhibit fungal β-xylosidase. This alkaloid was inactive on yeast α-glucosidase, α- or β-galactosidase, α-mannosidase, β-N-acetylhexosaminidase, β-glucuronidase, α-L-fucosidase. Fifty-percent inhibition of β-glucosidase was found to require about 10 μg/ml of castanospermine. Castanospermine was also a potent inhibitor of β-glucocerebrosidase when assayed with fibroblast extracts. Further, castanospermine also inhibited the lysosomal α-glucosidase, and this inhibition required comparable levels of alkaloid to that required for inhibition of β-glucocerebrosidase. However, a number of other lysosomal glycosidases were not sensitive to castanospermine (i.e., α- or β-galactosidase, α- or β-mannosidase, α- or β-L-fucosidase, β-N-acetylhexosaminidase, β-glucuronidase).

A second indolizidine alkaloid, epimeric with castanospermine, was isolated from seeds of *C. australe* (Molyneux et al. 1986). 6-Epicastanospermine was found to be a potent inhibitor of amyloglucosidase, (an exo-1,4-α-glucosidase), a weak inhibitor of β-galactosidase, and failed to inhibit β-glucosidase and α-mannosidase. The inhibition of amyloglucosidase was found to be competitive and to be more effective at higher pH values. 3,8-diepialexine isolated from *C. australe* was found to have glycosidase inhibition activity (Nash et al. 1988).

Chen et al. (1990) isolated the following indolizidine alkaloids from the seeds of *C. australe*: castanospermine, 6-epi-castanospermine, australine, 3,8-di-epi-alexine, and fagomine. Australine the pyrrolizidine alkaloid from *C. australe* was found to be a good inhibitor of the α-glucosidase amyloglucosidase (50% inhibition at 5.8 μM), but it did not inhibit β-glucosidase, α- or β-mannosidase, or α- or β-galactosidase (Tropea et al. 1989). Two new alexines, 1,7a-diepialexine and 7,7a-diepialexine isolated from *Castanospermum austral* inhibited mouse gut disaccharidase and fungal glucan 1,4-α-glucosidase (Nash et al. 1990). 7-deoxy-6-epi-castanospermine, a trihydroxyindolizidine alkaloid glycosidase inhibitor from *Castanospermum austral* seeds, inhibited amyloglucosidase and yeast α-glucosidase but was markedly less active as a glycosidase inhibitor than its isomer swainsonine and the tetrahydroxylated alkaloids castanospermine, 6-epi-castanospermine and australine. A tetrahydroxyindolizidine alkaloid, 6,7-diepi-castanospermine, isolated from the seeds of *Castanospermum australe* was found to be a

moderately good inhibitor of the fungal α-glucosidase, amyloglucosidase and a relatively weak inhibitor of β-glucosidase (Molyneux et al. 1991). It did not inhibit α- or β-galactosidase, α- or β-mannosidase, or α-L-fucosidase. The inhibition of amyloglucosidase was of a competitive nature. Australine also inhibited the glycoprotein processing enzyme glucosidase I, but had only slight activity toward glucosidase II. When incubated with cultured cells, this alkaloid inhibited glycoprotein processing at the glucosidase I step and induced the accumulation of glycoproteins with Glc3Man7-9(GlcNAc)2-oligosaccharides.

Pan et al. (1993) isolated castanospermine and swainsonine from *C. australe* seeds. These seeds had been reported to be toxic to animals and to cause severe gastrointestinal upset. Castanospermine was found to strongly and rapidly inhibit the activity of the disaccharidases, sucrase, maltase, and trehalase, with sucrase being the most sensitive to inhibition. The loss of activity of these enzymes, especially sucrase, in injected animals appeared to be due to a direct inhibition of enzyme activity, rather than to a change in the structure of the glycan chains of the enzyme. Swainsonine, an α-mannosidase inhibitor, when injected into animals, also drastically decreased the activity of the sucrase, but this alkaloid had no direct effect on sucrase activity although it did markedly altered the carbohydrate nature of this glycoprotein. In in-vitro studies with the purified enzyme, castanospermine was found to be a competitive inhibitor of intestinal sucrase, but it was a non-competitive inhibitor of intestinal maltase.

A polyhydroxylated pyrrolizidine alkaloid, 1-epialexine isolated from the leaves and stems of *C. austral* was found to be a weak inhibitor of β-mannosidase from *Cellullomonas fimi* (Jones et al. 2010).

Antiviral Activity

Castanospermine derived from the seeds of *Castanospermum australe* and its derivatives were found to have antiviral activity against the following viruses: dengue DEN type 1 virus [DEN-1] (Courageot et al. 2000; Whitby et al. 2005), Sindbis virus (Schlesinger et al. 1985); human immunodeficiency virus HIV (Walker et al. 1987; Liu et al. 1990; Sunkara et al. 1990; Taylor et al. 1991; Taylor et al. 1994; Bridges et al. 1994); Moloney murine leukemia virus (MOLV) (Sunkara et al. 1990); influenza virus (Pan et al. 1983); bovine diarrhea virus, hepatitis C virus (Whitby et al. 2004); cytomegalovirus (Yamashita et al. 1996); Rauscher murine leukemia virus (Ruprecht et al. 1989); and herpes simplex virus (Bridges et al. 1995). In cells, castanospermine acted as an endoplasmic reticulum α-glucosidase I inhibitor and reduced infection of a subset of enveloped RNA and DNA viruses in vitro.

Pan et al. (1983) confirmed castanospermine to be a potent inhibitor of glycoprotein processing as it inhibited glucosidase I. Thus, when influenza virus was raised in the presence of castanospermine, at 10 μg/ml or higher, 80–90% of the viral glycopeptides were susceptible to the action of endoglucosaminidase H, whereas in the normal virus 70% of the glycopeptides were resistant to this enzyme. Castanospermine inhibited the processing of the oligosaccharide portion of the influenza viral hemagglutinin.

Courageot et al. (2000) found that α-glucosidase inhibitors like castanospermine reduced dengue virus DEN type 1 virus production by affecting the initial steps of virion morphogenesis in the endoplasmic reticulum. α-glucosidase inhibitors such as castanospermine and deoxynojirimycin inhibited dengue virus type 1 infection by disrupting the folding of the structural proteins prM and E, a step crucial to viral secretion. Whitby et al. (2005) using in-vitro assays found that four serotypes of dengue virus were inhibited by castanospermine. Importantly, castanospermine prevented mortality in a mouse model of dengue virus infection, with doses of 10, 50, and 250 mg/kg of body weight per day being highly effective at promoting survival. Accordingly, castanospermine had no adverse or protective effect on West Nile virus mortality in an analogous mouse model.

Castanospermine (1,6,7,8-tetrahydroxyoctahydroindolizine) was reported to modify glycosylation by inhibiting α-glucosidase I. Castanospermine

was shown to inhibit syncytium formation induced by the envelope glycoprotein of the human immunodeficiency virus (HIV) and to inhibit viral replication (Walker et al. 1987). Castanospermine and its esters 6-*O*- and 7-*O*-acyl derivatives were found to be potent inhibitors of the human immunodeficiency virus (HIV) and potential anti-AIDS agents (Liu et al. 1990). Castanospermine (CAST), and its analogues, exhibited antiviral activity against Moloney murine leukemia virus (MOLV) and HIV-1 (Sunkara et al. 1990). The most effective analogue was 6-O-butanoyl CAST (B-CAST, MDL 28,574) with an IC_{50} of 0.05 μg/ml against MOLV. B-CAST showed an IC_{50} of 0.3 μg/ml against HIV-induced syncytial formation in HeLa T4+ cells. The compound also was more potent (IC_{50}: 0.15 μg/ml) than CAST (4–6 μg/ml) against productive infection in JM cells infected with HIV 1 (GB8 strain). The antiretroviral activity of B-CAST was further confirmed in Friend leukemia virus (FLV) infection in mice. B-CAST showed equivalent activity to AZT (azidothymidine) and was more potent than CAST in inhibiting FLV-induced splenomegaly in mice. The data presented suggested the potential of these novel glucosidase inhibitors as anti-HIV agents.

The 6-O-butanoyl derivative of castanospermine (MDL 28,574) was shown to be approximately 30-fold more potent than the naturally occurring molecule at inhibiting the replication of human immunodeficiency virus (HIV) (Taylor et al. 1991). The α-glucosidase 1 inhibitor, 6-O-butanoyl castanospermine (MDL 28574) was found to have antiviral activity for HIV which was manifested by a decrease in syncytia as well as the production of virus with altered gp120 and a reduced infectivity (Taylor et al. 1991). Further studies revealed that consistent with its improved anti-HIV activity, MDL 28,574 was more effective (50% inhibitory concentration [IC_{50}], 20 μM) than the parent molecule (IC_{50}, 254 μM) at causing the accumulation of glucosylated oligosaccharides in HIV-infected cells by inhibition of glycoprotein processing (Taylor et al. 1994). MDL 28,574, however, was less active (IC_{50}, 1.27 μM) than castanospermine (IC_{50}, 0.12 μM) against the mutual target enzyme, cellular α-glucosidase I, in a cell-free assay system. The increased effects of MDL 28,574 against α-glucosidase I in cell culture were attributed to the improved cellular uptake of the more lipophilic derivative. It was also demonstrated that pre-treatment of HIV-permissive CD4+ cells with MDL 28574 substantially reduced their capacity to bind with cells chronically infected with HIV-1 which resulted in decreased virus production (Bridges et al. 1994).

Whitby et al. (2004) using the closely related virus, bovine viral diarrhoea virus for hepatitis C virus (HCV) plaque assay and a cytopathic effect assay found that 6 O-butanoyl castanospermine (celgosivir) (IC_{50} 16 and 47 μM respectively) was more potent than N-nonyl DNJ (105 and 74 μM), castanospermine (110 and 367 μM) and N-butyl DNJ (>250 and 550 μM). The inhibition of viral genomes released from BVDV-infected cells by either castanospermine or celgosivir in parallel with the number of infectious units confirmed that these α-glucosidase I inhibitors thwarted the production or release of flavivirus particles.

α-glucosidase 1 inhibitor 6-*O*-butanoyl castanospermine (MDL 28,574) exhibited in-vivo antiviral activity against herpes simplex virus type 1 (HSV-1) (Bridges et al. 1995). Oral treatment of mice, cutaneously infected with herpes simplex virus type 1 (HSV-1) (strain SC16), with the α-glucosidase 1 inhibitor, 6-*O*-butanoyl castanospermine (MDL 28,574) significant delayed lesion development and reduced the amount of virus recovered from the brain. Castanospermine was found to completely inhibit the binding of the human cytomegalovirus glycoprotein B (gB) in the endoplasmic reticulum (Yamashita et al. 1996).

Castanospermine and deoxynojirimycin were known to inhibit the removal of glucose from high mannose asparagine-linked oligosaccharides, on the formation of Sindbis virus (Schlesinger et al. 1985). The growth of Sindbis virus was inhibited to much more at 37°C than at 30°C in baby hamster kidney (BHK) cells treated with either deoxynojirimycin or castanospermine. Both of these compounds also inhibited the proteolytic cleavage of the viral glycoprotein precursor, PE2, to the virion glycoprotein, E2, but did not prevent the migration of the glycoprotein to the cell surface.

Ruprecht et al. (1989) found that plaque formation by Rauscher murine leukemia virus (RLV) was inhibited by castanospermine, with IC_{50} of 2 μg/ml. RLV-exposed BALB/c mice treated with a 20 day course of castanospermine starting 4 hours postinoculation showed a dose-dependent inhibition of splenomegaly. Oral castanospermine therapy given to chronically RLV-infected mice lengthened average survival from 36 to 94 days when compared to untreated controls. Castanospermine was better tolerated orally than intraperitoneally at the same dose. Toxic effects included weight loss, lethargy, and dose-dependent thrombocytopenia. At the highest intraperitoneal dose, lymphoid depletion occurred in the thymus, spleen, and lymph nodes. The results suggested that castanospermine acted as an active antiviral agent in animals and that prolonged oral administration was tolerable.

Antihyperglycaemic Activity

Castanospermine was found to be a potent inhibitor of rat intestinal glycohydrolases in-vitro and prevented the hyperglycemic response to an oral sucrose challenge in-vivo (Rhinehart et al. 1987). Among the glycohydrolases tested, castanospermine was most effective against sucrase with an IC_{50} of 1.1×10^{-7} M. In-vitro, a significant effect was observed at concentrations <1 mg/kg in both normal and streptozotocin-treated rats. Castanospermine had a protracted duration of activity in-vivo with significant activity when administered 4 h before sucrose. Castanospermine at 150 μmol/kg injected intra-peritoneally into streptozotocin (STZ)-diabetic mice streptozotocin (STZ)-diabetic mice was found to lower blood glucose level in mice (Nojima et al. 1998).

Antitumour Activity

Castanospermine, an indolizidine alkaloid isolated from the seeds of the chestnut tree *Castanospermum australe*, was shown to prevent the normal glycosylational processing of the v-fms-transforming glycoprotein (Nichols et al. 1987). v-fms-transformed cells grown in -vitro in the presence of castanospermine accumulated immature forms of the glycoprotein that did not reach the cell surface. These treated cells reverted to the normal phenotype. In further studies using an in-vivo tumourigenicity model in nude mouse, castanospermine was found to be effective in retarding the growth of v-fms-transformed cells in-vivo, suggesting that this drug may offer an effective therapy against certain tumours, including some arising from activated proto-oncogenes that encoded glycoproteins such as growth factor receptors (Ostrander et al. 1988). Castanospermine was found to be a potent inhibitor of both glucosidase I and glucosidase II in leukemia lymphoma cell line, but glucosidase I appeared to be more sensitive (Palamarczyk and Elbein 1985).

Cholinergic Activity

Gilani et al. (1994) showed that the effect of crude saponins of *Castanospermum australe* (CA) in the dose range of 1–30 mg/kg produced a fall in blood pressure and heart rate in normotensive anesthetized rats. Pretreatment of animals with atropine (2 mg/kg) eliminated both hypotensive and bradycardiac effects of CA. In isolated guinea-pig atria, CA produced negative inotropic and chronotropic responses at 100–1,000 μg/ml. When tested on isolated guinea-pig ileum, it produced contractile responses similar to those of acetylcholine (ACh). All these responses of CA and ACh on cardiac and smooth muscle preparations were completely blocked by atropine (0.1 μg/ml). The results indicated that the crude saponins from *Castanospermum australe* mediated all their effects through a mechanism similar to that of acetylcholine.

Other Uses

Castanospermum australe is an ideal shade tree in parks, resorts and gardens, in addition it has a strong root system, which can be used to consolidate stream banks against erosion. It is valuable as a timber species. The wood is fine-grained and

takes a good polish; and is highly prized for cabinet work as well as used in construction and carving. The wood is also used for electrical switchboards because of high resistance to passage of electric current.

Comments

The tree is propagated by seeds.

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Cicer arietinum

Scientific Name

***Cicer arietinum* L.**

Synonyms

Cicer grossum Salisb., *Cicer kabulicum* Dixit, *Cicer physodes* Reichb., *Cicer rotundum* Jord. ex Alef., *Cicer sativum* Schkuhr., *Nochotta oleracea* S.G. Gmel.

Family

Fabaceae or Leguminosae, also placed in Papilionaceae

Common/English Names

Bengal Gram, Chickpea, Chickpea Bean, Egyptian Pea, Garbanzo Bean, Gram Pea

Vernacular Names

Arabic: Hummus, Hommos, Hhimmass, Hommos Malana;
Armenian: Sisér, Sisyr, Sisiér;
Brazil: Grão-De-Bico;
Burmese: Kalabèh;
Chinese: Ying Zui Dou, Ji Dou, Ji Tou Dou, Hui Hui Dou;
Czech: Cizrna Beraní;
Danish: Kikært, Kikerært;
Dutch: Sissererwten;
Eastonian: Harilik Kikerhernes;
Finnish: Kahviherne;
French: Cicer Tête-De-Bélier, Cicérole, Gairance, Pois Chiche;
German: Echte Kicher, Kichererbse, Kichererbsen;
Greek: Revithi, Revithia;
Hungarian: Bagolyborsó, Csicseri Borsó;
India: Butmah (Assamese), Butakala, Chanaabatulaa, Chanabartula, Chhola, Chotobata, Chotobut (Bengal), Chanaa, Chaniaa (Gujarati), Chan, Channaa Daal, Chanaa, Chana (Hindu), Kadale, Kaalu, Kariikadale (Kannada), Harbharaa (Marathi), Buta (Oriya), Chanaa, Chole (Punjabi), Chanaka, Harimantha, Salealpriya, Vajimantha (Sanskrit), Kadalaii, Kadalai, Konda Kadalai, Kothukadalai (Tamil), Harimandhakama, Harimandhakama, Sanagalu, Shanaga (Telugu);
Indonesia: Kacang Arab, Kacang Kuda;
Italian: Cece, Pisello Cece, Pisello Cornuto;
Japanese: Hiyoko Mame, Hiyoko Mame;
Korean: I Chip T'eu Kong, Ee Chip T'eu Kong, May Bu Ri Kong;
Malaysia: Kacang Arab, Kacang Kuda;
Nepalese: Canaa, Cana;
Norwegian: Bukkeert;
Pakistan: Chana;
Philippines: Garbanzo Bean;
Polish: Ciecierzyca Pospolita;
Portuguese: Grão De Bico, Grão Gravanço, Ervanço;

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Russian: Nut Baranii, Turetskii Gorokh;
Slovašcina: Čičerika Navadna, Navadna Čičerika;
Slovenian: Cícer Baraní;
Spanish: Garbanzo;
Sri Lanka: Kondi, Kodala (Sinhalese);
Swedish: Kaffeärt, Kikärt, Kikärtor;
Thai: Thua Hua Chaang;
Turkish: Nochut, Nohud.

Origin/Distribution

Cicer arietinum was possibly derived from *Cicer reticulatum* Ladizinsky in neolithic southeast Anatolia (Turkey) (Smartt 1990; Mabberley 1997). It is cultivated extensively in Pakistan, India, Ethiopia, Turkey and Mexico. Chickpeas are also grown in the Mediterranean, western Asia, the Indian subcontinent and Australia.

Agroecology

Chickpea is long day cool season crop that grows in on a sunny site in a cool, dry climate. It is found in semiarid areas on well-drained soil with residual water and pH 5–8.6. It grows on many soils, from sandy to sandy loams and black cotton soils. It has an optimum temperature range of 18–26°C day temperatures and 21–29°C night temperatures and annual rainfall of 600–1,000 mm. The crop is relatively drought tolerant. Frost, hailstones, and excessive rains damage the crop.

Edible Plant Parts and Uses

Chick pea is mainly consumed as a dry pulse. The fresh or dried seed is cooked in soups, stews, curries, porridge and eaten cold in salads. Chick peas and Bengal grams are used to make curries and are one of the most popular vegetarian foods in India, Pakistan, Bangladesh and the UK and Malaysia. Parched seeds can be eaten as a snack. The seeds can also be ground into a flour called gram flour and used with cereal flours for making bread, cakes, cookies, biscuits, chips etc. There are many nutritious and delectable Indian dishes made with chickpea flour. *Pokkodam* is a savoury made from rice flour and chickpea flour. It is often made during *Diwali* festival and also a best tea time snack. *Muruku,* an extruded, deep-fried, curried rice-chickpea cracker is made from rice and chickpea flour. Another *muruku* recipe uses sorghum and chickpea flour. *Mirchi Bajji* is an Indian street food made with chickpea flour and is popular during the monsoon season served with coconut chutney and also serves as snacks during tea times. Another variant is stuffed chilli *bajji* more popularly known as *mirapakaya bajji* in Telugu. Gluten free chickpea chips are made from rice flour, chickpea flour, pea flour, soy mixed spices and canola oil. Chips made from fermented chickpea flour contained significantly higher amounts of limiting amino acids than products prepared from non-fermented samples. Fermented chickpeas were found to have significantly higher relative nutritive value, limiting amino acids and decrease antinutritional factors such as raffinose and trypsin inhibitor (Zamora and fields 1979). Fermented (*tempeh*) chickpea flour showed higher particle size index, gelatinization temperature, dispersibility and resistant starch content, and lower gelatinization enthalpy and water solubility than unfermented flour (Angulo-Bejarano et al. 2008). Solid state fermentation (SSF) increased the content of the essential amino acids, total sulphur (methionine + cystine), total aromatic (phenyalanine + tyrosine), and threonine but decreased tryptophan content. SSF improved the *in vitro* and true protein digestibility (72.2–83.2% and 83.7–88.8%, respectively), protein efficiency ratio (PER, 1.59–2.31), cPER (1.54–2.21), and corrected protein digestibility (0.73–0.89). Chickpea *tempeh* flour may be considered for the fortification of widely consumed legume-based food products.

In Myanmar, chickpea flour is used to make "Burmese tofu" which is popular among the Shan people. Chickpea flour is used as a batter to coat various vegetables and meats before frying, such as with *panelle*, a chickpea fritter from Sicily. Chickpea flour is also used to make the Mediterranean flatbread *socca*. The ground

chickpea seed meal can be shaped into balls and fried as *falafel*, stirred into a batter and baked to make *farinata*, cooked and ground into a paste called *hummus* or roasted, spiced and eaten as a snack (such as *leblebi)* or fermented to make an alcoholic drink similar to sake. Chickpea flour can be used in sausages. English-type fresh skinless pork sausages in which 30% of the protein was replaced by unheated chickpea flour or by chickpea flour heated at 80°C for 1 h were found to have better microbiological quality than incorporation of unheated chickpea flour (Verma et al. 1987).

The roasted seed is a coffee substitute. The sprouts from matured seeds are eaten raw as vegetables. Young shoots, leaves and young seed pods are also eaten as vegetables. The green pods are shelled for the peas and eaten as snack or vegetable. In India, as well as in the Levant, unripe chickpeas are often picked out of the pod and eaten as a raw snack and the leaves are eaten as a green vegetable in salads. In the Philippines garbanzo beans preserved in syrup are eaten as sweets and in desserts such as *halo-halo*. Ashkenazi Jews traditionally serve whole chickpeas at a *Shalom Zachar* celebration for baby boys. In Uzbekistan, chick pea is used as an ingredient of "*pulof*".

Recent studies in Western Canada showed chickpea flour to be a potential source of high protein flour for use as an extender in emulsified meat products such as low fat pork bologna due to its superior technological functionality and minimal effects on flavour (Sanjeewa et al. 2010). Inclusion of chickpea flour improved the product's instrumental and sensory texture properties. Bologna with added Kabuli and Desi chickpea flour performed similar to the control (no added binder) for most flavour properties. Separate studies showed that chickpea-fortified spaghetti may be suited to uses such as fresh pasta, in soups, canning, and microwave re-heating (Wood 2009). Chickpea-fortified spaghetti was found to be acceptable to consumers, had reasonable pasta quality, including lower cooking loss and less stickiness than the control spaghetti and retained firmness better than durum semolina after refrigeration.

Botany

An erect, branched annual herb, up to 1 m tall with strongly nodulated deep roots. Stem is glandular and pubescent. Leaf is alternate, imparipinnately compound, with 11–17 dentate leaflets and leaf-like, 2–5-fid stipules. Leaflets are ovate to elliptic, 7–19 mm long, 4–10 mm broad, acute, mucronulate, glandular pubescent (Plates 1 and 2). Flowers in 1–2-flowered racemes, papilionaceous, pedicel 5–10 mm long, bracts 2–3 mm long. Calyx campanulate, deeply toothed, pubescent, 7–9 mm long. Corolla white, pink to purple. Vexillum 10–22 mm long. Fruit an inflated rhomboid-ellipsoid, pendulous, pubescent pod (Plates 1 and 2), 14–30 mm by 8–20 mm with

Plate 1 Chickpea pods and foliage (Peter White)

Plate 2 Close-up chickpea pod and dentate leaflets (Peter White)

1–4 seeds. Seeds are angular obovoid with a prominent beak, creamy to dark brown, surface smooth or wrinkled (Plates 3–5).

Plate 3 Kabuli chickpeas

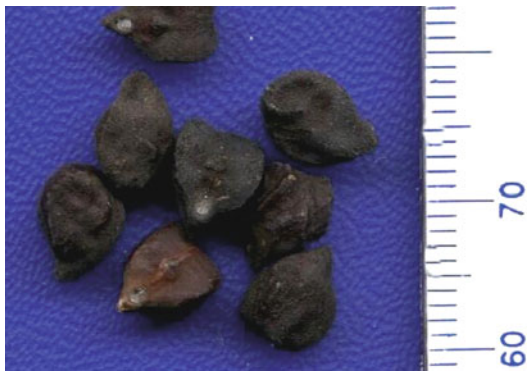

Plate 4 Desi chickpea cv black sona (Peter White)

Plate 5 Desi chickpea cv spotted sona (Peter White)

Nutritive/Medicinal Properties

Analyses carried out in the United States (USDA 2010) showed raw, mature chickpea seeds to have the following proximate composition (per 100 g edible portion): water 11.53 g, energy 364 kcal (1,525 kJ), protein 19.30 g, total lipid 6.04, ash 2.48 g, carbohydrates 60.659 g, total dietary fibre 17.4 g, total sugars 10.70 g, Ca 105 mg, Fe 6.24 mg, Mg 115 mg, P 366 mg, K 875 mg, Na 24 mg, Zn 3.43 mg, Cu 0.847 mg, Mn 2.204 mg, Se 8.2 μg, vitamin C 4 mg, thiamine 0.477 mg, riboflavin 0.212 mg, niacin 1.541 mg, pantothenic acid 1.588 mg, vitamin B-6 0.535 mg, total folate 557 μg, choline 95.2 mg, β-carotene 40 μg, vitamin A 67 IU, vitamin E (α-tocopherol) 0.82 mg, vitamin K (phylloquinone) 9 μg, total saturated fatty acids 0.626 g, total monounsaturated fatty acids 1.358 g, total polyunsaturated fatty acids 2.694 g, phytosterols 35 mg, tryptophan 0.185 g, threonine 0.716 g, isoleucine 0.828 g, leucine 1.374 g, lysine 1.291 g, methionine 0.253 g, cystine 0.259 g, phenylalanine 1.034 g, tyrosine 0.479 g, valine 0.809 g, arginine 1.819 g, histidine 0.531 g, alanine 0.828 g, aspartic acid 2.270 g, glutamic acid 3.375 g, glycine 0.803 g, proline 0.797 g and serine 0.973 g.

The seed is a good source of carbohydrates, dietary fibre, protein, niacin, folate and minerals like Ca, Fe, Mg, K, P, Zn and Cu. It also has vitamin A and β-carotene.

The kabuli chickpea cultivar was found to have larger seed (26 g/100 seeds) than desi type (21 g/100 seeds) (Khan et al. 1995). The hydration capacity per seed of desi (0.16 g) was lower than kabuli type (0.26 g). A positive correlation ($r = 0.87$) between seed weight and hydration capacity was observed. The mean cooking time of dry desi versus kabuli seed (124.5 versus 113.8 min) was reduced to 37.5 versus 32.8 min and to 28.8 versus 22.5 min when soaked overnight in water and in 0.5% solution of sodium bicarbonate respectively. The mean value of protein (25.4 versus 24.4%), fat (3.7 versus 5.1%), carbohydrate (47.4 versus 55%), crude fibre (11.2 versus 3.9%), ash (3.2 versus 2.8%)

and caloric value (327 versus 365 kcal/100 g) were for desi versus kabuli chickpeas respectively. There was no difference in the essential amino acid contents and in chemical scores of desi (65) and kabuli (67) chickpeas. The order of limiting amino acid was methionine + cystine, threonine and valine in both types. The chickpeas products contained 8.9–21.1% protein (N × 6.25), 3.1–21.8% fat, 53.4–75.9% carbohydrate, 1.6–11.1% crude fibre, 1.2–5.9% ash, 226–360 mg Ca, 126–315 mg P, 3.8–8.2 mg Fe, 1.8–5.4 mg Zn, 1.5–5.4 mg Mn, 0.6–1.1 mg Cu and 370–490 kcal per 100 g. All chickpea products provided 7–23%, 7–40% and 52–78% of the total calories from protein, fat and carbohydrates respectively.

The protein content of 6 chickpea strains were found to range from 20.9% to 25.27% (Dhawan et al. 1991). Albumin, globulin, prolamin and glutelin contents ranged from 8.39–12.31%; 53.44–60.29%; 3.12–6.89% and 19.38–24.40% respectively. Amino acid analysis of total proteins revealed that glutamic acid was present in maximum concentration followed by aspartic acid and arginine. Just like other pulse proteins, chick pea proteins were also found deficient in sulphur containing amino acids.

The chickpea cultivars Desi and Kabuli were found to vary significantly in their physical properties such as seed colour, size, 100-seed weight and 100-seed volume (Ravi and Harte 2009). Between the dry and wet milling, a higher yield (2–4%) of dhal was obtained from wet milling. Between the cultivars, Desi was found to be the higher dhal-yielding cultivar in both dry and wet milling methods. Fat, ash and protein contents were found to be higher in Kabuli than in Desi and the values were respectively 5.3%, 3.5% and 24.9% for Kabuli and 4.3%, 2.2% and 22.6% for Desi. The gel electrophoresis pattern of chickpea showed as many as 15 protein bands in flours from both the cultivars.

Wang et al. (2010) showed that the amino acids score of protein isolates from kabuli chickpea, desi chickpea and soybean could reach the FAO/WHO requirement for the essential amino acids for preschool children. The order of in-vitro digestibility was Kabuli (87.47%)>desi (80.82%)> soybean (71.04%). Their results indicated that, compared with soybean protein isolate, Chinese kabuli and desi chickpea protein isolates had higher digestibility value. Thus, chickpea protein, especially for kabuli protein, could be utilized as a good source of protein for human nutrition.

Studies by Xiang et al. (2008) found that the main α-galactooligosaccharides (α-GOS) in chickpea seeds were raffinose, stachyose, verbascose and an unknown glycoside, which was isolated, purified, and identified as ciceritol. Ciceritol, the main sugar in all the chickpea samples, accounted for about 50% of the total α-GOS. There were considerable variations in the levels of α-GOS and sucrose between cultivars, especially verbascose which could only be detected in 7 samples. With the highest amount of α-GOS and a low amount of sucrose, the cultivar 171 was the best choice for obtaining α-GOS for use as a prebiotic in functional foods.

Other Phytochemicals

Nine compounds were isolated and identified from dried and sprouted seeds of *C. arietinum*: 3-hydroxy-olean-12-ene (1), biochanin A-7-O-β-D-glucoside (2), cerebroside (3), 1-ethyl-α-L-galactoside (4), uridine (5), adenosine (6), trytophan (7), biochanin A (8), fomononetin (9) (Tan et al. 2007).

Both the total polyphenol content (TPC), total flavonoid content (TFC), were found to vary significantly among lines having coloured seed coats (black, red, brown, green, rubiginous, gray, yellow, cream, or beige) and were highly correlated to antioxidant activity (Segev et al. 2010). The seed coat was found to contain more than 95% of these compounds. Colored seeds contained up to 13-, 11-, and 31-fold more TPC, TFC, and antioxidant activity, respectively, than cream- and beige-colour seeds. Thus, coloured chickpea could be a potentially functional food in addition to its traditional role of providing dietary proteins and dietary fibres.

Two types of protein isolates A and B were prepared from ground chickpea seeds (Sánchez-Vioque et al. 1999). The percentage of protein recovered from chickpea flour in the preparation

of Isolates-A and B were 65.9% and 62.1%, respectively. Isolates-A and B contained 78% and 88.1% of protein, respectively, and had a balanced content of essential amino acids, with respect to the FAO pattern. The in-vitro protein digestibility ranged between 95.6% and 96.1%.

Ripening resulted in marked increase in the content of triglycerides, phosphatidyl choline and phosphatidyl ethanolamine as major components of chickpea lipids (Attia et al. 1996). Also, there was a marked rise in lipase and lipoxygenase activities with slight alterations in fatty acid composition of chickpea lipids. Minor changes in lipid composition were noticed owing to the decortication process applied to the two tested chickpea cultivars (Giza 1 and 2). Cooking and parching caused only small changes in lipid classes and fatty acids composition, but yielded a significant increase in peroxide value of chickpea lipids. There was a marked fall in lipoxygenase activity with complete inhibition of lipase activity due to cooking and parching.

Seven isoflavones were isolated from sprouted chickpea seeds: biochanin A (5,7-dihydroxyflavone-4′-methoxyflavone; calycosin (7,3′-dihydroxy-4′methoxyisoflavone; formononetin (7-hydroxy-4′-meth-oxyisoflavone; genistein (5,7,4′-trihydroxyisoflavone; trifolirhizin (maackiain-3-O-β-d-glucopyranoside; ononin (7-O-β-d-glucosyl-7-hydroxy-4′-methoxyisoflavone; and sissotrin (7-O-β-d-glucosyl-5,7-dihydroxy-4′-methoxyisoflavone (Zhao et al. 2009). Studies showed that four main isoflavones in chickpea seeds, i.e., isoflavones, formononetin, biochanin A, ononin, and biochanin A-7-O-β-D-glucoside, were substantially increased by biosynthesis during seed germination (Lv et al. 2009). The results showed that 14.2 mg of formononetin, 15.7 mg of biochanin A, 9.1 mg of ononin, 11.3 mg of biochanin A-7-O-β-D-glucoside were obtained from 150 mg of sprout extracts with the purity of 92.26%, 95.86%, 95.32%, and 96.56%, respectively.

Chana seedlings (*Cicer arietinum*) were found to contain the known compounds isoliquiritigenin, isoliquiritigenin-4′-glucoside, 4′,7-dihydroxyflavonol, daidzein, pratensein, and p-coumaric acid; and the hitherto unreported 4′,7-dihydroxyflavanon-3-ol (garbanzol) and biochanin-7-glucoside (Wong et al. 1965). Garbanzol was metabolized by chana seedlings as shown by its conversion into garbanzol-7-glucoside and 4′,7-dihydroxyflavonol. Changes in the content of free polyamines: putrescine, spermidine, spermine and cadaverine in the cotyledons and embryonic axis of *Cicer arietinum* during the first 24 h of germination were observed (Gallardo et al. 1992). A new dihydroxyflavanol, 2′, 4′-dihydroxy-6, 7-methlenedioxyflavanol, along with four known compounds, β-amyrin, β-sitosterol, methyl-tetracosanoate and stigmasterol were identified from chickpea seeds (Wu et al. 2010).

Cicer arietinum leaves and stems were found to contain the flavonol pigments: kaempferol 3-(malonylglucoside) and kaempferol 3-(apiosylmalonylglucoside) (Börger and Barz 1988). Two coumestanes which were present in small amounts in the roots of *Cicer arietinum* were identified as medicagol and 12-*O*-methylcoumestrol (Zilg and Grisebach 1969).

Chickpea Flour and Functional Food

Polar lipid composition of defatted chickpea flour and protein isolates was predominated by phosphatidylcholine, phosphatidylinositol and phosphatidylethanolamine (Sánchez-Vioque et al. 1998). Other compounds, in lower concentrations, were sterol glucosides, esterified sterol glucosides and digalactosyldiglycerides. Palmitic, oleic and linoleic acid were the major fatty acids in polar lipids. A reduction in the content of phosphatidylinositol and sterol glucosides in the protein isolates with respect to the defatted flour was observed, indicating that these compounds were more sensitive to the chemical treatment of the protein isolates. However, unsaturated fatty acids and unsaturated sterols content decreased in the protein isolates probably undergoing oxidative degradation.

Milán-Carrillo et al. (2000), compared four types of chickpea flours: fresh chickpea conventional flour; hardened chickpea conventional flour; fresh chickpea extruded flour; and hardened chickpea extruded flour. Extruded flours exhibited

higher values of total colour difference (24.0–28.7 versus 19.0–20.8), water absorption index (2.32–3.27 versus 2.12–2.15 g gel/g dry sample) and dispersibility (35.1–63.7 versus 25.2–26.0%) and lower Hunter 'L' value (86.5–87.4 versus 89.4–90.5), particle size index (61.5–67.4 versus 72.4–73.8%) and water solubility index (20.1–26.1 versus 27.5–30.8 g solids/g original solids) than conventional flours. The dehulling/softening/extrusion process ameliorated significantly in-vitro protein digestibility (9.3–21.7%), apparent digestibility (6.5–6.6%), true digestibility (5.8–7.5%), protein efficiency ratio (27.2–36.9%) and net protein ratio (5.2–14.0%) of chickpea flours.

The protein quality of chick pea flours as measured by protein efficiency ratio (PER), biological value (BV), true digestibility (TD), net protein utilization (NPU), essential amino acid composition, in-vitro protein digestibility (IVPD) and corrected amino acid indices (actual amino acid indices×IVPD) was significantly improved by germination, extraction and α-amylase treatments (Mansour 1996). The protein quality of germinated-α-amylase treatment was comparable with casein, while germinated-α-amylase treaded seeds appeared nutritionally superior to casein. The results indicated that the germinated-α-amylase and germinated-α-amylase-extracted treatments could be used successfully as a source of concentrated high quality protein for baby food production.

Cooked and dehydrated legume flours from chickpea and lentil could be considered as functional ingredients for food formulation (Aguilera et al. 2009). As a result of cooking, available starch contents of soaked chickpea and lentil were significantly increased (21% and 12%, respectively) and resistant starch decreased (65% and 49%, respectively) compared to raw flours. A similar trend was exhibited by dehydration, being more notable in lentil (73% of resistant starch decrease). The raw legume flours exhibited low oil-holding capacities, 0.95–1.10 ml/g, and did not show any change by thermal processing, whereas water-holding capacities rose to 4.80–4.90 ml/g of sample. Emulsifying activity and foam capacity exhibited reductions as a result of cooking and industrial dehydration processing.

Chung et al. (2008) investigated the *in-vitro* starch digestibility, expected glycemic index (eGI), and thermal and pasting properties of flours from pea, lentil and chickpea grown in Canada under identical environmental conditions. The protein content and gelatinization transition temperatures of lentil flour were higher than those of pea and chickpea flours. Chickpea flour showed a lower amylose content (10.8–13.5%) but higher free lipid content (6.5–7.1%) and amylose–lipid complex melting enthalpy (0.7–0.8 J/g). Significant differences among cultivars within the same species were observed with respect to swelling power, gelatinization properties, pasting properties and in-vitro starch digestibility, especially chickpea flour from desi and kabuli type cultivars. Lentil flour was hydrolyzed more slowly and to a lesser extent than pea and chickpea flours. The amount of slowly digestible starch (SDS) in chickpea flour was the highest among the pulse flours, but the resistant starch (RS) content was the lowest. The expected GI of lentil flour was the lowest among the pulse flours.

Chickpea contain many bioactive compounds which impart various pharmacological activities which are presented below.

Antioxidant Activity

A pectin (CAP) from the husk of *Cicer arietinum* was found to have a dominance of galacturonic acid and smaller amounts of galactose, arabinose, rhamnose, glucose, xylose and mannose (Urias-Orona et al. 2010). CAP exhibited a dose-dependent free radical scavenging activity, as shown by its DPPH radical inhibition. At 1.0 mg/ml CAP exhibited a scavenging rate of 29% on DPPH radicals. The evaluation of antioxidant activity suggested that CAP had good potential for DPPH radical scavenging activity and should be explored as a novel potential antioxidant.

Hypocholesterolemic Activity

The two isoflavones, biochanin A and formononetin from *C. arietinum* were found to be estrogenic

and also showed hypolipidemic activity in Triton WR-1339 induced hyperlipidemia in male albino rats (Siddiqui and Siddiqi 1976). Bengal gram was found to reduce the elevated serum cholesterol and free esterified cholesterol content of α- and β-lipoproteins of rats fed hypercholesterolemia inducing diets. Among isoflavones, biochanin A and formononetin from Bengal gram showed hypolipidemic activity in hypercholesterolemic rats but diadzein did not; p-coumaric acid also produced a significant reduction in serum cholesterol levels (Sharma 1979).

Among common legumes chickpea was found to be the most hypocholesterolemic, followed by black gram and green gram (Soni et al. 1982). Germinated chickpea was effective in reducing cholesterol levels in rats (Jaya et al. 1979), and roasted chickpea diets had a beneficial effect both on triglyceride and cholesterol levels in rats (Chandrasekhar et al. 1983). Gopalan et al. (1991) demonstrated that rabbits fed with 40 g soaked Bengal gram and those fed with 50 mg of biochanin A fortnightly showed a significant decrease of their lipids and lipoprotein in comparison to rabbits fed on egg yolk supplement thereby indicating the lipodiatic effect of these two substances. However, HDL cholesterol showed an increase in these two groups thereby confirming that an increased HDL cholesterol had a protective effect on the atherosclerotic process.

Zulet and Martínez (1995) showed that rats fed on a hypercholesterolemic diet containing saturated fat, cholesterol and cholic acid (H) had 123% higher serum cholesterol and 62% higher triacylglycerols concentrations than the animals receiving casein (C) protein. The LDL and VLDL cholesterol levels were 1,330% and 35% higher, respectively, and HDL cholesterol 34% lower in the group of animals administered the H diet as compared to controls. Further feeding of the hypercholesterolemic rats with animal protein (HC) resulted in a significant decrease of triacylglycerols (−70%), which reflected the decrease in the VLDL component. These effects on the lipid metabolism were more significant when the legume *Cicer aretinum* was present in the diet (HL). Rats fed chickpeas had significantly reduced concentrations of total cholesterol (−54%) and triacylglycerols (−70%) as well as the levels of LDL (−54%) and VLDL (−70%). In conclusion, a differential hypocholesterolemic effect between dietary casein and chickpea intake was found in a model of hypercholesterolemia induced by the diet. Chickpea inclusion in the diet was found to have beneficial effects on the lipid metabolism as compared to casein. This suggested that chickpea consumption may have a remedial effect in some changes of the lipid profile.

Antiobesity/Antidiabetic Activity

Dietary chickpeas was found to reverse visceral adiposity, dyslipidaemia and insulin resistance in rats induced by a chronic high-fat diet (Yang et al. 2007). The epididymal fat pad weight versus total body weight of rats was higher in the HFD (High fat diet) group than in the NFD (normal fat diet) group and lower in the HFD + CP (high fat diet + chick pea) group. Chickpea treatment also evoked a favourable plasma lipid profile reflecting decreased TAG (triacylglyceride), LDL-cholesterol (LDL-C) and LDL-C:HDL-cholesterol levels. HFD-fed rats had higher TAG concentration in muscle and liver, whereas the addition of chickpeas to the HFD markedly decreased TAG concentration (muscle, 39%; liver, 23%). The activities of lipoprotein lipase (LPL) in epididymal adipose tissue and hepatic TAG lipase in liver recorded a 40% and 23% rise respectively in HFD rats compared with those in NFD rats; dietary chickpeas completely normalised the levels. In addition, chickpea-treated obese rats also exhibited distinctly lower leptin and LPL mRNA concentration in epididymal adipose tissue. An insulin tolerance test, oral glucose tolerance test and insulin-releasing test showed that chickpeas significantly improved insulin resistance, and inhibited postprandial hyperglycaemia and hyperinsulinaemia induced by the chronic HFD. The present findings provided a rational basis for the consumption of chickpeas as a functional food ingredient, which may be beneficial for rectifying dyslipidaemia and preventing diabetes.

Hypoglycaemic Activity

Studies in six healthy subjects showed that Bengal gram dal (*Cicer arietinum*) and rajmah (*Phaseolus vulgaris*), were found to be more effective in lowering postprandial plasma glucose levels than wheat and rice as evidenced by the plasma glucose values obtained after taking 50 g dextrose (Dilawari et al. 1981). Further, the mean peak rise in plasma glucose was decreased by 82.1% with Bengal gram dal, 67% with rajmah, while wheat and rice showed reduction by only 25% and 16%, respectively.

The blood glucose response to all legumes, chick pea (*Cicer arietinum*), pigeon pea (*Cajanus cajan*), black bean (*Phaseolus vulgaris*), mung bean (*Phaseolus areus*) and white bean (*Phaseolus vulgaris*) was significantly lower compared to bread (wheat) (Panlasigui et al. 1995). The glycaemic response to chick pea was significantly lower than that to black bean, pigeon pea and mung bean. The glycaemic index of chick pea (13.87) was significantly lower than those of black bean (27.91), pigeon pea (30.99) and mung bean (44.38) (but was not different from that of white bean (19.48). The differences in the glycaemic responses among the legumes could be due to the differences in amount and kind of dietary fibre, amylose content and the presence of antinutrients. Legumes could therefore be added to the list of foods for diabetics and hyperlipidaemics and continuous consumption in larger amounts should be recommended.

Vanadium compounds have been recognized for their hypoglycemic effects; however, potential short and long-term vanadium toxicity has retarded the acceptance for therapeutic use (Mao et al. 2008). Studies showed that administration of chickpea sprout (CS) and of vanadium-enriched chickpea sprout (VCS) food on streptozotocin-induced (STZ) diabetic rats was found to ameliorate some hyperglycemic symptoms of the diabetic rats. Lipid metabolism was improved, blood glucose level decreased, body weight loss prevented, and impairment of diabetic related spatial learning and memory ameliorated. Compared with CS alone, VCS 100 (VCS + 100 ug sodium orthovanadate) food exhibited remarkably enhanced effectiveness in alleviating diabetes induced hyperglycemia and memory loss. Moreover, vanadium-enriched chickpeas appeared to abolish the vanadium induced toxicity associated with administration of this metal for diabetes. The results indicated that Vanadium containing (VCS) food could be a dietary supplement to improve diabetic status.

Antimicrobial Activity

Two antifungal peptides with novel N-terminal sequences, designated cicerin and arietin were isolated from seeds of the chickpea (Ye et al. 2002). The peptides exhibited a molecular weight of approximately 8.2 and 5.6 kDa, respectively. Arietin was more strongly adsorbed on CM-Sepharose than cicerin and manifested a higher translation-inhibiting activity in a rabbit reticulocyte lysate system. It exhibited a higher antifungal potency toward *Mycosphaerella arachidicola*, *Fusarium oxysporum* and *Botrytis cinerea*. Both were devoid of mitogenic and anti-HIV-1 reverse transcriptase activities.

Anticancer Activity

Chickpea protein hydrolysates with a high degree of hydrolysis inhibited the growth of Caco-2 cells (human colorectal carcinoma cells) by up to 45%, suggesting that chickpea-derived peptides may inhibit the growth of tumours in the colon (Girón-Calle et al. 2010). Proliferation of THP-1 cells (Human acute monocytic leukemia cells) was inhibited by up to 78% by direct exposure to the hydrolysates. However, bioavailability experiments using differentiated Caco-2 cells as a model of the intestinal barrier, in co-culture with THP-1 cells, showed that proliferation of the monocytic THP-1 cells was actually enhanced by up to 66%, which could represent an immunomodulatory activity.

Antinutritional Factors

Kunitz trypsin inhibitors have been found in chickpea during seed germination and seedling growth (Jimenez et al. 2007; Hernandez-Nistal et al. 2009). A new trisaccharide was isolated from an aqueous ethanolic extract of chick pea (*Cicer arietinum*) cotyledons (Quemener and Brillouet 1983). The new trisaccharide is an α-d-digalactoside of pinitol and is *O*-α-d-galactopyranosyl-(1–6)-*O*-α-d-galactopyranosyl-(1–2)-1d-4-*O*-methyl-*chiro*-inositol. As originating mainly from chickpea the name ciceritol was proposed. The seeds of seven commercially important legumes were analysed by HPLC and GC for cyclitols, cyclitol-derived oligosaccharides and sucrose α-d-galactosides. Ciceritol was detected in chickpea (2.80% per dehulled seed), lentil (1.60%), white lupin (0.65%), soya bean (0.08%) and bean (traces). The contribution of ciceritol and other α-d-galactosides to flatus was discussed on the basis of α-d-galactosidase sensitivity.

Soaking, boiling, roasting and frying of Bengal grams resulted in loss of phytic acid (Khan et al. 1988). Loss of phytic acid in pre-soaked grams increased with resting time. Immature brown grams contained much less phytic acid than dried mature brown grams but the loss of phytic acid on boiling and roasting was greater in the former than the latter. Soaking of white grams in sodium bicarbonate solution reduced the loss of phytic acid on soaking and heat treatments. The chemical composition and nutrient value of whole dry seeds of two chickpea cultivars were studied before and after cooking and before and after decortications (Attia et al. 1994). Differences between cultivars were less pronounced than those due to cultivation in different agroclimatic regions. Decortication caused considerable losses in dietary fibre components, Ca, Zn, Mg, K, polyphenols and ash contents. Significant increases in reducing sugars, crude protein, ether extract and starch contents and in-vitro protein digestibility were noticed. Decortication made no significant changes in phytic acid content or trypsin inhibitor activity. Significant and marked losses in ash (34–40%), sugar (32–42%), oligosaccharide (30–34%), mineral and anti-nutritional factor contents occurred upon cooking the seeds. Losses in minerals varied from 6.3 to 50.6 depending upon the element, the cultivar and the growing region. Percentage losses in phytic acid, polyphenols and trypsin inhibitor activity were in the ranges 24–34.5%, 58.7–62.2% and 53.6–59.9%, respectively. However, significant increases in dietary fibre components (8–20%) and in-vitro protein digestibility (10%) were observed.

Heat treatment of chickpea produced a decrease of methionine, cysteine, lysine, arginine, tyrosine and leucine, the highest reductions being in cysteine (15%) and lysine (13.2%) (Clemente et al. 1998). Protein content declined by 3.4% and in-vitro protein digestibility improved significantly from 71.8% to 83.5% after cooking. The decrease of lysine was higher in the cooked chickpea seeds than in the heated protein fractions, globulins and albumins. The structural modification in globulins during heat treatment seems to be the reason for the increase in protein digestibility, although the activity of proteolytic inhibitors in the albumin fraction was not reduced. Results suggest that appropriate heat treatment may improve the bioavailability of chickpea proteins.

Soaking of chickpeas produced losses of 0–18% thiamin, 0–4% riboflavin and 0–46% available niacin (Prodanov et al. 2004). In general, vitamin losses were greater when soaking was carried out in alkaline solution. In most of the studied legumes, cooking produced further decreases in vitamins. Cooking produced a loss of up to 51% thiamin, 66% riboflavin and 78% available niacin in chickpeas.

Traditional Medicinal Uses

Traditional medicinal applications of chickpea include uses for bronchitis, catarrh, catamenia, cholera, constipation, diarrhoea, dyspepsia, flatulence, snakebite, sunstroke, warts and as an aphrodisiac. An acid exudation from the seed pods is astringent and has been used in the treatment of dyspepsia, constipation and snakebite. Glandular secretion of the leaves, stems, and pods has been reported to have of malic and oxalic acids, giving a sour taste. These acids are believed to lower the

blood cholesterol levels. Seeds are considered antibilious. Chickpea has also been reported useful in leprosy and other skin diseases. The powdered seed is used for dandruff and also used as a face pack.

Other Uses

Chickpea is also used in baby shampoo, protein shampoo for normal hair, protein shampoo for dry/damaged hair, protein shampoo for oily/greasy hair, and in revitalizing hair oil. Seed and seed husk has been used for feeding horses and poultry.

Comments

Two main kinds of chickpea have been recognized:

(a) Kabuli – with lighter coloured, larger seeds and a smoother coat; mainly cultivated in Southern Europe, Northern Africa, Afghanistan, Pakistan, Chile; also introduced during the eighteenth century to the Indian subcontinent (Plate 3).

(b) Desi – with smaller, darker seeds and a rough coat; grown mostly in the Indian subcontinent, Ethiopia, Mexico and Iran (Plates 4 and 5).

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Cynometra cauliflora

Scientific Name

***Cynometra cauliflora* L.**

Synonyms

Cynometra acutifolia S. Vidal, *Cynometra cauliflora* var. *elongatis* Hassk., *Cynometra cauliflora* var. *subsessilis* Hassk.

Family

Fabaceae or Leguminosae, also placed in Caesalpiniaceae

Common/English Name

Nam-Nam

Vernacular Names

Indonesia: Namu-Namu, Nam-Nam, Ka-Namu-Namu (Manado, Sulawesi), Lamuta, Ulias (Ambon), Nam-Na, (Java), Nam-Nam, Kapi Anjing, Pukih (Sundanese);
Malaysia: Katong-Katong (Sabah), Puki Anjing, Salah Nama, Buah Katak Puru, Nam Nam (Peninsular);
Sri Lanka: Nam-Nam (Sinhalese);
Thailand: Amphawa (Central), Nang-Ai (Bangkok), Hima (Pattani).

Origin/Distribution

The species is indigenous to eastern Peninsular Malaysia and is widely cultivated in northern Peninsular Malaysia in kampongs (villages), and house garden. It is also cultivated in India, Sri Lanka and Indonesia.

Agroecology

It grows well in wet tropical lowlands in full sun or partial shade. It thrives in areas with an annual rainfall of 1,500–2,000 mm and daily temperatures of 22–35°C, preferably with a dry period.

Edible Plant Parts and Uses

Young, unripe fruit is very acid, ripe fruit is sourish-sweet and savoury, eaten raw (fresh) or stewed as also for the unripe fruit. The ripe fruit can be eaten cooked with sugar to make sweets (compote). It can also be made into a fruit salad, pickled, or be used to prepare a special '*sambal*' (a condiment based on pounded chilli). The Javanese eat them as flavouring with curry or used the less mature fruit in *rujuk* (fruit salad with savoury peanut sauce). The fruit can be fried with batter and makes a good fritter.

T.K. Lim, *Edible Medicinal And Non-Medicinal Plants: Volume 2, Fruits*,
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Botany

A small, much-branched perennial tree growing to 5 m tall with rough, grey-brown and robust trunk (Plates 2–4). The leaves are borne on very short petiole and 1-jugate – consists of two asymmetrical, oblong to oblong-obovate leaflets, 5–15 cm long by 2.5–7.5 cm wide, with oblique base and emarginate apex and entire margin, glossy, when young whitish to pinkish turning green above and paler green beneath with age (Plate 1). Flowers are small occur in axillary racemes on the trunk, i.e. cauliflorous (Plates 2–4). Flowers have deeply 4-partite, white or pink calyx, 5 lanceolate white or pale pink petals, free filaments, ovary with one ovule and filiform style. Pod is oblique, kidney shaped, 5–10 cm long by 5 cm wide with rough, knobbly and wrinkled surface, greenish-brown turning to pale greenish-yellow or yellow and dull looking when ripe (Plates 2–6). The flesh is juicy and yellow in colour, sour when immature, sourish-sweet and soft when ripe. Seed one – large, 3.5–6.5 cm long.

Plate 1 Juvenile pinkish and mature green leaves of nam-nam

Plate 2 Cauliflorous tiny, white flowers and immature fruit

Plate 3 Cauliflorous tiny flowers and fruit at the base of the robust trunk

Plate 4 Close-up of cauliflorous flowers and fruit on the robust trunk

Plate 5 Ripe brownish–yellow nam-nam fruit

Plate 6 Nam nam fruit sold in the market in Kota Bahru, Kelantan

Nutritive/Medicinal Properties

The nutrient composition of the fruit contains per 100 g edible portion: water 85 g, protein 1.5 g, fat 0.06–1.28 g, carbohydrate 10 g, fibre 1.4 g, vitamin A 150–500 I.U. and vitamin C 25 mg (Saidin 2000).

The fruits are reported to have useful medicinal properties too and are used in folk medicinal preparation. In fact, at some places, nam-nam fruit is sold in the market for this purpose only. The fruit has been used to treat loss of appetite. The seeds yield oil which is used in India for the treatment of skin diseases.

Other Uses

The tree makes an attractive ornamental plant in home gardens and is also potted and grown as a bonsai plant. The wood is close-grained and hard.

Comments

Nam-nam is readily propagated by seeds rather than by various forms of grafting and budding.

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Delonix regia

Scientific Name

***Delonix regia* (Bojer ex. Hook.) Raf.**

Synonyms

Delonix regia Hook. var. *flavida, Delonix regia* Hook. var. *genuine Stehle, Poinciana regia* Bojer ex Hook.

Family

Fabaceae also placed in Leguminosae, Caesalpiniaceae

Common/English Names

False Acacia, Flambouyant, Flamboyant, Flametree, Flame-Of-The-Forest, Gold Mohur, Gul Mohr, Julu Tree, Malinche, Peacock-Flower, Poinciana, Red Tree, Royal Poinciana

Vernacular Names

Arabic: Zahr El Gannah, Goldmore;
Bangladesh: Krishnachura;
Brazil: Flamboiã (Portuguese);
Burmese: Seinban;
Carolinian: Fáyárbaw, Nfayarbaw;
Chamorro: Arbol Del Fuego, Arbol Del Fuego, Atbot, Atbot, Atbut;
Chinese: Guo Luo Mai Liang;
Chuukese: Meei Flower;
Cook Islands: Marumaru, Pātai, Pū Pī, Puka Kai, Rākau Tāmarumaru (Maori);
Costa Rica: Malinche;
Danish: Flamboyant Træ;
Dutch: Flamboyant;
Eastonian: Kuning-Leekpuu;
Ethiopia: Dire Dawa Zaf (Amrahic);
Fijian: Sekoula;
French: Flamboyante, Flamboyant, Pacayer, Poinciana;
German: Fammenßaum, Feuerbaum;
Guatemala: Llama Del Bosque;
Haitian: Pye Flanbwayan;
Hawaiian: ‘Ohai ‘Ula;
Honduras: Guacamaya;
Hungarian: Tűzvirágfa;
I-Kiribati: Te Kai Te Tua, Te Tau, Te Tua;
India: Krishnachura, Chura, Radha (Bengali), Gulmohar, Gulmohr, Kattikayi, Peddaturyl, Shima Sunkesula (Hindu), Kempu Torai (Kannada), Mayarum, Mayirkonrai, Panjadi, Poo-Vahai (Tamil), Gulmohar (Urdu);
Indonesia: Merak;
Madagascar: Alamboronala, Hintsakinsa, Hitsakitsana, Kitasakitsabe, Sarongadra, Tanahou, Tsiombivositra;
Malaysia: Semarkat Api;
Mauritania: Voulatzana;
Mexico: Malinche;

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Nauruan: Bin;
Niuean: Pinē;
Papiamento: Flamboyan;
Pakistan: Gul Mohar;
Palauan: Nangiosákura, Nangyo;
Philippines: Cabellero;
Pohnpeian: Pilampwoia Weitahta;
Polish: Wianowłostka, Wianowłostka Królewska;
Samoan: Elefane, Tamaligi;
Spanish: Árbol De Fuego, Atbot Det Fuegu, Flamboyant, Acacia Roja, Clavellino, Flamboyán, Flor De Pavo, Framboyán, Guacamaya, Josefina, Morazán, Poinciana, Tabachine;
Sri Lanka: Mal-Mara (Sinhala);
Swahili: Mjohoro, Mkakaya (East Africa, Democratic Republic Of Congo, South Somalia, Northern Mozambique);
Swedish: Flamboyant;
Tahitian: Pakai, Puke, Ra'Ar Marumaru;
Thailand: Hang Nok Yung Farang;
Tongan: 'Ohai, 'Ōhai Lahi;
Tongarevan: Pātai;
Tuamotuan: Faefae;
Turkish: Ateş Ağacı, Cennet A;
Tuvaluan: Fuatausaga;
Ulithian: Warapig;
Vietnamese: Phượng, Phượng Vĩ;
West Africa: Sekeseke (Yoruba);
Yapese: Sakuranirow.

Origin/Distribution

Poinciana is a native of Madagascar, occurring in seasonally dry areas but its wild population is endangered. It has been introduced and naturalised elsewhere in the tropics and near tropics. It is cultivated and naturalized in dry areas of the west coast of Dominica. Poinciana is widely cultivated and may be seen adorning avenues, parks and estates in cities in the Caribbean and throughout the tropical/subtropical regions worldwide.

Agroecology

Its natural habitat is in the hot and humid tropical rainforest of West Malagasy, Madagascar. The Royal Poinciana requires a tropical or near-tropical climate, It occurs in dry to mesic, disturbed sites, in margin of forest and roadsides from sea level to 2,000 m elevation with mean annual temperatures of 14–30°C and mean annual rainfall of 700–1,200 mm. In the Northern Territory, Australia, it has invaded coastal monsoon vine thickets that have been damaged by cyclones. It grows in full sun or partial shade. It is a hardy tree, and can tolerate drought, poor soils and salty conditions. It grows well in moist, well-drained soil derived from limestone and sandy soils but will also grow on clayey soils.

Edible Plant Parts and Uses

The seeds are eaten raw as a snack in Madagascar. In Thailand, the inner flesh of beans can be eaten raw after removal of the outer testa. The young pods are edible and have good potential as a dietary protein source for humans.

Botany

A spreading, medium to large-sized, unarmed tree reaching 15–20 m in height. It has a short trunk, grey and smooth bark and root-like buttresses. Its crown is broad and umbrella-shaped, consisting of fine, delicate, lacy, fern-like foliage (Plate 1). Leaves are bi-paripinnate compound, 15–60 cm. long, with 9–24 pairs of opposite pinnae, 2–10 cm long; pinnules 10–30 pairs per pinnae, small, elliptic to oblong, 5–10 mm long, 2–4 mm wide (Plates 2 and 3), opposite, at first pubescent,

Plate 1 Large, spreading, crown with lacy, fern-like foliage

Plate 2 Clusters of brilliant, scarlet flowers

Plate 3 Pendant old, legume pod, flowers and fern-like leaves

Plate 4 Mature pods and flowering shoots

especially on margins and mid-vein, lower surface paler; petiole 2–4 cm long and grooved; stipules lanceolate. Flowers brilliant scarlet, in short, axillary, corymbose racemes near branch-tips on 5–8 cm long pedicels (Plates 2–4). Calyx 5 sepals, 28–35 mm long, all sepals joined (being deeply lobed), thick, green outside and reddish with yellow border within, reflexed when the flowers open, pointed, finely hairy. Corolla – 5 petals, spoon-shaped, long clawed, more or less unequal, 4–7 cm long, scarlet, the uppermost petal (standard) streaked with yellow or yellow-and-white; petals stalked, their distal part abruptly expanded, orbicular, with wavy-crinkled edges. Stamens 10 (curved inwards), free of the perianth, both opposite and alternating with the corolla parts, free of each other, filaments red and anthers versatile. Ovary monomerous, superior, 1 –celled with numerous ovules. Styles 1, simple. Fruit green and flaccid when young, turning to dark brown, hard, woody dehiscent legume, linear-oblong, flat, straight or curved, pendent pod, 30–60 cm long, 3–5 cm wide (Plates 3 and 4), containing numerous seeds. Seeds 30–45, hard, greyish, glossy, to 2 cm long, oblong-elliptic transversely mottled with a bony testa.

Nutritive/Medicinal Properties

Delonix regia seeds was found to have 42.5% protein (N x6.35) content, 1.1% moisture and oil content of 2.9% (Arora et al. 2010). The oil had an Iodine value of 110 (wij's), acid value of 2.65, saponification value of 186 and unsaponifiable matter of 2.67%. Fatty acid composition of the oil comprised C16:0 (palmitic) 9.1%, C18:0 (stearic) 6.1%, C18:1 (oleic) 21.3%, C18:2 (linoleic acid, w-6) 41.2%, C18:3 (linolenic) 18.6% and C20:0 (arachidic acid) 17.5%. The oil has been found rich in unsaturated acids especially omega-6 Linoleic acid. In another study, the oil yield from *Delonix regia* seeds was found to be 7%, carbohydrate content 39.5%, crude protein content 45.2% (Adewuyi et al. 2010). Neutral lipids were the dominant lipid fraction in the oils with linoleic as the most abundant fatty acid in the oil. Hydrocarbons, stigmasterol, phytol, sitosterol, ergost-4-en-3-one and ergost-5-en-3-ol were identified in the unsaponifiables of the oil. Studies by Abdullahi and Abdullahi (2005) found that the contents of crude protein (487.19 g/kg)

and lipid (65.0 g/kg) were significantly lowered in the boiled *Delonix regia* seeds, while the crude fibre (63.7 g/kg) was significantly increased, other nutrients were unaffected by boiling. Most amino acids were essentially unaffected by boiling, others like cysteine, glutamic acid, glycine, lysine, methionine and proline were reduced significantly. The antinutrients: tannins (830.2 g/kg), trypsin inhibitory activity (141.0 TIV/g), hydrocyanic acid (587.1 mg/kg) total oxalate (9.6 mg/kg), phytic acid (98.0 mg/k) and HCN (92.4 mg/kg) were significantly reduced in the boiled seeds.

Delonix regia seeds were found to contain a lectin which showed no specificity for human erythrocytes of ABO blood groups (Pando et al. 2002) It was found to be a monomer with a molecular mass of about 12 kDa. The optimal pH range for lectin activity was between pH 8.0 and 9.0, and the lectin was active up to 60°C. The lectin required Mn2+ for hemagglutinating activity. *Delonix regia* seed also contained a galactomannan with a D-mannose to D-galactose ratio of 4.0:1.0 (Tamaki et al. 2010). The galactomannan was found to compose of 1,4-linked ß-D-mannose, 1,4,6-linked ß-D-mannose, and terminal a-D-galactose. It was composed of pentasaccharide repeating-units.

The water-extract from *Delonix regia* flowers, was found to contain polyphenols and was reddish-coloured due to the presence of anthocyanins such as cyanidin-3-O-glucoside and cyanidin-3-O-gentiobioside cyanidin-3-O-rutinoside, pelargonidin 3-O-rutinoside (Saleh and Ishak 1976; Adje et al. 2008). The flower also contained carotenoids. The petals of *D. regia* contained 29 carotenoids (Jungalwala and Cama 1962). The major pigments identified we: phytoene, phytofluene, β-carotene, sγ-carotene, lycopene isomers, rubixanthin, lutein, zeaxanthin and several epoxy carotenoids. The sepals contained 18 carotenoids. Phytoene, phytofluene ,β-carotene, γ-carotene, lycopene isomers, lutein, zeaxanthin and carotenoid epoxides were the major carotenoids. Filaments contained 20 carotenoids, including phytoene, β-carotene, γ-carotene, cryptoxanthin, lutein, zeaxanthin, antheraxanthin, violaxanthin, chrysanthemaxanthin, flavoxanthin and other epoxy carotenoids. The highest concentrations of total carotenoids were found in anthers. Of the total carotenoids, 90% is zeaxanthin. The only other carotenoids present were β-carotene derivatives with traces of two uncharacterized carotenoids. Flavonol contents of *Delonix regia* flowers were 28.5, 31, and 33.5 μmol/g (expressed as quercetin equivalent), using acidified-water (0.01 N) media with sulphuric or citric acids (Adjé et al. 2010). Anthocyanin and phenolic acid contents were within the same range for these water media (5.6 μmol/g as cyanidin equiv. and 27.5 μmol/g as gallic acid (GA) equiv., respectively).

Flavone glycosides isolated from *Delonix regia* leaves included: kaempferol-3-O-glucoside, Kaempferol-3-O-rutinoside, kaempferol-3-O-rhamnosyl neohesperidoside, Kaempferol-3-O-neohesperidoside and Quercetin-3-O-rutinoside (Abou Zeid 2002).

Some pharmacological properties of *Delonix regia* reported are elaborated below.

Antimicrobial and Cytotoxicity Activities

Flower extract of Poinciana had been reported to exhibit antimicrobial activity and used as antibiotics against methicillin-resistant and sensitive *Staphylococcus aureus, Salmonella typhimurium*, *S. paratyphi, S. typhi, E. coli, Shigella dysenteriae* and *Pseudomonas aeruginosa*; and antifungal activity against five filamentous fungi (*Aspergillus niger, Alternaria alternata*, *Fusarium chlamydosporum, Rhizoctonia bataticola* and *Trichoderma viride*) and a yeast *Candida albicans* of clinical origin (Aqil and Ahmad 2003). Acetone and methanol fractions of *Delonix regia* flower extract exhibited antibacterial activity against clinical isolates of β-lactamase producing methicillin-resistant *Staphylococcus aureus* (MRSA) and methicillin-sensitive *S. aureus* (MSSA) (Aqil et al. 2005). Jahan et al. (2010), isolated five compounds, lupeol (1), epilupeol (2), β-sitosterol (3), stigmasterol (4) and p-methoxybenzaldehyde (5) from the petroleum ether and dichloromethane fractions of a methanolic

extract of the stem bark of *Delonix regia*. Antimicrobial screening of the different extracts (15 μg mm-2) was conducted by the disc diffusion method. The demonstrated by the petroleum ether, carbon tetrachloride and dichloromethane fractions exhibited antimicrobial activity with zones of inhibition ranging from 9–14, 11–13 and 9–20 mm, respectively, compared to kanamycin standard with the zone of inhibition of 20–25 mm. In brine shrimp lethality bioassay, the carbon tetrachloride soluble materials demonstrated the highest cytotoxicity with LC_{50} of 0.83 μg/ml, while petroleum ether and dichloromethane soluble partitionates of the methanolic extract revealed LC_{50} of 14.94 and 3.29 μg/ml, respectively, in comparison with standard vincristine sulphate with LC_{50} of 0.812 μg/ml.

Antioxidant and Antiarthritic Activities

Delonix regia was one of 12 traditional Indian medicinal plants that showed strong free radical scavenging activity with the DPPH method (Aqil et al. 2006). Phytochemical analysis of plant extracts indicated the presence of major phytocompounds, including phenolics, alkaloids, glycosides, flavonoids, and tannins. The ethyl acetate extract of *Delonix regia* flowers was found to have antioxidant and free radical scavenging activity (Bade et al. 2009). The ethyl acetate extract showed better antioxidant activity as compared to the standard one by DPPH radical scavenging and phenylhydrazine induced haemolysis of erythrocyte methods. IC_{50} values for DPPH radical scavenging and phenyl hydrazine induced haemolysis of erythrocyte were 29.69 and 14.586 μg/ml, respectively. Total polyphenolic and total flavonoids were 40.83% and 30.32% w/w, respectively. Results of a recent study indicated the flowers of *Delonix regia* to be rich source of potentially useful natural antioxidants like polyphenol and flavonoids (Shanmukha et al. 2011). The 70% alcoholic extract of total phenolic (TPC) and flavonoid content of *Delonix regia* flowers were found to be 34.44 and 30.45 mg/g respectively.

Ethyl acetate extract was found to contain quercetin. In another study, *Delonix regia* plant extract exerted good antioxidant activity (Mishra et al. 2011). The IC_{50} values tested by DPPH method was 38.4 μg/ml, and by Superoxide anion scavenging assay was21.8 μg/ml.

The alcoholic extract of *Delonix regia* flowers administered intraperitoneally to Freund's incomplete adjuvant induced arthritic adult female Wistar rats was found to exhibit antiarthritic activity (Chitra et al. 2010). Results suggested that the two doses of 200 and 400 mg/kg of alcoholic extract significantly reduced the paw edema volume as compared to diseased control animals. Treatment with *Delonix regia* also showed significant increase in antioxidant enzyme levels like Catalase (CAT), Glutathione peroxidase (GPx), Glutathione –S- Transferase (GST), reduced glutathione (GSH), and Vitamin C with decreased protein level and the values were almost analogous to that of normal values.

Tablet Formulation Uses

Studies found that gum obtained from *Delonix regia* seeds may be used as a substitute for tragacanth gum and acacia gum as a as a binder in a paracetamol tablet formulation (Adetogun and Alebiowu 2007) The results suggested that the granules containing *Delonix* gum had comparable packing property with those of tragacanth gum and acacia gum. The results of further studies suggested that while *Delonix regia* seed gum may be useful as a binder, its use at a low concentration would improve the balance between the binding and disintegration properties of tablets when a faster disintegration was desired, while its use at a high concentration could serve the desire for a modified or sustained release tablet formulation (Adetogun and Alebiowu 2009).

Antinutrient Activity

The Kunitz-type trypsin inhibitor was purified from to homogeneity and plate-like crystals seeds of *Delonix regia* (Polikarpov et al. 1999). A serine

proteinase inhibitor named DrTI, was purified from *Delonix regia* seeds inactivated trypsin and human plasma kallikrein with K(i)values 2.19×10(−8) M and 5.25 nM, respectively (Pando et al. 2001). It contained 185 amino acids and belonged to the Kunitz type family.

The Kunitz (STI)-type inhibitor isolated from *Delonix regia* seed was found to be an effective inhibitor of trypsin and human plasma kallikrein, but not of chymotrypsin and tissue kallikrein (Krauchenco et al. 2003). Hung et al. (2010) found that the *Delonix regia* trypsin inhibitor (DrTI) consisted of a single-polypeptide chain with a molecular mass of 22 kDa and containing two disulfide bonds (Cys44-Cys89 and Cys139-Cys149). Studies revealed that the Glu68 residue was the reactive site for DrTI and various other Kunitz-type trypsin inhibitors. The Cys139Gly mutant lost its inhibitory activity, whereas the Cys44Gly mutant did not, indicating that the second disulfide bond (Cys139-Cys149) to be critical to DrTI inhibitory activity, while the first disulfide bond (Cys44-Cys89) was not required.

Traditional Medicinal Uses

The extracts of *Delonix regia* plant parts are reported to have medicinal properties (Joy et al. 2001). In Cote D'Ivoire, traditional medicines are prepared from several parts of the tree, including the flowers. In the rural areas, water-extracts from *Delonix regia* flowers, are traditionally home made and used as healthy bioproducts and are known to have medicinal properties (Adje et al. 2008). The bark is also reported to be used as febrifuge in Indochina.

Other Uses

Royal Poinciana make excellent avenue/roadside trees. It is often planted as shade trees in dairy farms, tea plantations and compounds, and as live fence posts. The dark, hard heart wood is used in Sumatra for posts and supports for floorings and bridges; it is durable and resistant to insects although very susceptible to attack by dry-wood termites. Poinciana bark yields a gum similar to Arabic gum. The seed pods are used as a percussion instrument, *shak-shak* or *maraca* in the Caribbean. The wood and large old pods are used for fuel. The seeds contain gum that may find use in textile and food industries. Results of studies showed *Delonix regia* pod to be a very effective biosorbent in the removal of methylene blue dye from waste waters (Owoyokun 2009). Results of separate studies indicated the potential use of flamboyant pods as a precursor lignocellulosic material in the preparation of activated carbon. (Vargas et al. 2011). The hard, elongated seeds are occasionally used as beads. The seeds have good potential as a dietary protein source not only for humans but also for livestock. The leaves (with 39.5% protein) provide nutritious fodder and browse for livestock. Flowers are reputed to be good bee forage and also provide a dye.

Comments

The yellow-flowered variety, *Delonix regia* Hook. var. *flavida,* is less common than the red flowered variety.

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Dialium indum

Scientific Name

***Dialium indum* L.**

Synonyms

Dialium angustifolium Ridley, *Dialium javanicum* Burm. f., *Dialium laurinum* Baker, *Dialium marginatum* de Wit, *Dialium patens* Baker, *Dialium turbinatum* de Wit.

Family

Fabaceae or Leguminosae, also placed in Caesalpiniaceae

Common/English Names

Keranji, Luk Yee, Tamarind Plum, Velvet Tamarind

Vernacular Names

German: Samttamarinde;
Indonesia: Asam Keranji (Sumatra), Ki Ranji (Sundanese) Asem Kranji, Asem Cina, Kuranji, Pranji (Javanese) Karanjhi (Madurese);
Laos: Mak Kham Phep;
Malaysia: Enkeranji (Iban), Keranji Tebal Besar, Keranji, Keranji Paya, (Sarawak, Sabah), Keranji Kertas Besar, Asam Keranji Burong, Sepan, Tulang Dayong (Peninsular Malaysia);
Thailand: Luk Yee, Yi, Kayi Khao.

Origin/Distribution

Wild distribution of the species is found in Peninsular Thailand, Peninsular Malaysia, Borneo, Sunda Islands, Sumatra and Java.

Agroecology

In its natural habitat it is found in undisturbed mixed dipterocarp and sub-montane tropical forests from near sea level up to 1,200 m altitude. It occurs usually on hillsides and ridges on sandy to clay soils, but also on ultrabasic and limestone. In secondary forests, it is usually present as a pre-disturbance remnant tree. It grows well in well-drained, rich fertile soil with high organic matter and in humid shady environment or in partial shade. The tree seems to tolerate good as well as poor soil.

Edible Plant Parts and Uses

After harvesting, the fruits are dried in the sun for few days until the separation of the shell and the brown pulp occurs. In Sarawak, the brittle pericarp of the dried ripe fruit is broken off and the

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fleshy pulpy mesocarp is suck out and eaten and the seed disposed or spitted out.

The mesocarp is used as a candy-like snack food in Thailand, often dried, sugar-coated and spiced with chilli. It has a powdery tamarind -like texture, and is dark orange-brown in colour with a tangy sweetish-sourish, caramel flavour.

In Thailand two types of by- products are processed from the fruits.

(a) Luk yee paste – prepared from the brown pulp of fruits and mixed with sugar, chilli and salt. The pulp is then wrapped in thin plastic sheets for sale.
(b) Coated luk yee. This is prepared from fruits which are free from the outer shells. The fruits are either coated with sugar or a mixture of sugar, chilli and other ingredients. Coated luk yee can be either "sweet" or "hot" depending on the ingredients used.

Botany

A tall, slender tree up to 43 m with large thin buttresses and cylindrical trunk 95 cm across, dense and compact crown, smooth to rough, grey bark (Plates 1 and 2) that exudes red sap when injured. The sapwood is yellowish. Leaves are alternate, imparipinnate with small stipules. Leaflets are sub-opposite to alternate, 5–9, thin leathery, petiolate and hairy on the lower surface (Plate 3). Flowers are small, white, without petals and formed in terminal panicles. Bracts and bracteoles are small, calyx is 5-partite to near base, oblong with rounded apex; 2 free stamens, with short filaments and oblong anthers and a 2-ovuled, almost sessile ovary with short, filiform, subulate style with white silky hairs and small stigma. Fruit is a small dry, oval pod laterally compressed, 20 mm across, blue-black when ripe (Plate 4),

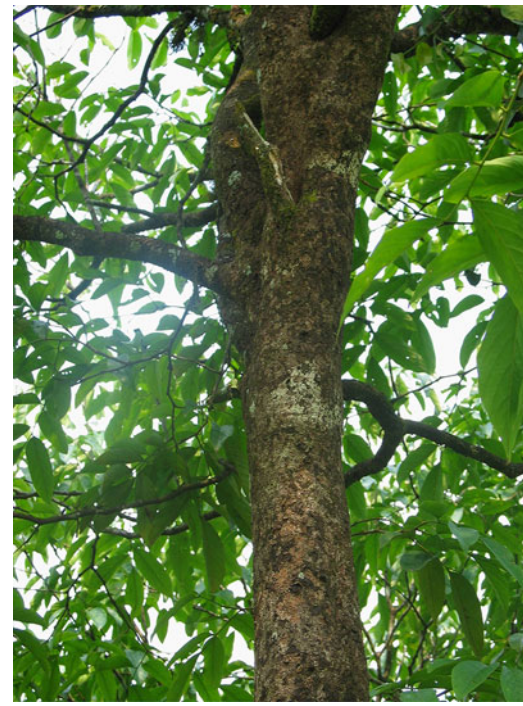

Plate 2 Tall, straight trunk with rough bark

Plate 1 Habit of young keranji tree

Plate 3 Imparipinnate leaf with alternate leaflets

Plate 4 Velvety, blue-black fruit and brown squarish seeds of velvet tamarind

brittle, indehiscent and covered with tiny hairs. Seed is dorsi-ventrally flattened, squarish, 7–8 mm across, 3 mm thick, glossy brown (Plate 4) and covered with fleshy pulp.

Nutritive/Medicinal Properties

The fruit is delicious, sweet and nutritious, rich in protein, carbohydrates, low in fat and also has vitamin C.

The nutrient composition per 100 g edible portion of the fruit pulp was reported as: energy 126 kcal, moisture 63.8%, protein 1.2%, fat 0.3%, carbohydrate 29.7%, crude fibre 0.2%, ash 4.8%, P 29 mg, K 438 mg, Ca 4 mg, Mg 4 mg, Fe 1.1 mg, Mn 18 ug, Cu 3.3 µg, Zn 9.1 µg and vitamin C 1.2 mg (Voon and Kueh 1999).

Dialium indum was one of six sweet-tasting plants examined for the free sugar/polyol content (Chung et al. 1997). The pericarp of the fruit was found to have 1.9% w/w yield of sugars/polyols.

Other Uses

The wood is utilized for the building of houses and boats as well as for the manufacture of rulers, oil presses, cog wheels, sledges used for timber extraction, and tool handles.

Comments

Two varieties have been recognised:

Dialium indum L. var. *indum* – Keranji (Br., Iban.), Keranji Batu – Peninsular Malaysia, Java, Borneo.

Dialium indum L. var. *bursa* (de Wit) Rojo – Bubuk (Dusun), Keranji (Malaya), Keranji Empelawa (Iban) – Peninsular Malaysia, Borneo.

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World Agroforestry Centre undated *Dialium indum*. http://www.worldagroforestry.org/sea/Products/AFDbases/wd/asps/DisplayDetail.asp?SpecID=1050

Entada phaseolides

Scientific Name

***Entada phaseolides* (Linn.) Merr.**

Synonyms

Acacia scandens (L.) Willd., *Entada formosana* Kaneh., *Entada gigas* (L.) Fawc. & Rendle, *Entada koshunensis* Hayata & Kaneh., *Entada parvifolia* Merr., *Entada polystachya* DC., *Entada pursaethe* DC., *Entada scandens* (L.) Benth., *Entada schefferi* Ridley, *Gigalobium scandens* (L.) Hitchc., *Lens phaseoloides* L., *Lens phaseoloides* Stickm., *Mimosa gigas* L., *Mimosa scandens* L., *Pusaetha scandens* (L.) Kuntze, *Strepsilobus scandens* (L.) Raf.

Family

Fabaceae or Leguminosae, also placed in Mimosaceae

Common/English Names

Cali Bean, Calinut, Elephant creeper, Elva, Elva Climber, Garbee Bean, Gila Bean, Go-go, Go-go Vine, Gogo, Mackay Bean, Matchbox Bean, Go-go, Monkey Ladder Pod, Nicker Bean, Sea Bean, Sea Heart, St Thomas Bean

Vernacular Names

Brazil: Cipó-Da-Beira-Mar;
Burmese: Nyin;
Chinese: Ke Teng;
Columbia: Bejuco Parta, Cobalonga, Habo, Ojo De Buey, Parta (Spanish);
German: Riesenhülse, Westindische Haselnuß;
India: Bor Gilla, Ghila, Gila Lewa, Gilar Lot (Assamese), Gilagach, Gilla, Pangra (Bengali), Chhui, Shuri, Sue Budu (Garo), Barabi, Barabi Chian (Hindu), Chappebelli, Doddakampi, Haleballi, Halle, Hallebilu, Hallekayiballi, Palleburu (Kannada), Ahakkatela, Anatata, Entada, Kakavalli, Kakkavalli, Makkanka, Paranta, Parin- Perunkakkavalli, Paranda, Paringakavalli, Paringakakavully, Perimkakuvalli, Perumkakkavalli, Vattavalli (Malayalam), Kangkhil (Manipur), Garambi, Garbe, Girambi (Marathi), Giridi (Oriya), Gilla, Prthvika (Sanskrit), Anaittellu, Camuttirappuliyan, Cillu, Irikki, Kirancakamirakkoti, Kirancakamiram, Nukkuki, Nukkukikkoti, Ottolakkoti, Ottolam, Perumancati, Peruntellu, Peyarttavakkoti, Peyarttavam, Sillu, Tel, Tellu, Tellukkoti, Viccali, Viccalittellu, Yanaittellu (Tamil), Gila-Tiga, Gilatige, Gillatige, Peddamadupu, Tandramanu, Tikativva (Telugu);
Indonesia: Bendoh, Gandu (Java), Chariyu (Sundanese);
Malaysia: Akar Belu, Akar Beluru, Akar Belerang, Akar Kupang, Sentok, Sintok;

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Mexico: Alampepe;
Philippines: Tamayan (Bagobo), Balonos, Gogo (Bisaya), Bayogo (Cebu-Bisaya), Kessing, Kezzing (Ibanag), Dipai (Igorot), Lipai, Lipay (Iloko), Balugo, Gogong-Bakai, Gogong-Bakay, Gugu (Pampangan), Gogo (Panay Bisaya), Barugo, Barugu, Bayogo (Samar-Leyte-Bisaya), Gogo (Tagbanua), Balugo, Bayogo, Gogo, Gugo, Gugu (Tagalog);
Samoa: Tupe;
Sri Lanka: Maha Puswel, Maha Pusvael (Sinhalese);
Thai: Maba, Kam Ton, Saba;
Tonga: Pa'anga.

Origin/Distribution

The species is indigenous to tropical Africa: Sierra Leone to Tanzania, Madagascar; tropical Asia: India to South China and Malaysia and tropical north Australia. It was probably introduced to Mexico.

Agroecology

Gila bean is strictly a tropical species; in its native range it occurs in humid forests at low and medium, 200–1,300 m altitudes.

Edible Plant Parts and Uses

Gila bean is cultivated for food and detergent production in the Philippines, India to South China and Java. Seed kernels are eaten after removal of the hard seedcoats and after careful preparation by boiling or roasting. In India, the boiled seeds are consumed by Kharib tribes of Assam and Ocean tribes such as Onges and Great Andamanese (Vadivel et al. 2008). The soaked seed kernels are roasted, boiled and eaten by northeast tribal groups such as Garo, Khasi, Naga and Kannikkars of Tamil Naidu and Kerala (Mohan and Janardhanan 1993; Siddhuraju et al. 2001). The half-ripened seeds are used as coffee substitute in South America (Janardhanan and Nalini 1991; Siddhuraju et al. 2002).

Young leaves are eaten as vegetables in India and Indonesia. The seed oil is also edible.

Botany

The plant is a very large, woody, branched, evergreen climber (liana) with thick 10–12 cm, spirally twisted stem and dark brown and rough bark. Leaves 10–25 cm, on short petiole and tripinnate, the apical pair transformed into a long tendril. Pinnae stalked, usually 4 in number with oblong, elliptic or narrowly obovate, 2.5–5 cm long, coriaceous, glabrous, simple leaflets (Plates 1 and 2). Leaflet has obtuse emarginate apexand slightly obtuse base. Spikes 15–25 cm, solitary or arranged in a panicle, villous with pubescent bracts. Flowers slightly fragrant. Calyx campanulate and 5-toothed. Petals 5, green with reddish base, oblong, glabrous, slightly united at base, apex acute. Stamens white, slightly longer than corolla. Ovary glabrous with a filiform style. Fruits, few pendant legumes, 50–100 cm long and 7–10 cm wide, somewhat curved, slightly constricted between the seeds (Plates 3 and 4). Seeds 5–11 are hard, dark brown, orbicular, flat, 4–6 cm in diameter, testa brown, brilliant Gand woody.

Nutritive/Medicinal Properties

Entada phaseoloides seeds were reported to contain high level of proteins (17.4–24.7%) with major proportion of albumin proteins, a balance amino acid composition, more nitrogen solubility, high content of lipid (3.1–10.8%) with predominant unsaturated fatty acids and high content of digestible starch (Janardhanan and Nalini 1991; Mohan and Janardhanan 1993; Vijayakumari et al. 1993; Siddhuraju et al. 2002)

The seeds of *Parkia roxburghii* were found to contain higher contents of crude protein and crude lipid compared to *E. phaseoloides* resulting in high energy value (Mohan and Janardhanan 1993). Both types of seeds were found to be rich

Plate 1 Gila bean leaves

Plate 2 Close-up of leaflets

Plate 3 Long and short curved gila bean pods (*middle* and *bottom*)

Plate 4 Dried, mature Gila bean pod

in potassium and iron. The seeds of *E. phaseoloides* were found to be a rich source of minerals such as magnesium, phosphorus, zinc and manganese. Albumins and globulins constituted the predominant fractions of the seed proteins. In both seeds, the contents of the essential amino acids, isoleucine, leucine, tyrosine and phenylalanine, were fairly high. Fatty acids such as oleic and linoleic acids were found to be relatively high in both the tribal pulses. Gila bean seeds were found to be rich in crude fibre and lipid with a major proportion of unsaturated fatty acids with

linoleic acid as the predominant fatty acid (Vijayakumari et al. 1993). The seeds also possessed good levels of iron, zinc and manganese but were high in levels of free phenols, tannins and L-DOPA.

Siddhuraju et al. (2002) reported that gila bean seed kernel comprised 66.1% of the seed weight (18.41 g) and contained 256.7 g/kg crude protein, 108.1 g/kg lipid, 27.3 g/kg ash and a high content of carbohydrate (585.7 g/kg). The levels of potassium, phosphorus, zinc and iron were similar to those in conventional pulses. Among the different protein fractions of seed kernels, albumins constituted the major storage proteins (69.7%). The kernel proteins were rich in essential amino acids, particularly sulphur-containing amino acids, and their levels appeared to be higher than the FAO/WHO reference protein for a 2–5-year-old growing child and soybean, and comparable to hen egg. Seed kernel lipids contained high levels of unsaturated fatty acids, oleic and linoleic acids, which accounted for 83% of the total fatty acid recovered. The in-vitro digestibility of the kernel protein was low (67%).

In separate studies, the fatty acids in *Entada phaseolides* seed oil were found to be myristic 0.3%, palmitic 9.1%, stearic 4.4%, arachidic 1.7%, behenic 1.6%, oleic 35.8%, linoleic 46.7% and linolenic 0.4% (Sengupta and Basu 1978). The special characteristic of this oil is its content of 6.9, , 17.0, 19.2, 5.0, 24.1 and 10.4% of monosaturated diolein 6.9%, monosaturated dilinolein 9.6%, saturated oleo linolein 17%, dioleo-linolein 19.2%, triolein 5%, oleo dilinolein 24.1% and trilinolein 10.4%.

Five new triterpenoid saponins, pursaethosides A–E (1–5), were isolated from the n-BuOH extract of the seed kernels of *Entada pursaetha* along with the known phaseoloidin. Pursaethosides C–E (3–5) possess as a common structural feature entagenic acid as aglycon, which is rare among triterpene saponins. Compounds 2–4 and phaesolidin were found to be not cytotoxic when tested against HCT 116 and HT-29 human colon cancer cells. Phascoloidin, homogentisic acid 2-O-β-D -glucopyranoside was isolated from the seeds of *Entada phaseoloides* (Barua et al. 1988).

The structure of Entada saponin (ES)-III, one of the main saponins of *Entada phaseoloides* bark, was established to be 3-O-[β-d-xylopyranosyl (1→2)-α-l-arabinopyranosyl (1→6)] [β-l-glucopyranosyl (1→4)]-2-acetamido-2-deoxy-β-l-glucopyranosyl-28-O-[β-l-apiofuranosyl (1→3)-β-d-xylopyranosyl(1→2)][(2-O-acetoxyl)-β-d-glucopyranosyl-(1→4)] (6−O(R) (−)2,6-dimethyl-2-trans-2,7-octadienoyl)-β-d-glucopyranosyl echinocystic acid (Okada et al. 1987). A high performance liquid chromatography method was developed for the simultaneous determination of three major active constituents in *Entada phaseoloides*, namely phaseoloidin, entadamide A, entadamide A-β-d-glucopyranoside (Dong et al. 2010). Four sulfur-containing amide compounds were isolated from the n-BuOH-soluble fraction of *Entada phaseoloides* seed ethanol extract and identified as entadamide A-β-D-glucopyranosyl-(1→3)-beta-D-glucopyranoside, entadamide A, entadamide A-β-D-glucopyranoside and clinacoside C (Xiong et al. 2010).

Parts of the plant have been reported to have various pharmacological properties.

Anticancer Activity

Liu et al. (1972) isolated a crystalline saponin from the seed kernels of *Entada phaseoloides*, with the tentative empirical formula C45H82O27. Acid hydrolysis yielded a crystalline sapogenin C30H48O5 which appeared to be identical with entagenic acid, together with arabinose and xylose. The saponin showed significant activity against Walker 256 carcinosarcoma in rats.

The extract from *Entada phaseoloides* was one of 29 plants that exhibited photo-cytotoxic activity (Ong et al. 2009). The plant extract was able to reduce the in-vitro cell viability of human leukaemia cell-line HL60 by more than 50% when exposed to 9.6 J/cm(2) of a broad spectrum light when tested at a concentration of 20 μg/ml. It had potential to be used in photodynamic therapy.

Antiinflammatory Activity

Two new sulfur-containing amides, entadamide A and entadamide B, isolated from the seeds of *Entada phaseoloides*, were found to inhibit the 5-lipoxygenase activity of RBL-1 cells at 10^{-4} g/ml

(Ikegami et al. 1989a). This finding suggested that entadamides A and B may be examples of a new type of antiinflammatory drug. A third new sulphur-containing amide, entadamide C, was isolated from the leaves of *Entada phaseoloides* together with entadamide A (Ikegami et al. 1989 b). The stereostructure of entadamide C was established as (R)-(+)-trans-N-(2-hydroxyethyl)-3-methylsulphinylpropenamide, the sulphoxide form of entadamide A.

Antiulcerogenic Activity

Ethanol extract of *Entada phaseoloides* seeds was found to possess marked antiulcer activity using several models that included aspirin plus pylorus ligation induced gastric ulcers in rats, HCl-ethanol induced ulcer in mice and water immersion stress induced ulcers in rats (Ramakrishna et al. 2008).

Molluscicidal Activity

The butanol fraction of the methanol extracts of the bark of *E. phaseoloides* was found to be highly toxic against the amphibious snail *Oncomelania quadrasi,* intermediate host of *Schistosoma japonicum* with the LC_{50} of 3.6–5.8 ppm (Yasuraoka et al. 1977). The active molluscicidal fraction contained at least two kinds of saponins. Preliminary field trials, however, showed that doses higher than 40 g per square meter would be needed to produce a satisfactory molluscicidal effect under field conditions.

Genotoxicity Activity

In a study of 138 medicinal plant preparations examined for genotoxicity, *Entada phaseoloides* was 1 of 12 plants that exhibited detectable genotoxicity in any system (Lim-Sylianco and Shier 1985).

Antinutritional Factors

Antinutritional factors such as total free phenols, tannins, L-DOPA (3,4-dihydroxyphenylalaline) were detected in the seeds and haemagglutinating activity also were also assayed (Mohan and Janardhanan 1993). The seed kernel exhibited high trypsin and chymotrypsin inhibitor activities (96.65 mg TI/g and 30.02 CIU/mg sample respectively) in addition to containing phenolics, phytic acid, lectins and oligosaccharides Siddhuraju et al. (2002). Another dominant toxic constituent was identified as a group of triterpenoid saponins (3.21%), which exhibited haemolytic activity (HeU) against cattle erythrocytes and induced high mortality in fish. A potent Kunitz type trypsin inhibitor (ESTI) was purified to homogeneity from *Entada scandens* seeds (Lingaraju and Gowda 2008). The amino-terminal sequence of ESTI revealed significant homology to the Kunitz-type protease inhibitors of legume plants. ESTI was found to contain a single disulfide bridge unlike a single chain polypeptide in other inhibitors from Mimosoideae species. ESTI inhibited bovine trypsin and inhibited the midgut proteinase of the fifth instar larvae of Rice moth (*Corcyra cephalonica*) with an IC_{50} of 26.4 μM. ESTI exhibited a mixed type competitive inhibition at lower concentration and pure competitive at higher inhibitor concentrations. However, in recent studies, Vadivel et al. (2008) reported that the high concentrations of anti-nutritional substances present in gila bean seeds were effectively decreased by autoclaving treatment without affecting their nutritional profile. The mature seeds were found to have high level of protein 26.8%, lipid 9.5%, fiber 15.7%, ash 5.4% and carbohydrates 42.5%. Rats fed with autoclaved seeds included in their diet for 28 days exhibited better growth performance as such as feed intake (239 g) and body weight gain (67.4 g). Additionally the protein quality parameters such as protein efficiency ratio, true digestibility, biological value, net protein utilization and utilizable proteins of gila bean were also significantly improved by the autoclaving treatment when compared with soaking, cooking and roasting.

Traditional Medicinal Uses

The plant has been used in traditional system of medicine in Asia (CSIR 1952; Burkill 1966;

Ramakrishna et al. 2008) , the seeds are considered tonic, emetic, antiperiodic and anthelminthic. The seeds and bark are rich in saponins and have been used as hair wash and soap. A decoction of the seed paste has been used for washing wounds and itches. The pods have been used for chest complaints and a poultice of pulverised seeds used as poultice to relive painful inflammations and administered internally for constipation, contraception, snake bites, enterosis, abdominal complaints and colic in children and as aphrodisiac. A paste of the seeds is applied to relieve inflammatory glandular swellings in the axilla known as *Khaka Bilari* in India. Bark powder is used for stomach ulcer and the seed powder in fever and headache.

Other Uses

Gila bean is cultivated for food and detergent production in the Philippines, India to South China and Java. The whole plant is rich in saponins and is used as detergent. Fresh liana has been used for making fish traps, the seeds used as fish poison in the Philippines. The seed oil is used as fuel. Seeds have been used for polishing and in games. When strung together the seeds are used as anklets, part of the *kailao* dance costume in Tonga. In Manipur, the seeds are used in making rosaries. They were also used as playing pieces in an ancient disc-throwing game, *lafo*. Bark fibres are manufactured into textiles, ropes and nets.

Comments

Gila bean is usually propagated by seeds or air-layering.

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Glycine max

Scientific Name

***Glycine max* (L.) Merril**

Synonyms

Dolichos sofa Linn., *Glycine angustifolia* Miq., *Glycine gracilis* Skvortsov, *Glycine hispida* (Moench.) Maxim., *Glycine hispida* var. *brunnea* Skvortsov, *Glycine hispida* var. *lutea* Skvortsov, *Glycine soja* (L.) Merr., *Phaseolus max* Linn. (basionym), *Phaseolus sordidus* Salisb., *Soja angustifolia* Miquel, *Soja hispida* Moench., *Soja japonica* Savi, *Soja max* (L.) Piper, *Soja soja* Karst., *Soja viridis* Savi.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Green pod – Edame
Seed – Green Soybean, Soja bean, Soy, Soy bean, Soybean, Soyabean
Sprouts – Bean Sprouts, Seed Sprouts, Soyabean sprouts

Vernacular Names

Arabic: Fûl Sûyah;
Azerbaijan: Ekme Soya;
Belarusan: Soya Shchatzinistaya;
Brazil: Soja;
Burmese: Lasi, Pengapi, Peryatpym;
Chinese: Da Dou, Da Dou Chi, Hak Tau, Huang Dou, Huang Da Dou, Tai Tau, Tau Nga, Tau Ge, Wong Tau;
Croatian: Soja;
Czech: Sója Luštinatá,
Danish: Sojabønne, Soya, Soyabønne;
Dutch: Soja Hispada, Soja Sort, Sojaboon;
Eastonian: Karvane Sojauba, Põld-Sojauba, Sojauba;
Esperanto: Sojfabo;
Finnish: Soijapapu;
French: Haricot Soja, Pois Soja, Soja;
Galician: Soia;
German: Fettbohne, Japanische Bohnen, Ölbohne, Soajabohne, Sojasüsbohne, Soya;
Hungarian: Kultúrszója, Szója, Szója(Bab), Szójabab, Termesztett Szója, Trópusibab;
India: Gari Kalai (Bengali), Bhat, Bahtwar, Bhetmas, Ram Kurthi, Ramkurhti (Hindu), Vilayati Chowra (Sind);
Indonesia: Kacang Bulu, Kacang Jepun, Kedelai;
Italian: Fava Soja, Glicine, Pianta Di Soia, Soia, Soja;

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Japanese: Daizu , Edamame, Shoyu;
Khmer: Sândaèk Sieng, Sândaèk An Gen Sar;
Korean: Kong;
Laotian: Thwàx Khôn, Thwàx Tê;
Latvian: Sarmataine Soja;
Lithuanian: Gauruotoji Soja, Soja;
Malaysia: Kacang Bulu, Kacang Bulu Rimau, Kacang Jepun, Kacang Soya;
Moldavian: Soe Mare;
Mong: Tarimal Sharbuurtzag;
Norwegian: Soyabønne;
Philippines: Balatong , Soya, Utau (Tagalog);
Polish: Soja;
Portuguese: Soja;
Romanian: Soia;
Russian: Glitzine Krupneishaya, Glitzine Shchetinistaya, Kitaiskie Boby, Soewyj Bob, Soja, Soya Kulturnaya, Soya Posevnaya, Soya Zhestkovolosistaya;
Slovašcina: Soja Navadna
Slovencina: Sója Fazuľová;
Spanish: Frijol De Soya, Haba Soya, Soya;
Sri Lanka: Boo Mae (Sinhala);
Swedish: Sojaböna;
Swiss: Sojabona;
Taiwan: Mao Dou;
Thai: Thua Lueang, Thua Phra Lueang, Thua Rae;
Tibetan: Rgya-Sran;
Turkish: Çin Lubyasi, Soya Fasülyesi, Soya Lubyasi;
Vietnamese: Dâu Nành, Dâu Tuog, Dâu Tuong, Quantan.

Origin/Distribution

Soybean is native to China and is deemed to have been domesticated from *Glycine soja* Sieb & Zucc. in Northeast China (Hymowitz and Newell 1980). Wild form of soybean, *G. soja*, is also found in China, Far East region of Russia, Japan, Korea, and Taiwan. Soyabean is known only in cultivation and has been traditionally grown in the Far East, however nowadays it is cultivated in many, tropical, subtropical and warm temperate countries. The main global producers of soybean in descending order are USA, Brazil, Argentina, China, and India. In southeast Asia, Indonesia is the leading producer followed by Thailand, Vietnam and the Philippines.

Agroecology

Soybean cultivation extends from the equator to latitudes 55°N and 55°S, from near sea-level to 2,000 m elevation. Optimal growth is found in areas with mean annual temperatures of 20–30°C. Temperatures below 20°C and above 32°C reduce floral initiation and fruit set, while temperatures above 40°C retards growth and is detrimental to seed production. Soybean is intolerant of excessive heat and severe winters. It is a short day plant but some cultivars are insensitive to photoperiodism. The crop has been reported to tolerate annual rainfall of 3,000–4,000 mm and to require at least 500 mm water during the growing season although 850 mm is optimal.

Soybean can grow in a wide range of soils, with optimum growth in moist, fertile, well-drained, alluvial soils with a good organic content. It is intolerant of low acid soils and its associated manganese, aluminium and iron toxicities. It thrives best in the pH range of 6–6.5. Acidic soils have to be limed to raise the pH to 6–6.5.

Edible Plant Parts and Uses

Pods (Plates 1 and 2), seeds (beans) (Plate 5) and germinated sprouts (Plates 3 and 4) are consumed. Unripe seeds are eaten as vegetable and dried seeds eaten whole, split or sprouted. Young green pods are boiled briefly with salt and eaten as *eda-mame* (Japanese), *qing dou, mao dou* (Chinese), *put kong* (Korean). The green beans of immature pods are eaten, usually soften by boiling, on its own or season with sugar or soy sauce. Soybean is also eaten boiled and pickled with salt or vinegar called *hitashi mame.* Roasted soybeans or soy nuts called *iri-mame* (Japanese) or *chao da dou* (Chinese), are eaten like peanuts. They are sometime coated with flavourings. Baked soy nuts are lower in fats than fried. Soy nut butter or soy butter is made from roasted soy nuts and used

Plate 1 Short bushy soybean plant

Plate 2 Soyabean pods

Plate 3 Soybean sprouts

Plate 4 Close-up soybean sprouts

Plate 5 Soyabean seeds

as a peanut butter substitute. It is quite similar to peanut butter in taste and texture but is less flavoursome and contains but has significantly less total and saturated fat than peanut butter and is cholesterol free. Soy nut butter is now being used as a peanut butter alternative in schools and camps. Soy bean sprouts, *huang da ya, dao dou ya* (Chinese), *diazu no, moyahsi* (Japanese), *kong na mool* (Korean), *tauge soya* (Malay) are packed with nutrients and are popularly used in salads, stir fries with other vegetables, stews, soups and noodles. Soybeans are also used as fermenting stock to make a brand of vodka.

Soybean is also used in other edible forms that include soybean oil, soy lecithin, soy flour, textured soya protein (TSP) and processed products and by-products that include non-fermented and fermented food.

Soybean oil is a widely used 'vegetable oil'. Soybean oil is very popular because it is nutrient rich, healthful, cheap and has a high smoke point. Soybean oil more polyunsaturated

and monounsaturated fats and very much less saturated fats and contain no cholesterol. The high smoke point of soybean oil facilitates its use as frying oil. However, the high-proportion of oxidation-prone linolenic acid is undesirable for some uses, such as cooking oils in restaurants. Soybean oil is often hydrogenated to increase its shelf life or to produce a more solid product. Soybean oil is also used by the food industry in a variety of food products including salad dressings, sandwich spreads, margarine, bread, mayonnaise, non-dairy coffee creamers and snack foods.

Another soybean by-product is soy lecithin which is extracted from soybean oil. Soy lecithin consists of three types of phospholipids: phosphatidylcholine, phosphotidylinositol and phosphatidylethanolamine. It is generally used as a natural emulsifier or stabilizer in various food applications, for example, it promotes solidity in margarine and imparts consistent texture to dressings and other creamy products. Lecithin is also utilised in chocolates and coatings and to counteract spattering during frying. Its nutrient value is elaborated in the next section of the chapter. Lecithin provides an excellent source of choline, which is essential to every living cell in the body and is one of the main components of cell membranes.

Soy flour or soybean flour is one of the most widely used products of soybean. In Japanese, it is known as *kinako*, in Chinese, *chao dou-fen, dou fen*, in Korean, *kong ka au* and *bubuk kedelai* in Indonesian. In the West, the soybean flour industry has experienced tremendous growth over the past few decades. Soy flour is prepared by first roasting the soybeans, removing their coatings and then ground into powder. Natural or full-fat soy flour is made from unextracted, dehulled beans, and contains about 18–20% oil. Owing to its high oil content a specialized Alpine Fine Impact Mill must be used for grinding rather than the more common hammer mill. Full-fat soy flour contains the natural oils that are found in the soybean. Defatted soy flour is obtained from solvent extracted flakes; it has most of the oils removed during processing and contains <1% oil. Soy flour is extremely rich in high quality protein (about 50%), fibre (about 5%) and is an excellent source of iron, calcium and B-vitamins (see next section of the chapter). Soy flour is manifold more nutritious than wheat flour. It contains higher levels of protein, calcium, phosphorus, iron, thiamine and riboflavin than wheat flour and is gluten free. Both kinds of soy flour will give a nutritional protein boost to food; however, defatted soy flour is even more concentrated in protein than full-fat soy flour. Soy flour is widely used in an amazing array of food products like fudges, candies, pies, cakes, rolls, doughnuts, pasta, pancake mixes and frozen desserts. Some meat loaves and other prepared meat products use soy flour. Soy flour is used at home to thicken gravies and cream sauces, and added to a variety of baked foods. Soy flour also prevents baked food from becoming stale. In fried foods, like doughnuts, soy flour reduces the amount of fat that is absorbed by the dough. Soy flour imparts a rich colour, fine texture, tenderness and moistness to baked goods. *Kinako* (soybean flour) is commonly used in Japanese cuisine, e.g. in *warabimochi,* a famous *kinak*o-covered sweet. Soy flour can also be used to prepare a quick, homemade soymilk. Low-fat soy flour (with 4.5–9% fat) is made by adding back some oil to defatted soy flour. Lecithinated soy flour is made by adding soya lecithin (up to 15%) to defatted, low-fat or high-fat soy flours to increase their dispersibility and impart emulsifying properties.

Another soy by-product is soybean paper, *manenori* or *nama-nori-san*. These colourful sheets can be used to wrap sushi, spring roll or as a dessert wrap. It is made from soybean protein, soy flour, glycerol, soybean oil, water and edible food dyes.

Another soybean by-product is texturized or textured soy protein (TSP), also known as textured or texturized vegetable protein (TVP), soy meat or soya meat. TSP is a meat analogue or mock meat made from defatted soy flour by thermoplastic extrusion or steam texturization to impart structure and shape. It is available as dried or frozen flakes, granules, or chunks, and it has a chewy, meaty texture when it is cooked. It is easy and quick to cook with a high protein content equal to that of meat and contains no fat. In addition to protein, these soy protein ingredients

contain other naturally occurring soy constituents, such as isoflavones, fibre, and saponins. TVP is made into a diverse variety of vegetarian or vegan foods including traditionally meat dishes such as chili, spaghetti Bolognese, sloppy joes, tacos, veggie burgers, or burritos.

Other Non-fermented Soy Foods

Besides the above, other traditional non-fermented food uses of soybean include soymilk, and its byproducts, tofu, tofu skin and okara (residues). Fermented byproducts such as soy yoghurt, soy cream, soy sauce, soy nuggets, kefir (fermented milk) and cheese analogues are also made from soymilk.

Soy milk, soya milk, soybean milk, soy juice is a drink or beverage that can be made at home by soaking dry soy beans (seeds) in water overnight or at least 3 h and grinding them with water; the resultant slurry is then boiled and the insoluble material is removed by filtration. Soy milk is called *dòu nǎi, doujiang, dou ru* in Chinese*, tōnyū* in Japanese, *kong kook* in Korean. In Singapore it is called *tau-huey-tzui (*Mandarin) or *tau hoe chúi* in the local Hokkien dialect. In Malay it is called *susu soya* or *air tauhu*. Soymilk is unsweetened and is usually sweetened using cane sugar or brown sugar. In China, salted soy milk is popular. "Sweet" and "salty" soy milk are both traditional Chinese breakfast foods. In curries, coconut milk can be substituted with soya milk. Soy milk is used in many kinds of Japanese cuisine, such as in a base soup for *nabemono* (steam boat dish). In Korean cuisine, soy milk is used as a soup for making *kongguksu*, cold noodle soup eaten mostly in summer. Soy milk is available commercially in cans, bottles and various sized tetrapaks. Commercial soymilks and related products may be classified, according to their composition, as follows:

(a) Plain (or traditional) soymilk containing about 4% protein. Made by water extraction of whole soybeans, using a bean to water ratio of 1:5.
(b) Dairy-type soymilk, formulated so as to have a composition roughly similar to that of dairy milk. Bean to water ratio 1:7. Protein content 3.5%. Slightly sweetened, contains added oil, salt. May contain imitation milk flavour, namely vanilla-flavored, coffee-flavored or chocolate flavored, fortified or with added Ca, Vitamin A and D formulations.
(c) Soy beverages: sweetened and flavoured drinks, containing about 1% protein. Bean to water ratio 1:20.
(d) Cultured products – any of the above type after lactic fermentation or acidification with lactic acid including soy yogurt, soy kefir (fermented milk drink) and soybased cheese analogues. Soy yogurt is made from soy milk using yogurt bacteria (*Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus salivarius* subsp. *thermophilus*) and sometimes additional sweeteners, like fructose, glucose, or sugar. It is a good alternative for those who wish to avoid dairy products; like vegans, ovo-vegetarians, Jews, for people with Phenylketonuria (OKU) or other dangerous diseases, and for those with lactose intolerance or milk allergy. Soy based cheese analogues may be lower in fat compared to their dairy counterparts. Soy cheese analogues are cholesterol-free and are often a source of soy protein and isoflavones.
(e) Blends – mixtures of soymilk and other vegetable or dairy milks.
(f) Soy ice cream – made from soy milk and soy yogurt or soy milk and silken tofu with added syrup and flavoured with vanilla or with mashed up fruits.
(g) soy mayonnaise, soya mayonnaise or tofu mayonnaise- made from soy milk, soybean oil, vinegar, salt, mustard, modified maize starch, guar gum, citric acid, water. Being lactose free, it is a good substitute for those who wish to avoid egg-based mayonnaise. *Nayonaise* is a well-respected brand.
(h) Infant formulas based on soy milk are used by lactose-intolerant babies and for babies that are allergic to cow milk proteins. The formulas are sold in powdered, ready-to-feed, or concentrated liquid forms.

Bean curd skin, tofu skin, or bean curd sheets, *yuba* or *uba* in Japanese, *doufu p*i or *toufu lao,* is

Plate 6 Bean curd stick (tofu bamboo)

Plate 7 Bean curd sheet (tofu skin, yuba)

the sweet, protein-rich, firm layer (Plate 7) that forms on top of heated soymilk. The films are removed and dried in the sun into yellowish sheets. Dried *yuba* comes as sheets, rolls, knots, and many other forms. The skin is available in very thin sheet called *nama yuba* or thick sheets in some Asian market stores. Tofu skin can also be bunched up to stick form and dried called beanstick, beancurd stick, *Chinese yuba*, dried bean stick, *bamboo yuba*, as *tofu bamboo*, *fŭ zhú* (Mandarin), *fuchuk pi* (Cantonese); *phù trúc* (Vietnamese) and *kusatake* (Japanese) (Plate 6). Tofu skin needs to be rehydrated with water before using but can be directly added into soup or stews. Yuba is also available frozen. On rehydrated, tofu skin assumes a soft rubbery texture and bunched together or moulded into different shapes and cooked further to imitate various meat, forming meat analogues in vegan cuisine. Tofu skin is also used as wrappers for dim-sum. Bamboo tofu is used in lamb stews and in dessert soup. In Malaysia for example, popular vegetarian dishes using tofu skin include dried yuba (*t'im chok*), vegetarian sausage (*chak tie*), vegetarian duck (*chai ak*), vegetarian salted fish (*chai kiam hu*), vegetarian chicken (*chai kai*), or vegetarian meat (*chai tu kar*). By layering and stacking the sheets in a certain manner, an imitation of chicken breast with the skin on can be created. The effect is completed by frying the "skin" side of the tofu chicken until it is crispy. Similar foods, such as yuba sausage, is popular in a Singapore dish containing rolled bamboo yuba in a medium thick tan sauce called *ching-sha fuzhu.* Novel and tasty hors d'oeuvres and crisp yuba chips are also popular.

Soybean curd, tofu, soybean cake, soya bean cake, *tofu* (Japanese), *dòu fu* (Chinese), *doo bu* (Korean), *tahu* (Indonesian), *tokua* (Philippines) is made from soy milk by coagulating and pressing the resultant curds. Two types of coagulants are used commercially – salts calcium sulfate, magnesium chloride and calcium chloride and acids coagulant such as acetic acid, citric acid or glucono δ-lactone an organic acid used especially for silken and soft tofu. Enzymes such as papain can also be used but is not used commercially. Tofu or bean curd, or dòufu, is a traditional and much relished food in East Asia and southeast Asia. It originated in the Han dynasty in ancient China and was then introduced into Korea and Japan and other parts of southeast Asia. Tofu is an important source of food for Buddhism and its spread coincided with the spread of Buddhism in Asia. Tofu is cheap, high in protein, low in fat, and very versatile. Tofu can be eaten fresh without or with cooking and is used in a vast array of Asian cuisines that include salads, soups, stews, stir-fries, casseroles, noodles, porridge, congee, desserts, etc. Tofu being bland is also eaten fresh with soy sauce, oyster sauce or sesame oil or fried garlic oil or fried onion oil. Tofu is also available smoked, pickled, flavoured, baked, and deep-oil fried. A wide variety of tofu is available in local markets to connoisseurs around the world and used for various cuisines and recipes:

(a) Soft/silken tofu, *sui doufu* in Chinese, *kinugoshi tōfu* in Japanese, *sundub*u in Korean, is undrained tofu that contains the highest

moisture content of all fresh tofus and generally contains 5–6.4% protein. Soft tofu has the following nutrient composition: energy 63 kcal/100 g, water 88.0% protein 6.0% carbohydrate 3.5%, protein/fat ratio 1.7 (Anonymous 1986). Soft/silken tofu has a very soft, creamy, fine texture similar to fine custard. It is the preferred tofu for shakes, dips, custards, puddings, smoothies, parfaits, cheesecakes and dressings. In Korean cuisine, soft tofu is used to make a thick stew called *sundubu jjigae.* In Japan, soft mashed tofu is used with chopped vegetables to make *ganmodoki*. In Malaysia, mashed soft tofu is mixed with minced pork to make meatballs or meatloaf. Soft tofu is available either fresh in tubs or in aseptic packages that do not need refrigeration. Some variation exists among soft tofus. Black *douhua* a type of silken tofu made from plain black soy beans and soybeans. The texture of black bean tofu is slightly more gelatinous than regular *douhu*a and the colour is greyish in tone. This type of tofu is eaten for the earthy "black bean" taste.

(b) *Douhau*, *dòu huā* or *dòufu huā* in Chinese, is very soft tofu with even higher moisture content. It is a very popular dessert in East and Southeast Asia. In Malaysia, *doufu hua* is usually served warm with white or dark (palm) sugar syrup, or with pandan-flavoured sugar or served cold with longans. In the Philippines, *douhau* is eaten with brown sugar and sago. In Vietnam, *dòu huā* is called *đậu hủ* and is eaten with powdered sugar and lime-juice or with a ginger-flavoured syrup. With the addition of flavorings such as finely chopped spring onions, dried shrimp, soy sauce, chilli sauce, *douhua* is a popular breakfast dish across China. This type of tofu would be good for making shakes, dips, custards, puddings, smoothies, parfaits and dressings.

(c) Regular tofu contains 6.5–9.4% protein. Regular tofu has the following nutrient composition: energy 79 kcal/100 g, water 84.9%, protein 7.8% carbohydrate 4.3% and protein/fat ratio 1.9 (Anonymous 1986). This is halfway between the custard-like consistency of silken tofu and the denser texture of firm tofu (Plate 8). It is a good choice to scramble it like eggs, or use it in place of ricotta cheese in a casserole, or used in frankfurters and burgers.

Plate 8 Regular and firm tofu

(d) Firm tofu is *lǎo dòufu* in Chinese, *momendōfu* in Japanese. Although drained and pressed, this form of fresh tofu still contains a fair amount of moisture. Firm tofu generally contains 9.5–13.9% protein. Firm tofu has the following nutrient composition: energy 102 kcal/100 g, water 79.3%, protein 10.6%, carbohydrate 5.3% and protein/fat ratio 2.0 (Anonymous 1986). It has the firmness of raw meat but bounces back readily when pressed. The texture of the inside of the tofu is similar to that of firm custard. The skin of this form of tofu takes the pattern of the muslin cloth used to drain it and is slightly more resilient to damage than its inside. It can be picked up easily with chopsticks. Firm tofu is excellent for stir-fries and the grill as it holds its shape well. It is also used in tofu balls, frankfurters and burgers. Pan fried cubes of firm tofu, seasoned with soy sauce, garlic, and other ingredients is served in the Korean dish, *dubu gui*. Cubes of cold, uncooked firm tofu seasoned with soy sauce, scallions, and ginger, prepared in a manner similar to the Japanese *hiyayakko*, are also enjoyed. *Hiyayakko* comprised firm tofu with grated ginger, green onions and /or *katsuobushi* shavings with soy sauce. The popular

bar food, or *anju*, called *dubu kimchi*, comprised boiled, firm tofu served in rectangular slices around the edges of a plate with pan fried, sautéed or freshly mixed *kimchi* in the middle. In Central Java, Indonesia, a popularly relished dish is *Tahu Bacem*. It consists of firm tofu boiled in coconut water, mixed with galangal, salam leaves, coriander, shallots, garlic, tamarind and palm sugar. When the coconut water has evaporated, the tofu is fried until crisp golden brown. *Tahu Bacem* is often eaten in accompaniment with *tempeh* and fried chicken.

(e) Extra Firm Tofu or pressed tofu, is called *nigari tofu* (Japanese), *dòu gān (*Mandarin)*, dou fu kon* (Cantonese). It generally contains 14% or more protein. Extra firm tofu has the following nutrient composition: energy 115 kcal/100 g, water 79.3%, protein 14.0% , carbohydrate 5.3% and protein/fat ratio 2.9 (Anonymous 1986). With much of the moisture pressed out of it, this kind of tofu holds it shape and absorbs marinades better than firm tofu. It has the firmness and consistency of fully cooked meat and has a rubbery texture. Extra firm tofus are the best choice for grilling and stir-fries.

Shredded dried tofu or *dòu gān sī* or *gān sī* in Chinese, is pressed especially flat and sliced into long strings with a cross section smaller than 2 mm × 2 mm, and resembles loose, cooked noodles. It can be served cold or stir-fried, or similar in style to Japanese *abura-age*. Tofu can be deep fried. Deep frying changes the characteristics of tofu and renders it elastic and chewy. Tofus such as firm and dry tofu, with their lower moisture content are cut into bite-sized cubes or triangles and deep fried until they develop a golden-brown, crispy surface (in Chinese, *zhà dòufu*,). These may be eaten on their own or with a light sauce, or further cooked in liquids; they are also added to hot-pot dishes or included as part of the vegetarian dish called *luohan zhai*. This is similar to *atsuage*, also called *nama-age* in Japanese, which is pressed tofu cake deep fried to impart a crispy and meaty exterior and a soft interior. The Japanese like to cut it into cubes and use it in stir-fries and soups. A large proportion of the tofu production in Japan is further processed to a large variety of deep-fried products. In Japan, cubes of lightly coated and fried tofu topped with a *kombu dashi*-based sauce are called *agedashi-dofu* (Plate 9). Thin and soft varieties of tofu are cut into thin slices and deep fried in oil until they are light and airy in their core, often called tofu puff (*dòupào*, *doufupao*, *youdoufu*, or *doubu* in Chinese), or *dou fu pok* (Cantonese) literally "bean bubble," describing the shape of the fried tofu as a bubble. In Japanese this form is called *abura-age, aburage, usu-age, usuage inariage,* or *yub*u in Korean. They are commonly blanched, seasoned with *mirin* and soy sauce and served in dishes such as *kitsune udon*. They can be cut open like a pouch and filled with rice to make *inari sushi*, and are called *yubu chobap* in Korea. They are also used as a meat substitute in soups or with meat and other ingredients. In Malaysia, *dou fu pok* is popularly used in *bak kut teh* (Chinese dish of pork ribs simmered in peppery and garlic soup and served with rice), in stews and curry laksa.

Plate 9 Fried tofu (Tofu puff, *dou-fu pok*)

To prepare flavoured tofu, the flavours need to be added to curdling soy milk while the tofu is being produced. Egg tofu or *tamagodōfu* (Japanese), *dàn dòufu, rìběn dòufu* (Chinese) is a popular savoury flavored tofu prepared by incorporating filtered beaten egg into the soy milk before the coagulant is added. The mixture is filled into plastic tubes and allowed to curdle. The tofu is then cooked in its packaging and sold. Egg tofu has a pale golden color imparted by the egg ingredient. Other flavoured tofus are the dessert dishes called peanut tofu *(luòhuāshēng dòufu*

in Chinese and *jimami-dōfu* in Japanese), almond tofu (*xìngrén dòufu* in Chinese*; annindōfu* in Japanese), mango tofu, coconut tofu and longan tofu. Most dessert types have the texture of silken tofu and are served cold.

Okara (Japanese) or soy pulp or tofu lees, is the white or yellowish pulp consisting of insoluble parts of the soybean which remain in the filter sack when pureed soybeans are filtered in soymilk production. It is called *xuě huā caì*, *dòufu zhā* in Chinese, *kongbiji* in Korean. Okara is moist and crumbly, rich in fibre, protein and starch left over when soy milk has been extracted from ground soaked soybeans. Okara is sometimes used in Japanese and Korean cuisines. It is also an ingredient for vegetarian burgers in western countries.

Tofu sour cream – is made from tofu, it is lower in fats and more nutritious than ordinary sour cream. One common recipe is to mix silken tofu, oil (olive or vegetable), rice vinegar, lemon juice and salt; mash the ingredients and whip in the blender and then refrigerate.

Fermented Soy Food

Sufu (fu-ru) is the name that first appeared in the literature for the popular, highly-flavoured, fermented cheese-like product that originated from China during the Wei Dynasty (220–265 AD) (Wang and Hesseltine 1970; Han et al. 2001). Transliterally, sufu (*fu-ru*) means "moulded milk" and tosufu (*doufu-ru*) means "moulded soymilk". Because of the numerous dialects in China and the difficulties of phonetic translation from Chinese into English, sufu has appeared in literature under many different names. The following appellations for sufu in the literature have been found: *sufu, tosufu, fu-ru, dou-fu-ru, tou-fu-ru, toefu-ru, jiang-dou-fu* (Mandarin), *dau fu-yu, fu-yu, foo-yue* (Cantonese), *tāu-tā, tāu-kiâm, tāu-jú* (Hokkien), and *teu fu nen* (Hakka). In Japan, sufu is also known as *tofuyo, nyu-fu* or *funyu* (Yasuda and Kobayashi 1989); in Vietnam as *chao;* in the Philippines as *ta-huri;* in Thailand *as tao-hu-yi;* and in Indonesia as *taokaoan* (Beuchat 1995). The preponderances of names have confused Westerners and people in Asia. Officially, sufu should be named *Furu* (or *Doufuru*) in Chinese. This fermented bean curd is also commonly referred to as fermented tofu, pickled tofu or tofu cheese. Sufu is commonly used as a condiment and is consumed at breakfast to flavour rice, porridge, gruel or congee.

Sufu is made by fungal solid-state fermentation of tofu with fungal starters that include *Actinomucor* spp., *Mucor* spp. and *Rhizopus* spp. (Han et al. 2001). The resulting "*pehtze*" is aged in salt, followed by ripening in a dressing mixture containing one or more of the various ingredients such as salt, *angkak* (red kojic rice), alcoholic beverage, sugar, flour (or soybean) paste and some spices. Choice of processing can result in mould fermented sufu, naturally fermented sufu, bacterial fermented sufu, or enzymatically ripened sufu. Depending on the choice of dressing mixture, red, white or grey sufu may be obtained. Red sufu (Plate 10) contains much larger amounts of alcohols, esters, and acids, which may be due to the fermentation of *angkak* (red kojic rice or red qu), a product of solid fermentation of cooked rice with *Monacus purpureus*. The outside colour of red sufu is red to purple, and the inside colour is light yellow to orange. White sufu (Plate 11) has similar ingredients as red sufu in the dressing mixture but without *angkak*. It has an even light yellow colour inside and outside and is less salty than red sufu. In grey sufu the dressing mixture contains the soy whey left over from making tofu, salt and some spices. Grey sufu is ripened with a special dressing mixture, which could be dominated by both bacteria and

Plate 10 Red sufu (red Fu-yu)

Plate 11 White sufu (white fu-yu)

Plate 12 Fermented black beans (soy nuggets, douche)

mould enzymes and results in a product with a strong, offensive odour.

Douchi, dòuchǐ, toushih (Chinese) or *touchi, hamanatto* (Japanese) or in English, Chinese fermented black beans, soy nuggets, (Plate 12) is a popular flavour seasoning among the Chinese. *Douchi* is made by fermenting and salting dried soybeans. The process turns the beans black, soft, and mostly dry with a sharp, pungent flavour, spicy smell and salty taste. It is sold in plastic packages or bottles. *Douchi* is especially used to flavor fish or vegetable stir-fries such as bitter melon and chicken pieces. Other delicious dishes made with *douchi* are "Steamed Spare ribs with Fermented Black Beans and Chili Pepper", "Braised Mud Carp with Fermented Black Beans" and "Shrimp with Lobster Sauce and Black Beans".

Stinky tofu or *chòu dòufu* is a soft tofu that has been fermented in a unique vegetable and fish brine. It has a potent, pungent odour that smells like faecal or rotten matter but is relished as a snack when deep-fried in boiling oil. The deep-fried, bite-sized, square blocks are threaded into a stick, pasted with a sweet spicy sauce and eaten. The snack is popular among the Chinese, in southeast Asia, Taiwan and China.

Natto, nattou or fermented soy cheese, is a popular, traditional Japanese food made from soybeans fermented with *Bacillus subtilis.* Natto is highly nutritious, rich in proteins; it has a potent, pungent smell, and a sticky texture. In Japan *nattō* is most popular in the eastern regions, including Kantō, Tōhoku, and Hokkaido. In Japan, it is a popular breakfast food and school lunch especially in the Tottori prefecture in central Japan. The Japanese like to serve it on rice or put it in sushi or miso soups. It is available in Japanese markets or health food stores frozen, freeze-dried, or fresh in straw bundles. Natto is eaten in many ways. *Natto* is mixed with cheese, soysauce and sugar. *Natto* can be mixed with minced chicken, and then stir-fried in sesame oil, ginger, and garlic. *Natto* is eaten with rice, curry, Chinese noodles, Japanese style pasta, and tempura. Many countries produce similar traditional soybean foods fermented with *Bacillus subtilis*, such as *shuǐdòuchǐ* of China, *cheonggukjang* of Korea, *thua nao* of Thailand, *kinema* of Nepal and the Himalayan regions of West Bengal and Sikkim, India.

Soy sauce or soya sauce (English), *jiang you, chiang yu, chǐyóu* (Chinese), *shoyu* (Japanese), *kang jang* (Korean) *kecap* (Indonesia, Malaysia), *tayo* (Philippines), is a condiment produced by fermenting soybeans and lower amounts of other grains with fungi like *Aspergillus oryzae* or *Aspergillus soyae*, along with water and salt. After the fermentation, which yields *moromi*, the *moromi* is pressed, and two substances are obtained: a liquid, which is the soy sauce, and a cake of wheat and soy residue, the latter being usually reused as animal feed. Soy sauce is a traditional savoury ingredient in Oriental cuisines. In more recent times, it is also being used in Western cooking and other parts of the world.

There are three main types of Chinese soy sauce:

– Light soy sauce (*shēngchōu*, *jiàng qing, pak yóu)* an opaque, lighter brown soy sauce. It is

the main soy sauce used for seasoning, since it is saltier, has less noticeable color, and also adds a distinct flavour. It is added to food during or after cooking. Two variants are commonly found, the first press like extra virgin oil called *touchōu* is of superior flavour and quality, and fetches a premium; and a double-fermented, delicate type called *shuānghuáng* that is used primarily as a dipping sauce.

– Dark and old soy sauce (*lǎochōu, hak yóu*), a darker and slightly thicker soy sauce that has been aged longer and contains added molasses to give its distinctive appearance. It is richer, slightly sweeter and less salty than light soy sauce. It adds colour and flavour to food and is usually added to food during the cooking process.
– Thick, caramelised soy sauce (*jiàngyóugāo*) a dark, flavorsome soy sauce that has been thickened with starch and sugar. It is occasionally flavored with mono sodium glutamate. It used to add colour to food, meat, noodles during cooking or as a dipping sauce.

Japanese soy sauce or *Shōyu* is traditionally divided into five main categories depending on differences in their ingredients and method of production. Most, but not all Japanese soy sauces have wheat as an ingredient, which tends to give them a slightly sweeter taste than Chinese soy sauce. *Shōyu* also possesses an alcoholic, sherry-like flavor, sometimes enhanced by the addition of small amounts of alcohol as a natural preservative.

Soy paste or soybean paste, *miso* (Japanese), *miso dou jiang, jiang, chiang* (Chinese), *tauco* (Indonesia, Malaysia) *tao si* (Philippines), is a thick paste made from soybeans and grains that has been fermented and then aged for up to 3 years. Miso is a staple in Japan, where it is used to flavour soups, dipping sauces, meats, and dressings. In Japan, there are hundreds of varieties of miso. The darker varieties are saltier and more pungent, the lighter ones are sweeter and milder. Miso is always added to soups and stews at the end, since boiling it destroys beneficial bacteria and causes it to curdle. Miso is available in liquid and powdered form.

Tempeh or tempe, *tian bei* (Chinese), *tempe* (Japanese) *tempeh, tempeh kedelai* (Indonesia), *tempeh* (Malaysia), (Plates 13 and 14) is a meat analogue or meat substitute of Indonesian origin. Tempeh is made from soybeans and other grains that have been inoculated with a starter mould, *Rhizopus oligosporus* and allowed to ferment. It is rich in protein and fibre with a chewy texture and salty, nutty and strong flavour. It is a staple protein source in Indonesia especially in the island of Java. Tempeh is usually simmered or steam briefly for around 20 minutes before using. It used like meat, marinated, grilled, cooked in stews, fried, or crumble into pieces and fried. There are many variants of tempeh, for example, *tempe bacem* – tempeh boiled with spices and palm sugar, and then fried briefly to enhance the taste; *tempe busok* – rotten tempeh used as flavouring; *tempe gembus* – made from okara; *tempe goreng* – fried tempeh (Plate 15); *tempe*

Plate 13 Tempe slab

Plate 14 Tempe slab sliced

Plate 15 Fried tempeh thins

Plate 16 Slabs of tempe onchom

mendoan – thinly sliced tempeh, battered and quickly deep fried; *tempe kering* – raw tempeh cut into little sticks, deep fried then mixed with spices and sugar, often mixed with separately fried peanuts and anchovies; and *tempe onchom*-orange coloured tempeh (Plate 16) fermented with the mould, *Neurospora sitophila*.

Botany

A coarse, bushy, annual, herb, 0.2–1.8 m tall, erect sometimes twinning at the apex, brownish or greyish pubescent (Plate 1). Leaves alternate, pinnately trifoliolate, borne on 2–20 cm long petioles, stipules broadly ovate, 3–7 mm long, acuminate (Plates 1 and 2). Leaflets on 1.5–4 mm petiolules, papery, broadly ovate, sub-orbicular, or elliptic-lanceolate, 5–12×2.5–8 cm, base broadly cuneate or rounded, apex acuminate or obtuse, mucronate; terminal leaflet larger, lateral leaflets smaller and obliquely ovate. Inflorescences terminal or axillary, usually five to eight flowered compact racemes, sometimes single-flowered or paired in lower axils. Flowers are small, bisexual, papilionaceous; calyx tubular with 2 upper and 3 lower lobes, setose, persistent; corolla, 4.5–10 mm, purple, pale purple, pink or white; standard obovate-suborbicular, base clawed, apex slightly emarginate; wings crenate, base narrow, with claws and auricles; keels obliquely obovate, with short claws; stamens 10 dialdephous; ovary hirsute; style curved with capitate stigma. Legume succulent, pendant, oblong, slightly curved, 3–15 cm by 1–1.5 cm, dehiscent, silky hairy (Plates 1 and 2). Seeds 2–5, ovoid to sub-globose, 1-×5–8 mm, seed coat smooth, yellow, green, brown or black or blotched and mottled, with distinct, elliptic hilum (Plate 5).

Nutritive/Medicinal Properties

Nutrition profile of soybean

As is evident from its nutrient profiles below soybean pods, seeds and sprouted seeds provide rich sources of high quality protein. Soybeans germinated for 2–3 days were found to be the most suitable for use as functional food materials (Huh et al. 2007). With the progression of germination period, crude protein content gradually increased to 30.19% on the 5th day of germination. However, crude fat content tended to decrease to14.30% on the 5th day of germination. Total amino acid content peaked on the 3rd day of germination at 80.875 mg%. Linoleic acid was highest among all the samples, ranging from 53.55% to 56.00%. The ability to inhibit platelet aggregation increased according to the germination period and then decreased again on the 5th day of germination. The alcohol dehydrogenase activity increased with increasing days of germination.

Soybean is one of only two known plant foods to contain all the essential amino acids, similar to those found in meat (the other plant food is amaranth seed, a wild green). The soybean is high in

fibre and protein, low in saturated fat, cholesterol-free, lactose-free, a good source of omega-3 fatty acids, vitamins especially vitamin E (tocopherols, well known antioxidants) and nutrients. It is also high in phytoestrogens especially isoflavones. Some soy food products provide rich sources of calcium and iron, such as Chinese tofu or tempeh (made with a calcium coagulant) and calcium fortified soy drinks. The nutritive composition of selected soy food products such as soybean cooking oil, soybean lecithin, soy flour, soy milk, soy sauce, shoyu soya sauce, tempeh and sufu (soybean curd cheese) are shown below.

Proximate nutrient composition of raw, green soybean pods (*Glycine max*) per 100 g edible portion was reported as: water 67.5 g, energy 147 kcal (614 kJ), protein 12.95 g, total lipid 6.80 g, ash 1.70 g, carbohydrate 11.05 g, total dietary fibre 4.2 g, Ca 197 mg, Fe 3.55 mg, Mg 65 mg, P 194 mg, K 620 mg, Na 15 mg, Zn 0.99 mg, Cu 0.128 mg, Mn 0.547 mg, Se 1.5 μg, vitamin C 29.0 mg, thiamine 0.435 mg, riboflavin 0.175 mg, niacin 1.650 mg, pantothenic acid 0.147 mg, vitamin B-6 0.065 mg, total folate 165 μg, choline 15.3 mg, vitamin A 9 μg RAE, vitamin A 180 IU, total saturated fatty acids 0.786 g, 14:0 (myristic) 0.006 g, 16:0 (palmitic) 0.570 g, 18:0 (stearic) 0.210 g, total monounsaturated fatty acids 1.284 g, 16:1 undifferentiated (palmitoleic) 0.011 g, 18:1 undifferentiated (oleic) 1.286 g, total polyunsaturated fatty acids 3.20 g, 18:2 undifferentiated (linoleic) 2.283 g, 18:3 undifferentiated (linolenic) 0.376 g, phytosterols 50 mg, tryptophan 0.157 g, threonine 0.516 g, isoleucine 0.570 g, leucine 0.926 g, lysine 0.775 g, methionine 0.157 g, cystine 0.118 g, phenylalanine 0.586 g, tyrosine 0.464 g, valine 0.576 g, arginine 1.042 g, histidine 0.348 g, alanine 0.582 g, aspartic acid 1.508 g, glutamic acid 2.433 g, glycine 0.539 g, proline 0.607 g and serine 0.721 g (USDA 2010).

Proximate nutrient composition of raw, mature soybean seeds (*Glycine max*) per 100 g edible portion was reported as: water 8.54 g, energy 446 kcal (1,866 kJ), protein 36.49 g, total lipid 19.94 g, ash 4.87 g, carbohydrate 30.16 g, total dietary fibre 9.3 g, total sugars 7.33, Ca 277 mg, Fe 15.7 mg, Mg 280 mg, P 704 mg, K 1,797 mg, Na 2 mg, Zn 4.89 mg, Cu 1.658 mg, Mn 2.517 mg, Se 17.8 μg, vitamin C 6 mg, thiamine 0.874 mg, riboflavin 0.870 mg, niacin 1.623 mg, pantothenic acid 0.793 mg, vitamin B-6 0.377 mg, total folate 375 μg, choline 115.9 mg, betaine 2.1 mg, vitamin A 1 μg RAE, vitamin A 22 IU, β-carotene 13 μg, vitamin E (α-tocopherol) 0.85 mg, vitamin K (phylloquinone) 47 μg, total saturated fatty acids 2.884 g, 14:0 (myristic) 0.055 g, 16:0 (palmitic) 2.116 g, 18:0 (stearic) 0.712 g, total monounsaturated fatty acids 4.404 g, 16:1 undifferentiated 0.055 g, 18:1 undifferentiated (oleic) 4.348 g, total polyunsaturated fatty acids 11.255 g, 18:2 undifferentiated (linoleic) 9.925 g, 18:3 undifferentiated (linolenic) 1.330 g, phytosterols 161 mg, tryptophan 0.591 g, threonine 1.766 g, isoleucine 1.971 g, leucine 3.309 g, lysine 2.706 g, methionine 0.547 g, cystine 0.655 g, phenylalanine 2.212 g, tyrosine 1.539 g, valine 2.029 g, arginine 3.135 g, histidine 1.097 g, alanine 1.915 g, aspartic acid 5.112 g, glutamic acid 7.874 g, glycine 1.880 g, proline 2.379 g and serine 2.357 g (USDA 2010).

Proximate nutrient composition of raw, sprouted soybean seeds (*Glycine max*) per 100 g edible portion was reported as: water 69.05 g, energy 122 kcal (510 kJ), protein 13.09 g, total lipid 6.70 g, ash 1.59 g, carbohydrate 9.57 g, total dietary fibre 1.1 g, Ca 67 mg, Fe 2.10 mg, Mg 72 mg, P 164 mg, K 484 mg, Na 14 mg, Zn 1.17 mg, Cu 0.427 mg, Mn 0.702 mg, Se 0.6 μg, vitamin C 15.3 mg, thiamine 0.340 mg, riboflavin 0.008 mg, niacin 1.148 mg, pantothenic acid 0.929 mg, vitamin B-6 0.176 mg, total folate 172 μg, vitamin A 1 μg RAE, vitamin A 11 IU, total saturated fatty acids 0.929 g, 14:0 (myristic) 0.007 g, 16:0 (palmitic) 0.674 g, 18:0 (stearic) 0.249 g, total monounsaturated fatty acids 1.518 g, 16:1 undifferentiated (palmitoleic) 0.013 g, 18:1 undifferentiated (oleic) 1.492 g, 20:1 (gadoleic) 0.013 g, total polyunsaturated fatty acids 3.783 g, 18:2 undifferentiated (linoleic) 3.338 g, 18:3 undifferentiated (linolenic) 0.445 g, tryptophan 0.159 g, threonine 0.503 g, isoleucine 0.580 g, leucine 0.938 g, lysine 0.752 g, methionine 0.138 g, cystine 0.157 g, phenylalanine 0.641 g, tyrosine 0.477 g, valine 0.620 g, arginine 0.905 g, histidine 0.348 g,

alanine 0.549 g, aspartic acid 1.774 g, glutamic acid 1.966 g, glycine 0.503 g, proline 0.674 g and serine 0.651 g (USDA 2010).

Soybean cooking oil was reported to contain the following nutrient composition per 100 g: energy 848 kcal (3,699 kJ), total lipid 100 g, Fe 0.05 mg, Zn 0.01 mg, choline 0.2 mg, vitamin E (α-tocopherol) 8.18 mg, β-tocopherol 0.9 mg, γ-tocopherol 64.26 mg, δ-tocopherol 21.30 mg, vitamin K (phylloquinone) 183.9 μg; total saturated fatty acids 15.650 g, 16:0 (palmitic) 10.455 g, 17:0 (margaric) 0.034 g, 18:0 (stearic) 4.435 g, 20:0 (arachidic) 0.361 g, 22:0 (behenic) 0.366 g; total monounstaurated fatty acids 22.783 g, 18:1c undifferentiated (oleic acid cis) 22.550 g, 20:1 (gadoleic) 0.233 g, total polyunsaturated fatty acids 57.740 g, 18:2 undifferentiated (linoleic) 50.952 g, 18:2 n-6 c,c (omega-6 linoleic acid) 50.418 g, 18:2 t,t 0.533 g, 18:3 undifferentiated (linolenic) 6.789 g, 18:3 n-3 c,c,c (α-linolenic, ALA, omega-3 linolenic acid) 6.789 g, total trans fatty acids, 0.533 g, stigmasterol 59 mg, campesterol 62 mg, β-sitosterol 172 mg, β-sitostanol 4.483 mg and δ-5avenasterol 8.733 g (USDA 2010).

Mohamed and Rangappa (1992) found that the mean oil content of 17 vegetable soybean was 18.44%, with a range of 15.65–23.36%. The lipoxygenase activity ranged from 829.8 units/min/mg meal to 4,750.4 units/min/mg meal, with a mean of 2,176.3 units/min/mg meal. β-Sitosterol (45.95%) was the major plant sterol present, followed by stigmasterol (16.48%), campesterol (16.06%) and dihydroxybrassicasterol (5.62%). Palmitic, oleic and linoleic acids comprised over 90% of the total fatty acids. The means of linoleic (53.34%) and linolenic acids (9.19%) were higher than that reported for the grain-type soybean. Overall, the high oil, linoleic, linolenic and sterol content of vegetable-type soybeans make them a food with high nutritional quality.

Soybean lecithin oil was reported to contain the following nutrient composition per 100 g: energy 763 kcal (3,197 kJ), total lipid 100 g, choline 350 mg, vitamin E (α-tocopherol) 8.18 mg, vitamin K (phylloquinone) 183.9 μg; total saturated fatty acids 15.005 g, 14:0 (myristic) 0.101 g, 16:0 (palmitic) 11.984 g, 18:0 (stearic) 2.920 g, total monounstaurated fatty acids 10.977 g, 16:1 (palmitoleic) 0.403 g, 18:1undifferentiated (oleic acid) 10.574 g, total polyunsaturated fatty acids 45.318 g, 18:2 undifferentiated (linoleic) 40.182 g, 18:3 undifferentiated (linolenic) 5.136 g (USDA 2010). Duke (1983) reported soybean lecithin to contain 11.7% palmitic acid, 4.0 stearic, 8.6 palmitic, 9.8% oleic, 55.0 linoleic, 4.0 linolenic, and 5.5% C20 to C22 acids (including arachidonic). A globulin, glycinine, accounts for 80–90% of the total nitrogen protein of the seed. Glycinine contains 1.1% cystine, 1.8 methionine, 5.4 lysine, 1.7 tryptopbane, 2.1 threonine, 9.2 leucine, 2.4 isoleucine, 4.3 phenylalanine, 3.9 tyrosine, 2.2 histidine, 1.6 valine, 8.3 arginine, 0.7 glycine, 1.7 alanine, 5.7 aspartic acid, 19.0 glutamic acid, and 4.3% proline.

Full fat, raw soy flour was reported to have the following nutrient composition per 100 g edible portion: water 5.16 g, energy 436 kcal (1,824 kJ), protein 34.54 g, total lipid 20.65 g, ash 4.46 g, carbohydrate 35.19 g, dietary fibre 9.6 g, total sugars 7.50 g, Ca 206 mg, Fe 6.37 mg, Mg 429 mg, P 494 mg, K 2,515 mg, Na 13 mg, Zn 3.92 mg, Cu 2.920 mg, Mn 2.275 mg, Se 7.5 μg, thiamine 0.581 mg, riboflavin 1.160 mg, niacin 4.320 mg, pantothenic acid 1.590 mg, vitamin B-6 0.461 mg, total folate 345 μg, total choline 190.6 mg, β-carotene 72 μg, vitamin A 120 IU, vitamin E (α-tocopherol) 1.95 mg, vitamin K (phylloquinone) 70 μg, total saturated fatty acids 2.987 g, 14:0 (myristic) 0.057 g, 16:0 (palmitic) 2.192 g, 18:0 (stearic) 0.737 g, total monounsaturated fatty acids 4.561 g, 16:1(palmitoleic) 0.057 g, 18:1 undifferentiated (oleic) 24.507 g, total polyunsaturated fatty acids 11.657 g, 18:2 undifferentiated (linoleic) 10.280 g, 18:3 undifferentiated (linolenic) 1.378 g, tryptophan 0.502 g, threonine 1.500 g, isoleucine 1.675 g, leucine 2.812 g, lysine 2.298 g, methionine 0.466 g, cystine 0.556 g, phenylalanine 1.802 g, tyrosine 1.306 g, valine 1.724 g, arginine 2.679 g, histidine 0.931 g, alanine 1.627 g, aspartic acid 4.342 g, glutamic acid 6.689 g, glycine 1.597 g, proline 2.020 g and serine 2.002 g (USDA 2010).

Nutrient Profile of Soymilk

Proximate nutrient composition of soymilk per 100 g edible portion was reported as: water 93.18 g, energy 33 kcal (138 kJ), protein 2.88 g, total lipid 1.65 g, ash 0.64 g, carbohydrate 1.65 g, dietary fibre 0.4 g, total sugars 0.41 g, Ca 123 mg, Fe 0.44 mg, Mg 16 mg, K 123 mg, Na 35 mg, Zn 0.25 mg, Se 2.3 μg, riboflavin 0.210 mg, niacin 2.640 mg, total folate 10 μg, vitamin B-12 1.23 μg, vitamin A 206 IU and total saturated fatty acids 0.206 g (USDA 2010).

Nutrient Profile of Soy Sauce (Tamari)

Proximate nutrient composition of soy sauce (Tamari) per 100 g edible portion was reported as: water 66 g, energy 60 kcal (251 kJ), protein 10.51 g, total lipid 0.1 g, ash 17.82 g, carbohydrate 5.57 g, dietary fibre 0.8 g, total sugars 1.70 g, Ca 20 mg, Fe 2.38 mg, Mg 40 mg, P 130 mg, K 212 mg, Na 5,586 mg, Zn 0.43 mg, Cu 0.135 mg, Mn 0.499 mg, Se 0.8 μg, thiamine 0.059 mg, riboflavin 0.152 mg, niacin 3.951 mg, pantothenic acid 0.376 mg, vitamin B-6 0.200 mg, total folate 18 μg, total choline 38.4 mg, total saturated fatty acids 0.011 g, 16:0 (palmitic) 0.008 g, 18:0 (stearic) 0.003 g, total monounsaturated fatty acids 0.017 g, 18:1 undifferentiated (oleic) 0.017 g, total polyunsaturated fatty acids 0.044 g, 18:2 undifferentiated (linoleic) 0.039 g, 18:3 undifferentiated (linolenic) 0.005 g, tryptophan 0.181 g, threonine 0.407 g, isoleucine 0.487 g, leucine 0. 735 g, lysine 0.731 g, methionine 0.167 g, cystine 0.107 g, phenylalanine 0.534 g, tyrosine 0.342 g, valine 0.524 g, arginine 0.405 g, histidine 0.215 g, alanine 0.536 g, aspartic acid 0.882 g, glutamic acid 2.411 g, glycine 0.435 g, proline 0.806 g and serine 0.483 g (USDA 2010).

Nutrient Profile of Shoyu Soy Sauce (Soy and Wheat)

Proximate nutrient composition of shoyu soy sauce (made from soyabean and wheat) per 100 g edible portion was reported as: water 70.77 g, energy 53 kcal (221 kJ), protein 6.28 g, total lipid 0.04 g, ash 15.31 g, carbohydrate 7.61 g, dietary fibre 0.8 g, total sugars 1.70 g, Ca 19 mg, Fe 1.93 mg, Mg 43 mg, P 125 mg, K 217 mg, Na 5,637 mg, Zn 0.52 mg, Cu 0.104 mg, Mn 0.424 mg, Se 0.5 μg, thiamine 0.033 mg, riboflavin 0.165 mg, niacin 2.916 mg, pantothenic acid 0.297 mg, vitamin B-6 0.148 mg, total folate 14 μg, total choline 18.3 mg, betaine 29.8 mg, total saturated fatty acids 0.005 g, 16:0 (palmitic) 0.004 g, 18:0 (stearic) 0.001 g, total monounsaturated fatty acids 0.006 g, 18:1 undifferentiated (oleic) 0.006 g, total polyunsaturated fatty acids 0.019 g, 18:2 undifferentiated (linoleic) 0.016 g, 18:3 undifferentiated (linolenic) 0.002 g, tryptophan 0.090 g, threonine 0.254 g, isoleucine 0.297 g, leucine 0. 503 g, lysine 0.357 g, methionine 0.091 g, cystine 0.110 g, phenylalanine 0.330 g, tyrosine 0.228 g, valine 0.311 g, arginine 0.433 g, histidine 0.163 g, alanine 0.276 g, aspartic acid 0.674 g, glutamic acid 1,479 g, glycine 0.278 g, proline 0.461 g and serine 0.363 g (USDA 2010).

Nutrient Profile of Tempeh

Proximate nutrient composition of tempeh per 100 g edible portion was reported as: water 56.65 g, energy 193 kcal (807 kJ), protein 18.55 g, total lipid 10.80 g, ash 1.62 g, carbohydrate 9.39 g, Ca 111 mg, Fe 2.70 mg, Mg 81 mg, P 266 mg, K 412 mg, Na 9 mg, Zn 1.14 mg, Cu 0.560 mg, Mn 0.702 mg, thiamine 0.078 mg, riboflavin 0.358 mg, niacin 2.640 mg, pantothenic acid 0.278 mg, total folate 24 μg, vitamin B-12 0.08 μg, total saturated fatty acids 2.220 g, 14:0 (myristic) 0.020 g, 16:0 (palmitic) 1.50 g, 17:0 (margaric) 0.030 g, 18:0 (stearic) 0.60 g, total monounsaturated fatty acids 3.000 g, 17:1 (heptadecenoic) 0.050 g, 18:1 undifferentiated (oleic) 2.750 g, 20:1 (gadoleic) 0.040 g, total polyunsaturated fatty acids 3.827 g, 18:2 undifferentiated (linoleic) 3.591 g, 18:3 undifferentiated (linolenic) 0.220 g, tryptophan 0.194 g, threonine 0.796 g, isoleucine 0.880 g, leucine 1.430 g, lysine 0.908 g, methionine 0.175 g, cystine 0.193 g, phenylalanine 0.893 g, tyrosine

0.664 g, valine 0.920 g, arginine 1.252 g, histidine 0.466 g, alanine 0.960 g, aspartic acid 1.995 g, glutamic acid 3.292 g, glycine 0.754 g, proline 1.030 g and serine 1.019 g (USDA 2010).

Nutrient Profile of Soybean Curd Cheese (Sufu)

Proximate nutrient composition of soybean curd cheese (sufu) per 100 g edible portion was reported as: water 70.9 g, energy 151 kcal (630 kJ), protein 12.50 g, total lipid 8.10 g, ash 1.60 g, carbohydrate 6.90 g, total sugars 1.60 g, Ca 188 mg, Fe 5.60 mg, Mg 228 mg, P 222 mg, K 199 mg, Na 20 mg, Zn 1.72 mg, Cu 0.380 mg, Mn 0.889 mg, Se 16.8 μg, riboflavin 0.140 mg, niacin 0.500 mg, pantothenic acid 0.116 mg, vitamin B-6 0.070 mg, total folate 22 μg, total choline 62.5 mg, vitamin A (RAE) 2 μg, β-carotene 25 μg, vitamin E (α-tocopherol) 0.60 mg, vitamin K (phylloquinone) 4.6 μg, total saturated fatty acids 1.172 g, 14:0 (myristic) 0.022 g, 16:0 (palmitic) 0.860 g, 18:0 (stearic) 0.289 g, total monounsaturated fatty acids 1.789 g, 16:1 (palmitoleic) 0.022 g, 18:1 undifferentiated (oleic) 1.766 g, total polyunsaturated fatty acids 4.572 g, 18:2 undifferentiated (linoleic) 4.032 g and 18:3 undifferentiated (linolenic) 0.540 g (USDA 2010).

At different stages of sufu preparation, the total amino acid in tofu, *pehtze* and salted *pehtze* amounted to 547, 551 and 351 mg/g dry matter, respectively (Han et al. 2004). Free amino acids (FAA) increased from total 1.3–15.6 mg/g DM in pehtze after fermentation of tofu by *Actinomucor elegans* and to 11.9 mg/g DM in salted *pehtze*. During ripening up to 80 days, total FAA in red sufu increased from 28 to 88 mg/g (8% salt), 28–63 mg/g (11% salt) or 26–42 mg/g (14% salt). In white sufu, the levels of FAA were generally higher and the effect of salt was less inhibitory. Levels of FAA in white sufu increased in 80 days from 33 to 104 mg/g (8% salt), 27–92 mg/g (11% salt) and 19–73 mg/g (14% salt). The pattern of essential amino acids compared favourably with those of eggs and cow's milk. While FAA increased during ripening of red and white sufu, the ratio of each amino acid remained essentially constant, and glutamic acid, leucine, aspartic acid, alanine, phenylalanine and lysine were found in large quantities. However, in grey sufu the ratio was different, with large proportions of leucine, alanine, isoleucine, valine and phenylalanine found after ripening. The amino acid profile of red sufu (g/100 g sufu) was reported by Wang (1995) as follows: alanine 0.32 g, arginine 0.38 g, aspartic acid 1 g, cystine 0.59 g, glutamic acid 2.15 g, glycine 0.54 g, histidine 0.20 g, isoleucine 0.88 g, leucine 0.81 g, lysine 0.59 g, methionine 0.51 g, phenylalanine 0.59 g, proline 0.38 g, serine 0.34 g, threonine 0.45 g, tryptophan 0.09 g, tyrosine 0.54 g and valine 0.16 g. The main acid content of grey sufu g/100 g sufu was reported as: alanine 0.70 g, arginine 0.27 g, aspartic acid 0.66 g, cystine 0.20 g, glutamic acid 2.08 g, glycine 0.42 g, histidine 0.18 g, isoleucine 0.58 g, leucine 0.95 g, lysine 0.29 g, methionine 0.14 g, phenylalanine 0.59 g, proline 0.29 g, serine 0.27 g, threonine 0.23 g, tryptophan 0.05 g, tyrosine 0.25 g and valine 0.58 g (Wang 1995).

Other Phytochemicals in Soy Bean/Soy Products

A total of 111 volatile compounds were found in fermented soybean curds (Chung 1999). Major classes of compounds included alcohols (32) and esters (25). Twelve common compounds including six esters, four alcohols, one ketone, and one miscellaneous compound had a dry weight of >1,000 μg/kg of sample. The quantity of ethanol detected might produce large numbers of ethyl esters that contribute to the desirable fruity and floral notes for the final products. A total of 83 volatile compounds were found in commercial plain sufu (Chung et al. 2005). Alcohols (17), acids (15), and esters (16) were the major classes. The rest of the classes were miscellaneous compounds (9), aldehydes (7), alkanes (5), aromatic compounds (5), ketones (3), furans (2), S-containing compounds (2), and other N-containing compounds (2). Acetic acid, methional, ethyl (Z,Z)-9,12-octadecadienoate,

ethyl (Z)-9-ocatadecenoate, and 3-methylbutanoic acid were some of the potent odorants found. Hwang and Chou (1999) identified a total of 61 volatile compounds including 22 esters, 18 alcohols, 7 ketones, 3 aldehydes, 2 pyrazines, 2 phenols and 7 other compounds from the 75-day aged sufu products preared using *Actinomucor taiwanensis*. Quantitatively and qualitatively, less volatile components were found in Sufu ageing without ethanol than those ageing with ethanol. A significantly higher amount of ester was observed in sufu aged with ethanol than those aged without ethanol.

Soybean and soy food products are rich sources of bioactive isoflavones. The isoflavones in non-fermented soy foods are for the most part in the form of glycoside conjugates (Barnes 2010). Isoflavones and their metabolites are well absorbed and undergo an enterohepatic circulation. They are also termed phytoestrogens because they bind to the estrogen receptors although weakly compared to physiologic estrogens. This estrogenicity is not the only mechanism by which isoflavones may have bioactivity – they inhibit tyrosine kinases, have antioxidant activity, bind to and activate peroxisome proliferator regulators alpha and gamma, inhibit enzymes in steroid biosynthesis, strongly influence natural killer cell function and the activation of specific T-cell subsets, and inhibit metastasis.

A total 16 isoflavones, including three aglycones, three glycosides, two glycoside acetates, and eight glycoside malonates were identified in 30 varieties of Edamame and tofu soybeans (Wu et al. 2004c). The main isoflavones in soybean seeds were daidzein and genistein glycoside and their malonate conjugates. Trace levels of daidzein and genistein acetyl glycosides were found only in the mature dry soybean seeds. Total isoflavones ranged from 0.02% to 0.12% across Edamame varieties, harvested while the seeds were still immature, and from 0.16% to 0.25% in tofu varieties, harvested when the seeds were physiologically mature. Isoflavone aglycons and glycosides (genistin, genistein, daidzein, daidzin, glycitin, glycitein, ononin, formononetin, sissotrin, and biochanin A) were determined in roots, stems, leaves, and soy pods in soybeans of five Czech varieties (Kledjus et al. 2005). The absolute limits of detection per sample injection (5 μL) were the highest for biochanin A (166.2 fmol) and the lowest for genistin (17.0 fmol). The recoveries of 96–106% were obtained for the different concentrations of the isoflavone aglycons and glycosides. The highest isoflavone concentrations were found in roots (12.5 μg/g dry weight), while the amounts were about 3–1,100 μg/g fresh weight in different varieties of soybeans. Quantitative differences were found in total isoflavones and phenolic compounds among Korean soybean cultivars with different seed weight and grown at different sites (Lee et al. 2008). The relationship of total isoflavones and phenolic compounds of small and medium soybean seeds were significantly higher than that of large soybean seeds. The hydroxybenzoic acid group in all sizes of seeds cultivated at six sites in Korea was the major phenolic compound , followed by flavonoid and hydroxycinnamic acid. In small seeded cultivars at Yeoncheon, the total isoflavone concentration was positively correlated with acetylglycoside and negatively correlated with malonylglycoside. In medium and large seeded soybeans cultivated at Yeoncheon, a significantly positive correlation was observed between acetylglycoside and glycoside, between aglycone and glycoside, and between aglycone and acetylglycoside, whereas a significantly negative correlation was found between malonylglycoside and glycoside, between acetylglycoside and malonylglycoside, and between aglycone and malonylglycoside. In large soybean seeds cultivated at Chuncheon, significantly positive and negative correlations were similar to those of medium seeds.

The phenolic acid derivatives genistein, daidzein, and coumestrol were identified for the first time in unhydrolyzed soybean root extracts (Porter et al. 1985). The total isoflavone concentration in Serbian soybean cultivars was found to be between 2.24 and 3.79 mg/g dry bean weight (Cvejić et al. 2009). The total concentration of daidzein and its derivatives varied from 0.96 to 1.82 mg/g, total glyciteines from 0.34 to 0.53 mg/g, and all genistein derivatives from 0.86 to 1.67 mg/g dry bean weight. Values of genistein

and genistin in soybeans, soy nuts and soy powder were found to be in the range of 4.6–18.2 and 200.6–968.1 μg/g food, respectively (Fukutake et al. 1996). The levels for soy milk and tofu (bean curd) were 1.9–13.9 and 94.8–137.7 μg/g food, respectively. Contents of isoflavones in fermented soybean products – *miso* (fermented soybean paste) and *natto* (fermented soybeans), were 38.5–229.1 μg/g food for genistein and 71.7–492.8 μg/g food for genistin. Thus, the level of genistein in the fermented soybean products was higher than in soy beans and soybean products such as soy milk and tofu. Soy sauce was also found to contain both isoflavones, but at levels lower than in *miso* and *natto*. Japanese daily intake of genistein and genistin was estimated to be 1.5–4.1 and 6.3–8.3 mg/person, respectively. These levels were much higher than those for Americans or Europeans, whose mortality rates for breast, colon and prostate cancers were greater than the Japanese. Nakamura et al. (2000) studied the contents of 6 isoflavonoids in 11 domestic and imported soybeans, and 12 kinds of soybean-based processed foods in Japan and the Japanese daily intake of isoflavonoids from those foods. The total isoflavonoids (daidzein, glycitein, and genistein) were examined with acid hydrolysis and the intact isoflavonoids (daidzein, glycitein, genistein, daidzin, glycitin, and genistin) were studied without hydrolysis. *Kinako* (a roasted soybean powder) had the highest concentration of isoflavonoids and soy sauce the lowest. The contents and composition of the isoflavonoids in the 11 soybeans differed according to species and country of origin. The manufacturing methods or ingredients were found to influence the level of isoflavonoids found in the processed foods. The level of aglycone tended to be higher in *miso* and soy sauce, which were heated and fermented during the manufacturing process. Daily intake of isoflavonoids from soybeans and soybean-based processed foods by Japanese was estimated as 27.80 mg/day (daidzein 12.02 mg, glycitein 2.30 mg, and genistein 13.48 mg).

The isoflavone aglycon and glucoconjugate content of commercially prepared and "home-prepared" high- and low-soy foods were compared (Wiseman et al. 2002). Soybeans (774 mg/kg total isoflavones) and soybean-containing foods had the highest isoflavone concentration of the foods examined. The low-soy foods contained very low contents (<8 mg/kg total isoflavones) of the isoflavone aglycons and glucoconjugates. The levels of daidzin, daidzein, 6″-O-malonyldaidzin, 6″-O-acetyldaidzin, genistein, genistin, 6″-O-malonylgenistin, 6″-O-acetylgenistin, glycitin, glycitein, 6″-O-malonylglycitin, and 6″-O-acetylglycitin were also determined. High- and low-soy 11 day rotating menus were developed from the analyzed foods to provide 100.0 and 0.5 mg of isoflavones per day, respectively.

Thermal processing of tofu was found to affect the profile of genistein, daidzein, genistin, daidzin, and their acetyl- and malonyl-β-glycosides (Grün et al. 2001). Total isoflavone content decreased, most probably attributed to leaching of isoflavones into the water. The decrease in the total isoflavone content was almost exclusively due to a decrease of the daidzein series as the level of the genistein series was little affected by the treatments. Strongly temperature dependent decreases of the aglycon suggested possible thermal degradation of daidzein in addition to losses due to leaching. Appreciable amounts of soybean isoflavones were lost in the whey during conventional tofu manufacturing (Wu et al. 2004b). They found that pre-treatment of soy milk with koji enzyme extract could enhance tofu isoflavone recovery. Soy milk daidzein and genistein contents increased while daidzin and genistin contents declined as the time of enzyme pretreatment of the soy milk increased. After 30 min of pretreatment, daidzin, genistin, daidzein, and genistein contents recovered in tofu products were higher than those of the control. The total recoveries of daidzin, genistin, daidzein, and genistein in the tofu products increased from 54.9% to 64.2%. Profile of isolaflavones in tofu was also influenced by the water-to-bean ratio (Kao et al. 2004). The content of extracted daidzin and genistin in soy milk increased with increasing water-to-bean ratios from 5 to 9 and attained the maximum concentration at the ratios of 9–11. In contrast, the concentration of extracted free isoflavones (daidzein and genistein) was not

affected by the water-to-bean ratio at the range of 5–11, and their extracted amounts in soy milk were 2-4-fold those in raw soybean. Free isoflavones were found to be primarily derived from daidzin, genistin, malonyldaidzin, and malonylgenistin through enzymatic hydrolysis during the making of soy milk. Tofu made with water-to-bean ratios of 9:1 and 10:1 had the maximal retentions of daidzin and genistin. The retained amount of free isoflavones declined significantly as the water-to-bean ratio increased from 7 to 11, due to their weakening hydrophobic interaction with protein.

Soyasaponins are a group of nutraceutical oleanane triterpenoids found in soybean and other legumes that have been associated with some of the health benefits achieved by consuming plant-based diets (Zhang et al. 2009a). Bioactive soyasaponins were isolated in relatively pure forms (>80%) from soybean (soyflour) and a commercial preparation (Gurfinkel et al. 2005). Acetylated group A soyasaponins were isolated. Partial hydrolysis of group B soyasaponins produced a mixture of soyasaponin III and soyasapogenol B monoglucuronide. RP-LPLC of deacetylated group A soyasaponins separated soyasaponin A1 and A2 (38% methanol); of group B soyasaponins isolated soyasaponin I (50% ethanol); and of the partial hydrolysate separated soyasaponin III from soyasapogenol B monoglucuronide (50% ethanol). Zhang et al. (2009b) developed a method that maximized recovery of DDMP (2,3-dihydro-2,5-dihydroxy-6-methyl-4H-pyran-4-one)-conjugated saponins and generated an extract containing primarily soyasaponins I and III. Alkaline hydrolysis in anhydrous methanol generated the maximum amount of soyasaponins I and III as compared to aqueous methanol and acid hydrolysis in both aqueous and anhydrous methanol. The soyasaponin I content was enhanced by 175%, and soyasaponin III enhanced by 211% after alkaline hydrolysis. Further, after alkaline hydrolysis, a majority of DDMP-conjugated group B soyasaponins such as betag, betaa, gammag, and gammaa transformed into the non-DDMP-conjugated soyasaponins I and III. Soyasaponin Bh, a triterpene saponin containing a unique hemiacetal-functional five-membered ring was isolated from soybean (Ali et al. 2009). Soysaponin I showed a weak estrogenic effect in the yeast estrogen screen (YES) assay.

Non-digestible carbohydrate fraction (NDCF) comprised of a variety of bioactive compounds that escape digestion in the small intestine. Non-digestible carbohydrate fraction of soybean was mainly composed of dietary fibre and non-digestible oligosaccharides (Jiménez-Escrig et al. 2010). Brazilian soybean cultivars were found to have an average NDCF value of 32.80 g per 100 g dry weight. Insoluble dietary fibre was the major fraction of dietary fibre, amounting to 98% average. Uronic acids were significantly higher than neutral sugar in insoluble dietary fibre and soluble dietary fibre fractions. There was a large amount of Klason lignin (84.14%) of dietary fibre. Mannose was the major neutral sugar in soluble dietary fibre, while galactose and arabinose were predominant in insoluble dietary fibre and stachyose in non-digestible oligosaccharides. Dietary fibre and non-digestible oligosaccharides were in the same proportion (94.2:5.8) in tested cultivars.

A new triterpene alcohol, bacchara-12,21-dien-3β-ol was isolated from the unsaponifiable lipid of soybean oil from soybean seeds (Akihisa et al. 1994).

Health Benefits of Soybean, Isoflavones and Other Phytochemicals

Soybeans contain all of the essential amino acids necessary for human nutrition and other bioactive nutraceuticals and have been consumed since antiquity. A plethora of scientific publications have been published on the phytochemicals, pharmacological properties and associated health issues on soybean and soy foods. This chapter captures only a fraction of the voluminous studies conducted, endeavouring to highlight the salient and important pharmacological activities of the bioactive constituents of soybean with selected up-to-date published information. A profusion of published work has been focused on bioactive nutraceuticals like soy isoflavones and

their associated pharmacological properties (Barnes et al. 2010; Miyazawa et al. 1999; Suthar et al. 2001; Doerge and Sheehan 2002; Wu et al. 2004a, b, c; Jenkins et al 2000a, b, 2002; 2003a, b; Messina 2010). Comparatively less publications have been focused on other bioactive soy phytochemicals that include soyasaponins (Gurfinkel et al. 2005; Ali et al. 2009; Zhang et al. 2009b; Tsai et al. 2010a, b; Zhang and Popovich 2010); glyceollins (Salvo et al. 2006; Burow et al. 2001; Zimmermann et al. 2010; Payton-Stewart et al. 2010); lunasin and lunasin-like peptides (de Mejia and Dia 2009; Hsieh et al. 2010); Bowman Birk Inhibitors (Marín-Manzano et al. 2009; Hsieh et al. 2010; Anta et al. 2010); anthocyanins and procyanidin (Takahata et al. 2001; Xu and Chang 2008a; Nizamutdinova et al. 2009; Slavin et al. 2009), antimicrobial soybean toxin (Morais et al. 2010) and anti-nutritional components such as soy glycinin and β-conglycinin (Liu et al. 2008; Krishnan et al. 2009); lysinoalanine (Struthers 1981; Friedman et al. 1984); trypsin and chymotrypsin inhibitors (Liener 1994; Yuan et al. 2008; Ho and Ng 2008; Ye and Ng 2009; Fang et al. 2010a, b; Ribeiro et al. 2010); lectins (Bardocz et al. 1996; Lajolo and Genovese 2002; Czerwinski et al. 2005; Lin et al. 2008); oligosaccharides and galacto-oligosaccharides (Choct 1997; Bouhnik et al. 2004; Espinosa-Martos and Rupérez 2006; Macfarlane et al. 2008; Jiménez-Escrig et al. 2010; Kumar et al 2010).

The reported pharmacological properties of soy and its phytochemicals include antioxidant, estrogenic, antidiabetic, antihypercholesterolemic, antihyperlipidemic, antiobesity, antihypertensive, anticancer, antimutagenic, hepatoprotective, antiosteoporotic, antiviral, bifidogenic, antiinflammatory, immunomodulatory, neuroprotective, wound healing, antimicrobial, goitrogenic anti-skin aging, anti-photoaging activity and the effects of antinutritional factors. To a large extent, these pharmacological attributes of soybean are attributable to the presence of isoflavones in soya bean (Messina 2010). Accumulating evidence from molecular and cellular biology experiments, animal studies, and, to a limited extent, human clinical trials have reported on the potential beneficial health effects of isoflavones in various types of diseases such as osteoporosis, cardiovascular diseases, menopausal symptoms, and various types of cancer. More dynamic research is warranted before some of these health benefits of soybean are conclusively established. The health benefits of soya are not without controversy. The review in 2006 undertaken by the American Heart Association (AHA) found that earlier research indicating that soy protein, as compared with other proteins, has clinically important favourable effects on LDL cholesterol and other cardiovascular disease (CVD) risk factors has not been confirmed by innumerable research reported during the past decade (Sacks et al. 2006). The review panel also found that soy isoflavones had not been shown to reduce post menopause "hot flashes" in women and results were mixed with regard to soy's ability to slow postmenopausal bone loss. The efficacy and safety of isoflavones to help prevent or treat cancers of the breast, endometrium or prostate was also controversial. However, the review asserted that, "soy products such as tofu, soy butter, soy nuts, or some soy burgers should be beneficial to cardiovascular and overall health because of their high content of polyunsaturated fats, fibre, vitamins, and minerals and low content of saturated fat. Using these and other soy foods to replace foods high in animal protein that contain saturated fat and cholesterol may confer benefits to cardiovascular health. Soy protein also may be used to increase total dietary protein intake and to reduce carbohydrate or fat intake". These pharmacological properties of soybean and soy food foods and associated health benefits are elaborated below.

Antioxidant Activity

The total phenolic content (TPC), isoflavone content and antioxidant activities in Virginia soybeans were varied significantly among different genotypes (Chung et al. 2008). The V01-4937, V03-1144, and MFS-511 soybeans exhibited the highest TPC values of 3.89, 3.63, and 3.53 mg of gallic acid equivalent/g of seeds, respectively. Malonylgenistin was the major isoflavone in all

soybean seeds, accounting for 75–83% of the total measured isoflavones. The V01-4937 variety had the highest total isoflavones and malonylgenistin concentration followed by V03-5794. V01-4937 and Teejay exhibited the strongest ORAC (oxygen radical absorbance capacity) values, which were 70% higher than that of the V00-3493 soybean, which had the lowest ORAC value (115.7 μmol of Trolox equivalent/g of seeds). The MFS-511, V01-4937, and Teejay soybeans exhibited the highest DPPH (2-diphenyl-1-picryhydrazyl) radical scavenging activities of 4.94, 4.78, and 4.64 μmol of Trolox equivalent/g of seeds. Of all cultivars, V01-4937 soybean, was the best with highest TPC, ORAC value, and isoflavone content as well as the second highest DPPH scavenging activity. The highest and lowest total isoflavone contents of Ohio soybeans were 11.75 and 4.20 μmol/g soy, respectively, with a mean of 7.12 μmol/g soy (Lee et al. 2004). Antioxidant activities of soybean extracts ranged from 7.51 to 12.18 μmol butylated hydroxytoluene (BHT) equivalent/g soy using the DPPH method. Lipid and water soluble antioxidant activities of soybean extracts ranged from 2.40 to 4.44 μmol Trolox equivalent/g soy and from 174.24 to 430.86 μmol ascorbic acid equivalent/g soy, respectively, using the photochemiluminescence method. The range of total isoflavones was 558.2–1,048.6 μg/g of soy in Indian cultivars, and it was 627.9–1,716.9 μg/g of soy in the case of Bulgarian cultivars (Sakthivelu et al. 2008). DPPH radical scavenging activity did not differ significantly among the cultivars and did not correlate with total isoflavones, whereas total phenolic compounds correlated well with total isoflavones and weakly with DPPH. Malonylglucoside of all the aglycones, total genistein and total daidzein exhibited strong correlation with total isoflavones, whereas acetylglucoside and aglycone levels did not significantly correlate with total isoflavone. Soy isoflavones were found to markedly protect ECV304 endothelial cells in-vitro against hydrogen peroxide damage and to stimulate nitric oxide (NO) synthesis (Paulo et al. 2009). The data indicated that these isoflavones could potentially act as an NO promoter and as an antioxidant.

Takahata et al. (2001) found seed coats of brown soybean cv. Akita-Zairai and black soybean to have high DPPH radical-scavenging attributable to their high content of polymerized procyanidin. The extract from black soybean had a longer LDL oxidation lag time than that from yellow soybean (Takahashi et al. 2005). When divided into the seed coat and the mixture of the germ and cotyledon, the diluted extract solution from the black soybean seed coat prolonged the lag time significantly more than the original extract of the yellow soybean seed coat. In contrast, antioxidant effects of the extract from the mixture of germs and cotyledons were similar in both black and yellow soybeans. The seed coat of black soybean had higher polyphenol content than that of yellow soybean (29.0 and 0.45 mg/g, respectively). The mixture of the germ and cotyledon hydrolysed by β-glucosidase in both soybeans displayed a stronger inhibitory effect on low density lipoprotein (LDL) oxidation than that before being hydrolysed by β-glucosidase. The results suggested that black soybeans may be more effective in inhibiting LDL oxidation than yellow soybeans because of total polyphenols contents in its seed coat. Further, aglycones, abundant in soybeans fermented or hydrolysed by β-glucosidase, may play a crucial role in the prevention of oxidation-related diseases. Xu and Chang (2008b) found that black soybean cultivars grown in the North Dakota-Minnesota region possessed significantly higher total phenolic content (TPC), total flavonoids content (TFC), 2-diphenyl-1-picryhydrazyl free radical scavenging activity (DPPH), ferric reducing antioxidant power (FRAP), and oxygen radical absorbance capacity (ORAC) values than all yellow soybean cultivars. However, black soybean cultivars did not show significantly higher individual phenolic contents (except for anthocyanins), such as phenolic acids and isoflavones, than the yellow soybean cultivars. Correlation assays revealed that TPC, total isoflavones, total phenolic acids, daidzin, genistin, malonyldaidzin, daidzein, genistein, and trans-cinnamic acid significantly correlated with ORAC values of yellow soybeans. Both isoflavones and phenolic acids contributed to the ORAC values of yellow soybeans. In another

study, Xu and Chang, (2008a) found the seed coat to have much higher total phenolic indexes and antioxidant activities than whole and dehulled black soybean. Dehulled black soybean exhibited similar levels of total phenolic content, total flavonoid content, 2-diphenyl-1-picryhydrazyl (DPPH) radical scavenging activity, ferric reducing antioxidant power (FRAP), and oxygen radical absorbance capacity (ORAC) activities as compared to whole yellow soybean. Cyanidin-3-glucoside, petunidin-3-glucoside, and peonidin-3-glucoside were found in the seed coat but not in dehulled black soybean and yellow soybean. Among benzoic acid detected, caffeic and chlorogenic acid were the predominant phenolic acids. Whole black soybean and dehulled black soybean exhibited similar isoflavone contents in 7-O-β-glucosides and malonylglucosides of daidzein and genistein. The seed coat possessed significantly lower 7-O-β-glucosides and malonylglucosides of daidzein and genistein, acetylglycitin, and total isoflavones than whole and dehulled black soybean. When measured with the DPPH and FRAP methods, the seed coat contributed 90% of the total antioxidant capacity of black soybean. However, when measured with the ORAC method, the seed coat and dehulled portion contributed approximately equally the total antioxidant capacity of black soybeans. The information generated from this study on the distribution and content of their active components is useful for the effective use of black soybeans as an ingredient for promoting health. Slavin et al. (2009) found that black seed coat soybeans had the highest total phenolic content (TPC), oxygen radical absorbance capacity (ORAC), hydroxyl radical scavenging capacity (HOSC), and 2, 2′-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid) (ABTS) radical scavenging values, in addition to the highest isoflavone content, and were the only colour to contain cyanidin-3-glucosid.

As compared to the raw soybeans, all thermal processing methods elicited significant declines in total phenolic content (TPC), total flavonoid content (TFC), condensed tannin content (CTC), monomeric anthocyanin content (MAC), DPPH free radical scavenging activity (DPPH), ferric reducing antioxidant power (FRAP), and oxygen radical absorbing capacity (ORAC) in black soybeans (Xu and Chang 2008c). Pressure steaming produced significant increases in TPC, CTC, DPPH, FRAP, and ORAC in yellow soybeans. Steaming caused a greater retention of TPC, DPPH, FRAP, and ORAC values in both yellow and black soybeans as compared to the boiling treatments. The pressure steaming treatments elicited significant increases in gallic acid and 2,3,4-trihydroxybenzoic acid, whereas all treatments caused significant decreases in two predominant phenolic acids (chlorogenic acid and trans-cinnamic acid), and total phenolic acids for both yellow and black soybeans. All thermal processing caused significant increases in aglucones and β-glucosides of isoflavones, but caused significant decreases in malonylglucosides of isoflavones for both yellow and black soybeans. All thermal processing caused significant decreases of cyanidin-3-glucoside and peonidin-3-glucoside in black soybeans. As compared to the raw soy milk, all thermal processing significantly reduced TPC values and significantly increased TFC values for all soybean varieties (Xu and Chang 2009). All processing methods significantly increased DPPH and FRAP values in the soy milk processed from yellow soybean varieties. Ultrahigh-temperature (UHT) processing increased their ORAC values, but traditional and steam processing reduced their ORAC values. However, in the case of the soy milk from black soybean, all processing reduced ORAC values as compared to the raw soy milk. None of processing affected total phenolic acids, chlorogenic, and trans-cinnamic acid, as well as (+)-catechin. However, all processing significantly affected contents of total isoflavones and individual isoflavones. Thermal processing caused significant increases in 7-O-β-glucosides and acetylglucosides, but caused significant decreases in malonylglucosides and aglycones. Indirect UHT processing transformed more isoflavones from malonylglucosides into 7-O-β-glucosides than the direct UHT did. Results of studies indicated that various thermal processing methods changed not only phytochemicals but also the potential health-promoting effects of soy milk (Xu et al. 2010). The laboratory ultra-high temperature

(UHT) and the two-stage processed soy milk displayed relatively higher total phenolic content, total flavonoid content, saponin and phytic acid than those processed by the traditional and steam processed methods. Thermal processing significantly increased antioxidant capacities of soy milk, but decreased cellular antioxidant capacities as compared to the raw soy milk. The raw and all processed soy milk dose-dependently exerted antipoliferative activities against human HL-60 leukemia cells, AGS gastric tumour cells, and DU145 prostate cancer cells. The raw soy milk, but not the processed soy milk, exhibited a dose-dependent antiproliferative effect against colorectal adenocarcinoma Caco-2 cells.

Immature soybeans are becoming increasingly popular as a snack/vegetable to exploit the health benefits of soybean. Studies showed that bioactive phytochemicals other than isoflavones and tocopherols may decline with the progress of soybean seed maturity (Kumar et al. 2009). Significantly higher levels of tocopherols and isoflavones were observed in immature seeds picked at late reproductive stages. Delta-tocopherol was the predominant form of tocopherol, whereas in subsequent reproductive stages as well as at complete maturity stage, the gamma-isomer contributed most to the total tocopherol content. Genistein was, the major form of isoflavone at all reproductive stages. Reduction in free radical scavenging activity, total antioxidant capacity, and total phenolic content in late-picked seeds attendant with increased content of tocopherol and isoflavone isomers was observed. Tepavcević et al. (2010) found that total isoflavone content varied significantly according to soybean cultivar but not origin. The highest and the lowest total isoflavone concentrations were 4.59 and 1.45 mg/g of dried soybean weight, respectively. Total polyphenolic content ranged from 2.13 to 3.45 mg of gallic acid equivalents/g of dried soybean weight. The IC_{50} value of free radical scavenging activity of soybean extracts assayed by 2,2-diphenyl-1-picrylhydrazyl ranged from 1.40 to 3.35 mg/ml. Negative correlation between total polyphenolic content and IC_{50} was found, but there was no correlation between total isoflavone content and IC_{50}. Solid state fermentation with *Bacillus subtilis* enhanced the total phenolic and flavonoid content as well as antioxidant activity of the black soybean extract (Juan and Chou 2010). Among the various extracts examined, the acetone extract of fermented black soybeans exhibited the highest total phenolic and flavonoid content. The acetone extract and the methanol extract of fermented black soybeans displayed the highest DPPH free radical-scavenging effect and Fe^{2+}-chelating ability, respectively.

Two 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging compounds identified as 2,4,4′-trihydroxydeoxybenzoin and 3′-hydroxydaidzein were isolated from soybean *miso* (Sugiyama et al. 2010).

Soy and Estrogenic Activity

Soybean has been reported to be rich sources of phytoestrogens, the principal isoflavones being daidzein, genistein and glyceitin (Mazur et al. 1998; Boue et al. 2003; Ørgaard and Jensen 2008). As a result of their structural similarities to endogenous estrogens, isoflavones exert weak estrogenic effects by competing with 17β-estradiol (E2) for binding to the intranuclear estrogen receptors (ERs) and elicit estrogenic or antiestrogenic effects in various tissues (Ørgaard and Jensen 2008). Daidzein and genistein are responsible for many of the health benefits of soy (Mazur et al. 1998; Barnes 1997; Messina and Barnes 1991). Soybean isoflavones have multiple beneficial health effects especially on estrogen-deficient diseases such as menopausal symptoms (Zhang et al. 2007). HPLC analysis and MTT [3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide] cell proliferation assay using MCF-7 cells revealed that soybean flour not only contained a high content of isoflavone aglycones but also had estrogenic activity. MTT data revealed that both genistein and daidzein exhibited estrogenic effects at lower concentrations and antiproliferative effects at higher concentrations. One μmolar genistein and 10 μM daidzein

exerted significant estrogenic activities, which were not more than that of the endogenous level of 17 β-estradiol. The results suggested isoflavones to be useful in estrogenic therapy.

A novel isoflavone, glycinol, a precursor to glyceollin, produced in elicited soy, was found to exhibit potent estrogenic activity (Boué et al. 2009). Glycinol exhibited a marked estrogenic effect on estrogen receptor (ER) signalling between 1 and 10 μM, which correlated with comparable colony formation of MCF-7 cells at 10 μM. Glycinol also induced the expression of estrogen-responsive genes and showed high binding affinity to both ER alpha and ER beta. These results suggested glycinol was estrogenic and may represent an important component of the health effects of soy-based foods. Glycitein (4′,7-dihydroxy-6-methoxyisoflavone) accounting for 5–10% of the total isoflavones in soy food products, was isolated from soy germ to 99% purity (Song et al. 1999). Studies in weaning female B6D2F1 mice showed that glycitein had weak estrogenic activity, comparable to that of the other soy isoflavones (genistein and daidzein) but much lower than that of exogenous estrogens, DES (diethylstilbestrol) and 17β-estradiol. Recent studies showed that perinatal exposure of male rats to soy isoflavones induced proliferative activity in Leydig cells, the predominant source of the male sex steroid hormone testosterone (Sherrill et al. 2010). Isoflavones have the capacity to act directly as mitogens in Leydig cells, because genistein treatment induced Leydig cell division in-vitro. Enhanced proliferative activity in the prepubertal period increased Leydig cell numbers, which alleviated deficits in androgen biosynthesis and/or augmented serum and testicular testosterone concentrations in adulthood. These observations indicated that the perinatal exposures of male rats to isoflavones affected Leydig cell differentiation, and that including soy products in the diets of neonates had potential implications for testis function.

Clinical intervention studies indicated that soy isoflavones did not exert feminizing effects on men (Messina 2010). Findings from a recently published meta-analysis and subsequently published studies indicated that neither isoflavone supplements nor isoflavone-rich soy affected total or free testosterone levels, sperm or semen parameters, despite contrasting results from some rodent studies. Messina (2010) reiterated that findings from animal studies suggesting that isoflavones increased the risk of erectile dysfunction were not applicable to men, because of differences in isoflavone metabolism between rodents and humans and the excessively high amount of isoflavones to which the animals were exposed.

Soy and Breast Cancer

The Women's Health Initiative (WHI) study found breast cancer risk to increase in women receiving hormone replacement therapy (Messina 2002). Because research suggests that it is the combination of estrogen plus progestin, and not estrogen alone, that increases breast cancer risk, soy seems unlikely to increase risk because it has no progestin activity.

A recent nested case-control study and meta-analysis of numerous epidemiological studies showed an inverse correlation between genistein intake and breast cancer risk (Taylor et al. 2009). Genistein (5,7,4′-trihydroxyisoflavone) had been reported to have anti-proliferative effects on mitogen-stimulated cell growth of human breast cancer cells in culture and to be a candidate for use in the prevention of breast cancer (Barnes 1997). Populations with diets high in soy protein and low in animal protein were found to have lower risks of prostate and breast cancers than other populations (Michelfelder 2009). In a meta-analysis of prospective study, Dong and Qin (2011) identified 4 studies of breast cancer recurrence and 14 studies of breast cancer incidence. They found that soy isoflavones consumption was inversely associated with risk of breast cancer incidence. However, the protective effect of soy was only observed among studies conducted in Asian populations but not in Western populations. Soy isoflavones intake was also inversely associated with risk of breast cancer recurrence. Stratified analyses suggested that menopausal status may be an important effect modifier in these associations. A large, population-based,

prospective cohort study of 73,223 Chinese women who participated in the Shanghai Women's Health Study provided strong evidence of a protective effect of soy food intake against premenopausal breast cancer (Lee et al. 2009). Adult soy food consumption, measured either by soy protein or isoflavone intake, was inversely associated with the risk of premenopausal breast cancer, and the association was highly statistically significant. High intake of soy foods during adolescence was also associated with a reduced risk of premenopausal breast cancer. Women who consumed a high amount of soy foods consistently during adolescence and adulthood had a substantially reduced risk of breast cancer. No significant association with soy food consumption was found for postmenopausal breast cancer.

A case-control study with 358 incident breast cancer patients and 360 age-matched controls with no history of malignant neoplasm in Korea found a significant inverse association between soy intake and breast cancer risk (Cho et al. 2010). After data stratification by menopausal status, the protective effect was observed only among postmenopausal women. The association between soy and breast cancer risk did not vary according to estrogen receptor (ER)/progesterone receptor (PR) status, but the estimated intake of soy isoflavones exhibited an inverse association only among postmenopausal women with ER+/PR + tumours. Recent studies by Kang et al. (2010) found that high dietary intake of soy isoflavones was associated with lower risk of recurrence among post-menopausal patients with breast cancer positive for estrogen and progesterone receptor and those who were receiving anastrozole as adjuvant endocrine therapy. The role of soy isoflavone intake and the risk of breast cancer recurrence by hormone receptor status, menopausal status, and tamoxifen therapy were studied in a cohort of 1,954 female breast cancer survivors, diagnosed during 1997–2000 (Guha et al. 2009). The prospective follow-up study lasted 6.31 years and 282 breast cancer recurrences were confirmed. Suggestive trends for a reduced risk of cancer recurrence were observed with increasing quintiles of daidzein and glycetin intake compared to no intake among postmenopausal women and among tamoxifen users. Among postmenopausal women treated with tamoxifen, there was an approximately 60% reduction in breast cancer recurrence comparing the highest to the lowest daidzein. Soy isoflavones consumed at levels comparable to those in Asian populations may reduce the risk of cancer recurrence in women receiving tamoxifen therapy and, appeared not to interfere with tamoxifen efficacy. The association of soy food intake and breast cancer survival was studied in a cohort of 5,042 female breast cancer survivors, aged 20–75 years, diagnosed between March 2002 and April 2006 and recruited and followed up through June 2009 in conjunction with the Shanghai Breast Cancer Survival Study (Shu et al. 2009). During the median follow-up of 3.9 years (range, 0.5–6.2 years), 444 deaths and 534 recurrences or breast cancer-related deaths were documented in 5,033 surgically treated breast cancer patients. Soy food intake, as measured by either soy protein or soy isoflavone intake, was inversely associated with mortality and recurrence. The multivariate-adjusted 4-year mortality rates were 10.3% and 7.4%, and the 4-year recurrence rates were 11.2% and 8.0%, respectively, for women in the lowest and highest quartiles of soy protein intake. The inverse association was evident among women with either estrogen receptor-positive or -negative breast cancer and was observed in both users and nonusers of tamoxifen. The scientists concluded that among women with breast cancer, soy food consumption was significantly associated with decreased risk of death and recurrence. Results of a principal components analysis study wherein 629 incident breast cancer cases were diagnosed among the 34,028 Singaporean women in 2005, supported the hypothesis that a diet of vegetables, fruit, and soy had an early-acting protective effect on breast carcinogenesis (Butler et al. 2010). With greater intake of the vegetable-fruit-soy dietary pattern, a dose-dependent trend was observed for decreasing breast cancer risk among postmenopausal women. A stronger association for the vegetable-fruit-soy pattern was observed among postmenopausal women with > or

=5 years of follow-up. No trend was observed for a greater intake of the meat-dim sum dietary pattern and increased breast cancer risk.

In addition to the amount of soy isoflavones consumed, the form and food source of isoflavones, timing of isoflavone exposure, estrogen receptor status of tumours, and equol-producer status and hormonal profile of individuals may modify the association between soy isoflavone intake and the risk of breast cancer and explain the heterogeneity of results from studies (Nagata 2010).

The available epidemiologic and animal data suggested that early soy intake reduced breast cancer risk (Messina and Hilakivi-Clarke 2009). The safety of soy isoflavone, genistein is of concern as it has been shown to activate estrogen receptor (ER)-α and ER-β and act as an estradiol in multiple target tissues thereby promoting the growth of ER-positive human breast cancer (Hilakivi-Clarke et al. 2010). Their review suggested that women consuming moderate amounts of soy throughout their life have lower breast cancer risk than women who do not consume soy; however, this protective effect may originate from soy intake early in life. Findings obtained in two recent human studies showed that a moderate consumption of diet containing this isoflavone did not increase the risk of breast cancer recurrence in Western women, and Asian breast cancer survivors exhibited better prognosis if they continued consuming a soy diet. They proposed that reduction in breast cancer risk involved epigenetic changes causing alterations in the expression of genes that regulated mammary epithelial cell proliferation and differentiation. Lifetime soy consumption at a moderate level may prevent breast cancer recurrence through mechanisms that change the biology of tumours; e.g. women who consumed soy during childhood develop breast cancers that express significantly reduced human epidermal growth factor receptor 2 levels. However, continued investigation of the early soy intake hypothesis are warranted particularly to ascertain the cellular targets of soy action and to identify the signalling pathways mediating the effects on mammary gland morphology and susceptibility to breast cancer.

The soybean isoflavone, genistein inhibited the growth of F3II mouse mammary adenocarcinoma cells in-vivo and in-vitro, in part due to its effect on specific cell cycle regulatory proteins. Additionally, genistein fed to mice as part of the soy extract resulted in a greater degree of inhibition of mouse mammary adenocarcinoma tumour growth, compared to tumour growth of animals fed an equivalent amount of genistein alone (Hewitt and Singletary 2003). This suggested that genistein along with other constituent(s) in the soy extract may also contribute to suppression of F3II tumour growth. Following intake of soy milk and soy supplements, isoflavones attained exposure levels in breast tissue at which potential health effects may occur (Bolca et al. 2010). After soy administration, genistein and total daidzein levels, expressed as aglycone equivalents, ranged from 135.1 to 2,831 nmol/l and 105.1 to 1,397 nmol/l, respectively, in hydrolysed serum and from 92.33 to 493.8 pmol/g and 22.15 to 770.8 pmol/g, respectively, in hydrolysed breast tissue. The main metabolites identified in nonhydrolysed samples were genistein-7-O-glucuronide and daidzein-7-O-glucuronide, with an overall glucuronidation of 98%. Total isoflavones showed a breast adipose/glandular tissue distribution of 40:60, and their mean derived 17β-estradiol equivalents toward estrogen receptor beta were 21-fold and 40-fold higher than the 17β-estradiol concentrations in adipose and glandular fractions, respectively. Recent animal studies indicated that consumption of soy foods may increase cancer metastasis (Martínez-Montemayor et al. 2010). Results showed that daidzein increased while genistein decreased mammary tumour growth by 38% and 33% respectively, compared to vehicle. Daidzein enhanced lung and heart metastases while genistein decreased bone and liver metastases. Combined soy isoflavones did not affect primary tumour growth but increased metastasis to all organs tested, which include lung, liver, heart, kidney, and bones. The disparate responses of breast cancers to genistein and daidzein diets were attributable to differential regulation of Rho GTPases, initiation factors, and survivin.

At non-cytotoxic concentrations (0.1–50 μM) genistein induced dose-dependent spindle-cell morphology and significantly reduced motility in both B16 melanoma and F3II mammary carcinoma cell lines (Farina et al. 2006). Genistein inhibited urokinase-type plasminogen activator secreted by F3II cell monolayers, while generating an increase in the proteolytic activity of B16 cells. However, the compound did not modify the MMP-9 and −2 produced by tumour cells. In-vivo, i.p. administration of genistein at a dose of 10 mg/kg/day reduced tumour-induced angiogenesis in syngeneic mice implanted with B16 or F3II cells. Similar antiangiogenic effects were obtained with a soybean-based diet. The data suggested that tumour cell migration and proteolysis may be associated with the antitumour and antiangiogenic activity of soy isoflavone genistein. Dietary exposure to the soy isoflavone genistein (GEN) upregulated phosphatase and tensin homologue deleted on chromosome ten (PTEN) expression in mammary epithelial cells in-vivo and in-vitro, consistent with the breast cancer protective effects of soy food consumption (Dave et al. 2005). Subsequent findings confirmed that PTEN and p53 cross-regulation induced by soy isoflavone genistein promoted mammary epithelial cell cycle arrest and lobuloalveolar differentiation (Rahal and Simmen 2010). This mechanistic basis for PTEN pathway activation underpinned the antitumour properties of soy dietary factors and may have important implications for reducing breast cancer risk. Recent studies by Ullah et al. (2010) suggested that soy isoflavone, genistein induced apoptosis in breast cancer cells through mobilization of endogenous copper ions and generation of reactive oxygen species. They showed that genistein was able to target endogenous copper leading to prooxidant signalling and consequent cell death. Such a mechanism elucidated the anticancer effect of genistein as also its preferential cytotoxicity towards cancer cells.

Barnes (1997) reported that rats treated neonatally or prepuberally with genistein had a protracted latency before the appearance of 7,12-dimethylbenz[a]anthracene-induced mammary tumours and a pronounced reduction in tumour number. Rats administered genistein after 35 days of age had smaller changes in breast cancer risk, with a maximum reduction in mammary tumour number of 27%. In ovariectomized nude mice, dietary genistein increased cell proliferation of human breast cancer MCF-7 cell xenografts compared with a control diet. This estrogen-like effect of genistein was not observed in non-ovariectomized rats. Tumour growth in female Balb/c mice implanted with estrogen-independent human breast cancer cells, MDA-MB-231, was significantly reduced in the soy extract-treated group compared to the control and genistein-treated groups (Kim et al. 2008). In contrast tumour volumes increased sharply in the control group and the genistein-treated group. Immunohistochemistry of proliferating cell nuclear antigen (PCNA) also revealed that the soy extract treatment effectively reduced cell proliferation of the implanted tumours. The data suggested that soy extract was more potent than genistein in the inhibition of tumour growth, presumably resulting from the synergistic effect of the various bioactive components in the soy extract. The soy phytochemical extract exerted more significant antitumour and antiangiogenic activity than the single phytoestrogen in a postmenopausal ovariectomized rats with breast cancer induced by 7,12-dimethylbenz[α]anthracene (DMBA) (Kang et al. 2009). The extract inhibited proliferation and induced apoptosis in vitro and in vivo, and demonstrated antiangiogenic effects, which were evidenced by lower microvascular density, reduced plasma vascular endothelial growth factor, and increased plasma endostatin levels. Animal studies showed that early exposure of animals with DMBA-induced breast cancer to enantiomers of equol, a key soy isoflavone metabolite, were not chemopreventive, but neither did it increase tumour formation in response to DMBA (Brown et al. 2010). This suggested that exposure in early life (neonatal and prepubertal) did not influence breast cancer risk.

The estrogen-like effects of soy isoflavones may have a detrimental effect in breast cancer patients. Genistein was found to exhibit a biphasic effect on the growth of MCF-7 breast cancer

cells in-vitro, stimulating proliferation at low concentrations but inhibiting it at high concentrations (Messina and Loprinzi 2001). In ovariectomized athymic mice implanted with MCF-7 cells, both genistein and soy protein were found to dose-dependently stimulate tumour growth. However, in intact mice fed estrogen, genistein inhibited tumour growth. They reported that two studies in premenopausal women suggested that soy exerted estrogenic-like effects on breast tissue, recently conducted year-long studies indicated that isoflavone supplements did not affect breast tissue density in premenopausal women and may decrease density in postmenopausal women. These latter effects were opposite to those of hormone replacement therapy (HRT). Importantly, substantial data suggested that the progestogen, not the estrogen, component of HRT increases risk of developing breast cancer. Further they reported that recently conducted studies failed to find that even HRT reduced survival in breast cancer patients. Helferich et al. (2008) found that genistein could act as an estrogen agonist resulting in proliferation of estrogen-dependent human breast cancer tumours in-vivo and its activity could be modulated by the presence of other bioactive components in complex soy foods such as soy flour. Additionally, dietary genistein could negate the inhibitory effects of tamoxifen on estrogen-stimulated growth of MCF-7 breast cancer cell tumours implanted into ovariectomized athymic mice. The ability of the isoflavone genistein to induce the growth of mammary tumours in ovariectomized athymic nude mice implanted with estrogen-sensitive breast cancer cells had raised concern that soy foods, and especially isoflavone supplements, were contraindicated for patients with breast cancer and women at high risk of breast cancer (Messina and Wu 2009). However, findings from clinical studies, in which breast biopsies had been taken or breast tissue density measured after isoflavone exposure, were reassuring and contrasted with the proliferative effects of conventional combined hormone therapy. Understanding of the effect of soy and isoflavones on breast tissues remains imprecise. The Osteoporosis Prevention Using Soy (OPUS) study, a 2-year, multi-site, randomized, double-blinded, and placebo-controlled trial involving 406 postmenopausal women, soy isoflavone supplements were found not to modify breast density (Maskarinec et al. 2009). The findings offered reassurance that isoflavones do not act like hormone replacement medication on breast density. Soy isoflavones have functional similarity to human estrogens and may protect against breast cancer as a result of their anti-estrogenic activity or increase risk as a result of their estrogen-like properties.

Glyceollins are pterocarpan phytoalexins elicited in high concentrations when soybeans are stressed (Burow et al. 2001; Salvo et al. 2006; Zimmermann et al. 2010; Payton-Stewart et al. 2010). In contrast to the observed estrogenic effects of coumestrol, daidzein, and genistein derived from soy, glyceollins exhibited a pronounced anti-estrogenic effect of on ER (estrogen receptor) signalling, which correlated with a comparable inhibition of 17 β-estradiol-induced proliferation in MCF-7 breast cancer cells (Burow et al. 2001). Competition binding assays manifested a greater affinity of glyceollins for ER alpha vs. ER beta, which correlated to greater suppression of ER alpha signalling with higher concentrations of glyceollins. Glyceollin mixture from activated soy, containing three glyceollin isomers (I, II, and III) displayed distinct anti-estrogenic effects on estrogen receptor function and estrogen-dependent tumour growth in-vivo (Salvo et al. 2006). Treatment with glyceollin inhibited estradiol-stimulated tumour growth of MCF-7 breast cancer cells (−53.4%) and BG-1 ovarian cancer cells (−73.1%) in ovariectomized athymic mice. These tumour-suppressing effects corresponded with significantly lower estradiol-induced progesterone receptor expression in the tumours. In contrast to tamoxifen, the glyceollins exerted no estrogen-agonist effects on uterine morphology and partially antagonized the uterotropic effects of estrogen. The glyceollin mixture was also found to be effective as a potential anti-estrogenic, therapeutic agent that prevented estrogen-stimulated tumourigenesis and exhibited a differential pattern of gene expression from tamoxifen. Of the three isomers, glyceollin I was found to be the most potent antiestrogen

(Zimmermann et al. 2010). Glyceollin I may represent an important component of a phytoalexin-enriched food (activated) diet in terms of chemoprevention as well as a novel therapeutic agent for hormone-dependent tumours. Glyceollin I enantiomers were found to distinctly modulate ER (estrogen receptor)-mediated gene expression (Payton-Stewart et al. 2010). Glyceollin I enantiomers exhibited ability to inhibit estrogen responsive element transcriptional (ERE) activity and endogenous gene expression in MCF-7 cells.

Lunasin and Bowman Birk Inhibitor (BBI) were found to be the two main bioactive ingredients of soy Bowman Birk Inhibitor Concentrate (BBIC) a known cancer preventive agent now in human clinical trials (Hsieh et al. 2010). Based on inhibition of foci formation, lunasin was more efficacious than BBI on an equimolar basis. Oral administration of (3)H-labelled lunasin with lunasin-enriched soy resulted in 30% of the peptide reaching target tissues in an intact and bioactive form. In a xenograft model of nude mice transplanted with human breast cancer MDA-MB-231 cells, intraperitoneal injections of lunasin, at 20 and 4 mg/kg body weight, decreased tumour incidence by 49% and 33%, respectively, compared with the vehicle-treated group. However, injection with BBI at 20 mg/kg body weight exerted no effect on tumour incidence. Lunasin was found to inhibit cell proliferation and to induce cell death in the breast tumour sections. The data indicated that lunasin was the bioactive cancer preventive agent in BBIC, and BBI simply protected lunasin from digestion when soybean and other seed foods were consumed by humans. Mishra et al. (2010) showed that centchroman, a non-steroidal oral contraceptive candidate drug for breast cancer and glycine soya alone and jointly combated 7,12-dimethylbenz[α]anthracene-induced breast tumour in rats. Studies showed that dietary GS enhanced the therapeutic efficacy of tamoxifen against mammary tumours induced by 7, 12-dimethylbenz[α] anthracene in rats and minimized tamoxifen's hepatocarcinogenesis promotion potential (Mishra et al. 2011). Exposure to both tamoxifen and dietary glycine soya enhanced the anti tumour efficacy of tamoxifen via a combination of tumour cell apoptosis and inhibition of tumour cell proliferation and suppressed the growth of glutathione-S-transferase (GST-P)-positive liver lesions. Treatment with high-dose soy isoflavone, genistein (10 μmol/l), a tyrosine kinase inhibitor and agonist of estrogen receptor-β (ERβ), significantly enhanced the growth-inhibitory effect of trastuzumab on HER2-overexpressing, ERα/β-positive BT-474 breast cancer cells (Lattrich et al. 2011). Combinatory treatment using lower doses of trastuzumab exhibited similar effects as a single treatment with standard doses of this drug. This effect was absent in ERα-negative SK-BR-3 cells. The results indicated that genistein significantly enhanced the antitumoral effect of trastuzumab on BT-474 breast cancer cells in vitro.

Soy and Menopausal Symptoms

The results of the Heart and Estrogen/Progestin Replacement Study (HERS) I/II and the Women's Health Initiative (WHI) suggested that soy may have some of the advantages, but not the disadvantages, of combined hormone replacement therapy (at least with respect to the specific hormones and doses used in the HERS I/II and WHI) (Messina 2002). Large, long-term intervention studies examining disease outcome are warranted before precise conclusions can be deduce. Nevertheless, the evidence supported recommendations that menopausal women include soy in their diets (Messina 2002).

Okabe et al. (2011) demonstrated that the isoflavones of aglycone-rich fermented soybeans (Fsoy) were absorbed faster and in greater amounts than those of glucoside-rich non-fermented soybeans (Soy) in postmenopausal Japanese women. Serum levels of total isoflavones after 1–4 h were significantly higher in the Fsoy group than in the Soy group. The cumulative urinary excretion of total isoflavones after 2 h was significantly higher in the Fsoy group than in the Soy group. Individual isoflavones (daidzein, genistein and glycitein) showed similar trends to total isoflavones. Equol (a metabolite

from daidzein) did not differ between the two groups. Kim et al. (2010) suggested that glyceollins may be useful in the prevention or amelioration of postmenopausal complications because they had strong estrogenic activity, showing higher affinity for estrogen receptor (ER) beta than ERalpha. Glyceollins were more efficiently produced de novo in minced than in half-sliced soybean, following inoculation with *Aspergillus sojae*.

Results of a multicenter (15 sites), double-blind, randomized, placebo-controlled study of 177 postmenopausal women (mean age = 55 years) suggested that soy isoflavone extract was effective in reducing frequency and severity of hot flushes (Upmalis et al. 2000). No change in endometrium thickness evaluated by ultrasound, lipoproteins, bone markers, sex hormone-binding globulin and follicle-stimulating hormone, and vaginal cytology was observed in the isoflavone or placebo group. Faure et al. (2002) in their 4-month, multicenter, double-blind, randomized, placebo-controlled of 75 menopausal women study found that may help to reduce the frequency of hot flushes in climacteric women and may provide an attractive addition to the choices available for relief of hot flushes. By the end of week 16, patients taking soy extract had a 61% reduction in their daily hot flushes versus a 21% reduction obtained with the placebo.

The data from the double-masked, randomized, controlled, clinical trial of 241 community-dwelling women suggested that soy protein containing 42 or 58 mg of isoflavones was equally as effective as isoflavone-extracted soy protein for improving the number and severity of vasomotor symptoms in peri- and postmenopausal women (Burke et al. 2003). In a 3 month randomized trial of 60 postmenopausal women, oral and transdermal soy isoflavone treatment exhibited slight to moderate improvement in menopausal neurovegetative symptoms (hot flushes, Kupperman index and vaginal dryness) with a dose-related effect (Colacurci et al. 2004). A multicentric, open, prospective, observational and no-randomized clinical trial performed with 190 postmenopausal Spanish women found that treatment with a soy preparation rich in isoflavones (PHYTO SOYA) resulted in a significant improvement of climateric symptomatology that accompanied the lack of estrogen during menopause. A statistically significant reduction in the number of hot flushes with PHYTO SOYA was experienced by 80.82% women; only 5.48% patients did not improve with the treatment. The average reduction was 47.8%, which is equivalent to 4 hot flushes. All the other studied parameters also exhibited a statistically significant reduction. No severe side-effects were reported and tolerance was excellent.

In a double-blind, randomized, placebo-controlled study, of 80 Brazilian women (mean age = 55.1 years), administration of soy isoflavone extract exerted favourable effects on vasomotor symptoms and good compliance, and provided a safe and effective alternative therapeutic for postmenopausal women (Nahas et al. 2007). After 10 months, there was a significant reduction in frequency of hot flushes among isoflavone users when compared to those on placebo. Soy isoflavone was significantly superior to placebo, in reducing hot flush severity (69.9% and 33.7%, respectively). Endometrial thickness, mammography, vaginal cytology, lipids and hormonal profile did not change in both groups. In a 12-week prospective, randomized, double-blind, placebo-controlled multicenter trial of 180 women aged 40–65 years, reduction in moderate to severe hot flushes, hot flush intensity and Kupperman index were greater in the isoflavone treated group than in the placebo group (Ferrari 2009). The author concluded that in daily practice conditions, high doses of isoflavones, particularly genistein, could be employed for the management of hot flushes in postmenopausal women not treated with hormone replacement therapy due to their superior efficacy to placebo and very good safety profile. Results of a short-term prospective study suggested that isoflavones could be used to relieve acute menopausal symptoms (Cheng et al. 2007). Fifty-one healthy postmenopausal women finished the 12-week double-blind prospective study. In, hot flashes and night sweats were reduced by 57% and 43%, respectively in women receiving 60 mg

isoflavones daily. Immunohistochemical staining of endometrial and breast biopsy specimens disclosed that isoflavones did not affect expression levels of steroid receptors; estrogen receptors alpha, beta, and betacx; progesterone receptors A and B; or the proliferation marker Ki67. No side effects on body weight or lipoprotein lipids were noted.

In a multicentric, observational, open, prospective, longitudinal and cross-sectional study of 1,682 postmenopausal women with climacteric symptoms, administration of a compound containing 60 mg of dry soy seed extract (*Glycine max*) with 40% of total isoflavones, primrose oil and α-tocopherol, improved the climacteric symptoms after 3 and 6 months of treatment (Cancelo and Castelo 2010). The time of administration (morning or evening) of isoflavones did not modify its effect on climacteric symptoms. Results from the 6-month double-blind, randomized, placebo-controlled, parallel group trial of 191 women aged 55–76 years indicated that 80-mg soy-derived isoflavone daily supplementation did not improve performance on standard neuropsychological tests and overall quality of life in generally healthy Chinese postmenopausal women (Ho et al. 2007a). Types of complaints of adverse events were similar in the treated and placebo groups and included mainly gastrointestinal and musculoskeletal problems.

In a review of soyfood, soy isoflavones in alleviating menopausal symptoms, out of 19 trials identified (13 using a parallel design) involving more than 1,700 women, 6 trials were excluded from analysis, two that involved breast cancer patients, two that reported data on severity but not hot flush frequency, one that was not blinded, and one that did not include a control group (Messina and Hughes 2003). Based on a simple regression analysis of the remaining data set (13 trials), a statistically significant relationship ($P = .01$) between initial hot flush frequency and treatment efficacy was found. Initial hot flush frequency elucidated about 46% of the treatment effects, and hot flush frequency decreased by about 5% (above placebo or control effects) for every additional initial hot flush per day in women whose initial hot flush frequency was five or more per day. The researchers asserted that the available data, though tentative justify the recommendation that patients with frequent hot flushes consider trying soyfoods or isoflavone supplements for the alleviation of menopausal symptoms.

Huntley (2004) reviewed 13 randomised clinical trials on the association of soy preparation for the treatment of perimenopausal symptoms and found that the results were mixed and not conclusive. Four of these randomised controlled trials were positive, suggesting soy preparations were beneficial for perimenopausal symptoms. Six were negative; with one of the six showing a positive trend. Adverse event data from the trials suggested that there were no serious safety concerns with soy products in short-term use.

The meta-analysis of randomized controlled trials of isoflavone-rich foods or supplements versus placebo with a duration of at least 6 months, suggested that isoflavone intake did not alter breast density in post-menopausal women, but may cause a small increase in breast density in premenopausal women (Hooper et al. 2010). The data suggested no overall effect of dietary isoflavones on breast density in all women combined or post-menopausal women. However, there was a modest increase in mammographic density in premenopausal women without heterogeneity but this effect was lost in one of three sensitivity analyses. In the meta-analysis of Bolaños et al. (2010), 19 published, randomized, placebo-controlled clinical trials of 12-week intervention duration of intervention postmenopausal women affected with hot flashes attributed to the climacterium were analysed. The overall combined results and the results by subgroups (according to the type of supplement used) showed a significant tendency in favour of soy. However, it was still difficult to establish conclusive results given the high heterogeneity found in the studies. The findings of the Women's Health Initiative in USA had resulted in a sharp decline in the use of estrogen therapy and increasingly more menopausal women were turning to soy foods as an alternative to estrogen therapy for the treatment of menopausal symptoms (Levis and Griebeler 2010). The evidence of the efficacy of soy foods

in alleviating menopausal vasomotor and urogenital symptoms was limited and often with conflicting results. The available evidence from a systematic review of 25 trials involving 2,348 participants suggested that phytoestrogens available as soy foods, soy extracts, and red clover extracts did not improve hot flushes or other menopausal symptoms (Krebs et al. 2004). Similarly, the systematic review of 30 trials performed by Lethaby et al. (2007) concluded that there was no evidence of effectiveness in the alleviation of menopausal symptoms with the use of phytoestrogen treatments (dietary soy, soy extracts, red clover extracts). Most of the trials in the review were small, of short duration and poor quality. Some trials found a slight reduction in hot flushes and night sweats with phytoestrogen-based treatment but overall there was no indication that phytoestrogens worked any better than no treatment. There was no evidence of adverse effects with short term use.

Soy and Osteoporosis

As oestrogen deficiency is the major cause in the pathogenesis of osteoporosis, hormone-replacement therapy remains the main option for prevention (Coxam 2008). The use of dietary phytoestrogens such as soy isoflavones for the prevention of osteoporosis had raised considerable interest because of the increased concern about the adverse risks and disadvantages associated with the use of hormone-replacement therapy (Messina 2002; Branca 2003). However, the evidence in support of a bone-sparing effect in post-menopausal women was still mixed and far from convincing (Branca 2003; Sacks et al. 2006). Recent clinical studies in osteopenic and osteoporotic, postmenopausal women supported the breast and uterine safety of purified naturally derived genistein administered for up to 3 years (Taylor et al. 2009). Most studies had been conducted on soybean isoflavones (genistein and daidzein), either in the purified form or as a soybean-based product or extract (Branca 2003). In vitro studies using primary cell cultures or stabilised cell lines indicated that treatment with genistein may lead to a reduction in bone resorption, but effects on bone formation had also been demonstrated. Studies using animal models had provided beneficial and conflicting evidence of major improvements in bone mass or bone turnover following soybean ingestion. Cross-sectional observations in Asian populations with moderately high intakes of soybean isoflavones (50 mg/day) had shown that women in the high quartile of intake had higher bone mineral density (BMD) and lower bone turnover, an effect that had not been shown in populations with low average intakes especially in the western countries. The clinical efficacy of soya foods in preventing osteopenia depended on their intestinal metabolism (Coxam 2008). Short-term studies generally suggested that soy isoflavones reduced bone loss in postmenopausal women; however, such effects had been observed primarily only at the spine, and longer-term studies were needed (Messina 2002). Some of such studies are elaborated below.

In the Japanese population-based osteoporosis (JPOS) study, 3,465 women out of the original 4,550 women were used to estimate the prevalence rate of osteoporosis in Japanese women, (Iki et al. 2001). The prevalence rates of osteoporosis according to WHO criteria in the present subjects aged 50 through 79 years were calculated as 38.0% at the spine, 11.6% at the femoral neck and 56.8% at the distal one-third site of the radius, and those in the Japanese female population of the same age were estimated to be 35.1%, 9.4% and 51.2%, respectively. A five-fold difference was observed among the prevalence rates at different skeletal sites, which suggests that the different definitions of osteoporosis should be established for the different skeletal sites. The prevalence rate diagnosed at the femoral neck seemed to be lower in the present study than those reported for Caucasians. This might account for a lower incidence rate of hip fracture in Japanese women. Japanese fermented soybeans (natto in Japanese), which contain a large amount of menaquinone-7, may help prevent the development of osteoporosis (Ikeda et al. 2006). They conducted the Japanese Population-based Osteoporosis study involving a large cohort of

944 healthy Japanese women aged 20–79 years. They found significant positive associations between natto intake and the rates of changes in BMD at the femoral neck and at the distal third of the radius in the postmenopausal women. No significant association was observed between the intake of tofu or other soybean products and the rate of BMD change in the postmenopausal women. Natto intake may help prevent postmenopausal bone loss through the effects of menaquinone 7 or bioavailable isoflavones, which are more abundant in natto than in other soybean products.

For bone health and osteoporosis prevention in Japanese, Kubota and Shimizu (2009) recommended adequate amounts of soybean and soy products be consumed on a daily basis as soybean and various types of soy products, such as *natto*, tofu, *miso*, and soy sauce are rich in plant proteins, calcium and isoflavones. *Natto*, fermented soybeans, contains vitamin K, which is involved in the activation of osteocalcin. A randomised single-blind acute cross-over design study in 12 Australian osteopenic post-menopausal women averaged age 56.7 years showed that calcium absorption from fortified soymilk was found to be comparable to that of cows' milk (Tang et al. 2010).

Soybeans are a good source of bone-healthy nutrients. Studies on the osteogenetic effects of soy isoflavone genistein on human cell line MG63 osteoblasts found that genistein stimulated the production of mineralized bone extracellular matrix by osteoblasts (Morris et al. 2006). Genistein-treated osteoblasts were found to possess a more organized cytoskeleton, and genistein's inhibitory effect upon cell proliferation was associated with exposure of phosphatidylserines on the external plasmalemma surface. Further, genistein-treated osteoblasts were found to synthesize relatively high levels of collagen and alkaline phosphatase and, even in a nonosteogenic growth medium, formed mineralized bone noduli. Studies by Jones et al. (2005) found that the soy isoflavone, genistein inhibited cultures of rat L6 skeletal muscle cells in-vitro. A combination of phytoestrogens elicited significant inhibition of cell proliferation, but not to the extent observed with genistein alone. At higher total combined concentrations, daidzein and glycitein were found to be able to outcompete genistein for receptor sites. These results suggested that soy isoflavones in the diet may potentially modulate normal growth and development in humans and animals that consume soy-based products.

Consumption of 17 α-ethinylestradiol or daidzein was found to be more efficient than genistein in preventing ovariectomy-induced bone loss in female wistar rats (Picherit et al. 2000). Studies in ovariectomized rats showed that bone mineral density of the lumbar spine was the only bone outcome that significantly benefited from the combination of soy and high calcium compared with soy or high calcium alone (Breitman et al. 2005). Studies found that long-term (3 months) equol (main metabolite from soy isoflavone) consumption, like genistein and daidzein, in the ovariectomized rat, produced bone sparing effects (Mathey et al. 2007). Chronic exposure (1 month) to soy isoflavones (genistein and daidzein) in postmenopausal women resulted in plasma concentrations as high as 2.5–5 μmol/l of each isoflavone, but did not induce the ability to produce equol (Védrine et al. 2006). Adding indigestible sugars, such as fructooligosaccharides or live microbial as *Lactobacillus casei*, in the diet significantly improved daidzein protective effects on the skeleton. Studies by Devareddy et al. (2006a) suggested that, although incorporation of either soy or fructo-oligosaccharides (a prebiotic) in the diet of ovariectomized rats improved bone mineral density of the whole body, tibiae, and lumbar vertebrae, their combination had no any additive effects. However, in terms of microarchitecture, the combination of soy and fructo-oligosaccharides had a greater effect in reversing the loss of certain microarchitectural parameters such as tibial trabecular number, separation, and thickness. The prebiotic could modulate intestinal microflora, rendering soy isoflavones bioavailable by facilitating their conversion to equol. In a parallel study, Devareddy et al. (2006b), found that soy protein did not restore bone loss in osteopenic rats; however, higher doses of isoflavones may be required to

reverse the loss of tibial microstructural properties.

The findings of Hooshmand et al. (2010) suggested that although a genistin-rich isoflavones diet could increase the bone mineral density in female rats with ovariectomized (Ovx)-induced bone loss, combination of genistin-rich isoflavones and fructooligosaccharides, a prebiotic, exerted greater effect in preventing bone loss in the rat model. The genistin-rich isoflavones diet was found to significantly increase the whole-body, right femur, and fourth lumbar BMD by 1.6%, 1.48%, and 1.3%, respectively in comparison with the Ovx control. The combination of genistin-rich isoflavones diet and 5% fructooligosaccharides further augmented whole-body, right femur, and fourth lumbar BMD more compared to the genistin-rich isoflavones diet.

Short-term neonatal exposure of mice to isoflavones provided protection against the deterioration of bone tissue in females but not males after a decline of endogenous sex steroid production (Kaludjerovic and Ward 2009, 2010). Females treated with daidzein + genistein had higher femur and vertebral bone mineral content and bone mineral density compared with the control group with corn oil. Microstructural analysis revealed that ameliorations in bone mineral density generated by daidzein + genistein or diethylstilbestrol were coupled with greater trabecular thickness at the lumbar spine. Importantly, structural improvements resulted in bones that were more resistant to fracture with daidzein + genistein compared with the control. Consumption of yellow and black soybeans, and sword beans (*Canavalia gladiata*) was found to have a distinct protective effect on bone loss in ovariectomized rats by inhibiting bone turnover and preventing bone resorption (Byun and Lee 2010). Femur and spine bone mineral density were significantly higher in the yellow soybean and sword bean groups than in the black soybean group. Femur bone mineral content was the highest in the yellow soybean group, and spine bone mineral content was not significantly different between the various bean groups. The sword bean group showed significantly lower osteocalcin (a bone formation biomarker) and deoxypyridinoline (a bone resorption biomarker) levels than the yellow and black soybean groups. There were no significant differences between the yellow and black soybean groups. TNF-alpha (a bone resorption cytokine) concentrations were not significantly different between the groups.

Several animal studies on soy protein and soy isoflavones found no benefits to bones. The results of studies in 3-month-old intact Sprague-Dawley female rats suggested that dietary isolated soy protein and isoflavones had no effect on bone and the vagina during premenopausal period, but may have an adverse effect on the uterus (Nakai et al. 2005). In a parallel study the group found that in sexually mature ovariectomized rats ,dietary intake of isoflavones had a minimal beneficial effect on bone with no effect on the reproductive tract (Bahr et al. 2005).

A baseline cross-sectional analysis of the association between dietary soy protein intake and bone mineral density/content was performed on comprised 454 healthy Chinese women (mean age 55.1 ± 3.57) within the first 12 years of postmenopause (Ho et al. 2003). The study demonstrated that, among women after the initial few years postmenopausal, soy protein/isoflavones consumption had a modest but significant association with hip bone mineral density as well as total body bone mineral content. Messina et al. (2004) examined 15 clinical trials of <1 year duration and involving <30 participants for the effects of isoflavones or isoflavone-rich soy protein on bone mineral density. The findings from these studies were inconsistent but generally suggested that isoflavones reduced bone loss in younger postmenopausal women. Similarly, they found that epidemiologic data were limited but generally showed that among Asian populations isoflavone intake was associated with higher bone mineral density. The clinical data suggested that approximately 80 mg/day isoflavones were needed to derive skeletal benefits whereas the epidemiologic data suggested lower amounts were efficacious. They supported the notion encouraging postmenopausal women concerned about bone health to incorporate soyfoods into their diet. Epidemiological studies in Asia assessing

diets containing traditional whole soy foods had shown a positive association with bone mineral density and fracture protection (Reinwald and Weaver 2010). However, smaller scale intervention studies in the west, mainly with isolated soy protein (SP) and purified or concentrated soy isoflavones (SI) rather than whole soy foods had generated inconsistent results. Consumption of SI, often at higher concentrations than would be available in traditional Asian diets, is not yielding concrete evidence that might be expected in support of their benefit to bone health. Meta-analysis of randomized controlled trials including data from 1,240 menopausal women revealed that daily ingestion of an average of 82 (47–150) mg soy isoflavones (aglycone equivalent) for 6–12 months significantly increased spine bone mineral density (BMD) by 22.25 mg/cm^2, or by 2.38% compared with controls (random-effects model) (Taku et al. 2010b, c). Subgroup analyses indicated that the varying effects of isoflavones on spine BMD across trials might be associated with study characteristics of intervention duration (6 vs. 12 months), region of participant (Asian vs. Western), and basal BMD (normal bone mass vs. osteopenia or osteoporosis). No significant effects on femoral neck, hip total, and trochanter BMD were found. The meta-analysis study showed that soy isoflavone extract supplements increased lumbar spine BMD in menopausal women. A meta-analysis of nine randomized controlled trials with a total of 432 subjects showed that isoflavone intervention significantly inhibited bone resorption and stimulated bone formation (Ma et al. 2008). The urinary deoxypyridinoline (a bone resorption marker) decreased significantly in those who consumed isoflavones. While the serum bone-specific alkaline phosphatase (a bone formation marker) increased significantly with isoflavone intake versus placebo. These favourable effects occurred even if <90 mg/day of isoflavones were consumed or the intervention lasts less than 12 weeks.

The systematic review and meta-analysis of randomized controlled trials undertaken by Taku et al. (2010b, c) showed that soy isoflavone supplements moderately decreased the bone resorption marker, urinary deoxypyridinoline, but did not affect bone formation markers, bone alkaline phosphatase and serum osteocalcin, in menopausal women. The effects varied between studies. In a double-blind, randomized controlled trial of nonosteoporotic postmenopausal women, soy isoflavone supplementation did not exert a bone-sparing effect except for a modest effect at the femoral neck (Alekel et al. 2010). In a randomized, double-blind, placebo-controlled, parallel, multicenter trial of 237 healthy early postmenopausal women (average age 53 ± 3) ingestion of soy foods containing 110 mg/day of soy isoflavone aglycone equivalents for 1 year did not prevent postmenopausal bone loss and did not affect bone turnover in apparently healthy early postmenopausal white women (Brink et al. 2008).

Soy and Cardiovascular Disease

The American Heart Association (AHA) Dietary Guidelines for Healthy American Adults stated that although there was some evidence that when soy protein was substituted for animal protein, total and LDL cholesterol could be reduced, the findings were mixed and inconclusive (Erdman 2000). The AHA Nutrition Committee concluded that the use of soy foods was consistent with the AHA Dietary Guidelines, but no recommendation was made to include soy protein in the diet. Epidemiological studies had reported that southeast and east Asian populations who consume soy foods as a dietary staple have a lower incidence of cardiovascular disease compared to those who consume a typical Western diet. The Women's Health Initiative (WHI) study found women receiving hormone replacement therapy to have increased risk of coronary heart disease (CHD) and the Heart and Estrogen/Progestin Replacement Study (HERS) I/II and WHI found increases in venous thromboembolic disease in such women (Messina 2002). Currently there is no or little evidence to suggest that soy will increase venous thromboembolic disease or stroke. There are promising data suggesting that soy may decrease CHD risk, although studies conducted thus far have examined only markers of risk and not actual CHD events.

A variety of clinical trials had demonstrated that consuming 25–50 g/day of soy protein to be both safe and effective in reducing LDL cholesterol by about 4–8%. (Erdman 2000). This effect was observed in clinical trials additional to the benefits of a National Cholesterol Education Program (NCEP) Step I diet and was greater in more-hypercholesterolemic subjects. There was an apparent synergy among the components of intact soy protein, which provided the maximum hypocholesterolemic benefit. Several components associated with soy protein had been implicated in lowering cholesterol: trypsin inhibitors, phytic acid, saponins, isoflavins, and fibre (Erdman 2000). Lichtenstein (1998) reported that substitution of soy for animal protein can result in lower saturated fat and cholesterol intakes, thereby indirectly resulting in a more favourable blood cholesterol level and potentially reducing coronary heart disease risk. Erdmann (2000) in his review concluded that it was prudent to recommend including soy protein foods in a diet low in saturated fat and cholesterol to promote heart health.

Voluminous published literature indicated that protein from soybeans reduced blood cholesterol concentrations in experimental animals as well as in humans (Potter 1995). The mechanism and component of soy responsible had not been comprehensively established but several hypotheses had been suggested. One notion was that soy protein ingestion impaired cholesterol absorption and/or bile acid reabsorption. Another proposed that alterations in endocrine status, such as change in insulin:glucagon ratio and thyroid hormone contents were responsible. The metabolic changes such as enhanced cholesterol synthesis, enhanced bile acid synthesis (or faecal bile acid excretion), enhanced apolipoprotein B or E receptor activity and decreased hepatic lipoprotein secretion and cholesterol content have been observed on soy protein ingestion in a range of animal models, and in some cases human studies. These changes were associated with an increased clearance of cholesterol from the blood. It was hypothesised that amino acid composition or proportionality of soy caused changes in cholesterol metabolism (possibly via the endocrine system). Another suggested that non-protein soy components such as saponins, fibre, phytic acid, minerals and the isoflavones may affect cholesterol metabolism either directly or indirectly. Soybean Bowman-Birk protease inhibitor (BBI) was found to be highly effective inhibitor of human chymase, exhibiting reaction properties better than physiological inhibitors described to date (Ware et al. 1997). Chymase is a serine proteases produced in mast cells and released upon degranulation. It facilitates angiogenesis via the local production of angiotensin II, a hormone that constricts blood vessels causing high blood pressure. Lichtenstein (1998) reported that soybean isoflavone fraction, consisting mainly of genistein, daidzein and glycetein, had been shown to have a hypocholesterolemic effect in animals and humans. Potential mechanisms by which soy protein and/or isoflavones induced lowering of blood cholesterol concentrations include thyroid status, bile acid balance and the estrogenic effects of genistein and daidzein. Some studies had also suggested that isoflavones exhibited antioxidant properties and to have favourable effects on arterial compliance.

Studies had shown that estrogen replacement therapy (ERT) reduced the risk of cardiovascular diseases in postmenopausal women (Pan et al. 2001). Soybean isoflavones, a group of natural phytoestrogens, with only weak estrogenic activity would not have side effects such as carcinogenesis and feminization in men (Messina 2010) compared to estrogen replacement therapy with associated carcinogenic side effects in women and feminizing effects in men. Pan et al. (2001) found that soy isoflavones, genistein, daidzein and glycitein inhibited proliferation and DNA synthesis of aortic smooth muscle cells from stroke-prone spontaneously hypertensive rats (SHRSP) in a concentration-dependent fashion. Inhibition was significant at 3 μmol/l of genistein and 10 μmol/l of both daidzein and glycitein. Each isoflavone significantly inhibited platelet-derived growth factor (PDGF)-BB-induced smooth muscle cell proliferation at concentrations as low as 0.1 μmol/l. The results suggested that soy isoflavones may be useful in preventing atherosclerotic cardiovascular diseases. Results of studies conducted by Sandoval et al. (2010)

suggested that genistein would exert a protective effect on vascular endothelium, due to its regulatory action on endothelial proliferation, apoptosis and leucocyte adhesion, critical events in vascular diseases. The molecular mechanism displayed by the phytoestrogen involved the participation of the estrogen receptor and the activation of the NO pathway. In-vitro studies in rat aortic endothelial cell showed that soy isoflavone genistein significantly augmented cell proliferation in a wide range of concentration (0.001–10 nm). Genistein partially attenuated leucocyte adhesion not only under basal conditions, but also in the presence of bacterial lipopolysaccharides (LPS). Genistein down-regulated the enhancement in mRNA levels of E-selectin, vascular cell adhesion molecule-1 and P-selectin elicited by the proinflammatory agent bacterial LPS. The regulation of endothelial cell programmed death induced by the isoflavone was also demonstrated. Incubation with 10 nm Genistein prevented DNA fragmentation caused by the apoptosis inductor hydrogen peroxide.

Studies showed that ovariectomized rats supplemented with black soybean or sword bean had lower plasma triglyceride levels than those supplemented with the casein diet (Byun et al. 2010). Animals fed black soybean had significantly lower plasma total cholesterol (TC), and low-density lipoprotein cholesterol (LDL-C) levels than those fed sword bean, yellow soybean or casein. Hepatic total lipid levels were significantly lower in the yellow soybean and sword bean groups, and cholesterol levels were significantly lower in the sword bean group than in the casein group. Superoxide dismutase and catalase activities were significantly higher in the groups fed beans compared to the casein group. Hepatic thiobarbituric acid reactive substances (TBARS) levels were also significantly lower in the black soybean and sword bean groups than the casein group. The results suggested that consumption of various types of beans may inhibit oxidative stress by increasing antioxidant activity and improving lipid profiles. Evidently, intake of black soybean resulted in the greatest improvement in risk factors associated with cardiovascular disease.

Soy protein was found to elicit a lower level of serum cholesterol in rabbits than did a soy protein-amino acid mixture, suggesting the presence of factors in soy protein that counteracted the effects of hypercholesterolemic amino acids (Carroll and Kurowska 1995). Soy protein was also less hypercholesterolemic than casein in other animal species, particularly when the diet contained cholesterol, and substitution of soy protein for animal protein in the diet reduced the concentration of serum cholesterol in humans. This effect although somewhat variable was generally greater in hypercholesterolemic than in normocholesterolemic subjects. The differing effects of dietary proteins on serum cholesterol concentrations in humans and in rabbits were primarily due to changes in LDL cholesterol, and the hypercholesterolemia produced by dietary casein was associated with down-regulation of hepatic LDL receptors. Among soy-derived products, only the soy protein peptide, 7 S globulin inhibited apo B secretion and 14 C-acetate incorporation when tested in Hep G2 cells at a concentration of 1.0 g/l (Lovati et al. 2000). The findings supported the hypothesis that if one or more peptides could reach the liver after intestinal digestion, they may elicit a cholesterol-lowering effect. The series of studies conducted by Peluso et al. (2000) suggested that the hypocholesterolemic mechanism of dietary soy protein involved a cooperative interaction between the protein and isoflavone-enriched fraction that decreased hepatic lipid concentrations. They hypothesized that modulation of liver and plasma lipid homeostasis could also lower blood platelet sensitivity. In obese fa/fa Zucker rats, plasma total cholesterol, was 21 and 29% lower in the low isoflavone soy protein (38 mg isoflavones/kg diet; LI) and high isoflavone soy protein (578 mg isoflavones/kg diet; HI) groups, respectively, than in the casein group. Liver weight and liver triglyceride and cholesteryl ester concentrations were 27%, 33% and 46% lower, respectively, in the LI group than in the casein group. In a complementary study, of 5-week-old male Sprague-Dawley rats, thrombin-mediated platelet serotonin release in-vitro was 13% lower in the HI group than in the casein group. In a third study of 7-week-old male

Sprague-Dawley rats, incorporation of the isoflavones extract to the atherogenic diet lowered the liver triglyceride concentration by 33% relative to the atherogenic diet without isoflavones. Adam et al. (2004) found that relative to mice fed casein/lactalbumin-based diets after 4 months, the extent of atherosclerosis was reduced in ovariectomized female mice fed all soy protein-containing diets (isoflavone-containing soy protein isolate, β-conglycinin (7 S globulin, a major soy storage protein), glycinin (11 S globulin, another major soy storage protein), β-conglycinin-devoid soy protein, and W008 (a peptide fraction produced by hydrolysis and precipitation of soy protein isolate). Relative to mice fed isoflavone-containing soy protein isolate, atherosclerosis was reduced only in mice fed the β-conglycinin-containing diet. Mean reductions were 39 and 67% in male and ovariectomized female apoE null mice and 66% in male LDL receptor null mice. The researchers concluded that a diet rich in β-conglycinin exerted atheroprotective effects that greatly exceeded those of isoflavone-containing soy protein isolate and did not depend on LDL receptors or influences on plasma lipoproteins. Separate studies demonstrated that the soy β-conglycinin diet reduced serum triglyceride levels by acceleration of beta-oxidation, suppression of fatty acid synthase and/or increased triglyceride faecal excretion, and also diminished serum glucose and insulin levels (Moriyama et al. 2004). The activities of two enzymes related to fatty acid beta-oxidation were higher while that of fatty acid synthase was lower in livers of β-conglycinin-fed mice than of casein-fed both mice. Messenger RNA levels of acyl-CoA oxidase (fatty acid beta-oxidation related enzyme) were significantly higher in livers of beta-conglycinin-fed mice than of both casein-fed mice. In contrast, mRNA levels of SREBP-1 and 2 tended to be lowered in livers of soy protein-fed mice than of both casein-fed mice. The results suggested that soy β-conglycinin could be a potentially useful dietary protein source for the prevention of hypertriglyceridemia, hyperinsulinemia, and hyperglycemia, risk factors for atherosclerosis.

Rats fed the soy protein diet exhibited significantly lower expression of SREBP-1 mRNA than rats fed the casein diet (Ascencio et al. 2004). Soy protein intake also reduced the expression of fatty acid synthase (FAS) and malic enzyme, leading to low hepatic lipid depots of triglycerides and cholesterol, whereas rats fed the casein diet developed fatty liver. Long-term consumption of soy protein maintained normal insulin concentrations compared with rats fed casein, which were hyperinsulinemic. The data suggested that soy protein regulated SREBP-1 expression by modulating serum insulin concentration, thus preventing the development of fatty liver. Tovar et al. (2005) found that serum and hepatic cholesterol and triglyceride concentrations, as well as VLDL-triglyceride and LDL-cholesterol, were significantly lower in rats fed soy protein than in Zucker obese fa/fa rats fed a casein diet for 160 days. The reduction in hepatic cholesterol was associated with a low expression of liver X receptor-alpha and its target genes, 7-α hydroxylase and ABCA1. Soy protein also lowered the expression of SREBP-1 in adipocytes and several of its target genes, FAS, stearoyl-CoA desaturase-1, and δ5 and δ6 desaturases, decreasing lipogenesis even in the presence of hyperinsulinemia and preventing the development of hepatic lipotoxicity. Reduction in SREBP-1 was not associated with the presence of soy isoflavones. Animal studies indicated that β-conglycinin increased adiponectin levels and improved glucose tolerance (Tachibana et al. 2010). In oral glucose administration, the β-conglycinin-fed rats exhibited a significant decrease in the area under the glucose curve as compared with the casein-fed rats. Thirty minutes after intraperitoneal insulin injection, the hypoglycemic effect was significantly greater in the β-conglycinin-fed rats than in the casein-fed rats. The liver sterol regulatory element-binding-protein-1 (SREBP-1) mRNA expression level was significantly lower and the plasma adiponectin level was significantly higher in the beta-conglycinin-fed rats than in the casein-fed rats. The hypotriglyceridemic effect of β-conglycinin depended on a significant decrease in the level of very-low-density-lipoprotein triglycerides. The results

indicated the ability of β-conglycinin to decrease plasma lipid concentrations may be due to increased insulin sensitivity of the liver.

Soy isoflavones supplementation was found to reduce hypercholesterolemia, the production of heat shock proteins HSP60, HSC70 heat shock chaperone protein 70) and HSP70 and reactive antibodies to HSC70 in serum and to HSC70 and HSP70 in aorta, as well as, the cholesterol content in atherosclerotic lesions in rabbits fed a casein-based atherogenic diet (Pereira and Abdalla 2006). Rats fed isoflavone-poor soy protein isolate had markedly lower concentrations of liver cholesterol and lower concentrations of triglycerides in the liver and in plasma than rats fed casein (Shukla et al. 2007). The isoflavone-poor soy protein isolate affected cellular lipid homeostasis by the down-regulation of SREBPs sterol-regulatory element-binding proteins) and its target genes in the liver, which we involved in the synthesis of cholesterol and triglycerides.

Rabbits fed low and high soy isoflavone (Iso) diets had decreased LDL-cholesterol, increased HDL-cholesterol and lower concentrations of LDL (−) in blood plasma and aortic atherosclerotic lesions than the non-supplemented Control group (Teixeira Damasceno et al. 2007). IgG autoantibodies reactive to LDL(−)were higher in plasma of the Control group in comparison with the High and Low Iso groups. However, the aortas from animals that consumed isoflavones showed higher levels of IgG reactive to LDL(−) than the Control group. The results showed that soy isoflavones exerted hypolipidemic effects and decreased the pro-inflammatory LDL(−) subfraction in blood plasma and aorta of hypercholesterolemic rabbits.

Monascus-fermented soybean extracts (MFSE) enriched with bioactive mevinolins (natural statins) and aglycone isoflavones (daidzein, glycitein, and genistein) was found to exert an additive hypolipidemic effect in hyperlipidemic rats than unfermented soybean extracts (UFSE), with a higher level of glucoside isoflavones (daidzin, glycitin, and genistin) without mevinolin (Pyo and Seong (2009). The oral administration of MFSE (200 and 400 mg/kg body weight) significantly decreased the serum total cholesterol, triglyceride, and low-density lipoprotein cholesterol (LDL-C) levels and increased high-density lipoprotein cholesterol (HDL-C) levels in hyperlipidemic rats. The MFSE group had a significantly lower 3-hydroxyl-3-methylglutaryl-coenzyme A (HMG-CoA) reductase activity and higher atherogenic index (calculated as HDL-C/LDL-C) when compared with the UFSE group (400 mg/kg body weight). Treatment with both MFSE200 and MFSE400 groups for 40 days significantly lowered the activities of serum aspartate aminotransferase and alanine aminotransferase, as compared to the high-fat diet group. The results indicated that MFSE exerted a more potent hypolipidemic action via improvement of the lipid profiles and down-regulated HMG-CoA reductase activity than UFSE in hyperlipidemic rats. Soy yogurt, soy yogurt supplemented with isoflavones and placebo exerted significant reductions in total cholesterol level (38.1%, 27.0% and 26.6%, respectively) in hypercholesterolemic rabbits (Cavallini et al. 2009). Significant increases in serum HDL-C level were detected in animals that ingested soy yogurt, with or without the isoflavone supplement (55.2%), *Enterococcus faecium* culture (43.3%) or placebo (35.8%). Intake of soy yogurt and soy yogurt supplemented with isoflavones prevented the rise of oxLDL Ab (oxidized low density lipoprotein antibodies) during the study period. Rabbits treated with soy yogurt supplemented with isoflavones exhibited the greatest reduction (51.4%) in atherosclerotic lesion area in the whole aorta, compared to the group fed only with the hypercholesterolemic diet. The findings suggested soy yogurt could be consumed as an alternative means of reducing the risk of cardiovascular disease by improving the lipid profile and inhibiting oxLDL Ab formation and also suggested that isoflavone supplementation may enhance the antiatherosclerotic effect of soy yogurt.

Sirtori et al. (1995) in their studies of >1,000 patients over the preceding 20 years found in man, similar to experimental animals, soy protein may in some way up-regulate LDL receptors depressed by hypercholesterolemia or by dietary cholesterol administration. In their extensive review of literature they found similar findings

were also reported by others when administering textured vegetable protein (TVP) or TVP-like items to subjects with well-characterized hypercholesterolemia (Fredrickson type II). Data were less consistent for treatment of patients with marginal hypercholesterolemia or hypercholesterolemia already rectified by a standard diet before administration of soy products. However, the TVP diet was found effective when normolipidemic individuals were made hypercholesterolemic by dietary cholesterol administration. Hyperlipidemic Mexican subjects with the ABCA1 R230C genotype showed lower HDL-levels and were better responders to dietary portfolio treatments with soy protein and soluble fibre for increasing HDL-C concentrations than subjects with the R230R genotype (Guevara-Cruz et al. 2010).

In a randomized, double-blind crossover trial of 51 women soy supplementation in the diet of nonhypercholesterolemic, nonhypertensive, perimenopausal women resulted in significant improvements in lipid and lipoprotein levels, blood pressure, and perceived severity of vasomotor symptoms (Washburn et al. 1999). Significant decreases in total cholesterol (6% lower) and low density lipoprotein cholesterol (7% lower) were observed in the soy diets compared with the carbohydrate placebo diet. A significant decline in diastolic blood pressure (5 mmHg lower) was noted in the twice-daily soy diet, compared with the placebo diet. No significant effects were observed for triglycerides, high density lipoprotein cholesterol or frequency of menopausal symptoms. These data confirmed the potential importance of soy supplementation in reducing chronic disease risk in Western populations. In a randomized, crossover-controlled trial, soy isoflavones were found to significantly improve the lipid profile across the menstrual cycle in normocholesterolemic, premenopausal women (Merz-Demlow et al. 2000; Wangen et al. 2001). Total cholesterol, HDL-cholesterol, and LDL-cholesterol concentrations changed significantly across menstrual cycle phases. During specific phases of the cycle, the high-isoflavone diet lowered LDL cholesterol by 7.6–10.0%, the ratio of total cholesterol to HDL cholesterol by 10.2%, and the ratio of LDL to HDL cholesterol by 13.8%. Although of small magnitude, these effects could contribute to a lower risk of developing coronary heart disease in healthy people who consume soy over many years. Studies in 81 moderately hypercholesterolemic men showed that consuming as little as 20 g soy protein per day instead of animal protein for 6 weeks reduced concentrations of non-HDL cholesterol and apo B by approximately 2.6% and 2.2%, respectively (Teixeira et al. 2000).

In a double-blind, randomized, parallel, single-center trial of 156 healthy men and women, Crouse et al (1999) found that naturally occurring isoflavones isolated with soy protein lowered the plasma concentrations of total and LDL cholesterol without affecting concentrations of triglycerides or high-density lipoprotein cholesterol in mildly hypercholesterolemic volunteers consuming a National Cholesterol Education Program Step I diet. Ethanol-extracted isolated soy protein did not significantly reduce plasma concentrations of total or LDL cholesterol. In a 1-month randomized crossover study of 31 hyperlipidemic subjects, consumption of high-isoflavone foods was found to be associated with reduced levels of circulating oxidized LDL even in subjects taking vitamin E, with no evidence of increased urinary estrogenic activity (Jenkins et al. 2000a). The researcher concluded that soy consumption may reduce cardiovascular disease risk without increasing the risk for hormone-dependent cancers. In another randomized crossover design study as part of an ad libitum National Cholesterol Education Program (NCEP) step 2 therapeutic diet (<7% saturated fat and <200 mg/day cholesterol), 20 hyperlipidemic men and postmenopausal women completed a 8-week test and control soy dietary treatments (Jenkins et al. 2000b). The findings suggested that a combination of acceptable amounts of soy, vegetable protein, and soluble-fibre foods as part of a conventional low-fat, low-cholesterol therapeutic diet was effective in further reducing serum lipid risk factors for cardiovascular disease. In a separate study of 41 hyperlipidemic men and postmenopausal women, substitution of soyfoods for animal products for a month, regardless of

isoflavone concentration, reduced the coronary artery disease (CAD) risk because of both modest reductions in blood lipids and reductions in oxidized LDL, homocysteine, and blood pressure (Jenkins et al. 2002). Compared with the control diet, , both high- and low-isoflavone soy diets exerted significantly lower total cholesterol, estimated CAD risk, and ratios of total to HDL cholesterol, LDL to HDL cholesterol, and apolipoprotein B to A-I. No significant sex differences were observed, except for systolic blood pressure, which in men was significantly lower after the soy diets than after the control diet. On the basis of blood lipid and blood pressure changes, the calculated CAD risk was significantly lower with the soy diets.

In a parallel group study of 130 men and women, adding 30–50 g soy protein daily to a lipid-lowering diet significantly reduced LDL-cholesterol levels without increasing lipoprotein(a) levels (Tonstad et al. 2002). Plasma total homocysteine concentrations also decreased, suggesting a novel, possibly antiatherosclerotic effect. Soy protein, regardless of isoflavone content, was found to modulate serum lipid ratios in a direction beneficial for cardiovascular disease risk in healthy young men (McVeigh et al. 2006). In a 4 week randomized crossover design study of 35 healthy males, comparing milk protein isolate (MPI), low-isoflavone soy protein isolate (low-iso SPI; 1.64 mg aglycone isoflavones/day), and high-isoflavone SPI (high-iso SPI; 61.7 mg aglycone isoflavones/day), urinary isoflavones were significantly greater with consumption of the high-iso SPI than with that of the low-iso SPI or MPI. The ratios of total to HDL cholesterol, LDL to HDL cholesterol, and apo B to apo A-I were significantly lower with both SPI treatments than with MPI treatment. Similar results that consumption of soy protein modulated some serum lipids in a direction beneficial for CVD risk was obtained in a subsequent study in a double-blind, randomized, crossover, placebo-controlled intervention study design of 29 adults with diet-controlled type 2 diabetes (Pipe et al. 2009). Soy protein isolate (SPI) consumption increased urinary isoflavones compared with MPI. SPI consumption significantly reduced serum LDL cholesterol, LDL cholesterol:HDL cholesterol, and apolipoprotein B:apolipoprotein A-I compared with MPI. SPI did not affect serum total cholesterol, HDL cholesterol, triacylglycerol, apolipoprotein B, or apolipoprotein A-I. The results of the randomized clinical trial of 40 randomized clinical trial in which 40 PD patients (20 males, 20 females) patients (20 males, 20 females) by Tabibi et al. (2010) indicated that textured soy flour (containing 14 g of soy protein) consumption for 2 months reduced serum lipoprotein(a) concentration, a risk factor for cardiovascular disease in peritoneal dialysis patients. The elevated mean serum Lp(a) concentration was reduced significantly, by 41%, in the soy group at the end of week 8 compared to baseline; the reduction was also significant compared to the control group. There were no significant differences between the two groups in mean changes in serum triglyceride, total cholesterol, HDL-C, LDL-C, apo B100, or apoAI. Studies in 30 sedentary males aged 18–30 years randomly assigned to milk protein, isoflavone-poor soy (Soy-), or isoflavone-rich soy (Soy+) diets showed that postprandial triacylglycerol and triacylglycerol area under curve increased after soy-consumption supporting the postprandial state as a more sensitive indicator of soy ingestion effects on CVD risk factors compared with the fasting lipid profile (Santo et al. 2010). Fasting glucose concentrations were not different after any protein supplementation. Additionally, the absence of isoflavones in soy protein may have deleterious consequences on purported cardio-protective effects.

Zhuo et al. (2004) conducted a meta-analysis of 8 randomized controlled trials published from 1966 to 2003 that described the effects of soy protein isolate (SPI) intake with measured isoflavone levels on blood lipids in humans and found that with identical soy protein intake, high isoflavone ingestion produced significantly greater decreases in serum LDL cholesterol than low isoflavone intake, demonstrating that isoflavones had LDL cholesterol-lowering effects independent of soy protein. Decreases in serum LDL cholesterol concentration were noted in hypercholesterolemic and normocholesterolemic

subjects. Zhan and Ho (2005) conducted a meta-analysis of 23 eligible randomized controlled trials published from 1995 to 2002 to identify and quantify the effects of soy protein containing isoflavones on the lipid profile. They found that soy protein containing isoflavones significantly lowered serum total cholesterol, LDL cholesterol, and triacylglycerol and significantly increased HDL cholesterol, but the changes were related to the level and duration of intake and the sex and initial serum lipid concentrations of the subjects. The meta-analysis performed by Reynolds et al. (2006) considered 41 randomized controlled trials that investigated the effect of soy protein supplementation on serum lipid levels in adults published between 1966 and 2005, and involved a total of 1,756 adults. Soy protein supplementation was associated with a significant reduction in mean serum total cholesterol (−5.26 mg/dl), low-density lipoprotein cholesterol (−4.25 mg/dl), and triglycerides (−6.26 mg/dl) and a significant increase in high-density lipoprotein cholesterol (0.77 mg/dl). Meta-regression analyses found a dose-response relation between soy protein and isoflavone supplementation and net changes in serum lipids. The results indicated that soy protein supplementation reduced serum lipids among adults with or without hypercholesterolemia. They concluded that replacing foods high in saturated fat, trans-saturated fat, and cholesterol with soy protein may have a beneficial effect on coronary risk factors. Taku et al. (2007) conducted a meta-analysis of 11 of randomized controlled trials published from 1990 to 2006 on the effects of soy protein intake in humans and found that soy isoflavones significantly lowered serum total cholesterol and LDL cholesterol but did not alter HDL cholesterol and triacylglycerol. Soy protein that contained enriched or depleted isoflavones also significantly improved lipid profiles in humans. Reductions in LDL cholesterol were larger in hypercholesterolemic than in normocholesterolemic subjects. Liang et al. (2009) performed a case-control study in southern China during 2007–2008 wherein soy food consumption, dietary intake and lifestyle information were obtained from 374 incident ischemic stroke patients and 464 hospital-based controls and subjected to logistic regression analyses. Increased consumptions of dried soybean, tofu, soymilk and total soy foods were associated with reduced risks of ischemic stroke after adjusting for confounding factors. An inverse association between habitual soy food consumption and the risk of ischemic stroke for Chinese adults was found. A study of 134 males and 261 females aged 40–65 years old, in Guangzhou showed that moderate intakes of soy isoflavone as part of a regular diet appeared to be associated with favourable blood lipid levels (Zhang et al. 2010). Ranges of dietary soy isoflavones intake among 134 males and 261 females were from 0 to 61.96 mg/day and 0–82.52 mg/day, with means of 11.95 mg/day, 14.90 mg/day, respectively. Compared with the low-intake group, the levels of total cholesterol and LDL cholesterol in total population and total cholesterol in women were reduced by 7.06%, 10.13% and 7.48%, respectively in high-intake group. The meta-analysis of the AHA Soy Advisory data gave a mean LDL-C reduction of 0.17 mmol/l (n = 22) or 4.3% for soy, which was confirmed in 11 studies reporting balanced macronutrient profiles (Jenkins et al. 2010). The calculated displacement value of soy (13–58 g/day) using NHANES III population survey data was a 3.6–6.0% reduction in LDL-C attributable to displacement of saturated fats and cholesterol from animal foods. The LDL-C reduction due to the combined intrinsic and extrinsic effects of soy protein foods ranged from 7.9% to 10.3%. The researcher concluded that soy remained one of a few food components that reduced serum cholesterol (>4%) when added to the diet.

Sacks et al. (2006) found that in 22 randomized trials, isolated soy protein with isoflavones, as compared with milk or other proteins, decreased LDL, but their effect was small. Significant effects on HDL cholesterol, triglycerides, lipoprotein (a), or blood pressure were not evident. Among 19 studies of soy isoflavones, the average effect on LDL cholesterol and other lipid risk factors was nil. Thus, they asserted that the direct cardiovascular health benefit of soy protein or isoflavone supplements was minimal at best. However, much less is known about the potential

impact of high-protein diets on risk factors for CVD and more dynamic research is warranted. In contrast, soy products such as tofu, soy butter, soy nuts, or some soy burgers should be beneficial to cardiovascular and overall health (Sacks et al. 2006) because of their high content of poly-unsaturated fats, fibre, vitamins, and minerals and low content of saturated fat (Krauss et al. 2000). Using these and other soy foods to replace foods high in animal protein that contain saturated fat and cholesterol may confer benefits to cardiovascular health (Jenkins et al. 2003a). Soy protein also may be used to increase total dietary protein intake and to reduce carbohydrate or fat intake. A meta-analysis of 10 well-controlled studies comprising 959 subjects (336 men and 623 women); average age ranged from 41 to 67 years was performed to assess the effect of soy-associated isoflavones on cholesterol concentrations (Weggemans and Trautwein 2003). The findings indicated that consumption of soy-associated isoflavones was not related to changes in LDL or HDL cholesterol. The data from studies by Campbell et al. (2010) indicated that 1-year soy protein supplementation did not confer cardiovascular benefits, in terms of favourable alterations in the lipid profile, in the cohort of moderately hypercholesterolemic postmenopausal women. There was a trend for total cholesterol and high-density lipoprotein cholesterol levels to increase after 1 year of soy protein supplementation. There were no significant differences in low-density lipoprotein cholesterol or triglyceride levels; however, a significant increase in Apo B levels and a significant decrease in Apo A levels were noted. In a single-blind, randomized, controlled trial conducted on 32 postmenopausal women, soymilk consumption failed to show a significant hypocholesterolemic in the postmenopausal female population despite good dietary compliance (Beavers et al. 2010b). Plasma high-density lipoprotein, plasma total cholesterol LDL, and triglycerides were not significantly different between groups post-intervention or from baseline. Further, sub-analyses controlling for dyslipidemia and lipid-lowering medication usage did not significantly alter results.

Soy and Obesity

Obesity has been reported to be associated with hyper-insulinemia, insulin resistance, and abnormalities in lipid metabolism, and poses one of the most important risk factors in the development of Type II diabetes, cardiovascular disease, atherosclerosis, and certain cancers (Ørgaard and Jensen 2008). Because of the lower frequency of these diseases in Asian countries, focus has been centred on Asian diet which comprises considerably of soy and soy-based products. The health benefits associated with soy consumption have been attributed to the content of isoflavones, the main class of the phytoestrogens in soy. Genistein, daidzein, and glycitein are the principal isoflavones in soy.

Studies showed that body weights were significantly lower in Phyto-600 (soy isoflavone rich) fed male rats (Lephart et al. 2004). Body and adipose tissue weights were decreased in Phyto-600 vs. Phyto-free fed rats. Food and water intake was greater in Phyto-600 animals, that displayed higher hypothalamic (NPY) thyroid levels (and a tendency for higher glucose levels) and increased uncoupling protein (UCP-1) mRNA levels in brown adipose tissue, but lower plasma leptin and insulin levels, vs. Phyto-free fed males. The results demonstrated that consumption of a soy-based (isoflavone-rich) diet, significantly changed several parameters involved in maintaining body homeostatic balance, energy expenditure, feeding behaviour, hormonal, metabolic and neuroendocrine function in male rats. Similar studies showed that body weights were significantly lower in Phyto-600 (soy isoflavone rich) fed ovariectomized rats compared to Phyto-free diet within 1 week and during long-term consumption of soy isoflavones (Bu et al. 2005). Concomitantly, Phyto-600 fed animals displayed significantly less adipose deposition and lower serum leptin levels than Phyto-free values although the Phyto-600 diet displayed greater food/water intake compared to Phyto-free levels. No changes in thermal pain threshold or stress hormone levels (adrenocorticotropic hormone (ACTH) and corticosterone) were observed after activation of the

hypothalamic-pituitary-adrenal (HPA) stress axis in female rats. Taken together, the data showed that consumption of soy isoflavones increased metabolism, demonstrated by significantly decreased body weights, adipose tissue deposition and leptin levels, but did not change nociception or stress hormone responses, as evaluated by thermal pain threshold, serum corticosterone and adrenocorticotropic hormone levels in chemically-induced oestrous ovariectomized rats.

Combined intervention of soy isoflavone and moderate exercise was found to prevent body fat accumulation and bone loss in ovariectomized mice (Wu et al. 2004a). Similarly, Oh et al. (2007) showed that a combined treatment of moderate exercise and soy isoflavone supplementation could exert a beneficial effect on weight control and lipid profiles, and offer protection from exercise-induced oxidative stress in ovariectomized rats. Rats fed soy diets had lower hepatic sterol regulatory element binding protein-1 (SREBP-1) expression and higher SREBP-2 expression than those fed casein diets, leading to less hepatic lipid deposition (Torre-Villalvazo et al. 2008). In contrast, long-term high fat – soya protein consumption prevented hyperleptinemia in comparison with rats fed high fat-casein. Rats fed soy protein diet showed higher adipocyte perilipin mRNA expression and smaller adipocyte area than those fed casein diets, which was associated with a lower body fat content. Further, the lipid droplet area in brown adipose tissue was significantly lower in rats fed soy diets than in those fed casein diets and it was associated with higher uncoupling protein-1 (UCP-1) expression. As a consequence, rats fed the soy diets gained less weight than those fed the casein diets, in part due to an increase in the thermogenic capacity mediated by UCP-1. The results suggested that the type of protein consumed and the presence of fat in the diet modulated lipid metabolism in adipose tissue and liver. In a subsequent study Torre-Villalvazo et al. (2009) evaluated the effect of dietary soy protein on cardiac lipid accumulation and ceramide formation during obesity. Obesity is an epidemic condition strongly associated with cardiovascular morbidity and mortality. Heart disease secondary to obesity is associated with myocardial steatosis, leading to ceramide synthesis and cell dysfunction in a process known as lipotoxicity. They found that soy protein ingestion led to lower cholesterol and triglyceride levels in the hearts of rats and ob/ob mice in association with a greater PPARalpha mRNA level and a lower concentration of SREBP-1 mRNA than those fed casein. The ceramide level was also lower in hearts of rats and ob/ob mice that were fed soy protein in conjunction with lower serine palmitoyl transferase (SPT)-1 and tumour necrosis factor-alpha mRNA levels. The results indicated that dietary soy protein could reduce the heart ceramide concentration by reducing the expression of SPT-1, a key enzyme in the formation of this sphingolipid in the heart of obese rodents, and by reducing lipid accumulation. They concluded that soy protein consumption may be considered as a dietary therapeutic approach for lipotoxic cardiomyopathy prevention. Animal studies showed that soy isoflavone could prevent obesity induced by high-fat diet and ovariectomy through regulating hypothalamus and peripheral orexigenic gene expressions associated with food intake (Zhang et al. 2010).

In a multicentric randomized longitudinal prospective cohort study of 87 healthy obese postmenopausal women, diet, physical exercise and daily oral intake of a soy isoflavones extract (Fisiogen (R)) containing 200 mg of *Glycine max*, which corresponded to 80 mg of isoflavone (60.8 mg of genistein, 16 mg of daidzein and 3.2 mg of glicitein) were found to have a beneficial effect on serum leptin, adiponectin and TNF-alpha in healthy obese postmenopausal women after 6 months of treatment (Llaneza et al. 2011).

High dosage of isoflavone (187.4 mg/kg body weight per day) was found to decrease ovariectomized rat's weight gain significantly through reducing food utilization rate (Na et al. 2005).However; soy isoflavone did not influence the growth rates of the rat organ and body. In a separate study, Kishida et al. (2008) found that soy isoflavone lowered the food intake in female rats regardless of ovarietomy, but not in the male animals. Dietary soy isoflavone significantly increased the concentration of serum isoflavones, especially equol (a metabolite of daidzein), regardless of gender or ovariectomy. Dietary soy

isoflavone did not affect either serum estradiol concentration or uterine and didymus weights. Contrary to the hypothesis currently in vogue, the researchers asserted that the reduction in food intake caused by soy isoflavone may not be a purely estrogenic effect. This was based on the findings that the effects of soy isoflavones on food intake and on the reproductive organs differed from the corresponding effects produced by estrogen, estradiol.

Studies showed that differences in the protein distribution of 15 soy genotypes led to different potentials for the reduction of fat accumulation (Martinez-Villaluenga et al. 2008). The inhibition of lipid accumulation of soy alcalase hydrolysates in 3 T3-L1 adipocytes ranged from 29% to 46%. Soy hydrolysates made from genotypes with 45.3% of total protein as β-conglycinin, on average, showed significantly higher inhibition of lipid accumulation compared to those with 24.7% of extracted total protein as β-conglycinin. Beta-conglycinin was found to embed more peptides than glycinin subunits that inhibited lipid accumulation and induced adiponectin in 3 T3-L1 adipocytes. In another study, soybean genotype enriched in β-conglycinin was found to decrease lipid accumulation (33–37% inhibition) through downregulation of gene expression of lipoprotein lipase and fatty acid synthase in 3 T3-L1 adipocytes (Martinez-Villaluenga et al. 2009). Soy protein hydrolysates derived from soybean enriched in β-conglycinin, inhibited LPS (lipopolysaccharide)-induced iNOS/NO and COX-2/PGE(2) inflammatory pathways in macrophages. In subsequent studies, three peptides purified from soybean β-conglycinin inhibited fatty acid synthase by interaction with the thioesterase catalytic domain (Martinez-Villaluenga et al. 2010). The results of these studies suggested that soy ingredients containing β-conglycinin may be important food components for the control of lipid accumulation in adipose tissue.

Soy and Antihypertensive Activity

Evidence from the review of 46 papers suggested a small beneficial effect of protein on blood protein, especially for plant protein (including soy proteins) (Altorf-van der Kuil et al. 2010). A blood pressure lowering effect of protein may have important public health implications. Taku et al. (2010a) identified 3,740 articles, of which 14 randomized controlled trials (789 participants) were included in the meta-analysis to clarify the effects of soy isoflavone extract supplements on systolic and diastolic blood pressure (SBP and DBP) in adult humans. Soy isoflavone extracts were found to significantly decreased SBP but not DBP in adult humans, and no dose-response relationship was observed. Daily ingestion of 25–375 mg soy isoflavones (aglycone equivalents) for 2–24 weeks significantly decreased SBP by 1.92 mmHg compared with placebo in adults with normal blood pressure and prehypertension. They recommended more studies to address factors related to the observed effects of soy isoflavones on SBP and to verify the effect in hypertensive patients.

Angiotensin-converting enzyme (ACE) inhibitory peptides, derived from a multitude of plant and animal proteins such as milk, soy or fish, represent sources of health-enhancing components (De Leo et al. 2009). These ACE inhibitory peptides can be enzymatically released from precursor proteins in-vitro and in-vivo, respectively during food processing and gastrointestinal digestion. They have shown the ability to lower blood pressure by limiting the vasoconstrictory effects of Angiotensin II and potentiating the vasodilatory effects of Bradykinin. Studies showed that the angiotensin I converting enzyme (ACE) inhibitory peptide His-His-Leu (HHL) derived from Korean fermented soybean paste exerted antihypertensive activity in-vivo (Shin et al. 2001). The IC_{50} value of the HHL for ACE activity was 2.2 μg/ml in-vitro. The synthetic tripeptide HHL, generated a significant decline of ACE activity in the aorta and led to lowered systolic blood pressure (SBP) in spontaneously hypertensive (SH) rats compared to control. Triple injections of the synthetic tripetide HHL, 5 mg/kg of body weight/injection elicited a significant decrease of SBP by 61 mmHg after the third injection. In another study, casein miso paste was prepared by adding casein at various concentrations during miso paste fermentation in order to release angiotensin-I converting enzyme (ACE)

inhibitory peptides (Inoue et al. 2009). Two types of antihypertensive peptides, Val-Pro-Pro and Ile-Pro-Pro were obtained casein hydrolysate by using *Aspergillus oryzae* protease. ACE inhibitory activity of the casein miso paste was higher than that of the general (casein-free) miso paste after fermentation for 7 days. The concentrations of ACE inhibitory peptides, Val-Pro-Pro and Ile-Pro-Pro, were increased in the casein miso paste during the fermentation. Compared to water and the general miso paste, significant antihypertensive effects of casein miso paste were confirmed in spontaneously hypertensive rats at a dosage of 1.8 g of the casein miso paste/kg of body weight. The results suggested that casein miso paste may have the potential to control blood pressure in humans.

The average antioxidant capacities of 70% ethanol extracts from *Monascus*-fermented soybean (MFSE) after 15 days fermentation at 30°C were increased by a 5.2–7.4-fold as assayed by 1,1-diphenyl-2-picrylhydrazyl [DPPH] radical scavenging when compared with those of the unfermented soybean extracts (Pyo and Lee 2007). The significant antioxidant properties of MFSE were attributed to its content of bioactive mevinolins and isoflavone aglycones, which were derived from the soybean during *Monascus*-fermentation. It was also found that the water extract having a molecular mass 1–3 kDa showed the highest ACE inhibitory activity (65.3%), which was considerably higher (6.5 times) than the control. ACE-inhibitory peptides in salt-free soy sauce obtained by *Aspergillus oryzae* fermentation of soybean were found to be transportable across caco-2 cell monolayers. (Zhu et al. 2008). The three transportable ACE inhibitory di-peptides were identified Ala-Phe, Phe-Ile and Ile-Phe. Ala-Phe and Ile-Phe, but not Phe-Ile, exhibited ACE-inhibitory activity with IC_{50} values of 165.3 and 65.8 μM, respectively. Kinetic studies revealed that Ile-Phe exhibited greater affinity toward the transport compared with Ala-Phe and Phe-Ile. Fermentation with *Bacillus* spp. as a starter organism was found to enhance anthocyanin content, the angiotensin converting enzyme inhibitory effect, and the reducing activity of black soybeans (Juan et al. 2010). It was found that the ACE inhibitory activity of the extracts of soybean and viscous material from the fermented black soybeans varied with extraction solvents and starter organism, yet increased as the fermentation period was protracted, regardless of starter organism. After 18 h of fermentation, the water extract of bean showed less ACE inhibitory activity than did the respective 80% ethanol extract. In contrast, the water extract of viscous material showed a higher ACE inhibitory activity than the respective ethanol extract. With respect to extraction yield, it was found that the ACE inhibitor in the fermented black soybean could be extracted more efficiently with water than 80% ethanol. Fermentation with *Bacillus subtilis* BCRC 14715 was also found to increase the anthocyanin content of black soybean and the reducing activity of the extracts. Further, the 80% ethanol extract showed a higher reducing activity than the water extract.

Matsui et al. (2010) investigated the antihypertensive effect of newly fermented salt-free soy (SFS) sauce in spontaneously hypertensive rats. As a result of 13-week SFS-administration, they found a significant antihypertensive effect. Vasoconstriction experiment revealed the thoracic aorta rings from the SFS group evoked a >2-fold higher increase in the angiotensin II-stimulated constrictive response compared with the rings from the control group, suggesting that the SFS-ingestion would be effective in possessing a higher vessel tone. This finding strongly demonstrated that the developed SFS would be greatly beneficial for health and useful for health-related industries. A peptide-enriched soy sauce-like seasoning termed Fermented Soybean Seasoning (FSS), was developed by Nakahara et al. (2010) by modifying the process of soy sauce brewing. The FSS has a 2.7-times higher level of total peptides than regular soy sauce. The angiotensin I-converting enzyme (ACE) inhibitory activity of FSS (IC_{50} = 454 μg/ml) was greater than that of regular soy sauce (IC_{50} = 1,620 μg/ml). The FSS demonstrated antihypertensive effects both in spontaneously hypertensive rats and in Dahl salt-sensitive rats during continuous feeding. The ACE inhibitory

substances were purified from FSS and identified as Ala-Trp IC_{50} = 10 μM; Gly-Trp IC_{50} = 30 μM; Ala-Tyr IC_{50} = 48 μM; Ser-Tyr, IC_{50} = 67 μM; Gly-Tyr, IC_{50} = 97 μM; Ala-Phe, IC_{50} = 190 μM; Val-Pro, IC_{50} = 480 μM; Ala-Ile, IC_{50} = 690 μM; Val-Gly, IC_{50} = 1,100 μM; and a nicotianamine, IC_{50} = 0.26 μM. The concentrations of these substances in the FSS were higher than that in regular soy sauce.

Isoflavones in soybean ACE inhibitory peptide fraction were found to have negligible contribution to the blood-pressure-lowering property in a short-term feeding study (Wu and Muir 2008). The dominant isoflavones in the ion-exchanged soybean ACE inhibitory peptide fraction were aglycones and nonacylated isoflavones, accounting for 95.8% of the total concentration of 987.7 μg/g. It was estimated that the isoflavone concentration in the soybean ACE inhibitory peptide fraction was 25 times less than the minimal effective isoflavone dose reported. Producing soybean hydrolysate led to a nearly 40% loss of isoflavones compared with the original soybean flour, but the isoflavone composition did not alter and the dominant isoflavone chemicals remained as 6''-O-malonylgenistin and 6''-O-malonyldaidzin. In-vitro study also showed that adding isoflavones into both soybean flour hydrolysate and soybean ACE inhibitory peptide samples to a concentration of as high as 31.5% (w/w) did not affect ACE inhibitory activity (IC_{50} values).

Soybean isoflavones of genistein and biochanin A, its analogue, promoted the activity for generating tissue-plasminogen activator from human cervical cancer cells (HeLa S3) and human umbilical vein endothelial cells (HUVEC) (Yatagai et al. 2007). Substantial fibrinolytic activity was observed for two types of isoflavones. Genistein showed the highest level of fibrinolytic activity at 12.4 times the control, and for biochanin A, the level was 3.5 times the control. Fibrinolytic activity of HUVEC incubated with 25 μM of biochanin A was much higher than that of the control, suggesting that these soybean isoflavones could have beneficial effects on blood circulation in-vivo.

Soy and Antidiabetic Activity

In a cross-over randomized, double blind, placebo-controlled trial of 20 type 2 diabetic subjects, Hermansen et al. (2001) found that dietary supplementation with Abalon (soy protein [50 g/day] with high levels of isoflavones [minimum 165 mg/day] and cotyledon fibre [20 g/day]) exhibited beneficial effects on cardiovascular risk markers in type 2 diabetic subjects. Compared to placebo, Abalon exerted significant reductions in LDL cholesterol, LDL/UHDL ratio, apolipoprotein (apo) B100, triglycerides, and homocysteine, whereas the total cholesterol value tended to be less significant but still lower. No change occurred in HDL cholesterol, apo B100/apo A1 ratio, plasminogen activator inhibitor 1, factor VIIc, von Willebrand factor, fibrinogen, lipoprotein(a), glucose, HbA1c, or 24-hour blood pressure. This improvement was noted even in individuals with near-normal lipid values. In a randomized, double blind, placebo-controlled, cross-over trial of 32 women, dietary supplementation with soy phytoestrogens (soy protein 30 g/day, isoflavones 132 mg/day) favourably altered insulin resistance, glycemic control, serum lipoproteins in postmenopausal women with type 2 diabetes (Jayagopal et al. 2002). Thus, improving their cardiovascular risk profile. Phytoestrogen supplementation demonstrated significantly lower mean values for fasting insulin, insulin resistance, HbA(1c) (glycosylated haemoglobin), total cholesterol, and free thyroxine. No significant change occurred in HDL cholesterol, triglycerides, weight, blood pressure, creatinine, dehydroepiandrosterone sulfate, androstenedione, and the hypothalamic-pituitary-ovarian axis hormones.

In a randomized, double-blind, active placebo-controlled clinical trial involving 30 postmenopausal Taiwanese women, soy isoflavones (100 mg) and 0.625 mg conjugated estrogen were found to be equally effective in lowering fasting blood glucose and insulin levels after 6 months of treatment (Cheng et al. 2004). The average blood genistein concentration was 6–10 times higher in the isoflavone group than in the estrogen group.

In a crossover randomized clinical trial of 14 Type 2 diabetic patients with nephropathy, soy inclusion was found to modify heart disease factors and improve kidney function (Azadbakht et al. 2003). Significant reductions were found in total cholesterol, triglyceride and LDL-c, urinary urea nitrogen and proteinuria (after soy vs. animal protein consumption). There were no significant changes in HDL-c, LDL-c/HDL-c levels. In another longitudinal randomized clinical trial of 41 type 2 diabetic patients with nephropathy (18 men and 23 women) they found that soy protein consumption significantly lowered cardiovascular risks such as fasting plasma glucose, total cholesterol LDL cholesterol, serum triglyceride and serum C-reactive protein concentrations compared to control groups (Azadbakht et al. 2008). Significant improvements were also observed in proteinuria and urinary creatinine by consumption of soy protein. Azadbakht and Esmaillzadeh (2009) also reported in a crossover, randomized clinical trial was conducted among 14 type 2 diabetic patients (10 men and 4 women) that soy consumption reduced urinary urea nitrogen, proteinuria, blood sodium, and serum phosphorus compared with animal protein. Serum and urinary creatinine, blood urea nitrogen, serum calcium, and potassium levels were not significantly changed in soy-protein versus animal-protein consumption.

Ho et al. (2007a) conducted a 12 month, double-blind, randomized, placebo-controlled trial in 203 postmenopausal Chinese women aged 48–62 years to ascertain the effects of soy isoflavones on glycemic control. They found that soy isoflavone supplementation had a favourable effect on fasting glucose in women, but had no significant effect on serum lipids.

The 6 month randomized, double-blind, placebo-controlled trial of 180 postmenopausal Hong Kong Chinese women with prediabetes or early untreated diabetes did not confirm the hypothesis that soy protein with or without isoflavone supplementation had favourable effects on glycemic control and insulin sensitivity (Liu et al. 2010b). Three or 6 months intervention with soy protein with or without isoflavone supplementation did not result in favourable changes in the descriptors for glycemic control and insulin resistance, namely fasting and 2-h post load glucose, fasting and post load insulin, glycated serum protein, and homeostasis model assessment for insulin resistance and beta-cell function. The meta-analysis of 10 randomized controlled trials published from January 1990 to December 2009, showed that isoflavone use was not associated with a significant glycemia reduction in perimenopausal and postmenopausal non-Asian women (Ricci et al. 2010). However, the reported significant insulin and homeostasis model assessment insulin resistance changes suggested that soy isoflavones and genistein alone had a beneficial effect on glucose metabolism.

Key enzymes involved in the enzymatic breakdown of complex carbohydrates, pancreatic α-amylase and intestinal α-glucosidase, had been targeted as potential avenues for modulation of type 2 diabetes-associated post-prandial hyperglycemia (McCue et al. 2005). Long-term type 2 diabetes can lead to numerous biological complications, such as hypertension and cardio-vascular disease. Water-soluble extracts of soybean optimized for phenolic content via sprouting or bioprocessing by dietary fungus (*Rhizopus oligosporus, Lentinus edodes*) were found to exhibit inhibitory activity against porcine pancreatic α-amylase (PPA), yeast α-glucosidase, and rabbit lung ACE in-vitro (McCue et al. 2005). All of the soybean extracts possessed marked anti-amylase activity, with extracts of R. oligosporus-bioprocessed soybean having the strongest inhibitory activity, but only slight anti-glucosidase activity. Anti-enzyme activity was slightly associated with total soluble phenolic content per se, but seemed more associated to the length of sprouting or bioprocessing of the soybean substrate. Short-term sprouting or bioprocessing seemed to improve anti-amylase activity, while long-term sprouting or bioprocessing seemed to aid anti-glucosidase activity. While ACE activity was strongly inhibited by all of the soybean extracts (44–97%), only sprouting was found to increase this inhibition and bioprocessing of soybean with *L. edodes* decreased inhibitory activity of soybean extract. The results suggested that

sprouting and dietary fungal bioprocessing of soybean enhanced the anti-diabetic potential of soybean extracts, potentially through modulation of the phenolic profile of the extract, and further suggested that enzyme inhibitory activity may be associated to phenolic antioxidant mobilization during spouting and/ or bioprocessing.

Korean fermented soybean products such as doenjang, kochujang, and chungkookjang may help prevent or attenuate the progression of type 2 diabetes (Kwon et al. 2010). Several studies revealed improvements in insulin resistance and insulin secretion with the consumption of these fermented products. Human intervention trials are required to reach definitive conclusions, nevertheless, the evidence did suggest that fermented soy products may be better for preventing or delaying the progression of type 2 diabetes compared with nonfermented soybeans (Kwon et al. 2010). Kwon et al. (2006) found that in comparison to cooked soybeans (CSB), an increase in isoflavonoid aglycones in Chungkookjang (CKJ), a traditional fermented unsalted soybean, enhanced glucose utilization via activating insulin signalling and stimulating PPAR-gamma activity in adipocytes. Further, CKJ was found to contain small peptides that improved glucose-stimulated insulin secretion in insulinoma cells, suggesting that, CKJ was superior to CSB in anti-diabetic action. They also found that reduction of hepatic glucose output was greater in CKJ than CSB (Kwon et al. 2007). They concluded that fermented soybeans mainly with *Bacillus subtilis* improved hepatic insulin sensitivity better than unfermented soybeans by enhancing hepatic insulin signalling cascade in diabetic rats. They also found that Kochujang, a Korean fermented red pepper plus soybean paste, improved glucose homeostasis in 90% pancreatectomized diabetic rats by reducing insulin resistance, not by enhancing beta-cell function (Kwon et al. 2009). The improvement was associated with decreased hepatic fat storage by the activation of adenosine monophosphate kinase. The compositional changes in isoflavonoids and peptides that occurred during a longer fermentation period as in meju, dried fermented soybean, without the use of salt, enhanced the antidiabetic effect of soybeans (Kwon et al. 2011). Meju contained mostly isoflavonoid aglycones and small peptides, respectively, as opposed to mostly glycosylated isoflavonoids and proteins in the original soybeans. Daidzein, methanol (M-60) and water (W-60) extracts from meju that had fermented for 60 days exerted better insulin-sensitizing actions by activating peroxisome proliferator-activated receptor-γ in 3 T3-L1 adipocytes than did unfermented soybeans. Min6 insulinoma cells treated with genistein, M-60, and W-60 exhibited greater glucose-stimulated insulin secretion capacity and greater β-cell viability than those treated with unfermented soybeans. Further, genistein, daidzein, and M-60 stimulated glucagon-like peptide-1 secretion in enteroendocrine NCI-H716 cells, which generated insulinotropic actions.

Glyceollins, a category of phytoalexins produced by soybean under fungal stress, was found to improve insulin-stimulated glucose uptake in 3 T3-L1 adipocytes without activating the peroxisome proliferator-activated receptor-gamma agonist (Park et al. 2010). They lowered triacylglycerol accumulation in adipocytes. Further, glyceollins slightly ameliorated glucose-stimulated insulin secretion without palmitate treatment in Min6 cells, and they potentiated insulinotropic actions when 500 μM palmitate was used to induce beta-cell dysfunction. Glyceollins also potentiated GLP-1 (glucagon-like peptide-1) secretion to enhance insulinotropic actions in enteroendocrine cells. The scientists concluded glyceollins normalized glucose homeostasis by potentiating beta-cell function and survival, and improving glucose utilization in adipocytes.

Gobert and Duncan (2009) explored the consumption, perceptions and knowledge of soy among adults with type 2 diabetes in Canada. They found that soy consumers were significantly more likely to be vegetarian, lactose intolerant and shun cow's milk and significantly less likely to take medications, when compared to soy non-consumers. There were no significant differences between soy consumers and soy non-consumers in factors related to diabetes management. The prevalence of soy consumption was 19% and mainly consumed on a weekly basis and most

often at breakfast. The three most commonly consumed soy products were soy beverage, tofu and roasted soy nuts. More than half (63.8%) of soy non-consumers had consumed soy in the past and the major reason for no longer consuming soy was 'dislike taste, texture or appearance'.

Daily intake of 40 mg of soy isoflavones together with a Mediterranean diet and exercise reduced insulin resistance in postmenopausal women with insulin resistance (Llaneza et al. 2010). It was significantly better than lifestyle changes alone. Statistically significantly lower values of HOMA-IR (homeostasis model assessment of insulin resistance) scores were found in the soy isoflavones group at 6, 12, 18 and 24 months. Changes in HOMA-IR values were also clearly related to body mass index, abdominal circumference and treatment.

Soy and Prostate Cancer

In vitro, the main soybean isoflavone, genistein was reported to inhibit prostate cancer cell growth; in animals, most but not all studies show isoflavone-rich soy protein and isolated isoflavones inhibit prostate tumour development; and only limited epidemiologic data indicated soy intake to reduce prostate cancer risk (Messina 2003). Studies using animal models that emulate human prostate cancer facilitate experimental analysis of phytochemicals that exhibit anti-prostrate activity. Zhou et al. (1999) found that dietary soy products may inhibit experimental prostate tumour growth through a combination of direct effects on tumour cells such as reduction in tumour volumes, reduced tumour cell proliferation, increased apoptosis and reduced microvessel density and indirect effect on tumour angiogenesis in mice. The angiogenic protein insulin-like growth factor-I was reduced in the circulation of mice fed soy protein and phytochemical concentrate. In subsequent studies, Zhou et al. (2002) demonstrated that in male SCID mice orthotopically implanted with the androgen-sensitive human prostate cell line LNCaP, dietary supplements of soy protein, genistin, and soy phytochemical concentrate reduced primary tumour weight by 42%, 57% and 70% respectively using different molecular pathways. All three soy supplements significantly elevated tumour apoptosis and reduced microvessel density, with no significant change in tumour proliferation. Each supplement exerted a distinct serum androgen response. Genistin produced the greatest reduction in dihydrotestosterone (DHT) and total serum testosterone and the most increase in testosterone to DHT ratio. Soy protein generated the greatest reduction in bioactive androgen. Only soy phytochemical concentrate significantly inhibited metastases to lymph nodes and lungs, and elicited a significant increase in tumour p53 expression. Jang et al. (2010) found that of anthocyanin extracted from black soybeans may be effective in decreasing the volume and suppressing the proliferation of the prostate in rats. The prostate weights in the anthocyanin-administered rats were significantly lower than in the benign prostatic hyperplasia (BPH)-induced group. Injected testosterone led to prostatic hyperplasia as observed histologically, but anthocyanin administration helped to prevent this change. Apoptotic body counts were significantly higher in groups receiving anthocyanin than in the BPH-induced group.

Studies in nude mice showed that genistein combined with prostate tumour irradiation gave greater control of the growth of the primary tumour and metastasis to lymph nodes than genistein or radiation alone, resulting in greater survival (Hillman et al. 2004). After radiation and genistein treatment, an increase in giant cells, apoptosis, inflammatory cells, and fibrosis was observed with decreased tumour cell proliferation consistent with increased tumour cell destruction. Long-term therapy with genistein after prostate tumour irradiation significantly increased survival. The scientists (Raffoul et al. 2007) further found that treatment with soy isoflavones elicited no increase in metastasis to para-aortic lymph nodes in contrast to the consistent increase caused by pure genistein. Prostate tumours treated with soy isoflavones and radiation, exhibited tumour destruction and in-situ tissue alterations, comparable with genistein and

radiation effects. However, genistein, but not soy isoflavones, caused induction of HIF1-alpha in prostate tumours, suggesting that induction of hypoxia by pure genistein could contribute to increased metastasis. The studies further demonstrated the safety and potential role of soy isoflavones for enhancing the therapeutic effect of radiotherapy in prostate cancer. Similarly, Wang et al. (2006) found that in both models of orthotopic xenograft in nude mice and orthotopic RM-9 prostate tumours in syngeneic C57BL/6 mice, pretreatment with genistein, followed by radiotherapy was more effective and safer for prostate cancer treatment than genistein alone, which promoted metastatic spread to regional lymph nodes. More recent studies by Singh-Gupta et al. (2010) found that daidzein could be the component of soy isoflavones that protected against genistein-induced metastasis. Daidzein inhibited cell growth and potentiated radiotherapy, affecting APE1/Ref-1, NF-kappaB and HIF-1alpha, but at lower levels than genistein and soy, in AR + and AR- PCa (prostate cancer) cells. Ahmad et al. (2010) found that soy isoflavones intake in conjunction with radiation therapy could reduce the urinary, intestinal, and sexual adverse effects in patients with prostate cancer. At 3 months, soy-treated patients had less urinary incontinence, less urgency, and better erectile function as compared to the placebo group. At 6 months, the symptoms in soy-treated patients were further improved as compared to the placebo group. These patients had less dripping/leakage of urine, less rectal cramping/diarrhoea and less pain with bowel movements than placebo-treated patients. There was also a higher overall ability to have erections.

Wang et al. (2009) reported that 4 isoflavone fractions prepared from soybean cake and isoflavone standards genistein and daidzein were effective inhibiting prostate cancer (LNCaP and PC-3) cell growth at a low dose of 5 and 10 μg/ml. All the treatments did not affect Bcl-2 protein expression significantly in both LNCaP and PC-3 cells. A decrease in cyclin B1 expression of LNCaP was noted for all the treatments, with the mixture of acetylglucoside and aglycon exerting the most pronounced effect. But for PC-3, a decline in cyclin B1 expression was exhibited for all the isoflavones, with the exception of malonylglucoside, glucoside and acetylglucoside fractions. Epigenetic modifications of DNA, such as the promoter CpG dinucleotide island demethylation of tumour suppressor genes that occurred after treatment by soy isoflavones (genistein and daidzein) , might be related to the protective effect of soy on prostate cancer (Vardi et al. 2010). Genistein was postulated as the major contributor to the effect of soy proteins on cellular pathways in incidence of prostate cancer; however, the expression of different genes using soy protein isolates suggested complexity in the many compounds found in whole soy (Liss et al. 2010a). Liss et al. (2010b) reported that soy protein appeared to regulate prostate cancer via the Wnt/beta-catenin pathway. Their data demonstrated that the effect of soy protein effect on prostate cancer may occur via the frizzled 3 receptor with activation of glycogen synthase kinase 3 (GSK-3) leading to increased degradation of beta-catenin and cell growth.

Zhou et al. (2003) found that the combination of soy phytochemical concentrate and black tea synergistically inhibited prostate tumourigenicity, final tumour weight and metastases to lymph nodes in-vivo and significantly reduced serum concentrations of both testosterone and dihydrotestosterone in-vivo. Inhibition of tumour progression was associated with reduced tumour cell proliferation and tumour angiogenesis. Hsu et al. (2010a, b) in their mini-review asserted that dietary factors such as green tea and soy that had been reported to inhibit inflammation and nuclear factor-kappa B (NF-kappaB) may serve as effective chemo-preventive agents against prostate cancer in men. Chronic inflammation had been proposed as a major risk factor of prostate cancer, acting as both an initiator and promoter. Specifically, the nuclear factor-kappa B (NF-kappaB) pathway had been implicated as an important mediator between chronic inflammation, cell proliferation and prostate cancer.

Jenkins et al. (2003b) found that soy consumption had no significant effect on serum total or free prostate specific antigen despite the fact that soy intake was sufficient to reduce low-density

lipoprotein cholesterol, the estimated coronary heart disease risk and the serum concentration of oxidized low-density lipoprotein measured as conjugated dienes in the 3–4-week study of 46 healthy middle-aged men with a range of starting PSA values. They concluded that at levels of soy intake which reduced low-density lipoprotein cholesterol any potential benefits of soy consumption on prostate cancer were likely to occur for reasons other than alterations in hormone activity. Hussain et al. (2003) in a pilot study of patients with prostate cancer having rising serum prostate-specific antigen (PSA) levels, soy isoflavones intervention was found to benefit some patients with prostate cancer . Although there were no sustained decreases in PSA qualifying for a complete or partial response, stabilization of the PSA occurred in 83% of patients in hormone-sensitive and 35% of hormone-refractory patients. There was a decrease in the rate of the rise of serum PSA in the whole group following the soy isoflavone intervention. Serum genistein and daidzein levels increased during supplementation. No significant changes were observed in serum levels of testosterone, IGF-1 (Insulin-like growth factor 1), IGFBP-3 (Insulin-like growth factor-binding protein 3), or 5-OHmdU (5-hydroxymethyl-2′-deoxyuridine).

Yan and Spitznagel, (2009) conducted a meta-analysis on the association of 15 epidemiologic studies on soy consumption and 9 on isoflavones with prostate cancer risk in men. The results suggested that consumption of soy foods was associated with a reduction in prostate cancer risk in men and the protection may be associated with the type and quantity of soy foods consumed. In another meta-analysis, Hwang et al. (2009) found that soy food consumption could lower the risk of prostate cancer. The summary odd ratios ORs (95% CI) for total soy foods were 0.69 and 0.75 for nonfermented soy foods. Among individual soy foods, only tofu yielded a significant value of 0.73. Consumption of soybean milk, miso, or natto did not significantly reduce the risk of prostate cancer. Genistein and daidzein were associated with a lower risk of prostate cancer. Hsu et al. (2010a, b), found that soy food products with a combination of active compounds may be more efficacious and safer as chemo-preventive agents than individual compounds. They found that soy extract induced a significantly higher percentage of LnCap and PC3 prostate cancer cells undergoing apoptosis than genistein or daidzein. No significant changes in cell cycle arrest or apoptosis were observed in non-cancerous benign prostate hyperplasia (BPH-1) cells treated with soy extract, suggesting that the effects of soy extract may be tumour cell specific. In contrast, both genistein and daidzein induced apoptosis in BPH-1 cells, suggesting that individual isoflavones may have cytotoxicity in non-cancerous cells. They also found that the induction of apoptosis was independent of the nuclear factor kappaB (NF kappaB) pathway.

Soy and Colonic/Gastric Cancer

Purified soyasaponins and soyasapogenins were found to suppress the growth of HT-29 colon cancer cells, over a concentration range of 0–50 ppm (Gurfinkel and Rao 2003). Soyasaponin I and III, soyasapogenol B monoglucuronide, soyasapogenol B, soyasaponin A1, soyasaponin A2, and soyasapogenol A and mixtures comprising acetylated group A soyasaponins, deacetylated group A soyasaponins, and group B soyasaponins were evaluated. The most potent compounds were the aglycones soyasapogenol A and B, which showed almost complete suppression of cell growth. In contrast, the glycosidic soyasaponins were largely inactive. Soyasaponin A(1), A(2), and I, group B and deacetylated and acetylated group A fractions had no effect on cell growth. Soyasaponin III and soyasapogenol B monoglucuronide were marginally bioactive. The results suggested that the bioactivity of soyasaponins increased with increased lipophilicity. Also results from in vitro fermentation suggested that colonic microflora readily hydrolysed the soyasaponins to aglycones. These observations suggested that the soyasaponins may be an important dietary chemopreventive agent against colon cancer, after alteration by microflora. Soy saponin was found to be effective in-vitro in preventing WiDr human colon cancer by affecting cell morphology, cell

proliferation enzymes, and cell growth (Tsai et al. 2010a, b). Clemente et al. (2010) reported that naturally occurring protease inhibitors, Bowman-Birk inhibitors (BBI) from soybean and related proteins, to have potential health-promoting properties within the gastrointestinal tract. They found that two major soybean isoinhibitors, IBB1 and IBBD2 exhibited anti-proliferative properties against HT29 colon adenocarcinoma cells with IC_{50} values of 39.9 and 48.3μM, respectively. The cell cycle distribution pattern of HT29 colon cancer cells was affected by BBI treatment in a dose-dependent manner, with cells becoming blocked in the G0-G1 phase. The anti-proliferative properties of BBI isoinhibitors from soybean revealed that both trypsin- and chymotrypsin-like proteases involved in carcinogenesis should be considered as potential targets of BBI-like proteins. Lunasin, a naturally occurring peptide from soybean, was found to stimulate apoptosis in HT-29 colon cancer cells by activating apoptotic mitochondrial pathways and inducing expression of the pro-apoptotic nuclear clustering (Dia and Mejia 2010). Lunasin caused cytotoxicity to HT-29 cells and induced G2/M cell cycle arrest with simultaneous increased in p21 expression. All high doses of hydrolysed soybean (black, yellow, brown) extracts except the green genotype significantly reduced HT-29 human colorectal cancer cell number compared to control at 3 hours of treatment time, whereas the high dose of isoflavone standard treatment took 72 hours to show a significant reduction (Slavin et al. 2009).

Raju et al. (2009) found that pre- and postnatal exposure to dietary soy isoflavones for 26 weeks suppressed the growth of colon tumours in male rats. The over-expression of ERbeta in both rat colon tumours and DLD-1 human colon adenocarcinoma cells caused by soy isoflavones suggested that estrogen receptor, ERbeta, was a critical mediator in alleviating its cancer-preventive effects. Dietary supplementation of soy isoflavones was found to suppress colon carcinogenesis in a chemically induced rat cancer model (Min et al. 2010). The isoflavones suppressed 1,2-dimethylhydrazine -induced aberrant crypt foci formation and COX-2 expression in a dose-independent manner.

Very limited human research suggests that soy may decrease colon cancer risk, but this is highly speculative (Messina 2002). The data from a community-based prospective study of soy products and gastric cancer involving 30,304 (13,880 men and 16,424 women) in Takayama, Japan, over years of follow-up suggested that soy intake may reduce the risk of death from stomach cancer (Nagata et al. 2002). In men, the highest compared to the lowest tertile of total soy product intake was significantly inversely associated with death from stomach cancer after controlling for covariates. Decreased hazard ratios for the highest compared to the lowest tertiles of total soy product intake was observed in women, although this association was of marginal significance.

Results of studies of 84 gastric cancer cases and 336 matched controls selected from the Korean Multi-Center Cancer Cohort by Ko et al. (2009) suggested that the association between IL-10 genetic polymorphisms and gastric cancer risk was modified by soybean product intake. The combined effect between IL-10 gene variants of −592 GG/GA, −819 TC/CC, or −1,082 AG/GG and low intake of soybean products had an increased risk for gastric cancer compared with the group with no risk gene variants and a high intake of soybean products. Among the low-soybean product intake group, IL-10 CCG haplotype had an increased risk of gastric cancer relative to the ATA haplotype. A meta-analysis was conducted on 28 independent studies including 16 case-control studies, 10 cohort studies and 2 cross sectional studies from 53 relevant articles published in English and Chinese on soy consumption and gastric cancer from 1988 to 2008 (Tong et al. 2010). The findings suggested that consumption of soybean products and tofu was inversely associated with gastric cancer, while miso consumption could increase the risk to gastric cancer. Ko et al. (2010) conducted a nested case-control study made up of 131 cases and 393 matched controls within the Korean Multicenter Cancer Cohort to ascertain the role of soy food in gastric cancer. Their finding suggested a beneficial effect of high soybean product intake for gastric cancer risk. High serum concentrations of isoflavones (genistein, daidzein, equol) were found to be associated with a decreased risk for gastric cancer.

Kim et al. (2011) conducted a meta-analysis on 20 studies on fermented soy food intake and gastric cancer risk and 17 studies on non-fermented soy food consumption and gastric cancer risk. They found a high intake of fermented soy foods was significantly associated with an increased risk of gastric cancer risk whereas an increased intake of non-fermented soy foods was significantly associated with a decreased risk of gastric cancer. The meta-analysis conducted by Yan et al. (2010) found that consumption of soy foods was associated with an approximately 21% reduction in colorectal cancer risk in women but not in men.

Fermented soya beans, tempe prepared by inoculation with *Rhizopus microsporus* var. *microsporus*, was found to reduce the adhesion of enterotoxigenic *Escherichia coli* (ETEC) to intestinal epithelial cells of pig and human origin and prevent against diarrhoeal diseases (Kiers et al. 2002; Roubos-van den Hil et al. 2009, 2010b). The bioactive component of tempe was found to contain arabinose derived from the arabinan or arabinogalactan side chain of the pectic cell wall polysaccharides of the soybeans, which was probably released or formed during fermentation by enzymatic modifications (Roubos-van den Hil et al. 2010b). Studies also showed that using soya beans as substrate, fermentation with several fungi (*Mucor, Rhizopus* spp. and yeasts) as well as *Bacillus* spp. resulted in bioactive tempe, whereas fermentation with lactobacilli showed no bioactivity (Roubos-van den Hil et al. 2010a). Antimicrobial activity of tempe extract was found against *Bacillus stearothermophilus* (Kiers et al. 2002).

Soy and Lung Cancer

Seow et al. (2009) studied the reproductive variables, soy intake, and lung cancer risk in a prospective cohort of middle-aged and elderly Chinese women in Singapore among whom 91% were lifetime non-smokers. Among 35,298 women (mean follow-up time, 9.6 years), 298 cases of incident lung cancer were documented, of which 189 (63.4%) occurred in non-smokers. Compared with nulliparous women, those with one to two, three to four, and more than five live births had relative risks of between 0.49 and 0.59 for all lung cancers, and between 0.32 and 0.42 for adenocarcinomas. This relationship was observed in both smokers and non-smokers. Dietary soy isoflavonoid intake was associated with a statistically significant inverse trend among non-smoking women. The findings further supported the role of hormonal factors in the aetiology of lung cancer among non-smoking women, and were consistent with emerging experimental evidence.

Shimazu et al. (2010) conducted a large-scale, population-based prospective cohort study in 36,177 men and 40,484 women aged 45–74 years with no history of cancer at baseline in 1995–1999. During 11 years (671,864 person-years) of follow-up, they documented 481 male and 178 female lung cancer cases. In men they found an inverse association between isoflavone intake and risk of lung cancer in never smokers. A similar, non-significant inverse association was seen in never-smoking women. Matsuo et al. (2008) conducted a case-control study using 353 patients with non-small-cell lung cancers (NSCLCs) (122 EGFR (epidermal growth factor receptor) mutated and 231 EGFR wild-type) and 1,765 age-sex matched non-cancer control subjects to ascertain the impact of soy products on risk of development of NSCLCs. The findings showed that soy consumption may exert a protective association against the development of NSCLCs with EGFR mutations since soybean products demonstrated a protective association with EGFR mutated, but not EGFR wild-type NSCLCs. Gallo et al. (2008) found that soy phytochemicals retarded the in-vivo growth of non-small cell lung cancer (NSCLC; A549) xenografts in female athymic mice. The modulation of the Akt-signaling pathway observed in tumours of soy extract-treated mice may have a role in the activity observed. The results provided further support for the concept that consumption of phytoestrogens may be effective in delaying lung cancer progression. Shimazu et al. (2011) conducted a nested case-control study within a population-based prospective cohort study of 24,127 women aged 40–69 years from 1990 through 2006. They found that after exclusion of 20 lung cancer cases diagnosed in the first 3 years after blood collection, an

inverse association was found between plasma genistein concentration and lung cancer risk in Japanese women. Other isoflavones and total isoflavones were not associated with a significant decrease in the risk of lung cancer. The data supported the earlier observed association between isoflavone intake and lung cancer risk.

Li et al. (2004) found that high-Selenium soy protein dietary supplementation exerted greater inhibitory effect than the low-Selenium soy protein on pulmonary metastasis of murine B16BL6 melanoma cells in mice. The higher antimetastatic effect of the high-Selenium soy protein supplementation was attributed to selenium.

Zhou et al. (2008) found that genistein decreased viability of human lung adenocarcinoma cell line SPC-A-1 in both a dose and time dependent manner. Genistein significantly induced arrest of SPC-A-1 cells at the G2/M phase of the cell cycle and caused apoptosis of SPC-A-1 in both a dose and time dependent manner. Genistein altered expression profile of 20 genes, mainly consisting of the Bcl-2 family and TNF ligand and receptor family are involved in regulation of the apoptosis process. Singh-Gupta et al. (2011) found that soy isoflavones enhanced human A549 non-small cell lung cancer ell killing induced by radiation. Soy isoflavones sensitized cancer cells to radiation both in-vitro and in-vivo. Soy isoflavones and radiation caused increased DNA damage and inhibition of repair, leading to cell killing.

Soy and Renal/Urinary Tract Diseases

Su et al. (2000) found that genistein and combined soy isoflavones (genistein, daidzein, and biochanin-A) exerted a significant tumour suppressor effect on bladder cancer cells in vivo. Genistein caused a dose-dependent induction of G2-M cell cycle arrest and suppression of cdc2 kinase activity. However, both daidzein and biochanin-A directly induced apoptosis without altering cell cycle distribution. The researchers asserted that the results justify the potential use of soybean foods as a practical chemoprevention approach for patients with urinary tract cancer. Zhou et al. (1998) found that pure soy isoflavones (genistein, genistin, daidzein, and biochanin A) and soy phytochemical concentrate exerted in-vitro, dose-dependent growth inhibition of murine (MB49 and MBT-2) and human (HT-1376, UM-UC-3, RT-4, J82, and TCCSUP) bladder cancer cell lines, although the magnitude of inhibition varied among lines. Soy isoflavones induced a G2-M cell cycle arrest in all human and murine lines. Further, some bladder cancer lines displayed DNA fragmentation consistent with apoptosis. In-vivo studies showed that genistein, dietary soy phytochemical concentrate at 1%, or dietary soy protein isolate decreased mice tumour volume by 40%, 48%, or 37%, respectively, compared with controls. Soy products reduced angiogenesis, increased apoptosis, and slightly reduced proliferation while showing no histopathological effects on the normal bladder mucosa. Their data suggested that soy isoflavones could inhibit bladder tumour growth through a combination of direct effects on tumour cells and indirect effects on the tumour neovasculature. Singh et al. (2006) found that genistein inhibited 253 J B-V human bladder cancer cell growth in a time- and dose-dependent manner via G(2)-M arrest, down-regulation of nuclear factor kappaB (NF-kappaB), and induction of apoptosis. Mice treated with genistin and SPC (isoflavone-rich soy phytochemical concentrate) had reduced final tumour weights by 56% and 52%, respectively, associated with induction of tumour cell apoptosis and inhibition of tumour angiogenesis in vivo.

Dietary soy protein compared with casein delayed the progression of disease in polycystic kidney disease male and female Han:SPRD-cy rats (Aukema and Housini 2001). Soy protein-fed disease-affected animals had lower kidney weight, water content and cyst size, lower serum urea and creatinine, and higher creatinine clearance. In disease-affected females, dietary soy protein resulted in normalized serum creatinine and creatinine clearance. Kidney insulin-like growth factor-I (IGF-I) level was lower in normal animals, in females, and in animals consuming the soy protein diet, indicating an ameliorating role for dietary soy protein in polycystic kidney disease. Similar findings were reported by Fair

et al. (2004) who found that dietary soy protein compared with casein delays disease progression in an early stage (1–3 weeks) of chronic kidney disease in Han:SPRD-cy weanling rats. Soy protein feeding significantly reduced renal fibrosis by 22% and 38% after 1 and 3 weeks of diet, and cyst growth was 34% lower after 3 weeks. Dietary soy protein also partially ameliorated the inhibition of prostaglandin E(2) production observed in diseased kidneys. In another study, nephrotic syndrome rats fed 20% soy protein had improved creatinine clearance and decreased proteinuria, hypercholesterolemia, hypertriglyceridemia, as well as VLDL-triglycerides and LDL cholesterol compared with nephrotic syndrome rats fed the 20% casein diet (Tovar et al. 2002). In addition, the soy protein diet decreased the incidence of glomerular sclerosis, and proinflammatory cytokines in kidney. Ingestion of the soy protein diet by control rats reduced the gene expression of SREBP-1, malic enzyme, fatty acid synthase and increased HMG-CoAr, HMG-CoAs and LDLr. Nephrotic syndrome rats fed the soy diet also had lower HMG-CoAr and LDLr mRNA levels than nephrotic syndrome rats fed casein. The findings suggested that the beneficial effects of soy protein on lipid metabolism were modulated in part by SREBP-1. However, in nephrotic syndrome rats, the benefit may be through a direct effect of this protein on kidney rather than mediated by changes in expression of hepatic lipid metabolism genes. In another study, the scientists (Peng et al. 2009) found that dietary soy protein reduced polycystic kidney disease progression, reduced the levels of specific renal prostanoids and cPLA(2) in diseased kidneys, and reduced COX2 mRNA expression in both normal and diseased kidneys of Han:SPRD-cy rats. In a more recent study, soy diet was found to ameliorate renal injury in the Han:SPRD-cy rat (Ogborn et al. 2010). Soy diets preserved normal renal function and reduced relative renal weight, scores for cystic change, fibrosis, tissue oxidized LDL content, inflammation and epithelial cell proliferation. In post hoc testing, LIS (low isoflavone soy protein) produced a greater reduction in relative renal weight, cystic change and epithelial proliferation, whereas HIS (high isoflavone soy protein) exerted a significantly greater reduction in oxidized-LDL. Studies by Hwang et al. 2008) suggested that attenuation of early glomerular hypertrophy in young obese fa/fa rats by dietary soy protein may be mediated by the lower levels of 6-keto PGF(1alpha) since this would be expected to reduce glomerular hyperfiltration. Dietary soy protein feeding did not alter body weights or proteinuria but did result in 6% lower kidney weights and 16% smaller glomeruli in obese fa/fa Zucker rats. Cyclooxygenase activity was lower was lower in fa/fa rats given soy protein -based diets as compared to those given egg-white-based diets Also, dietary soy protein reduced renal 6-keto PGF(1alpha) levels. Separately, Anderson (2008) based on clinical observations hypothesised that "substitution of soy protein for animal protein results in less hyperfiltration and glomerular hypertension with resulting protection from diabetic nephropathy." He asserted that these components of soy protein: specific peptides, amino acids, and isoflavones may lead to the benefits. Substituting soy protein for animal protein may decrease hyperfiltration in diabetic subjects and may reduce urine albumin excretion.

A phenolic extract of soybean was found to attenuate cisplatin-induced nephrotoxicity in rats (Ekor et al. 2010). Following treatment with the extract, blood urea nitrogen, serum creatinine, urinary N-acetyl-β-D-glucosaminidase levels decreased in cisplatin-treated rats. The extract also decreased renal xanthine oxidase activity and serum nitrate/nitrite but increased renal myeloperoxidase activity. The extract improved liver histology and significantly increased the activities of the antioxidant enzymes measured [superoxide dismutase, catalase, glutathione-S-transferase], prevented glutathione depletion and decreased malondialdehyde level following cisplatin treatment. The extract also restored cisplatin-induced decrease in the activities of glucose-6-phosphatase and 5'-nucleotidase.

Studies by Satsu et al. (2009) found that an isoflavone fraction (IFF) from soybean dose-dependently suppressed TNF-alpha-induced IL-8 secretion at the transcriptional level in human intestinal Caco-2 cells, suggesting IFF of

soybean as a promising food component for preventing intestinal inflammation such as inflammatory bowel disease The soyasaponin fraction and soy peptide fraction had no significant effect on TNF-alpha-induced IL-8 secretion. Soyasaponins I and II, isolated from soybean, were found to inhibit renin activity, but soyasapogenol B had no effect (Takahashi et al. 2010). Renin is the most important enzyme in the renin-angiotensin system.

Soy and Hepatoma/Hepatoprotective Activity

An isoflavone-rich soy isolate affords protection against peroxidative damage in-vivo (Ibrahim et al. 2008). Mice fed the diet supplemented with soy isolate had significantly lower hepatic levels of malondialdehyde and conjugated dienes, when compared to the control group. The activities of catalase and superoxide dismutase were significantly increased in the liver of soy isolate-supplemented mice. The levels of vitamin E, glutathione, and ascorbic acid and the activities of glutathione peroxidase and selenium-nondependent glutathione peroxidase were not significantly altered by the soy isolate. The results evidently suggested that isoflavone supplementation conferred protection against peroxidative damage to membrane lipids in-vivo, possibly through enhancing the activities of the antioxidant enzymes catalase and superoxide dismutase.

Results of studies suggested that isoflavones might be promising agents for the treatment of human hepatoma (Su et al. 2003). Genistein, biochanin-A, and daidzein dose-dependently inhibited growth of all five human hepatoma cell lines, HepG2, Hep3B, Huh7, PLC, and HA22T. The isoflavones caused tumour cell death by induction of apoptosis through activation of the capase-3 pathway and downregulation of Bcl-2 and Bcl-XL expression. Cell cycle arrest was found not necessary for apoptosis. Soyasaponins I and III, monodesmodic oleanane triterpenoids found in soy, may contribute to the reported bioactive and chemopreventative properties of soy by the induction of apoptosis (Zhang and Popovich 2010). Studies in a hepatocarcinoma cell line (Hep-G2) showed that apoptosis was triggered through activation of the capase pathway.

Soy and Other Cancers

The recent increased consumption of soy foods and supplements in the American diet had raised concerns about the possible estrogen-like effects of natural isoflavones and possible promotion or propagation of estrogen-sensitive cancers (Taylor et al. 2009). These concerns were primarily based on in-vitro and animal data which suggested that genistein aglycone could stimulate tumour cell proliferation and growth in mice having deficient immune systems. Han et al. (2010) found that genistein dose-dependently inhibited the proliferation of human NPC cell line CNE2 cells. Genistein induced dramatic G2/M phase arrest in NPC cells. Further, genistein elevated mRNA expression levels, and the protein expression levels of the cell cycle regulators, p21(Cip1) and ATR (Ataxia telangiectasia and Rad3 related).

Genistein, a major isoflavone present in soy products, had been found to exhibit in-vitro and in-vivo antileukemic activity (Raynal et al. 2008) It was observed to dose- and time-dependently exert antineoplastic activity against myeloid and lymphoid leukemic cell lines. Further, genistein treatment of the leukemic cells reactivated tumour suppressor genes that were shut off by aberrant DNA methylation. Due to the longer half-life of genistein in humans, a soy-enriched diet has the potential to produce plasma levels of this isoflavone in the range of the concentrations used in-vitro that produced an antileukemic activity. Studies showed pure lunasin, a naturally occurring peptide containing an arginine-glycine-aspartate and lunasin enriched soy flour (LES) caused cytotoxicity to L1210 leukaemia cells with IC_{50} of 14 and 16 μM (lunasin equivalent), respectively. Cell cycle analysis showed that lunasin caused a dose-dependent G2 cell cycle arrest and apoptosis. Compared to untreated cells, treatment with 1 mg/ml LES showed a 6-fold increase on the expressions of caspases-8 and –9, and a 12-fold increase on the expression of caspase-3.

Antimutagenic Activity

Soy isoflavones, daidzein and genistein exhibited suppressive effect on umu gene expression of the SOS response in *Salmonella typhimurium* TA1535/pSK1002 against the mutagen 3-amino-1, 4-dimethyl-5 H-pyrido[4,3b]indole (Trp-P-1) (Miyazawa et al. 1999). Daidzein suppressed 73% of the SOS-inducing activity at concentrations <0.74 μmol/ml, and the ID(50) value was 0.37 μmol/ml. Genistein inhibited 95% of the SOS-inducing activity at concentrations <0.74 μmol/ml, and the ID_{50} value was 0.17 μmol/ml. Further to the antimutagenic activities of daidzein and genistein against Trp-P-1, furylfuramide and activated Trp-P-1 were assayed by an Ames test using *S. typhimurium* TA100. Studies in mice fed with pelleted commercial diet mixed with transgenic (TS)and conventional (CS) soybean at 10% or 20%, exhibited antimutagenic activity (Azevedo et al. 2010). The 10% and 20% CS and TS diets did not significantly decrease the frequencies of micronucleated polychromatic erythrocytes in bone marrow induced by cyclophosphamide. In contrast, chromosome aberration test revealed that the 10% and 20% CS diets significantly protected nucleated bone marrow cells against chemical-induced mutagenesis and also elicited a significant reduction in the total percentage of spontaneous aberrations. Among the treatments with TS, only the 10% TS diet reduced the percentage of total aberrations induced by cyclophosphamide. Further, treatment with 20% TS alone significantly decreased the mitotic index, indicating cytotoxic effects related to the treatment. Overall, the results suggested that, under the tested conditions, transgenic and conventional soybean had antimutagenic properties and were not toxic.

Antiviral, and Anticancer Activities of Soy Isoflavones, Soy Lectin and Trypsin Inhibitors

A dimeric 50 kDa melibiose-binding lectin was isolated from the seeds of the small glossy black soybean cultivar inhibited the activity of HIV-1 reverse transcriptase as well as the proliferation of breast cancer MCF7 cells and hepatoma HepG2 cells with an IC_{50} of 2.82, 2.6 and 4.1 μM, respectively (Lin et al. 2008). It had no antifungal activity. The lectin evoked maximal mitogenic response at about the same molar concentration as Con A. Of all the sugars tested, melibiose most potently inhibited the hemagglutinating activity of the lectin. A 48-kDa lectin (KBL) purified from Korean large black soybeans inhibited HIV-1 reverse transcriptase activity with an IC_{50} of 1.38 μM (Fang et al. 2010). However, it was destitute of cytokine releasing, mitogenic, ribonuclease and antifungal activities. Sugars such as D-(+)-galactose, D-(+)-raffinose, L-(+)-arabinose, α-D-(+)-melibiose, and α-lactose could inhibit the hemagglutinating activity of the lectin.

A trypsin inhibitor, with an N-terminal sequence highly homologous to those of 8-kDa Bowman-Birk trypsin inhibitors, isolated from the seeds of Hokkaido large black soybeans, inhibited HIV-1 reverse transcriptase with an IC_{50} of 38 μM (Ho and Ng 2008). It was devoid of antifungal activity. It inhibited proliferation in breast cancer (MCF-7) cells and hepatoma (Hep G2) cells with an IC_{50} of 35 and 140 μM, respectively. A 19 kDa A trypsin inhibitor, showing N-terminal sequence highly homologous to Kunitz-type trypsin inhibitors, inhibited HIV-1 reverse transcriptase with an IC_{50} of 0.16 μM (Ye and Ng 2009). It suppressed proliferation of MCF-7 breast cancer cells with an $IC_{50}$of 4.3 μM and HepG2 hepatoma cells with an IC_{50} greater than 25 μM. The trypsin inhibitor lacked antifungal activity and mitogenic activity towards mouse splenocytes. It inhibited trypsin with an IC_{50} of 19 μM and chymotrypsin with an IC_{50} of 14.3 μM. A Kunitz type trypsin inhibitor (KBTI), molecular weight 20107.645 Da, isolated from Korean large black soybeans, inhibited HIV-1 reverse transcriptase activity with an IC_{50} value of 0.71 μM (Fang et al. 2010). It exerted weak antiproliferative activity toward CNE-2 and HNE-2 nasopharyngeal cancer cells, MCF-7 breast cancer cells, and Hep G2 hepatoma cells. KBTI was devoid of mitogenic, ribonuclease and antifungal activities. It induced the release of pro-inflammatory cytokines such as TNF-alpha, IL-1beta, IL-2 and interferon-gamma at the mRNA level.

KBTI reduced the proteolytic activities of trypsin and α-chymotrypsin. Numerous studies had demonstrated a direct association between the intake of soybean and low cancer incidence, a fact related to the presence of Bowman-Birk inhibitor (BBI) and lectin in soybean (Anta et al. 2010). A perfusion reversed-phase-HPLC was developed for the rapid determination of the anticarcinogenic proteins Bowman-Birk inhibitor.

Isoflavones and their related flavonoid compounds had been reported to exert antiviral properties in-vitro and in-vivo against a wide range of viruses (Andres et al. 2009). Genistein being, by far, the most studied soy isoflavone in this regard, had shown to inhibit the infectivity of enveloped or nonenveloped viruses, as well as single-stranded or double-stranded RNA or DNA viruses. Flavonoids, including genistein, had been shown to reduce the infectivity of a variety of viruses affecting humans and animals, including areanviruses, adenovirus, herpes simplex virus, human immunodeficiency virus, porcine reproductive and respiratory syndrome virus, of Moloney murine leukaemia virus and rotavirus. Genistein, a general kinase inhibitor, was reported to have potential as an antiviral agent for arenaviral hemorrhagic fever (Vela et al. 2008, 2010). Arenaviruses are rodent-borne negative strand RNA viruses and infection of these viruses in humans may result in disease and hemorrhagic fever. Donovan et al. (2009) found that a mix of soy isoflavones or genistein alone could reduce severity of rotaviruses infectivity in the intestines. Stantchev et al. (2007) reported that genistein blocked HIV-1 entry and infection of human macrophages if applied before, during or immediately after the infection period, but not 24 h later. Numerous flavonoids including genistein when applied at various concentrations to Vero cells infected by Herpes simplex virus HSV-1 and 2, showed inhibitory effects on virus-induced cytopathic effect (Lyu et al. 2005). Genistein was reported to inhibit the fusogenicity of Moloney murine leukaemia virus envelope protein in XC cells (Kubo et al. 2003). Studies showed that soy genistein at dietary concentrations of 200–400 ppm was an orally active immune modulator that enhanced systemic serum porcine reproductive and respiratory syndrome (PRRS) virus elimination and body growth in virally challenged pigs (Greiner et al. 2001). Studies showed that during adenovirus infection, genistein, a broad inhibitor of tyrosine kinases, could decrease late viral mRNA translation and prevent viral inhibition of host cell protein synthesis without significantly affecting short-term viral mRNA abundance or replication (Xi et al. 2005). These results suggested that tyrosine kinase activity may play a role in promoting late viral protein synthesis.

Soy and Bifidogenic/Prebiotic Activity

Yellow soybean seeds were found to be a rich source of non-digestible galacto-oligosaccharides (Espinosa-Martos and Rupérez 2006). The relative percentage of galacto-oligosaccharides was higher in immature (47–53%) than in matured soybean seeds (21–34%). Ripe yellow soybean seeds showed a higher oligosaccharide content (1.84–1.95%), than unripe green seeds (1.43–1.61%). Low molecular weight carbohydrates in soybean seeds were mainly: stachyose, raffinose and sucrose. Kumar et al. (2010) found that sucrose and raffinose family oligosaccharides (RFOs) in soybean seeds were influenced by genotype and growing location. Sucrose content was found to be significantly higher at cooler location, however, differences observed for raffinose and stachyose contents across the growing locations were genotype-dependent. Soybean oligosaccharides and galacto-oligosaccharides because of their non-digestible nature is an important prebiotics. Prebiotics are defined as non-digestible food ingredients that beneficially affect the host by stimulating the growth and/or activity of beneficial bacteria such as *Bifidobacteria* and *Lactobacillus* in the colon (Macfarlane et al. 2008). Consumption of prebiotic oligosaccharides fructo-oligosaccharide derivatives and galacto-oligosaccharides can have significant health benefits, particularly in relation to their putative anti-cancer properties, influence on mineral absorption, lipid metabolism,

and antiinflammatory and other immune effects such as atopic disease. Bouhnik et al. (2004) in a double-blind randomised, placebo-controlled, parallel-group study of 64 human volunteers, found that non-digestible carbohydrates short-chain fructooligosaccharides, soybean oligosaccharides, galacto-oligosaccharides, and type III resistant starch were bifidogenic.

Supplementation with prebiotics was found to enhance the potential of soymilk as a carrier for probiotics (Yeo and Liong 2010b). In the presence of fructooligosaccharides (FOS), inulin, mannitol, maltodextrin and pectin, all strains *Lactobacillus* sp. FTDC 2113, *Lactobacillus acidophilus* FTDC 8033, *Lactobacillus acidophilus* ATCC 4356, *Lactobacillus casei* ATCC 393, B*ifidobacterium* FTDC 8943 and *Bifidobacterium longum* FTDC 8643 showed viability exceeding 7 log(10) colony-forming units/ml after 24 hours in prebiotic-supplemented soymilk (Yeo and Liong 2010b). Their growth was significantly increased on supplementation with maltodextrin, pectin, mannitol and FOS. Additionally, supplementation with FOS, mannitol and maltodextrin increased the production of lactic acid. Supplementation with FOS and maltodextrin also increased the α-galactosidase activity of probiotics, leading to enhanced hydrolysis and utilisation of soy oligosaccharides. Finally, prebiotic supplementation enhanced the utilisation of simpler sugars such as fructose and glucose in soymilk. Incorporation of probiotics into soymilk supplemented with prebiotic fructooligosaccharides (FOS), inulin, mannitol, maltodextrin and pectin also enhanced the in-vitro antihypertensive effect and production of bioactive aglycones in probiotic-fermented soymilk (Yeo and Liong 2010a). Proteolytic activity was increased in the presence of FOS, while the supplementation of inulin and pectin elevated the angiotensin I-converting enzyme inhibitory activity accompanied by lower IC_{50} values. The β-glucosidase activity was also enhanced in the presence of pectin. This led to higher bioconversion of glucosides to aglycones by probiotics, especially genistin and malonyl genistin to genistein. The study showed that soymilk could potentially be used as a dietary therapy to reduce the risks of hypertension and hormone-dependent diseases such as breast cancer, prostate cancer and osteoporosis.

In-vitro studies showed that soy Bowman-Birk inhibitor, a naturally occurring protease inhibitor with potential anti-inflammatory and chemopreventive properties within the gastrointestinal tract, did not affect the growth of the different bacterial groups in the faecal microbiota studied (lactobacilli, bifidobacteria, bacteroides, coliforms, enterobacteria, clostridia and total anaerobes) (Marín-Manzano et al. 2009). Thus, Bowman-Birk inhibitor retained significance as a bioactive compound in the human gastrointestinal tract.

Sony and Antinociceptive and Antiinflammatory Activities

Numerous research had reported decreases in cytokines and inflammation with either soy foods or soy isoflavones (Verdrengh et al. 2003; Curran et al. 2004; Hall et al. 2005; Yim et al. 2009); however, other studies had not found beneficial effects of soy isoflavones on markers of inflammation (Blum et al. 2003; Hilpert et al. 2005; Beavers et al. 2010a). Studies showed that the soy isoflavone, genistein exerted distinct anti-inflammatory properties affecting granulocytes, monocytes, and lymphocytes (Verdrengh et al. 2003). Mice exposed to genistein and immunized with collagen II exhibited somewhat lower degree of inflammation and joint destruction. Also, genistein treatment led to decreased levels of oxazolone-specific antibodies. Additionally, genistein treatment significantly lowered serum levels of autoantibodies to collagen II in immunized mice.

In animal studies, Currran et al. (2004) administered mice with a diet containing soy phytoestrogens and infected with *Mycobacterium avium* to establish a chronic infection and inflammatory response. They found that estrogen receptor alpha (ERaplha) signalling and dietary soy isoflavones could influence production of key regulatory cytokines (interferon -gamma, interleukin 12 and 18) in response to chronic bacterial infection.

Hall et al. (2005) conducted a randomized, double-blind, placebo-controlled, crossover

dietary intervention trial involving 117 healthy European postmenopausal women to assess the effects of isolated soy isoflavones on inflammatory biomarkers. They found that soy isoflavones had beneficial effects on C-reactive protein concentrations, but not on other inflammatory biomarkers of cardiovascular disease risk in postmenopausal women. The isoflavones also improved vascular cell adhesion molecule 1 (VCAM-1) in an ERbeta gene polymorphic genotypes. Studies showed that the soy isoflavone, genistein exerted distinct antiinflammatory properties affecting granulocytes, monocytes, and lymphocytes (Verdrengh et al. 2003). Mice exposed to genistein and immunized with collagen II exhibited somewhat lower degree of inflammation and joint destruction. Also, genistein treatment led to decreased levels of oxazolone-specific antibodies. Additionally, genistein treatment significantly lowered serum levels of autoantibodies to collagen II in immunized mice. Ethanolic extract of soybean seeds elicited significant anti-nociceptive and anti-inflammatory activities as compared to standards aminopyrine and indomethacin (Yim et al. 2009). The ear edema, paw edema, paw licking time, pain and writhes in mice were significantly reduced as compared to the control.

In a randomized, double-blind, placebo-controlled, crossover study of 24 postmenopausal women, consumption of 25 g of isolated soy protein daily for 6 weeks did not substantially affect markers of vascular inflammation (soluble interleukin-2 receptor (sIL-2r), E-selectin, P-selectin, intercellular adhesion molecule-1 (ICAM-1), and vascular cell adhesion molecule-1 (VCAM-1) in postmenopausal women with hypercholesterolemia (Blum et al. 2003). Results of studies in moderately hypercholesterolemic adults (men = 18, postmenopausal women = 14; 6 receiving hormone replacement therapy) suggested that inflammation may not only attenuate lipid responses, but also may aggravate dyslipidemia in hypercholesterolemic subjects consuming a cholesterol-lowering diet (Hilpert et al. 2005). The addition of soy or milk protein to the Step I diet did not affect lipids or inflammatory markers (C-reactive protein (CRP) and interkeukin-6). Regardless of protein source, those with low CRP exhibited significant decreases in LDL cholesterol (−3.5%) and the LDL:HDL cholesterol ratio (−4.8%), whereas those with high CRP had significant increases in LDL cholesterol (+4.8%), the LDL:HDL cholesterol ratio (+5.2%), apolipoprotein B (+3.8%), and lipoprotein(a) (+13.5%) compared with the run-in diet.

Findings from the single-blind, randomized controlled trial conducted in 31 postmenopausal women, failed to support the hypothesis that 4 weeks of daily soy milk ingestion could decrease systemic rises in markers of inflammation or oxidative defence (Beavers et al. 2010a). However, data did suggest that the downhill-running regime employed in the study could be effective in changing systemic markers of inflammation and oxidative defence enzyme activity, and that the consumption of soy may help obviate fluctuations in plasma TNF-alpha (tumour necrosis factor-alpha).

Studies showed that lunasin and lunasin-like peptides (5, 8, and 14 kDa) purified from defatted soybean flour inhibited inflammation in LPS-induced RAW 264.7 macrophage by suppressing NF-kappaB pathway (de Mejia and Dia 2009). Treatment with these peptides (10–50 μM) resulted in the inhibition of pro-inflammatory markers in lipopolysaccharide (LPS)-induced RAW 264.7 macrophages. The 5 kDa peptide inhibited most potently pro-inflammatory markers including interleukin-6 production, interleukin-1beta production, nuclear factor-kappa B (NF-kappaB) transactivation, cyclooxygenase-2 expression, nitric oxide production, inducible nitric oxide synthase expression, prostaglandin E(2) production, p65 nuclear translocation and p50 nuclear translocation.

The purified soybean Kunitz trypsin inhibitors (SKTIs) were found to inhibit human neutrophil elastase with an IC_{50} value of 8 μg and bovine trypsin (Ribeiro et al. 2010). At this concentration SKTI showed neither cytotoxic nor haemolytic effects on human blood cell populations. SKTI showed no deleterious effects on organs, blood cells or the hepatic enzymes ALT and AST in the mouse model of acute systemic toxicity. In

an in-vivo mouse model of LPS (lipoplysaccharide) acute lung injury, SKTI significantly and dose-dependently inhibited the inflammatory effects caused by elastase. Histological sections stained by haematoxylin/eosin confirmed this decrease in inflammation. The results showed that SKTI could be used as a pharmacological agent for the therapy of many inflammatory diseases.

Soy and Anti-skin Aging and Anti-photoaging Activity

Hazardous effects of UVB radiation include premature skin aging especially skin photocarcinogenesis. Pretreatment by topical application of hairless mice with anthocyanins from black soybean seed coats reduced UVB-induced reactive oxygen species levels and suppressed UVB-induced apoptotic cell death through the prevention of caspase-3 pathway activation and reduction of proapoptotic Bax protein levels (Tsoyi et al. 2008). The researchers concluded that anthocyanins from the seed coat of black soybeans may be useful compounds to modulate UVB-induced photoaging. In separate studies, Chiu et al. (2009) showed that in-vitro, UVB-induced HaCaT cell death and the phosphorylation of p38, JNK, and ERK1/2 decreased in the presence of isoflavone extract from soybean cake. In in-vivo studies, they found that the topical application of isoflavone extract before UVB irritation decreased the epidermal thickness and the expressions of COX-2 and PCNA and increased catalase concentration. Their results suggested that the anti-photoaging effect of isoflavone extract from soybean cake involved the inhibition of UVB-induced apoptosis and inflammation and the isoflavone extract may be a functional cosmeceutical candidate for skin photoaging. Huang et al. (2008) found that UVB-induced hydrogen peroxide production in keratinocytes was inhibited by soy isoflavones, genistein and daidzein, confirming that these two compounds could act as free radical scavengers when keratinocytes were photo-damaged. Glycitein exhibited no protective activity against photo-damage. The isoflavones in a non-ionized form (pH 6) showed higher skin deposition compared to the ionized form (pH 10.8). Genistein generally exerted greater skin absorption than did daidzein. However, daidzein permeation was enhanced when an aglycone mixture was used as the active ingredient. The safety profiles suggested no or only negligible stratum corneum disruption and skin erythema. They concluded that topical delivery may serve as a potent route for soy isoflavones against photoaging and photodamage. Zhao et al. (2009) showed that non-denatured soybean extracts induced elastin promoter activity, suppressed elastase activity and prevented elastic fibres from degradation by exogenous elastases in-vitro. Mouse and swine skins topically treated with soybean extracts exhibited enhanced elastic fibre network and increased desmosine concentration. Elastin expression was also augmented in human skin transplanted onto SCID mice in response to soy treatment. These data suggested that non-denatured soybean extracts may be used as skin care agents to reduce the signs of skin ageing.

Soy and Immunomodulatory Activity

Soy isoflavones are known to exert weak estrogenic activity by virtue of their structural similarity to estrogens such as 17β-estradiol (E2) (Grossman 1984; Sakai and Kogiso 2008; Ørgaard and Jensen 2008). Since sex hormones are known to modulate the human immune response (Grossman 1984), it may be possible that dietary isoflavones modulate the immune system, by acting either as estrogen agonists or antagonists (Ørgaard and Jensen 2008; Sakai and Kogiso 2008). Comparatively limited researches have been published regarding the relationship between soy isoflavone consumption and immune function. Genistein has been reported to suppress antigen-specific immune response in-vivo and lymphocyte proliferation response in-vitro, and enhanced the cytotoxic response mediated by NK and cytotoxic T cells and the cytokine production from T cells (Sakai and Kogiso 2008. Thus, the effect of genistein on immunity is immune cell-dependent. Due to its unique effect on immune

function, genistein has been used for the treatment of the diseases in animal models and it has been found that genistein inhibits allergic inflammatory responses.

Soy isoflavones like genistein had been reported to act as inhibitors of a number of enzymes like protein tyrosine kinase (Akiyama et al. 1987), topoisomerase I and II (Okura et al. 1988), and others important for proper functioning of the immune system. Recent animal and in-vitro studies had suggested that soy isoflavones like genistein, the most abundant isoflavone in soy at high concentrations may act as protein tyrosine kinase inhibitors and thus could act as immunosuppressive agents (Akiyama et al. 1987). Genistein thus may affect signalling pathways of immune cells and the subsequent innate and adaptive immune responses. Other soy isoflavones also played a role in immune response. Chan et al. (2009) found that nanonized (Nano-soy) black soybean supplementation improved immune response in senescence-accelerated-prone mice. They found that isoflavone (daidzein and genistein) intake was higher in the Nano-soy group than the microparticled (Micro-soy) group. The lymphoproliferation and production of interleukin-2 (IL-2) and interferon-gamma (IFN-gamma) in the Nano-soy group were significantly higher than those in the control and Micro-soy groups. At higher concentrations (>50 μM), daidzein only reduced IL-10 and IFN-gamma levels, whereas genistein reduced levels of the IL-2, IL-4, IL-10, IFN-gamma mRNA and protein. The results suggested that the improved immune response was attributable to higher daidzein content in the black soybean preparation. Sakai et al. (2010) found that mice treated with equol (20 mg/kg), a soy isoflavone, displayed a significantly higher level of ovalbumin-specific IgE and interleukin-3 than control mice. Levels of interferon (IFN)-gamma and interleukin (IL)-4 productions were not different between the control and equol groups. Strong induction of ovalbumin-specific IgE production by equol was also observed in ovariectomized BALB/c mice, suggesting that the immunomodulatory effect of equol was not affected by endogenous estrogen.

Tanaka et al. (2011) found a variety of the Japanese soybean, *Glycine max* cv. Kurosengoku (Kurosengoku), which activated Type-1 immunity in a Toll-like receptor (TLR)4- and TLR2-dependent manner. The Kurosengoku extract stimulated production of interleukin-12 and sequentially induced interferon gamma. The extract also enhanced production of IFN-γ from human PBMC by co-stimulation with anti-CD3 mAb in a TLR2- and TLR4-dependent manner. Their findings strongly suggested that Kurosengoku might a novel potential immuno-improving food.

Soy and Neuroprotective Activity

Findings of studies suggested that dark soy sauce exerted a protective role against acrylamide-induced neurotoxicity and, partly at least, through an anti-oxidative mechanism (Chen et al. 2009; Zhang and Zhang 2009). Dark soy sauce significantly ameliorated axonal degeneration, the ratio of myelinated nerves <3 μm in diameter, degree of central chromatolysis of the ganglion neurons in peripheral nerves, and numbers of synaptophysin (+) aberrant dots per mm cortex in the cerebellar molecular layer of acrylamide-treated rats before, after, or during acrylamide-exposure (Zhang and Zhang 2009). Dark soy sauce also significantly lowered the malondialdehyde level and elevated the superoxide dismutase activity in brain of acrylamide-treated rats during acrylamide exposure. Dark soy sauce exhibited a protective action against acrylamide-induced oxidative stress and biochemical perturbations in rats; and treatment with dark soy sauce during acrylamide exposure was more effective than after or before acrylamide treatment (Chen et al. 2009). Treatment only with acrylamide elicited a significant increase in lipid peroxidation level, lactate dehydrogenase, and serum creatine kinase activity, but a significant decrease in superoxide dismutase activity in brain homogenate, serum serotonin, corticosterone, 3, 5, 3′-triiodothyronine, and L-thyroxine, thyroid stimulating hormone, estradiol, progesterone, and plasma adrenaline in acrylamide treated rats.

Soy meal diet (with or without isoflavone) in ovariectomized rats with Alzheimer's disease elicited improvement of spatial learning and

memory performance across 18 acquisition trials suggesting soy meal to be a potential alternative to estrogen in the prevention and treatment of Alzheimer's disease. (Sarkaki et al. 2008). The results of further studies by Sarkaki et al. (2009) indicated that pre-treatment of Parkinsonian rats with different doses of dietary soy meal (with or without isoflavone) improved the spatial learning and memory and significantly prevented body weight increases after menopause. The data showed that long-duration dietary soy meal may have the potential neuroprotective effect against post-menopausal cognitive deficiency induced by degeneration of nigrostriatal dopaminergic system and constant body weight during post-menopausal life cycle.

Soy isoflavones, folic acid and their combination (soy isoflavone and folic) administration were found to exert neuroprotection against beta-amyloid 1-40-(A betal-40) induced neurotoxicity in rats (Ma et al. 2009). All three treatments significantly ameliorated the functional deficits of learning and memory caused by Abetal-40 administration. Intragastric pre-treatment with soy isoflavones, folic acid and their combination resulted in a significant increase of Abetal-40 lowered antioxidative activity and reversed the Abeta1-40-induced increase in the amount of amyloid-positive neurons. Similarly Zhao et al. (2010) found that the neuroprotection of soy isoflavone and soy isoflavone-folic acid combined administration was superior to individual treatment in rats with neurotoxicity induced by cyclophosphamide. The combined treatment halted DNA damage and neuron apoptosis induced by cyclophosphamide; upregulated Bcl-2 expression and down-regulated expression of Bax and P53 proteins.

Studies showed that soy isoflavones significantly attenuated d-galactose-induced in aging changes in mice, with high soy isoflavone treatment completely reversing most of these changes (Hsieh et al. 2009). D-galactose induced aging in mice by significantly increasing: (1) thiobarbituric acid-reactive substances in serum and brain; (2) protein carbonyls in liver, kidney and brain; (3) soluble extracellular receptors for advanced glycation end products in serum; (4) expression of Bax and caspase-3 proteins in splenocytes; (5) protein expression of Abeta, presenilin-1 and beta-site amyloid precursor protein cleaving enzyme-1 in brain. Natural aging mice also exhibited similar changes. This D-galactose-mimetic aging study showed that soy isoflavone effectively attenuated oxidative damage and improved parameters related to aging and Alzheimer's disease. Results of studies by Liu et al. (2010a) suggested that soy isoflavones could improve long memory performance in the aluminium exposed mice, possibly by modulating the metabolism of brain acetylcholine and amino acid neurotransmitters. The soy isoflavone treatment totally reversed aluminium-induced increases in acetylcholinesterase activity in the cerebral cortex and hippocampus of mice, and partially reversed the decreased aspartic and glutamic acid contents, two excitatory amino acid neurotransmitters, in the hippocampus.

Soy and Antimicrobial Activity

Soybean toxin (SBTX), a 44 kDa glycoprotein was found to be inhibitory to plant and human pathogenic fungi at concentrations far below the dose lethal to mice (LD_{50} = 5.6 mg/kg) (Morais et al. 2010). It inhibited spore germination of *Aspergillus niger* and *Penicillium herguei* and was toxic to *Candida albicans, Candida parapsilosis, Kluyveromyces marxiannus, Pichia membranifaciens* and *Saccharomyces cerevisiae*. The toxin caused cell-wall disruption, condensation/shrinkage of cytosol, pseudohyphae formation, and *P. membranifaciens* and *C. parapsilosis* cell death.

Soy and Wound Healing Activity

In-vitro studies showed that treatment with anthocyanins from black soybean seed coats could promote wound healing and prevent excessive inflammation (Nizamutdinova et al. 2009). Treatment of anthocyanins for 48 hours significantly promoted the migration of both human dermal fibroblasts and keratinocytes at 50 and 100 μg/ml concentrations.

Treatment of cells with anthocyanins stimulated wound-induced vascular endothelial growth

factor (VEGF) production in fibroblasts and keratinocytes. However, anthocyanins suppressed reactive oxygen species (ROS) accumulation and VEGF production in tumour nuclear factor- alpha (TNF-alpha)-stimulated endothelial cells. In addition, anthocyanin treatment dose-dependently reduced in the adhesion of inflammatory monocytes to endothelial cells. Anthocyanins also blocked both the translocation of nuclear factor-kappa B (NF-kappaB) p65 into the nucleus and the phosphorylation of the inhibitory factor kappaBalpha. Thus, the scientists asserted that treatment with anthocyanins from black soybean seed coats may be a potential therapeutic strategy to promote wound healing and to prevent inflammation in a persistent inflammatory condition.

Soy and Goitrogenic Activity

Numerous studies had implicated that soy-diet could induce goitre (Divi et al. 1997). They found that an acidic methanolic extract of soybeans contained soy isoflavones (daidzein and genistein) that inhibited thyroid peroxidase- (TPO) catalysed reactions essential to thyroid hormone synthesis. In the presence of iodide ion, genistein and daidzein prevented TPO-catalysed tyrosine iodination by acting as alternate substrates, yielding mono-, di-, and triiodoisoflavones. Genistein also inhibited thyroxine synthesis. The IC_{50} values for inhibition of TPO-catalysed reactions by genistein and daidzein were approximately 1–10 μM, concentrations that approached the total isoflavone levels (about 1 μM) previously measured in plasma from humans consuming soy products. In rats consuming genistein-fortified diets, high genistein levels were found in thyroid tissue in male and female rats and the activity of TPO in male and female rats was found to be reduced by up to 80% in a dose-dependent manner (Chang and Doerge 2000). Although these effects were clear and reproducible, other measures of thyroid function in vivo (serum levels of triiodothyronine, thyroxine, and thyroid-stimulating hormone; thyroid weight; and thyroid histopathology) were all normal. Additional factors appear necessary for soy to cause overt thyroid toxicity (Doerge and Sheehan 2002). Iodine deficiency greatly increased soy antithyroid effects, whereas iodine supplementation was protective. Besides iodine deficiency, other factors such as iodine additional soy components, other defects of hormone synthesis, or additional goitrogenic dietary factors were also important.

Soy and Antinutrients

Soybean was found to contain a number of antinutritional components that exert a negative impact on the nutritional quality of soy proteins like the protease inhibitors (trypsin and chymotrypsin inhibitors) and lectins (Liener 1994). Kunitz (1947) was the first to identify a soybean trypsin inhibitor with a molecular weight of 21,500. Trypsin inhibitors are proteins that interfere with nutrient absorption by reducing the activity of the proteolytic enzymes trypsin and chymotrypsin (Norton 1991). Hwang et al. (1977) found five trypsin and α-chymotrypsin inhibitors with low molecular weights (ranging from 6,800 to 8,600) in soybean seeds. Trypsin inhibitor activity (TIA), if present at a high level could cause pancreatic hypertrophy/hyperplasia, which ultimately resulted in an inhibition of growth (Liener 1994; Yuan et al. 2008). Consecutive blanching and ultrahigh-temperature (UHT) processing were found to be effective in eliminating TIA in soymilk (Yuan et al. 2008). Soybean and soy food products were found to contain the anti-nutrient lysinoalanine (Struthers 1981; Friedman et al. 1984). Exposing soy protein to alkaline conditions (pH 8–14) for various time periods (10–480 minutes), and temperatures (25–95°C at 10°C intervals) destroyed all of the cystine and part of arginine, lysine, serine, and threonine residues and were accompanied by the appearance of lysinoalanine and unidentified ninhydrin-positive compounds (Friedman et al. 1984). Proper control of temperature and pH in processing could reduce or eliminate lysinoalanine formation and lysinoalanine had not been shown to present a toxicological hazard to any species other than the rat (Struthers 1981). The small quantities of dietary lysinoalanine in food products on the market appeared to represent no

health hazard. Soybean meal also contained the phytohaemagglutinin glycoproteins, lectins (Lajolo and Genovese 2002). Lectins had been reported to bind to the intestinal epithelium of rats and interfered with nutrient absorption (Lajolo and Genovese 2002). When included at 0.73 mg/g diet, soybean lectins had also been shown to depress nitrogen retention and to increase nitrogen excretion via the urine, indicating interference with protein metabolism (Czerwinski et al. 2005). Further, soybean lectins reduced insulin production of rats given oral doses greater than 0.02 g/kg body weight (Bardocz et al. 1996). Of lesser significance were the antinutritional effects produced by relatively heat stable factors, such as goitrogens, tannins, phytoestrogens, flatus-producing oligosaccharides (raffinose and stachyose), phytate, and saponins (Liener 1994). In soybeans, phtyic acids occurred mainly as calcium and potassium salts (Mebrahtu et al. 1997; Mohamed et al. 2001). The carbohydrates in soybean meal were found to consist predominantly of non-starch polysaccharides and free sugars, such as, mono-, di- and oligosaccharides (Choct 1997). Starch was found at less than 1% (Choct 1997). Also meriting consideration is the allergenic components in soybeans. Soybean is acknowledged as one of the "big 8" food allergens (Krishnan et al. 2009). Soybean protein is used in a number of food products but is also a common cause of food allergy (Liu et al. 2008). Many reports had indicated that soy glycinin and β-conglycinin (including the alpha, alpha' and beta subunits) (Krishnan et al 2009) which make up one-third of protein in the soybean, had been characterized as major soybean allergens involved in food hypersensitivity (Liu et al. 2008). Liu et al. (2008) found that soybean-specific IgE and IgG1 antibodies increased, with high levels of histamine release, severe degranulation of mast cells and damage of the epithelium of small intestine in mice sensitized with glycinin and β-conglyinin.

Traditional Medicinal Uses

Traditional Chinese herbals suggest that the soybean is a useful remedy for the proper functioning of the bowels, heart, kidney, liver, and stomach. Soybean has been used to treat edema, common cold, skin disease, beriberi, diarrhoea, and toxaemia of pregnancy, habitual constipation, iron deficiency anaemia, and leg ulcers (Lu 2005). Tofu, soymilk and soybean sprouts are deemed beneficial to health. Tofu has been suggested to be good remedy for cold, fever, inflammations and urination problems. Soy milk is deemed good for lowering cholesterol and for its supply of calcium and iron. Soybean sprouts are used traditionally to cleanse toxins in lungs and suppress sputum production and also for treating, sore throat, dry lips, and cracked mouth ulcers. Sprouts are also considered an excellent diuretic for treating urination problems. A decoction of the soybean root is said to be astringent. Soy meal and flour are used to prepare diabetic foods due to the small amount of starch contained therein. Soybean diets are valued for acidosis. Since soybean oil has a high proportion of unsaturated fatty acid, it is recommended to treat hypercholesteremia.

Other Uses

Soya bean is cultivated for the extraction of oil, for the edible seeds (pulses) and for animal fodder. Soybean oil is used industrially in the manufacture of paints, linoleum, oilcloth, printing inks, soap, insecticides, and disinfectants. Lecithin phospholipids obtained as a by-product of the soy oil industry, are used as a wetting and stabilizing agent in food, cosmetic, pharmaceutical, leather, paint, plastic, soap, and detergent industries. Soy-based plastics used in cars were based on the addition of soybean flour and wood flour to phenolformaldehyde plastics. Commercial grades of natural soy lecithin are reported to contain a potent vasodepressor. Medicinally lecithin is indicated as a lipotropic agent. Soybean is listed as a major starting material for stigmasterol, once known as an anti-stiffness factor. Sitosterol, also a soy by-product, has been used to replace diosgenin in some antihypertensive drugs. Soy meal is very rich protein feed for livestock for which there is an increasing demand. Soy meal and soy bean protein are used in manufacture of synthetic

fibre, adhesives, textile sizing, waterproofing, fire-fighting foam and many other uses. Very high quality textile fibres are manufactured commercially from "okara" (soy pulp), a by-product of tofu production. The vegetative aerial portions of soy plant are used for silage, hay, pasture or fodder, or may be ploughed under as a green manure. Soybean straw can be used to make paper, stiffer than that made from wheat straw. Ash of soybean stem mixed with *Canarium* resin has been used to make joss-stick in Indo-China.

Biodiesel made from soy beans, can be used in place of petroleum diesel fuel for vehicles or generators heating oil for buildings. Unlike petroleum diesel, biodiesel is a renewable resource, and it creates less pollution than petroleum diesel. Tsai et al. (2010a, b) found soy-biodiesel to have promise for use as an alternative fuel for diesel generators to increase energy efficiency and reduce the particulate matter, total carbon, and polycyclic aromatic hydrocarbons emissions. However, soy biodiesel has some undesirable characteristics associated with the use of soy methyl esters as a direct replacement for petroleum diesel fuel (Wang et al. 2010). When compared to petroleum diesel, soy methyl esters have higher nitric oxide emissions, poorer cold flow, and a shorter shelf life. Careful choice of alcohol and triglyceride feedstock could improve these fuel properties.

Comments

Soybean is easily propagated using seeds.

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Inga edulis

Scientific Name

***Inga edulis* C. Mart**.

Synonyms

Feuilleea conferta (Benth.) Kuntze, *Feuilleea edulis* (Mart.) Kuntze, *Feuilleea scabriuscula* (Benth.) Kuntze, *Inga benthamiana* Meisner, *Inga conferta* Benth., *Inga edulis* var. *grenadensis* Urb., *Inga inga* (L.) Britton, *Inga minutula* (Schery) T.S. Elias, *Inga scabriuscula* Benth., *Inga scabriuscula* var. *villosior* Benth., *Inga vera* Kunth, *Inga vera* sensu Brenan, *Inga ynga* (Vell.) J.W.Moore, *Mimosa inga* L., *Mimosa inga* Vell., *Mimosa ynga* Vell.

Family

Fabaceae also placed in Leguminosae, Mimosaceae

Common/English Names

Food Inga, Ice-Cream Bean, Inga, Inga Bean, Monkey Tail, Monkey Tamarind, Sack-Sac

Vernacular Names

Aymara: Pa'qaya;
Bolivia: Inga De Macao;
Brazil: Abaremotemo, Abavemo, Anga, Engá, Ingá, Inga, Ingá-Caixao, Inga Cipo, Ingá-Cipó, Ingá-Da-Beirada, Ingá-Da-Praia, Ingá De Macaco, Inga De Metro, Ingá-De-Mico, Inga Doce, Ingá-Doce, Inga Macarrao, Ingá-Opeapiíba, Ingá-Rabo-De-Mico, Inga Timbo, Ingá-Timbó, Ingá-Verdadeira, Ingaí, Ingazeiro, Maingá De Metro, Rabo-De-Mico (Portuguese);
Czech: Inga Jedlá;
Colombia: Guama, Guamo;
Cook Islands: Kiko, Pakaie (Maori):
Costa Rica: Monkey Tail, Guaba Chililllo;
Eastonian: Söödav Ingauba;
Ecuador: Barisa Pacae, Estihua Pacae, Guaba, Guaba De Bejuco, Guabilla;
French: Pois Doux, Pois Ice-Cream, Pois Sucre, Pacayer;
French Guiana: Pois Sucre;
German: Essbare Inga, Inga-Früchte;
Guyana: Waikey;
Honduras: Chalaite, Cuajiniquil, Guaba, Guaba De Bejuco, Guama;
Martinica: Pois Doux;
Mexico: Chalahuite Guamo San Antonio, Guamo Santafereño, Guava, Guava Machete, Guavo-Bejuco, Inga Cipo, Jiniquil;
Peru: Pacay, Pacae, Guabilla, Pacae Soga, Pacae Silvestre, Rujino Shimbillo, Waupa, Guaba, Guaba De Bejuco;
Quechua: Pa'qay, Paccai (Cuzco);
Russian: Inga S'edobnaia, Struchok-Moroxhenoe;
Spanish: Guaba, Guano, Pacay De Perú, Guama, Guamo, Pacay, Pacae;

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Tahitian: Pakai;
Venezuela: Guama, Guamo, Guamo Liso.

Origin/Distribution

Inga edulis is native to South America – Amazonian Brazil, Bolivia, Peru, Ecuador, northwestern Argentine and Colombia. The species has also been introduced across most of tropical South America, Central America – Panama, Mexico and Costa Rica, northern Australia and Tanzania.

Agroecology

Inga edulis is a tropical species and its natural habitat is found in the warm, lowland wet tropical rainforest. However, it is adaptable to subtropical conditions as encountered in the highlands in its native range. It is found from sea level to 2,000 m altitude. Its optimum mean temperature ranges from 21–28°C but it will tolerate temperatures of up to 33°C. It prefers areas with mean annual rainfall above 1,200 mm. It is tolerant of moderate cold, frost free conditions, heavy rainfall of more than 3,000 mm and drought of up to 6 months that occurs in some areas. It is commonly abundant in ravines, along margins or rivers and adjacent forest usually in gaps as it is light demanding, along edge of streams in thickets and wooded swamps. *Inga edulis* is adaptable to a wide range of soil types including poor exisols, acid soils, swampy areas and flood plains that are inundated and water-logged for 2–3 months. Inga withstands soils from pH 4–8 and can tolerate high aluminium saturation (70–90%) in acid soils. The tree nodulates profusely even at pH 4.5 and fixes nitrogen. It also has mycorrhizae in its roots which play an important role in enabling the tree to take up phosphorus even though phosphorus is in very short supply in acid soils.

Edible Plant Parts and Uses

The translucent, white, cottony pulp around the seed is sweet and edible. Its taste is likened to that of vanilla ice-cream. The pulp is eaten fresh out of hand or used in flavoring various desserts. In Columbia, an alcoholic beverage is made from the pulp. The beverage, called *cachiri*, is consumed at a festival of the same name. The succulent testa is eaten off the seeds after removing them from the softened pod by twisting it open. The testa is sweet and soft but very full of fine fibres.

Botany

Evergreen or deciduous tree, normally less than 17 m but can reach 30 m high with a pale grey, smooth trunk and diameter up to 60 cm. The branches formed a spreading, moderately dense crown with branching occurring 2–3 m from ground level. Leaves are alternate, simple pinnate, 10–30 cm long with 4–6 pairs of opposite, dark-green, membranous, slightly pubescent, oval leaflets (Plates 1–3). The terminal leaflets is larger up to 18 cm long by 11 cm wide than the basal ones. Each pair is separated by winged rachis with a nectary gland in the rachis between each pair. Flowers are fragrant, sessile, pentamerous and are arranged in dense axillary spikes. Flower has a calyx tube with five puberulent, striate lobes, corolla with five silky, villous petals, 14–20 mm long, numerous white stamens, connate in lower half in a tube (Plate 4). Fruit longitudinally ribbed, cylindrical indehiscent leguminous pod, straight, curved or often spirally twisted up to 1 m long, pendant, green to yellowish brown (Plates 1–3). Seeds many (10–20), purplish-black, embedded in the sweet, cottony, white pulp.

Plate 1 Twisted, curved pod, young and old leaves of *Inga edulis*

Plate 2 Pendant, twisted and curved *Inga edulis* pods

Plate 3 Curved, twisted pods, flower and leaves

Plate 4 *Inga edulis* flowers

Nutritive/Medicinal Properties

The pulp of ripe fruit of *Inga* spp. was found to contain per 100 g edible portion, 60 cal energy, 83.0% moisture, 1.0 g protein, 0.1 g fat, 15.5 g total carbohydrate, 1.2 g fibre and 0.4 g ash (Duke 1983). The proximate composition of the edible pulp of *Inga edulis* fruit was reported by Lorenzi et al. (2006) per 100 g as: 97.7 cal., protein 2.62 g, fat 0.1 g, carbohydrate 21.6 g, Ca 28 mg, P 13.0 mg, Fe 0.80 mg, vitamin A 0.04 mg, vitamin B1 0.14 mg, vitamin B2 0.09 mg, niacin 1.12 mg, vitamin C 19.6 mg. Seeds of *Inga edulis*, eaten as vegetables, were reported to have per 100 g, 118 cal, 63.3% moisture, 10.7 g protein, 0.7 g fat, 24.0 g total carbohydrate, 1.6 g fibre, 1.3 g ash. Dried seeds of *Inga* spp. contain per 100 g, 339 cal energy, 12.6% moisture, 18.9 g protein, 2.1 g fat, 62.9 g total carbohydrate, 3.4 g fibre, 3.5 g ash. Seeds of the genus *Inga* were also reported to contain trypsin inhibitors and chymotrypsin inhibitors.

Antioxidant Activity

I. edulis is an interesting source of antioxidants. Its antioxidant capacity as measured by TEAC (Trolox Equivalent Antioxidant Capacity) and ORAC (Oxygen Radical Absorbance Capacity) were found to be highest in the leaves than in the bark, fruit and seeds in descending order (Silva et al. 2007b). In their study, they found a high correlation between TEAC and total phenolics (TP) ($r2 = 0.88$). TEAC was also significantly correlated with total flavanoids (TF) ($r2 = 0.75$). The TEAC value for *I. edulis* plant parts in terms of μmol TE (Trolox Equivalent)/g fresh weight (FW) were: leaf 58.1, bark 31.4, fruit 2.2, seed 1.0. The ORAC value in terms of μmol TE/g FW were: leaf 239.5, bark 200.7, fruit 17.5, seed 8.9. The total phenolics TP mg GAE (Gallic acid equivalent) per g FW were : leaf 9.8, bark 14.8, fruit 0.7, seed 0.4 and the total flavanoids (TF) mg CE (Catechin Equivalent) /g FW were leaf 3.31, bark 5.50, fruit 0.12, seed nd (not detected). The polyphenolic compounds identified in *Inga edulis* leaves were gallic acid, catechin, epicatechin, myricetin-3-rhamnopyranoside, quercetin-3-glucopyranoside and quercetin-3-rhamnopyranoside (Souza et al. 2007). The dry crude extract presented very high values for ORAC (11.16 mmol TE per g) and TP (496.5 mg GAE per g). The identified compounds were responsible for 9.53% and 12.10% of the ORAC

value and TP content of the *Inga edulis* leaf extract, respectively. The experimental values of phenolics from *Inga edulis* leaves using response surface methodology (RSM) agreed with those predicted within a 95% confidence interval, thus indicating the suitability of RSM in optimizing the extraction of phenolics from *I. edulis* (Silva et al. 2007a). The predicted values were 134.6 mg gallic acid equivalent/g dry matter (DM), 26.0 mg catechin equivalent/g DM and 13.8 mg rutin equivalent/g DM, for total phenolics (TP), total flavonoids (TFA), and total flavonols (TFO), respectively.

In a subsequent study, four Amazonian plants including *Inga edulis* were reported to possess antioxidant property (Souza et al. 2008). The plants under investigation showed a great range of TEAC (trolox equivalent antioxidant capacity) of 1.0 up to 347.1 μmol of trolox equivalent/g and ORAC (oxygen radical antioxidant capacity) of 6.7 up to 1396.4 μmol of trolox equivalent/g values. These values were highly correlated to the concentration in total phenolics (TEAC: r2 = 0.88; ORAC: r2 = 0.70,), and in total flavanoids, (TEAC: r2 = 0.75; ORAC: r2 = 0.74). Almost all extracts performed well in all assays of antioxidative capacity, with best activities found in leaves (compared to fruits and bark). Most antioxidative performance indicators ORAC (oxygen radical antioxidant capacity), TRAP (total radical trapping antioxidant parameter), LDL (low-density lipoprotein) protection correlated well with the TP (total phenolics) and TFA (total flavanoids) content of the extracts. Conversely, correlation was lower between TFO (Total flavonols) and these indicators, reflecting a lower involvement of these compounds in antioxidant processes. Erythrocyte protection against oxidant-triggered haemolysis showed no correlation with any of the phenolic content indicators, suggesting that most of these compounds had a low ability to protect lipid targets in the erythrocyte membrane. In contrast, protection of erythrocytes against haemolysis correlated positively with LDL protection. The extract of *I. edulis* leaves contained average amounts of polyphenols but ranked first in the majority of the tests, indicating the occurrence of particularly efficient compounds with very important antioxidant properties, which could be used for medicinal and other applications.

Traditional Medicinal Uses

It has been reported that nearly all Colombian species of *Inga* are used in traditional medicine. Decoctions of the leaves and bark are used as astringent in diarrhoea, as a lotion for arthritis and rheumatism. The root decoction is used for diarrhoea or dysentery, and if mixed with the rind of pomegranate is deemed more effective. Bark and fruit are used for dropsy and irritations of the intestinal linings. Native Indians used the plant as a nervine for headaches. Crushed (boil down) leaves of *Inga edulis* are drunk to relieve coughing and applied to sores on lips.

The leaves, bark and seeds of *Inga edulis* have been used in ethnomedicine in Amazonia as an antiinflammatory and anti-diarrhoeic (Silva et al. 2007b).

Other Uses

Inga edulis is used as shade trees for coffee, tea, cocoa and as live support trees for vanilla. They are also used as shade trees around dwellings, in parks, as avenue plantings, watershed preservation and in soil conservation. Their usefulness can be attributed to (a) rapid and spreading canopy growth for quick shade, (b) their high coppicing ability to recover after drastic pruning, (c) their high nitrogen fixing ability and litter rich in nitrogen, lignin and polyphenols for soil improvement and (d) effectiveness in preventing soil erosion especially for slope reclamation. Their branches provide a good and cheap source of firewood with a high calorific value and little smoke. The foliage can be fed to livestock. The seed has 11% protein in its dry matter so may be a useful feed for pigs.

Comments

Inga edulis is readily propagated from seeds.

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Inga feuillei

Scientific Name

***Inga feuillei* DC.**

Synonyms

Inga cumingiana Benth., *Inga feuilleei* DC., *Inga spuria* Humb. & Bonpl. ex Willd.

Family

Fabaceae, also placed in Leguminosae, Mimosaceae

Common/English Names

Inga, Inga Bean, Ice Cream Bean, Guama, Pacae Beans, Pacay

Vernacular Names

Brazil: Rabo De Mico (Portuguese);
French: Pois Sucre;
Peru: Pacae, Pacay, Pacae De Lima, Guama, Guamo, Guarna, Pa'qay, Pa'qaya, Pacae (Spanish).

Origin/Distribution

This species is a native of Peru and is cultivated there in gardens, where it is called *pacay*. It is often grown in the highland valleys and coastal lowlands of Peru and Equador. The species also has been introduced to other areas in Central and South America and elsewhere including Australia and Malaysia.

Agroecology

This species is more subtropical but share similar agro-ecological requirements as for *Inga edulis.* This Andean "Pacay" is widely grown in coastal lowlands of Perú as well as in highland valleys up to 1,500–1,800 m. The tree is most widespread in areas without a dry season with mean annual rainfall of 1,500–2,700 mm or with a short dry season of 3–4 months and minimum rainfall around 1,200 mm. It thrives at 25°C but will withstand brief periods of 35°C; at low temperatures, these trees are often damaged. The tree is adaptable to soils with pH of 4–8. The tree is tolerant of high aluminium saturation of 70–90% in acid soils, outgrowing many other leguminous trees under such conditions. It is a forest gap generator, and although seedlings often establish themselves in the shade of other trees, it needs

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light to grow, flower and fruit. The species nodulates profusely and is heavily mycorrhizal (vesicular arbuscular mycorrhizae) which helps in phosphate uptake from soil.

Edible Plant Parts and Uses

The tree pods are relished as favourite snacks for their sweet, white, mealy pulp. The fruits of the trees are quite edible and are often consumed by people of regions where this fruit grows. Its pods are much prized as snacks, and are sold in markets and by street vendors and relished by children. In Central America, the seeds are cooked and eaten as a vegetable. In Mexico, the seeds are roasted and sold outside theaters to moviegoers.

Plate 2 Pinnate leaves and flowers

Plate 1 Pacay flower and pod

Plate 3 Immature pacay pod

Plate 4 Ripe pacay pod

Botany

Inga feuillei is an evergreen, medium-sized legume tree growing to 15–30 m high. It has paripinnate compound leaf consisting of 3–4 pairs of opposite, large, dark-green, oval to broadly ellipsoid, tapering leaflets (Plates 2 and 3). The rachis is winged between each pair of leaflets, with a nectary gland at the base of each leaflet pair. Flowers are fragrant, sessile, pentamerous and are arranged in axillary spikes. Flower has a short, white calyx tube, 10–13 mm, corolla (13-) 20–24 mm, fully developed, long, thin, white filaments 40–45 mm, basal part of the stamens is fused into a tube shorter than the corolla, 12–17 mm long, adnate to this are the nectaries (Plates 1 and 2). Stamens numerous 75- (100–120) per flower. Gynoecium 1–2 carpellate. Male flowers with a small pistillode and occur with the hermaphrodite flowers. The fruit is a pendant, indehiscent pod, laterally flattened, four-sided or four angled with sulcate margins, straight or curved, green or brownish-yellow and reach a length of 30–50 cm (Plates 1, 3, and 4). The green seeds are embedded in the white, sweet cottony pulp.

Nutritive/Medicinal Properties

Refer to *Inga edulis* for its nutritive and medicinal value and traditional medicinal applications.

Other Uses

The uses are as described for *Inga edulis* and *Inga jinicuil*. They are multipurpose trees and are potentially valuable additions to gardens, orchards, fields, hedgerows, or wayside wastelands throughout the tropics. They also have excellent prospects as urban trees. In Mexico, coffee-plantation workers can double their annual salary by selling the pods from the *Inga* trees used to shade the coffee plants. Its wood can be used for furniture, boxes, crates, light construction, and general carpentry and also for firewood.

Comments

The tree is propagated from seeds which germinate readily.

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Inga jinicuil

Scientific Name

***Inga jinicuil* G. Don.**

Synonyms

Feuilleea jinicuil (Schltdl.) Kuntze, *Inga jinicuil* Schltdl., *Inga paterno* Harms, *Inga radians* Pittier.

Family

Fabaceae, also placed in Leguminosae, Mimosaceae

Common/English Names

Ice-Cream Bean, Jinicuil, Paterno

Vernacular Names

Costa Rica: Cuajinicuil, Guabo Caete;
El Salvador: Nacaspilo, Paterna, Paterno;
Guatemala: Paterna, Paterno;
Honduras: Paterna, Paterno;
Mexico: Algodoncillo, Bitzé, Chalahuite, Chalahuite De Monte, Coctzán, Cojinicuil, Cuajinicuil, Cuil Machetón, Uajinikuile Guajinicuil, Jinicuil;
Nicaragua: Guaba, Guava Extranjeira.

Origin/Distribution

Inga jinicuil (Inga paterno) is native to south-eastern Mexico through Central America to Costa Rica (Zarucchi 1986). In Mexico, it is found in the states of Puebla, Veracruz, Tabasco, Oaxaca, Guerrero, Michoacán and Jalisco.

Agroecology

In its native range it occurs from near sea level to 2,000 m elevation, in moist and well-drained soils. It is found in humid, mountain mesophyll forests and gallery forests along streams and in riparian zones. In its native range, the mean annual temperature hovers around 18°C and annual precipitation of 145 mm with a month of dry season.

Edible Plant Parts and Uses

Both the fresh arils and the cooked seeds of are popular for human consumption especially in El Salvador. The fruit pulp is used in popular dishes such as "*sanchoco*" in El Salvdor. The seeds are used as vegetables in local dishes and are sold fresh or preserved. Cooked seeds are eaten together with *Phaseolus* beans and *Chenopodium* leaves by the Chinatec Indian in Mexico.

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Plate 1 Paterno flowers

Plate 2 Paterno pinnate leaf with three pairs of leaflets

Botany

Inga jinicuil is a fast-growing, evergreen or semi-deciduous, tree, reaching 10–20 m in height and 40–50 cm girth. The trunk is fairly straight and spreading with ascending braches with dense foliage. Leaves are alternate, pinnately compound with three pairs of leaflets. The leaflets are entire, acuminate, lanceolate to elliptic (Plates 1 and 2), tapering base, glabrous, 8–11 cm long; juvenile leaves are copper-bronze turning green with maturity. Flowers are bisexual, pentamerous, borne in densely clustered spikes or heads with numerous very conspicuous long, white stamens, petals reduced (Plates 1). Fruits are indehiscent, oblong, dorsi-ventrally flattened, curved, 15–20 cm long by 12–18 mm wide and 8–11 mm thick, 15–30 cm long, green maturing to yellowish–brown (Plates 3 and 4). Seeds 4–6, 3–5 cm long, soft green embedded in sweetish, succulent, cottony-white pulp.

Plate 3 Curveded paterno pods

Plate 4 Close-view of mature paterno pod

Nutritive/Medicinal Properties

No published information is available on its nutritive value which would be similar to that of *Inga edulis*.

A novel amino acid, trans-4-methoxy pipecolic acid was isolated from the species (Morton et al. 1991).

Tea made from the fresh bark is given to women to accelerate slow labour during childbirth, and the fresh aril helps to cure constipation (Ayala 1994).

Other Uses

Inga jinicuil is commonly used as shade trees in coffee plantations in Central America (Mexico, Honduras, El Salvador, Guatemala, and Costa Rica) and as green manure.

Its branches are used for firewood and the timber used for construction in the rural areas. Its flowers are good source of nectar for honeybees.

Comments

Like other *Inga* spp, it can be readily propagated from seeds.

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Inocarpus fagifer

Scientific Name

***Inocarpus fagifer* (Parkinson) Fosberg**

Synonyms

Aniotum edulis J.R. Forst., *Aniotum fagiferum* Parkins., *Bocoa edulis* (J. R. Forst. & G. Forst.) Baill., *Cajanus edulis* (J.R. Forst. & G. Forst.) Kuntze, *Inocarpus edulis* J.R. Forst., *Inocarpus eludis* J.R. Forst. & G. Forst., *Inocarpus fagiferus* (Parkinson) Fosberg.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Otaheite Chestnut, Polynesian Chestnut, Tahitian Chestnut

Vernacular Names

Chuukese: Asas, Kurek;
Cook Islands: I'I (Maori);
French: Châtaigne De Tahiti, Châtaignier De Tahiti, Inocarpe Comestible;
Fiji: Drala Kaka, Ivi (Fijian), Ifi (Rotuman), Te Ibi (Banaban/Kiribati);
Germany: Tahitikastanie;
Horne Islands: Ifi;
Indonesia: Gatep (Bali), Ghajam (Madurese), Bosua (Sulawesi), Gatet (Sundanese), Japanese: Gayam, Tolok; Taiheiyou Kurumi;
Kosraen: Kurrak;
Malaysia: Tolok;
Marquesas: Ihi;
Niue: Ifi;
Papua New Guinea: Aila;
Philippines: Kayam (Tagalog);
Pohnpei: Mworopw;
Samoa: Gatae, Ifi;
Society Islands: Mape;
Solomon Islands: Julapa In Bugotu, Zulapa In Zabana (Isabel Island), Ivi, Komo, Mwaqe (Santa Ana Island), Ailali (In Kwara'Ae, Malaita Island) Dulafa (In To'Oabaita, Malaita Island), Dola (In Varisi, Choiseul Island), Ivi (In Roviana, New Georgia Island), Marovo (New Georgia Island), Naqi (In Nduke, Kolombangara Island);
Tahiti: Mapé, Rata;
Taiwan: Tai Ping Yang Li;
Tonga: Ngatae Fisi, Ifi;
'Uvea: Ifi;
Vanuatu: Namambe (Bislama).

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Origin/Distribution

The species is native to Indo-Malaysia and is naturalised after ancient aboriginal introduction in Micronesia, Melanesia and Polynesia (extending to the Marquesas). It is a recent introduction into Hawaii. It is cultivated in the Pacific islands as well as in New Guinea, Indonesia, especially Java and Sulawesi, the Philippines and occasionally in the neotropics.

Agroecology

The tree is adapted to the humid tropical conditions with mean annual temperatures of 20–35°C and mean annual rainfall of 1,500–4,300 mm, evenly distributed through out the year. Prolonged temperatures below 20°C has been reported to retard tree growth. It occurs in lowland seaside forest, swamps, marshes, waterlogged areas, and highly alkaline soils along shorelines from sea level to 500 m elevation. It also grows along the banks of rivers and streams, at the edges of villages, and in home gardens. It tolerates a wide range of soils from mildly acidic to very alkaline or saline coastal soils, from free draining soils to impeded drainage as well as seasonally waterlogged or even continually waterlogged soils. It tolerate soils of low to medium fertility, and can grow in a wide pH range of 5 mildly acid to pH 14 strongly alkaline soils. It is commonly found as understorey tree i.e. partial shade and also will grow well in full sun. It is not drought tolerant.

Edible Plant Parts and Uses

In Polynesia and Micronesia, Tahitian chestnut together with coconuts and breadfruit are important staple food crops of the people. Raw and cooked kernels are important seasonal cash crop and are sold in domestic markets. In Fiji, cooked kernels are wrapped with the leaves when sold in the market. The kernels of ripe fruits are eaten after boiling, roasting, grilling, baking, or mashed into tuber pudding in Papua New Guinea, Fiji, the Solomon Islands, Vanuatu, and Polynesia. Seeds have a chestnut flavour and are pleasant to eat. Some noteworthy dishes include *lap lap* (Vanuatu), *koko* (Fiji), and *masimasi* or *robe* (the western Solomon Islands). Unripe ones (ratta) are fermented and prepared to various dishes. The kernels are also dried or preserved in pits.

Botany

A medium-sized, evergreen, tree, 10–30 m high, with a deeply fluted trunk of 7–90 cm diameter and rough, flaky grey brown leathery bark. Leaves are alternate, distichous, simple, petiolate (0.2–2.5 cm long petioles), oblong, 16–39 cm by 7–13 cm, base obtuse-cordate, apex narrowed, acute to emarginate, margin entire, coriaceous, shining green above, pale green below and glabrous (Plates 1 and 2). Flowers are fragrant, yellowish-white or pinkish in small terminal spikes; calyx is tubular-campanulate, thinly membranous and bilobed;

Plate 1 Large leaves and ripe Tahitian chestnut fruit

Plate 2 Fruits formed at the tip of flowering twigs

Plate 3 Close-up of unripe and near-ripe fruit

petals 4–6, erect with recurved tips, yellowish-white, glabrous; stamens 8–12; ovary subsessile with 1 ovule; style short with oblique stigma. Fruit is an indehiscent pod, oblong to oval with oblique apex and compressed laterally, 4.5–13 cm by 3.5–12 cm, green to yellow or orangey-yellow when ripe (Plates 1–3), containing one large, white, reniform seed (kernel), 2–7 cm by 1.5–4 cm encased in a thin, brown, fibrous testa.

Nutritive/Medicinal Properties

The food value of raw Tahitian Chestnut kernels per 100 g edible portion (Dignan et al. 1994) was reported as: water 43 g, energy 858 kJ (208 kcal), protein 4.5 g, total fat 4.5 g, available carbohydrate 37 g, dietary fibre 4.2 g, Na 8 mg, Ca 29 mg, Mg 49 mg, Fe 1.3 mg, thiamine 0.26 mg, riboflavin 0.09 mg, niacin 1 mg, vitamin 2 mg, vitamin E 1 mg.

The nutritious kernels are rich in protein and carbohydrate.

The leaves, bark, and stems are used medicinally in folk medicine. The bark is astringent and a decoction has been used for intestinal complaints in eastern Malaysia and Java. In the Solomon Islands, the bark was grated and mixed with coconut milk or bark sap to treat urinary infections. In Tonga, the juice from the mesocarp of unripe fruits was used to treat insect bites and burns. In Fiji, all parts of the tree (roots, stem, bark and leaves) were believed to have various medicinal properties.

Other Uses

The tree is commonly planted as boundary markers. Its wood is utilised for general construction, furniture and wood carving, for tool handles, kava bowls, tape beaters, weapons, packing boxes and for fuel wood. The wood is used for making canoes in Rennell and Bellona, the Solomon Islands. In Tahiti, its bark is a source of dye. Gum from fruit is used for caulking canoes in Uvea. The kernel provides a good feed for free-range chickens. Leaves are used for indicating the value of pigs for ceremonial presentation in Vanuatu. Leaves are also used as fodder for cattle. The leaves were sewn together to make sails for boats in Wallis. The large leaves were traditionally used for wrapping parcels throughout the Pacific islands. In Tonga, the leaves were once used to cover the ground beneath mats and also used for making belts.

Comments

The species is not considered to be invasive.

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Lablab purpureus

Scientific Name

***Lablab purpureus* (L.) Sweet**

Synonyms

Dolichos albus Lour., *Dolichos altissimus* Lour., *Dolichos amoenus* Salisb., *Dolichos benghalensis* Jacq., *Dolichos ensiformis* Thunb., *Dolichos lablab* L., *Dolichos purpureus* L., *Lablab benghalensis* Medik., *Lablab ferrugineus* Medik., *Lablab lablab* (L.) Lyons, *Lablab leucocarus* Savi, *Lablab nankinicus* Savi, *Lablab niger* Medikus, *Lablab perennans* DC., *Lablab purpurea* (L.) Sweet, *Lablab rufus* Medik., *Lablab vulgaris* (L.) Savi, *Vigna aristata* Piper.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Bonavist, Bonavist Bean, Dolichos, Egyptian Bean, Egyptian Kidney Bean, Field Bean, Hyacinth Bean, Indian Bean, Indian Butter Bean, Lablab, Lablab Bean, Musical Bean, Papaya Bean, Poor Man's Bean, Rongai Dolichos, Sweet Pulse, Tonga Bean, Wild Bean, Wild Bean Creeper

Vernacular Names

Amharic: Amora-Guaya;
Arabic: Lablâb;
Argentina: Poroto De Egipto;
Burmese: Pe-Gyi;
Caribbean: Antaque, Banner Bean;
Chamorro: Cheribilla Apaka, Chuchumeko;
Chinese: Bia Bian Dou, Bian Dou, Pin Tau, Peng Pi Dou, Que Dou, Rou Dou, Tseuk Tau;
Columbia: Frijol Jacinto;
Czech: Dlouhatec Lablab;
Danish: Hjelmbønne, Hjelmboenne;
Dutch: Komak;
Eastonian: Lobauba;
El Salvador: Frijol De Adorno;
Fiji: Natomba, Ndralawa, Tomba;
Finnish: Hyasinttipapu;
French: Dolique, Dolique d'Egypte, Dolique Lab-Lab, Pois Antaque, Pois Boucoussou, Pois Nourrice;
Gambia: Nalvo (Manding-Mandinka);
German: Ågyptische Fasel, Faselbohne,Gemeine Lablab, Helmbohne;
Hawaii: Pāpapa, Pī;
India: Urahi, Urchi, Uri, Urshi (Assamese), Rajashimbi, Sim (Bengali), Valpadi (Gujarati), Sem, Val (Hindu), Avara (Kannada), Moang (Kashmiri), Vaal (Konkani), Avara (Malayalam), Baragudi (Oriya), Avarai, Mochai, Motchai (Tamil), Adavichikkudu, Chikkudu, Tellachikkudu (Telugu);
Indonesia: Avara, Kerara, Komak, Mochakotta;

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Italian: Fagiolo Egiziano, Fagiolo d'Egitto, Fagiolo Del Cairo, Dolico Egiziano;
Ivory Coast: Guangono Abrua (Anyi);
Japanese: Fuji Mame, Ingen, Henzu;
Kenya: Njahi;
Korean: P'Yontu;
Laos: Mak Thoua Peb;
Malaysia: Kacang Kara, Kara Kara, Kekara;
Mexico: Gallinita;
Nepal: Raaj Simii,Rajashimi, Simii;
Nigeria: Wáákén Baìbààyíí, Wáákén Dànfámíí (Huasa);
Peru: Frijol Chileno, Lenteja Bocona, Zarandaja;
Philippines: Itab (Bontok), Batau, Bataw (Bikol), Batau (Bisaya), Baglau (Cebu-Bisaya), Itab (Ifugao), Parsa, Parda-Atap (Iloko), Bátau, Sibachi, Sibatsi (Tagalog);
Portuguese: Cumandatiá, Dólico Do Egipto, Feijão Cutelinho;
Puerto Rico: Chicarros, Frijol Caballo;
Rapa Nui: Haricot;
Russian: Lobija;
Sri Lanka: Dambala, Hodhambala (Sinhalese);
Spanish: Frijol Caballero, Carmelita, Feijão Da India, Feijão Padre, Zarandajo;
Sudan: Lubia;
Thai: Thua Paep, Thua Nang;
Tonga: Pini'Ae Puaka;
Turkish: Lablab;
Vietnamese: Dâu Ván;
Venezuela: Quiquaqua, Caroata Chwata, Tapirano;
Zambia: Fiwi Bean.

Origin/Distribution

Hyacinth bean is believed to be native to the Old World tropics. Although its largest agro-morphological diversity occurs in South Asia, its origin appears to be Africa. It is one of the most diverse domesticated legume species and has multiple uses. Hyacinth bean is widely cultivated in the tropics and subtropics particularly in India and southeast Asia, Egypt and Sudan. It is probably an ancient introduction to the Pacific islands.

Agroecology

Hyacinth bean is a short day plant. It thrives in the temperature range 18–30°C with a minimum of 3°C. It has low frost tolerance, tolerating very light frosts. It is found from sea level to 2,000 m but prefers lower elevations. It is quite drought tolerant and will grow in areas with annual rainfall as low as 400 mm as it has a deep root system, the suitable rainfall regime is between 750 and 2,500 mm per annum. It is an extremely adaptable crop growing on a wide range of soils from light sandy soils, alluvial to heavy soils with a pH range of 4.5–8. It prefers well-drained soils and abhors water-logged conditions and brackish (saline) waters. It occurs on the coast; in sand, loam, clay; occupying coastal areas, hills, cleared farmland, rubbish tips; growing in cropland, on wasteland, in disturbed natural vegetation and in gardens. It is intolerant of moderate to heavy shading.

Edible Plant Parts and Uses

Hyacinth bean is popularly eaten as a vegetable in southeast Asia whereas in India and elsewhere it is predominantly used as a pulse often as dhal. The young pods are eaten in stir- fries with meat or sea-food, used in curries; immature green seeds are eaten boiled or roasted or processed into bean cake (Tofu) or fermented to *tempeh*. A flour is processed from the seeds and used to make a kind of vermicelli in China and Indo-China and exported to south east Asia. The beans are used in a special curry, *Vaala che Birde* during fasting festivals during *Shravan* month in Maharashtra, western India. In the Telangana region of Andhra Pradesh, India, the bean pods are chopped into small pieces and cooked as spicy curry during the Pongal festival season and is eaten with *Bajra* bread as a special delicacy. The seeds form the main ingredient in the dessert pudding dish called *chè đậu ván* in Huế, Vietnam. The Kikuyu people in Kenya boiled the beans (seeds) with ripe or almost ripe bananas and potatoes to prepare a sweet dish. Young shoots, leaves

and inflorescences are eaten cooked as spinach. Sprouts are comparable to mung bean or soya bean sprouts and likewise eaten. A protein concentrate can be made from the seeds.

Botany

Annual or short-lived perennial, scandent (twining) or trailing herb s with a robust, usually purplish stem, 3–6 m in length (Plate 1). Leaves are alternate, trifoliolate (Plates 1 and 3); stipulate on petioles 6–26 cm long. leaflets are broadly ovate-rhomboid, 6–10×6–10 cm, lateral ones oblique, base subtruncate, apex acute or acuminate, or mucronate, almost smooth above and short-haired underneath. Flowers arranged in inflorescences, in 2–5 flowered racemes; predominantly white or pink or purple, on pedicel 2–10 mm long (Plates 1 and 2). Calyx 5–8 mm long, 5 sepals, tubular, finely pubescent, upper 2 teeth wholly connate, lower 3 subequal. Corolla 5 petals, standard orbicular, 12 mm; wings with blade 10 mm; keel base attenuate. Stamens 10, free of the perianth, both opposite and alternating with the corolla parts, coherent to each other (9 fused, 1 free). Anthers non-versatile, dehiscing

Plate 1 Climbing plant habit with trifoliolate leaves

Plate 2 Flower inflorescence

Plate 3 Swollen hyacinth bean pods

Plate 4 Flattish hyacinth bean pods

Plate 5 Hyacinth bean pods and seeds

via longitudinal slits. Ovary monomerous, linear, superior, 1 -celled. Styles 1, simple, longer than ovary. Fruit legume pod 4–5 cm long, broadly scimitar shaped, smooth and beaked by the persistent style, slightly bulging (Plate 3) or flattish (Plates 4 and 5), purple, yellowish or pale green, dehiscent, containing 3–5 seeds. Seed green (Plate 5) turning to dark brown, black or pale tan or white, often speckled, hilum white, linear.

Nutritive/Medicinal Properties

Proximate nutrient composition of raw mature hyacinth bean seeds per 100 g edible portion (USDA 2010) was reported as: water 9.38 g, energy kcal 344 (1,439 kJ), protein 23.90 g, total fat 1.69 g, ash 4.29 g, carbohydrate 60.76 g, Ca 130 mg, Fe 5.10 mg, Mg 283 mg, P 372 mg, K 1235 mg, Na 21 mg, Zn 9.30 mg, Cu 1.335 mg, Mn 1.573 mg, Se 8.2 μg, thiamine 1.130 mg, riboflavin 0.136 mg, niacin 1.610 mg, pantothenic acid 1.237 mg, vitamin B-6 0.155 mg, total folate 23 μg, total saturated fatty acids 0.288 g, 18:1 undifferentiated (oleic) 0.076 g, 18:2 undifferentiated (linoleic) 0.715 g; tryptophan 0.199 g, threonine 0.925 g, isoleucine 1.143 g, leucine 2.026 g, lysine 1.632 g, methionine 0.191 g, cystine 0.279 g, phenylalanine 1.204 g, tyrosine 0.853 g, valine 1.239 g, arginine 1.755 g, histidine 0.684 g, alanine 1.067 g, aspartic acid 2.821 g, glutamic acid 3.880, glycine 1.028 g, proline 1.162 g and serine 1.315 g.

Mineral profiles of hyacinth seeds, viz., nitrogen, phosphorus, potassium and calcium content varied from 3.610% to 3.643%, 0.338% to 0.356%, 3.020% to 3.124% and 1.764% to 1.804%, respectively (Naeem et al. 2009). Seed protein of all accessions varied from 24.70% to 25.06%. Carbohydrate content ranged from 50.83% to 53.16% across all accessions tested. Accession A4 produced the highest tyrosinase activity in the seeds and higher nitrate reductase and carbonic anhydrase activities than the other accessions. Nodule-nitrogen and leghaemoglobin content ranged from 5.267% to 5.314% and 0.110–0.130 mM, respectively.

Protein contents of 4 hyacinth bean cultivars were found to vary from 22.7% to 26.1%, fat contents 1.1–2.0%, moisture contents 7.8–8.1%, ash contents 3.8–4.3%, fibre contents 9.3–10.9% and carbohydrate contents 48.3–53.6% (El Siddig et al. 2002). Phosphorus values ranged from 305 to 312, magnesium: 167.4–231.1, sodium: 6–9 and potassium: 183.3–214 mg/100 g. Tannin contents of the four hyacinth bean cultivars ranged from 201 to 353 mg/100 g, while the in-vitro protein digestibility of the four cultivars was in the range 59.2–62.0%. The variation in protein fractions was: albumin 1.8–2.5%, globulin 69.9–81.2%, prolamin 2.7–4.4%, G1-glutelins 0.8–1.8%, G2-glutelins 1.1–3.0%, G3-glutelins 10.0–11.9% and insoluble proteins 0.2–9.9%. Cooking studies indicated that albumin and globulin fractions decreased significantly for two cultivars after cooking. This decrease was accompanied by a significant increase in prolamin, G1-glutelins, G2-glutelins and G3-glutelins fractions.

Hyacinth seeds and leaves are nutritious. From the above, the seeds were found to be very rich in proteins, carbohydrate, fibre, thiamine, niacin, panthothenic acid, minerals like Ca K, Mg, Fe and P and 18 amino acids and the leaves excellent sources of protein and iron.

The following polysaccharides were identified in hyacinth bean seeds: galactopinitol, A, myo-inositol, 4-0 methyl myo-inositol D-form (Beveridge et al. 1977). A plant growth promoting steroidal lactone, dolicholide, (22R,23R)-2α,3α,22,23-tetrahydroxy-B-homo-7-oxa-5α-ergost-24(28)-en-6-one was isolated from immature seeds (Yokota et al. 1982). Eight steroidal plant-growth regulators, dolicholide, dolichosterone, homodolicholide, homodolichosterone, brassinolide, castasterone, 6-deoxocastasterone and 6-deoxodolichosterone, were purified from immature seeds of *Dolichos lablab* (Yokota et al. 1984). Five cytokinins, trans-zeatin, 9-β-d-ribofuranosyl-trans-zeatin, 9-β-d-ribofuranosyl-cis-zeatin, 6-(trans-4-O-β-d-glucopyranosyl-3-methyl-2-butenylamino) purine and 6-(trans-4-O-β-d-glucopyranosyl-3-methyl-2-butenylamino)-9-β-d-ribofuranosylpurine were identified from immature seeds of *Dolichos lablab* (Yokota et al. 1981). The following

polyamines (oxyalkyldiamines) were found in mature hyacinth bean seeds: diaminopropane, putrescine, spermidine, spermine, thermospermine and aminopropylhomospermidine (Hamana et al. 1992). Separate studies showed that both the total phospholipid contents and the molar fraction of phosphatidylcholine in the fried *D. lablab* seed samples were low as compared with the crude, raw seeds (Xu et al. 1991). *L. purpureus* proteins were found to be resistant to degradation by the commercial enzymes trypsin and chymotrypsin and were moderately resistant to pepsin, but were readily hydrolysed to smaller peptides by papain (Janarthanan et al. 2008). The isolated polypeptides from *L. purpureus* demonstrated that the extract contained proteins similar to isoforms of arcelins 3 and 4 and pathogenesis-related protein 1 (PvPR1) of *Phaseolus vulgaris*.

The seed flour of *Lablab purpureus* was found to contain 302 g/kg protein on a dry weight basis (Venkatachalam and Sathe 2007). Albumin, globulin, prolamin, and glutelin accounted for 22.8%, 45.1%, 1.8% and 30.3%, respectively, of the total soluble seed proteins. Albumin fraction had the highest trypsin inhibitory activity, while the globulin fraction registered the highest hemagglutinating activity. Sulfur amino acids were the first limiting amino acids in the total seed proteins. The proportion of essential to total [E/T(%)] amino acids for the bean flour was 36.97%. Among the protein fractions, glutelin fraction had the highest E/T (42.86%) followed by albumin (41.57%), globulin (39.87%), and prolamin (39.15%). Native globulin, although resistant to pepsin, was effectively digested in-vitro upon moist heat denaturation at 100°C for 30 min.

Some of the pharmacological attributes of hyacinth bean are reported below:

Anticancer Activity

Ingham **(**1977) identified the following flavonoids in *Lablab niger* hypoctyl: dalbergioidin, demethylvestitol, genistein, 2′-hydroxygenistein, isovestitol, kievitone, laxifloran, phaseolidin, vignafuran. Studies reported that the flavonoids, kievitone and genistein contributed to the prevention of carcinogenesis and showed potential in the treatment of certain forms of cancer (Morris 2003). Genistein (4′,5′,7-trihydroxyisoflavone) inhibited capillary proliferation in head and neck cancer tumours; it also assisted in the relief of menopause symptoms by binding to the same receptors as human oestrogen (Hoffman 1995). The isoflavonoid kievitone potently inhibited the proliferation of the oestrogen receptor (ER)-positive breast cancer cell lines MCF-7 and T47D and the ER-negative breast cancer cell line SKBR3 (IC_{50} values 5–18 μM). Similar concentrations of kievitone inhibited DNA synthesis of MCF-7 cells stimulated by insulin-like growth factor 1, insulin-like growth factor 2, basic fibroblast growth factor or transforming growth factor alpha with IC_{50} values 1–3 μM. DNA synthesis stimulated by 17, β-oestradiol was also inhibited (IC_{50} = 6 μM). Compared with kievitone, genistein was 3–9 times weaker as an inhibitor of the proliferation of the breast cancer cell lines and of growth factor-stimulated DNA synthesis. However, genistein was about 5-fold more potent than kievitone as an inhibitor of solubilised epidermal growth factor (EGF) receptor kinase activity and EGF receptor autophosphorylation. Alhasan et al., (1999; 2000; 2001) reported that genistein inhibited cell proliferation and induced cell cycle arrest at the G2-M phase in breast, prostate, and jurkat T cell leukemia cell lines and stimulated cell cycle arrest and apoptosis in a head and neck squamous cell carcinoma cell line HN4. They found that genistein elicited pleiotropic molecular changes that resulted in the inhibition of cell growth and the induction of apoptotic cell death of head and neck cancer cells, suggesting that genistein may be useful as a chemotherapeutic and/or chemopreventive agent for head and neck cancer. The down-regulation followed by the degradation of Cdc25C was an indicator of G2/M arrest and anti-proliferation effects of genistein. Taken together, these data provided strong molecular evidence for the anti-tumour activity of genistein in head and neck squamous cell carcinomas (HNSCC) cells. Genistein had also been reported to arrest cell cycle arrest at G2/M phase of human LNCAP prostate cancer

cells by modulating cyclin B expression and p21 cycle progression and thus prevented carcinogenesis (Kobayashi et al. 2002).

Hypocholesterolemic Activity

Studies found that the protein concentrates of *Phaseolus calcaratus* and *Lablab purpureus* were more potent at reducing raised serum cholesterol levels than that of *Phaseolus angularis* (Chau et al. 1998). Both significantly reduced levels of triglyceride and total and low-density lipoprotein cholesterol in the blood serum as well as liver total lipids and cholesterol contents. Further research reported that the legume insoluble dietary fibre (IDF) diets significantly reduced the levels of serum LDL cholesterol and liver cholesterol, but only *P. calcaratus* IDF diet significantly reduced the serum total cholesterol (Chau and Cheung 1999). Further, *D. lablab* IDF diet led to a significantly higher level of HDL cholesterol relative to the control. All the legume IDF diets were found to give a significantly higher values of HDL:total cholesterol ratios. Tyrosinase, found in the seeds, was reported to lower blood pressure and showed potential for the treatment of hypertension in humans (Beckstrom-Sternberg and Duke 1994).

Supplementation of rats' diet with dried powder of soaked Indian bean seeds reduced the plasma cholesterol to 72.5 from 178 compared with that of the control (61.5), although the liver cholesterol was still three times higher compared with the control (Ramakrishna et al. 2007). The 24 h germinated Indian bean cotyledons could effectively counteract the effects of added cholesterol on liver and plasma by their high fibre content coupled with large increase in ascorbic acid levels indicating the hypocholesterolemic effect of germinated Indian bean.

Adjuvant Activity

From the seeds of hyacinth bean, six new oleanane-type triterpene bisdesmosides, lablabosides A, B, C, D, E, and F, were isolated together with chikusetsusaponin IVa that displayed adjuvant activity (Yoshikawa et al. 1998). An adjuvant is a substance that helps and enhances the pharmacological effect of a drug or increases the ability of an antigen to stimulate the immune system. The identification of natural adjuvants capable of selectively promoting an efficient immune response against infectious agents would represent an important advance in immunology.

Antiviral and Antimicrobial Activity

Several lectins were also isolated from legumes and characterized with respect to their composition and sugar binding specificities and their ability to prevent HIV-1 infection (Animashaun et al. 1993). Twelve of the 13 mannose-specific lectins were found inhibitory to varying magnitudes. The most effective were *Machaerium biovulatum* agglutinin (MBA) and *M. lunatus* agglutinin (MLA) which at 0.4 μg ml^{-1} prevented the cytopathic effect of the virus. Lower protection was obtained with *Bowringia mildbraedii* agglutinin (BMA), *Galanthus nivalis* agglutinin (GNA), *Lablab niger* agglutinin (LNA) and *Dolichos lablab* agglutinin (DLA). All these lectins were more protective than Con A while MBA was nearly ten times more potent than any previously reported lectin.

An antifungal protein, possessing a molecular weight of 28 kDa and an N-terminal sequence resembling chitinases, was purified from the seeds of *Dolichos lablab* (Ye et al. 2000). The protein, designated dolichin, exhibited antifungal activity against the fungi *Fusarium oxysporum, Rhizoctonia solani,* and *Coprinus comatus*. Dolichin was capable of inhibiting human immunodeficiency virus (HIV) reverse transcriptase and α- and β-glucosidases implicated in HIV infection. It had very low ribonuclease and cell-free translation-inhibitory activities. In other studies, the n-hexane and chloroform extract of *D. lablab* beans exhibited significant antimicrobial effect against various bacteria like *Bacillus subtilis, Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia*

coli and antifungal activity against *Candida albicans* (Dahake et al. 2009). A 36-kDa α-amylase inhibitor isolated from *Lablab purpureus* (AILP) was found to inhibit the α-amylases from several fungi but had little effect on those from animal and plant sources (Fakhoury and Woloshuk 2001). The protein inhibited conidial germination and hyphal growth of *Aspergillus flavus*, a fungal pathogen that produces aflatoxin. The amino acid sequence indicated that AILP was similar to lectin members of a lectin-arcelin-α-amylase inhibitor family described in common bean and shown to be a component of plant resistance to insect pests. AILP also agglutinated papain-treated red blood cells from human and rabbit. The data indicated AILP to be a novel variant in the lectin-arcelin-α-amylase inhibitor family of proteins having lectin-like and α-amylase inhibitory activity.

Cholecystokinin Stimulatory Activity

Peptides derived from dolicholin, a phaseolin-like protein in *Dolichos lablab*, potently stimulated cholecystokinin secretion from enteroendocrine STC-1 cells and suppressed food intake (Sufian et al. 2007).

Mitogenic Activity

A mannoside-directed lectin purified from the seeds of *Dolichos lablab* was found to display high erythroagglutinating activity without blood group specificity. It highly activated murine T lymphocytes, and was found to have mitogenic properties (Favero et al. 1988). Although its main properties were similar to those of concanavalin A (Con A), the well-known mannoside-directed mitogen was devoid of sugar moiety. Several differences were found in some of the early events triggered by the two lectins during lymphocyte mitogenic stimulation: higher level of interleukin-2 (IL-2) synthesis, optimal dose for IL-2 synthesis at suboptimal mitogenic concentration, lack of ecto-5′ nucleotidase inhibition, and lack of mitogenic inhibition at high lectin concentration.

Stem Cell Research Application

In the USA, scientists found that extracts of kidney bean and hyacinth bean contained a mannose-binding lectin, called FRIL, and provided evidence that FRIL appeared to satisfy properties of a stem cell preservation factor (Colucci et al. 1999). FRIL was found capable of preserving primitive progenitors in suspension culture for protracted periods. FRIL's clinical utility involving procedures for stem cell transplantation, tumour cell purging before autologous transplantation, and ex vivo cultures used for expansion and stem cell gene therapy currently are being explored. The mannose/glucose-binding *Dolichos lablab* lectin (designated DLL) was purified from seeds of *Dolichos lablab* (Mo et al. 1999). DLL strongly precipitated murine IgM but not IgG. The recent finding that this lectin interacted specifically with NIH 3T3 fibroblasts transfected with the Flt3 tyrosine kinase receptor and preserved human cord blood stem cells and progenitors in a quiescent state for prolonged periods in culture, make this lectin a valuable tool in biomedical research. FRIL (Flt3 receptor-interacting lectin) was found to preserve hematopoietic stem cells effectively in-vitro through the mechanisms of down-regulation of cyclin D3 and CDK6 and activation of P53. P27 was found to be mostly involved in the differentiation of hematopoietic stem cells (Li et al. 2007).

Antiparasitic Activity

Six rotenoids (deguelin, dehydrodeguelin, rotenol, rotenone, tephrosin, and sumatrol) were isolated, identified, and quantified both in-vivo and in-vitro from plant parts of *Lablab purpureus* (Kamal and Mathur 2010). Among the plant parts, the maximum content was in the roots and minimum in the seeds. Toxicological studies of extracts showed bioefficacy against causal agents of malaria, dracunculiasis, and amoebiasis.

Antinutritional Factors

Antinutritional factors such as haemagglutinins, lectins, tannins, phytate, HCN, raffinose oligosaccharides, proteinase inhibitors and trypsin inhibitors were reported for the hyacinth seed (Deka and Sarkar 1990; Devaraj and Manjunath 1995; Vijayakumari et al. 1995).

Five cultivars of dolichos bean showed considerable variation in their nutritional and antinutritional factors in their mature seeds (Deka and Sarkar 1990). On a dry matter basis, the percentage of crude protein varied from 22·4 to 31·3, crude fibre, 7·62 to 9·63 and total carbohydrate, 54·2 to 63·3. The amounts (mg/100 g) of calcium, phosphorus, phytate phosphorus and iron ranged from 36·0 to 53·5, 388 to 483, 282 to 380 and 5·95 to 6·90, respectively. All the cultivars tested contained moderately high levels of TIA (trypsin inhibitor activity) 2,400–3,200 TIU/g, on a dry weight basis, of the seeds. Phytic acid and tannins varied from 1,000 to 1,350 and 2,000 to 2,205 mg/100 g, respectively.

The galactose-specific seed lectin identified from *Dolichos lablab*, designated as DLL-II, was found to be a tetrameric protein with an apparent native molecular mass of 120 kDa, and composed of two non-identical subunits of 31 and 29 kDa (Latha et al. 2006; Rameshwaram and Nadimpalli 2008; Rameshwaram et al. 2009). DLL-II appeared to be made of two polypeptide chains of 281(alpha) and 263(beta) amino acids respectively. The stems and leaves of the *D. lablab* plant also contained a galactose-specific lectin that cross-reacted with the seed lectin antiserum (antiserum raised against the 31 kDa subunit of DLL-II). The lectin binds to Con A and was found to be a potent inhibitor of galactose. In separate studies, seeds of *Dolichos lablab* var. *typicus* (Indian lablab beans) were found to contain a glucose/mannose specific lectin with molecular weight of 195 K (Tulasi and Nadimpalli 1997). This lectin cross-reacted with jack bean α-mannosidase suggesting antigenic similarity between these two legume mannosidases. A proteinase inhibitor resembling Bowman-Birk family inhibitors was purified from the seeds of *D. lablab* (Devaraj and Manjunatha 1999). The inhibitor had 12 mol% 1/2-cystine and a few aromatic amino acids, and lacked tryptophan. Silva-Lima et al. (1988) reported that the crude protein extract partially purified from seeds of *Dolichos lablab* agglutinated rabbit erythrocytes non-specifically with respect to blood groups. The hemagglutination of rabbit erythrocytes induced by the crude extract of *D. lablab* was inhibited most effectively by N-acetyl-D-glucosamine (3 mM) and α-methyl-D-mannoside (3 mM) followed by D-glucosamine (6 mM), D-mannose (6 mM) and D-glucose (12 mM).

The polyphenol oxidase (PPO) of field bean (*Dolichos lablab*) was found to be a tetramer made up of two subunits of mass 29 and 31 KDa (Kanade et al. 2009). The amino acid sequence of the tryptic peptides showed approximately 90% sequence identity to the D-galactose specific legume lectins. This protein exhibited haemagglutinating and PPO activity and was inhibited by D-galactose. Crude extracts of other legumes did not exhibit PPO activity, yet cross-reacted with anti-PPO antibodies. This dual function protein with PPO and haemagglutinating activity is unique to field bean. Both PPO and lectins are proteins that play a vital role in the defense mechanism of plants. The complementarity of these two simultaneous and independent powerful defense mechanisms exhibited by a single protein rendered it a candidate gene for the development of in-built plant protection.

Removal of Antinutrients

Both distilled water and sodium bicarbonate solution soaking and autoclaving of hyacinth bean seeds were found to significantly reduce the amounts of total free phenolics (85–88%) compared to raw seeds (Vijayakumari et al. 1995). Autoclaving for 45 min reduced the content of tannins by up to 72%. Soaking seemed to have limited effect in abolishing phytohaemagglutinating activity, whereas autoclaving for 45 min appeared to eliminate completely the haemagglutinating activity. The reduction in content of phytic acid was found to be higher in distilled-water soaking (28%) compared to sodium

bicarbonate solution soaking (22%). Only a limited loss in content of phytic acid was observed with cooking as well as autoclaving. Loss of HCN was greater under autoclaving (87%) compared to the other processes studied. Of the three sugars analysed, soaking reduced the level of verbascose more than that of stachyose and raffinose. Autoclaving reduced the content of oligosaccharides more efficiently (67–86%) than ordinary cooking (53–76%). Autoclaving improved the in-vitro protein digestibility (IVPD) significantly (13%). Of all the different water and hydrothermal treatments studied autoclaving seemed to be the most efficient method in improving IVPD and eliminating the antinutrients investigated except phytic acid.

Devaraj and Manjunath (1995) reported that all 10 varieties of *D. lablab* tested exhibited appreciable level of proteinase inhibitory activity (PIA). The trypsin inhibitory activity (TIA) (mean: 20,170 TIU/g) was relatively higher than the chymotrypsin inhibitory activity (CIA) (mean: 15,380 CIU/g). The nature of cooking medium and duration of cooking had marked effect on the PIA. The dry fried seeds lost their PIA very rapidly (91% in 20 min). Seeds cooked in slightly alkaline medium lost their PIA rapidly (89% in 30 min) compared to those cooked in acidic (80% in 30 min) and neutral pH (83% in 30 min). The PIA in green pods was also determined and they had only one third of the PIA (8,200 TIU/g and 8,125 CIU/g) found in the dry seeds.

Raw dry Indian bean was found to have a very high trypsin inhibitory activity (TIA) which gradually decreased by 51% during 12 h soaking period and further reduced to 17% at 32 h germination period (Ramakrishna et al. 2006, 2008). However, the overall reduction in polyphenols was 70%, tannins 46%, phytic acids 36%, phytate phosphorus 30% and 40–50% stachyose and raffinose were observed. Maximum reduction was observed in TIA and phytic acids with roasting, while the boiling and pressure cooking lowered the levels of polyphenols and tannins. Germination was more effective in reducing trypsin inhibitor activity, tannins, polyphenols and phytic acid than the various cooking treatments. The results indicated germination to be a simple biochemical enrichment tool to enhance the palatability, digestibility and nutritive value of the pulse.

Traditional Medicinal Uses

Various parts of the plant have been used in traditional folkloric medicine in Asia and Africa (Burkill 1966; Duke and Ayensu 1985; Chopra et al. 1986; Nguyen and Doan 1989; Beckstrom-Sternberg and Duke 1994; Morriss 2003; Bureau of Plant Industry 2005).

In Peninsular Malaysia, the Malays have used the leaves with rice flour and turmeric to make a poultice for ecema. Leaf juice mixed with the sap of leaves of *Stereopermum fimbriatum* has been used as ear-drop for ear-ache. A leaf infusion has been employed for gonorrhoea. In Indonesia, the leaves of a white-podded variety have been used in a cooling drink. The leaves are regarded as good for colic in Indo-China. In the Philippines, the leaves have been used for menorrhagia and leucorrhoea. The leaves are used as In East Africa the leaves are crushed and sniffed to cure headache. Leaves are employed as emmenagogue and to accelerate childbirth and to treat stomach disorders. Green leaves pounded in vinegar have been used as poultice to treat snakebites. In Rwanda, the leaves are taken in a decoction of a mixture with leaves of other plants in case of heart problems. In the Democratic Republic of Congo, an infusion of the leaves is drunk to cure tonsillitis and sore throat.

In Asia, the flowers are regarded as antivinous, alexiteric, emmenagogue and carminative and are prescribed in menorrhagia and leucorrhoea. In Indo-China the flowers are regarded as emmenagogue and prescribed in menorrhagia and leucorrheoa.

In Assam, salted juice from the pods has been used in cases of inflammation of the ear and throat. The pod contains high fibre and is used as a laxative.

The fully mature seeds are anthelmintic, antispasmodic, aphrodisiac, astringent, digestive, febrifuge, depurative and stomachic. They are used in the in the form of powder or a decoction

for treatment of sunstroke, nausea, vomiting, diarrhoea, enteritis, abdominal pain, alcoholism and arsenism. The Chinese regard the boiled, ripe seeds as a tonic and carminative. In India, the seeds are aphrodisiac and are also used for stopping nose bleeding. In Senegal the seed is given as a stomachic and antispasmodic and has been used in the treatment of cholera and sunstroke.

Other Uses

Hyacinth bean is a multipurpose crop since it is used for food, forage, soil improvement, soil protection and weed control (Schaaffhausen 1963; Morris 2003; Pengelly and Maass 2001). Hyacinth bean has been shown to be an acceptable legume option for use in cereal-legume-livestock systems in the moist savanna zone of West Africa (Ewansiha et al. 2007).

Hyacinth bean provides a good forage/fodder crop for cattle, sheep, goats and pigs either green or as hay or silage. Incorporating the legume into grass pastures enhances the quality, palatability and digestibility of the pasture. Besides being a good forage crop it is also grown as an ornamental for its purple blossoms. It is vigorous and fast growing plant and has *Rhizobium* bacteria in its root nodules which enrich the soil with nitrogen, making it an excellent green manure crop. Hyacinth bean is also a good cover crop for soil erosion, soil protection and weed control. It has been used as cover crops in coffee and coconut plantation and fruit tree orchards. The plant is often planted as second crop after paddy harvest. In Kenya, the seeds either baked or heated are used as a veterinary medicine to treat eye problems in sheep and lung complaints in cattle, goats and sheep.

L. purpureus has insecticidal activity. Janarthanan et al. (2008) reported that *L. purpureus* proteins at 2% in the diet resulted in retarded development of the storage cereal pests *Rhyzopertha dominica* and *Oryzaephilus surinamensis*, internal and external feeders of grain, respectively. A 5% dose of the *L. purpureus* fraction resulted in complete mortality of all larvae in both species. Lectins from hyacinth bean were found to be toxic to the cowpea pest, *Maruca vitrata* (Morris 2003). In seeds of wild lablab, high levels of chemicals such as vicilins, α-amylase inhibitors and lectins were found in quantities that may impart resistance to the bruchid, *Callosobruchus maculatus*.

Comments

Hyacinth bean generally can be grouped into two botanical types: the climbing, twining type that is late maturing and usually grown as a vegetable; and the bushy, field type which matures early and have more fibrous pods. Several hundred cultivars have been recognized and are cultivated: White-seeded red-flowered, Yellow-podded white-flowered, Black-seeded white-flowered, White-seeded white-flowered, Black-seeded red-flowered, Purple-podded, Pink-flowered, Red-flowered, Purple-flowered, Reddish-brown-seeded, Black-seeded cultivar, Dark-brown-seeded.

Certain cultivars contain cyanogenic gylcoside which is poisonous.

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Lens culinaris

Scientific Name

***Lens culinaris* Medikus**

Synonyms

Cicer lens (L.) Willd., *Ervum lens* L., *Lathyrus lens* (L.) Bernh., *Lens abyssinica* Alef., *Lens camelorum* (Spreng.) Webb & Berth., *Lens culinaris* subsp. *esculenta* Briq., *Lens culinaris* subsp. *macrosperma* (Baumg.) Barul., *Lens culinaris* subsp. *microsperma* (Baumg.) Barul., *Lens esculenta* Moench, *Lens disperma* (Roxb.) Webb & Berth., *Lens lens* Huth., *Lens nummularia* Alef., *Lens sativa* Heller, *Lens vulgaris* Delarbre, *Lentilla lens* (L.) W.Wight ex D.Fairchild, *Vicia lens* (L.) Cosson & Germain, *Vicia pisicarpa* H. Léveillé.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Cultivated lentil, Gram, lentil

Vernacular Names

Amharic: Ades, Messer;
Arabic: 'Adas;
Brazil: Lentilha;
Burmese: Pe Ni;
Chinese: Bing Dou, Bïng Dáu, Xiao Bian Dou;
Czech: Čočka Jedlá, Čočka Kuchyňská;
Danish: Linse, Linser;
Dutch: Linze, Linzen;
Finnish: Linssi;
French: Lentille, Lentille Comestible, Lentille Cultivée, Lentilles., Lentillon;
German: Küchen-Linse, Linse, Linsen, Speise-Linse;
Greek: Phake;
India: Massurmoha (Assamese), Buromussur, Masoor, Masur, Masuri, Masuridal (Bengali), Masur, Masur Dal, Masuridal (Gujarati), Dhal, Masur Dal, Masuur, Masuurii, Masuuriidaal (Hindu), Chanangi, Channangi, Masur Bele, Massur (Kannada), Musur (Kashmiri), Masur Parippu (Malayalam), Masura, Masuuraa (Marathi), Masura (Oriya), Chanching, Mahsuri, Masar, Masur, Mohi, Mohri (Punjabi), Misurpurpur, Mysore Paruppu (Tamil), Chirisanagalu, Misurpappu (Telugu), Dal, Masur (Urdu);
Hungarian: Lencse;
Indonesia: Kacang Serinding, Kacang Koro;
Italian: Lente, Lenticchia, Lenticchia Commune, Lenticchie;
Japanese: Aoi Mame;
Khmer: Lânti;
Korean: Len So Kong;
Malaysia: Kacang Dal;
Nepalese: Musaro, Musur;
Philippines: Patani (Tagalog);
Polish: Soczewica;

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Portuguese: Lentilha, Lentilhas;
Russian: Chechevitsa Obyknovennaia, Chechevitsa Pishchevaia;
Slovašcina: Leča Navadna , Navadna Leča;
Slovencina: Šošovica Jedlá;
Spanish: Lenteja, Lentejas;
Sri Lanka: Pothundhambala (Sinhala);
Swedish: Lins;
Thai: Thua Daeng, Thua Raatcha Maat;
Turkish: Mercimek, Mencu;
Uzbek: Adas;
Vietnamese: Đậu Lâng.

Origin/Distribution

Lentil (*Lens culinaris* Med. ssp. *culinaris*) is indigenous to the Near East and central Asia (Ladizinsky 1979). Helena Barulina (1930) in her classic monograph on the genus *Lens* has suggested that the cultivated lentils originated from the wild species *Lens orientalis* (Boiss.) Handel-Mazetti now *Lens culinaris* ssp. *orientalis* (Boiss.) Ponert as one of the first domesticated crop plant in eastern Mediterranean region most likely in eastern Turkey and northern Syria. This had been confirmed recently also by various molecular markers (Sharma et al. 1995b). The variation of subsp. *culinaris* is considerable, a primary centre of diversity is located from Hindukush to Afghanistan, secondary ones are in Ethiopia and the Mediterranean countries. The infraspecific variations has been studied by Barulina (1930), Sharma et al. (1995a, b) Ladizinsky Abbo (1996) – three subspecies, several geographical groups (greges) and more than 50 botanical varieties. Domestication of the lentil lead to the evolution of two major seed groups (formerly subspecies) – cultivar group macrosperma (6–9 mm seed diameter) in Mediterranean Europe, Asia minor and Americas and the cultivar group microsperma (2–6 mm diameter) mainly in western Asia and Ethiopia (Sharma et al. 1995a).

From the near east lentil spreads through southern Europe, the Middle east, north Africa and across the Indo-Gangetic plains. The current distribution of lentils ranges over temperate to subtropical and tropical-mountainous regions, in the Old World from Morocco to Myanmar and SW China in the east, from Central Russia to Ethiopia, South Africa in the south, in South and North America (Chile, Argentina, Peru, Canada, USA) and in Australia. The main lentil producers are India, Turkey and Syria and other countries of SW and S Asia, S Europe, Ethiopia and north America. Today, Canada is the world's largest exporter of lentils to the global marketplace, selling to over 100 countries each year. The most commonly grown lentils in Canada are the large green lentil (Laird-type) and the red lentil. Small and medium sized green lentils are also common as well as limited quantities of Spanish brown, French green and beluga lentils.

Agroecology

Lentil is adapted to cool growing conditions, and the young plants are tolerant of spring frosts allowing early spring planting dates. They are not suited to the hot, humid tropics where they are grown in the cool highlands above 3,000 m altitude. Lentil tolerates a mean annual temperature range of 6–27°C but 24°C is the optimum mean temperature for high economic yield. Lentils will produce high yields of good quality seed in areas with 750 mm per year but will tolerate mean annual rainfall of 280–2,430 mm. Lentils have been grown extensively in the semi-arid parts of the world, where they have slightly lower yields, but good seed quality. High humidity and excessive rainfall during the season encourages vegetative growth, which prevents good yield and can reduce seed quality. Excessive drought and/or high temperatures during the flowering and pod-fill period also reduce yields. Lentils are long-day plants though some cultivars are day-neutral.

Lentil is adapted to all soil types, including sandy, light loams, alluvial, clayey and black cotton soils provided there is good drainage. Lentil does not tolerate flooded or waterlogged soils, and does best on deep, sandy loam soils high in phosphorus and potassium. Lentils tolerate a pH range of 4.5–8.2 but thrive best at pH of 5.5–7.

Edible Plant Parts and Uses

Lentil seeds are sold in many forms, with or without the skins, whole or split. Lentils should not be eaten raw, due to the presence of anti-nutrients such as phytic acid, trypsin inhibitors and tannins. The seeds require a cooking time of 10–30 min, depending on the variety. The seeds can be cooked on their own or added to soups, stews etc. Lentils are widely consumed throughout India, the Mediterranean regions and the Middle East. They are frequently combined with rice, which has a similar cooking time and such lentil/rice dish is referred to in the Middle East as *mujaddara* or *mejadra*. Rice, lentils and potatoes are cooked together in *khichdi*, a popular, spicy, Indian dish. A similar dish of rice and lentil, *kusharie,* is made in Egypt and considered one of two national dishes. In Europe, South and North America, lentils are used to prepare soups, sometimes combined with chicken, oxtail, or pork. In rare cases the lentils are mixed with dairy cheese. The dried seed can also be ground into a powder and used with cereal flours in making bread, pasta, cookies etc., this greatly enhances the value of the protein in the bread.

Lentil seeds can be sprouted and eaten raw or cooked. The seed can be soaked for 12 h in warm water and then allowed to sprout for about 5 days. Young seedpods are used fresh or cooked like green beans.

Botany

Slender, semi-erect, annual plant with compact growth, 10–50 cm tall. Stem pubescent, angular and branched from the base. Stipules 3–7 mm, oblong, elliptic or lanceolate, entire, white and villous. Leaves alternate, compound with tendril at the tip, rachis densely hairy with 4–12 pairs of sessile, oval, pubescent leaflets, 6–20 × 2–5 mm (Plates 1–2). Flowers papilionaceous, bisexual in 1–4 flowered racemes., calyx pubescent, Corolla white or pink, pale blue, blue-purple, 4.5–6.5 mm, ovary shortly stalked and glabrous with 1–2 ovules and style hairy. Legume yellow, oblong,

Plate 1 Field planting of lentils (P. White)

Plate 2 Lentil seedling showing the oval, entire leaflets (P. White)

Plate 3 Green lentils

Plate 4 Brown lentils

Plate 5 Red lentils

inflated or compressed, smooth, 10–20 mm long. Seed small, 2–7 mm, round, biconvex, lens-shaped, yellow, greenish, tan, brown, red (Plates 3–5), black, purplish or mottled with red, orange, yellow or green to greenish yellow cotyledons.

Nutritive/Medicinal Properties

Nutrient composition of raw lentils (*Lens culinaris*) per 100 g edible portion (USDA 2010) was reported as: water 10.40 g, energy kcal 353 (1,477 kJ), protein 25.80 g, total fat 1.06 g, ash 2.67 g, carbohydrate 60.08 g, total dietary fibre 30.5 g, total sugars 2.03 g, sucrose 1.47 g, fructose 0.27 g, maltose 0.30 g; Ca 56 mg, Fe 7.54 mg, Mg 122 mg, P 451 mg, K 955 mg, Na 6 mg, Zn 4.78 mg, Cu 0.519 mg, Mn 1.330 mg, Se 8.3 µg, vitamin C 4.4 mg, thiamine 0.873 mg, riboflavin 0.211 mg, niacin 2.605 mg, pantothenic acid 2.140 mg, vitamin B-6 0.540 mg, total folate 479 µg, total choline 96.4 mg, vitamin A 2mcg RAE, vitamin A 39 IU, β-carotene 23 µg, vitamin E (α-tocopherol) 0.49 mg, α-tocopherol 4.23 mg, vitamin K (phylloquinone) 5 µg, total saturated fatty acids 0.156 g, 14:0 (myristic) 0.003 g, 16:0 (palmitic) 0.133 g, 18:0 (stearic) 0.015 g; total monounsaturated fatty acids 0.189 g, 16:1 undifferentiated (palmitoleic) 0.003 g, 18:1 undifferentiated (oleic acid) 0.180 g, 20:1 (gadoleic) 0.006 g, total polyunsaturated fatty acids 0.516 g, 18:2 undifferentiated (linoleic) 0.404 g, 18:3 undifferentiated (linolenic) 0.109 g.

Nutrient composition of raw red lentils (*Lens culinaris*) per 100 g edible portion (USDA 2010) was reported as: water 11.79 g, energy kcal 345 (1,445 kJ), protein 24.95 g, total fat 2.17 g, ash 1.94 g, carbohydrate 59.15 g, total dietary fibre 10.8 g, Ca 41 mg, Fe 7.56 mg, Mg 72 mg, P 294 mg, K 578 mg, Na 7 mg, Zn 3.90 mg, Cu 1.303 mg, Mn 1.417 mg, Se 8.2 µg, vitamin C 1.7 mg, thiamine 0.510 mg, riboflavin 0.106 mg, niacin 1.495 mg, pantothenic acid 0.348 mg, vitamin B-6 0.403 mg, total folate 204 µg, vitamin A 3 µg RAE, vitamin A 58 IU, β-carotene 35 µg, total saturated fatty acids 0.379 g, 10:0 (capric) 0.001 g, 12: (lauric) 0 0.002 g, 14:0 (myristic) 0.003 g, 15:0 (pentadecanoic) 0.003 g, 16:0 (palmitic) 0.284 g, 17:0 (margaric) 0.004 g, 18:0 (stearic) 0.042 g, 20:0 (arachidic) 0.014 g, 22:0 (behenic) 0.014 g, 24:0 (lignoceric) 0.012 g; total monounsaturated fatty acids 0.500 g, 18:1 undifferentiated (oleic acid) 0.490 g, 20:1 (gadoleic) 0.011 g, total polyunsaturated fatty acids 1.137 g, 18:2 undifferentiated (linoleic) 0.886 g, 18:3 undifferentiated (linolenic) 0.250 g; phytosterols 57 mg, stigmasterol 4 mg, campesterol 6 mg, β-sitosterol 47 mg; tryptophan 0.223 g, threonine 0.985 g, isoleucine 1.078 g, leucine 1.809 g, lysine 1.740 g, methionine 0.212 g, cystine 0.327 g, phenylalanine 1.230 g, tyrosine 0.667 g, valine 1.238 g, arginine 1.928 g, histidine 0.702 g, alanine 1.042 g, aspartic acid 2.758 g, glutamic acid 3.868 g, glycine 1.014 g, proline 1.042 g and serine 1.150 g.

Nutrient composition of raw sprouted lentils (*Lens culinaris*) per 100 g edible portion (USDA

2010) was reported as: water 67.34 g, energy kcal 106 (444 kJ), protein 8.96 g, total fat 0.55 g, ash 1.00 g, carbohydrate 22.14 g, Ca 25 mg, Fe 3.21 mg, Mg 37 mg, P 173 mg, K 322 mg, Na 11 mg, Zn 1.51 mg, Cu 0.352 mg, Mn 0.506 mg, Se 0.6 μg, vitamin C 16.5 mg, thiamine 0.228 mg, riboflavin 0.128 mg, niacin 1.128 mg, pantothenic acid 0.578 mg, vitamin B-6 0.190 mg, total folate 100 μg, vitamin A 2 μg RAE, vitamin A 45 IU, total saturated fatty acids 0.057 g, 16:0 (palmitic) 0.052 g, 18:0 (stearic) 0.006 g, total monounsaturated fatty acids 0.104 g, 18:1 undifferentiated (oleic acid) 0.104 g, total polyunsaturated fatty acids 0.219 g, 18:2 undifferentiated (linoleic) 0.181 g, 18:3 undifferentiated (linolenic) 0.038 g; threonine 0.328 g, isoleucine 0.326 g, leucine 0.628 g, lysine 0.712 g, methionine 0.105 g, cystine 0.334 g, phenylalanine 0.442 g, tyrosine 0.252 g, valine 0.399 g, arginine 0.611 g, histidine 0.257 g, alanine 0.356 g, aspartic acid 1.433 g, glutamic acid 1.258 g, glycine 0.319 g, proline 0.356 g and serine 0.495 g.

As seen from the above, lentils are one of the best vegetable sources of iron. This makes them an important part of a vegetarian diet, and useful for preventing iron deficiency. Iron is particularly important for adolescents and pregnant women, whose requirements for it are increased.

Kalogeropoulos et al. (2010) evaluated the bioactive micronutrients of cooked broad beans, chickpeas, two split peas varieties, two lentils varieties, pinto beans, black-eyed beans, five white beans varieties and white lupines. Crude protein was found to range from 6.1% to 11.5%, crude fibre 3.6% to 11.7%, and energy content 103 to 155 kcal/100 g. Phytosterols contents varied from 13.5 to 53.6 mg/100 g. Tocopherols and squalene ranged from 0.26 to 1.78 and 0.12 to1.74 mg/100 g, respectively. Legumes' lipids were rich in α-linolenic acid which comprised 2.5–41.7% of fatty acids. Total phenolic content of the cooked legumes ranged from 11.8 to 25.9 mg gallic acid equivalents/100 g, simple polyphenols ranged between 0.32 and 2.4 mg/100 g and triterpenic acids between 0.34 and 8.5 mg/100 g with lentils exhibiting the higher values in all cases. Among the simple polyphenols determined, flavonoids – mainly catechins-predominated in lentils and chickpeas, and phenolic acids in the rest of legumes.

Rozan et al. (2001) studied the amino acid content of seeds and 4-day-old seedlings in five species of lentil: *Lens culinaris, L. orientalis, L. ervoides, L. nigricans* and *L. odemensis*. The content of free protein amino acids in seeds varied among species and increased dramatically after germination. Asparagine was quantitatively most important in both seed and seedling. The amount of free non-protein amino acids was variable in seeds and seedlings. γ-Hydroxyarginine, γ-hydroxyornithine, α-aminobutyric acid and taurine were found in both seeds and seedlings. Homoarginine was found in four species but not in *L. orientalis* while γ-aminobutyric acid (GABA), α-aminoadipic acid (alpha-aaa) and three isoxazolinone derivatives: β-(isoxazolin-5-on-2-yl)-alanine (BIA), γ-glutamyl-BIA (γ-glu-BIA) and 2-carboxymethyl-isoxazolin-5-one (CMI) were found exclusively in the seedlings. CMI was identified for the first time in lentil species. Lathyrine, β-(2-amino-pyrimidine-4-yl)-alanine, which was reported to be in the seeds of some *Lathyrus* species was confirmed to be present also in the seedling of *L. culinaris* (trace amount), *L. nigricans* and *L. odemensis*. Trigonelline (N-methyl-nicotinic acid), a plant hormone, was present both in seeds and seedlings in different concentrations except in *L. ervoides*. A 2 S albumin protein (26.5 kDa) was identified from lentils (Gupta et al. 2008).

Studies by Thavarajah et al. (2007) showed that lentils grown in the Canadian prairies were enriched in selenium, an essential micronutrient needed for general well-being, including a healthy immune system and protection against cancer. Significant variations in total selenium contents were found with geographic location and cultivar; however, almost all the selenium (86–95%) in these field-grown lentils was present as organic selenium modelled as selenomethionine with a small component (5–14%) as selenate. As the toxicities of certain forms of arsenic and selenium are antagonistic, selenium-rich lentils may have a pivotal role to play in alleviating the chronic arsenic poisoning in Bangladesh. The total selenium concentration in lentils varied

between 425 and 673 μg/kg, providing 77–122% of the recommended daily intake in 100 g of dry lentils (Thavarajah et al. 2008). Over 70% of the selenium was present as selenomethionine with a smaller fraction (<20%) as inorganic selenium and very small amounts as selenocysteine.

The most abundant proanthocyanidins in the seed coat of lentils were found to be the polymers (65–75%), with a mDP of 7–9, followed by the oligomers (20–30%), with a mDP of 4–5 (Dueñas et al. 2003). Analyses showed that the major monomeric flavan-3-ol was (+) catechin-3-glucose, with lower amounts of (+)-catechin and (−)-epicatechin. In the oligomer fraction, various dimer, trimer, and tetramer proanthocyanidins constituents of catechin, gallocatechin, and catechin gallate units were identified, and several procyanidins and prodelphinidins from pentamers to nonamers constituted the polymer fraction. A major anthocyanin isolated from the acidified methanolic extract of Beluga black lentils was determined to be delphinidin 3-O-(2-O-β-D-glucopyranosyl-α-l-arabinopyranoside) (Takeoka et al. 2005).

Chromatographic separations of the methanol extract of lentils afforded several compounds including the novel 4-chloro-1 H-indole-3-N-methylacetamide as well as itaconic acid, arbutin, gentisic acid 5-O-[β-d-apiofuranosyl-(1 → 2)-β-d-xylopyranoside], and (6 S,7Z,9R)-9-hydroxymegastigma-4,7-dien-3-one-9-O-β-d-apiofuranosyl-(1 → 2)-β-d-glucopyranoside (Tsopmo and Muir 2010).

Lentil saponins were found to be triterpene glycosides, mainly soyasaponins I and betag (also known as VIota), with multiple health-promoting properties (Sagratini et al. 2009). In the 32 lentil samples, contents of soyasaponin I ranged from 28 to 407 mg/kg, whereas that of soyasaponin betag ranged from 110 to 1,242 mg/kg.

Studies using cooked bean or lentils as the unique protein source in balanced diets (containing 229 and 190 g of crude protein per kg dry matter) fed to young growing rats for 20 days resulted in higher protein, RNA relative masses (mg/100 g/BM) and protein synthesis rates (FSR and ASR) in the small and large intestines compared to the control rats (Pirman et al. 2006). In gastrocnemius and soleus muscles, protein and RNA contents and protein synthesis rates were significantly lower in the legume-fed groups than in the control rats. The results indicated that chronic intake of cooked lentils or beans increased protein synthesis rates in intestinal tissues and decreased them in muscles in rats. This effect was greater for beans than for lentils in the large intestine and in gastrocnemius muscle.

Lentils also have several pharmacological activities which are elaborated below.

Antioxidant Activity

Cultivar Morton exhibited the highest individual flavan-3-ols (catechin and epicatechin) and total flavonoids, as well as the highest antioxidant properties, cellular antioxidant activities (CAA) and peroxyl radical scavenging capacity (PRSC) among all lentils tested (Xu and Chang 2010). Five phenolic acids of the benzoic types and their derivates (gallic, protocatechuic, 2,3,4-trihydroxybenzoic, p-hydroxybenzoic acid, and protocatechualdehyde) and four phenolic acids of the cinnamic type (chlorogenic, p-coumaric, m-coumaric, and sinapic acid) were detected in the lentil cultivars. Two flavan-3-ols [(+)-catechin and (−)-epicatechin] and one flavone (luteolin) were also detected. Among the phenolic compounds detected, sinapic acid was the predominant phenolic acid, and (+)-catechin and (−)-epicatechin were the predominant flavonoids. These results showed that different lentil phenotypes possessed considerable variations in their individual phenolic compounds, as well as chemical and cellular antioxidant activities. Caffeic acid, catechin, epicatechin, and total flavonoids significantly correlated with peroxyl radical scavenging assay. Cellular antioxidant assay significantly correlated with chemical antioxidant assay, oxygen radical absorbance capacity (ORAC).

The insoluble indigestible fraction (IIF) in cooked seeds of three pulses (black bean, chickpea and lentil) was higher than the soluble counterpart (soluble indigestible fraction, SIF) (Hernández-Salazar et al. 2010). The SIF value was highest in black beans, while no difference

was found between chickpeas and lentils. Black beans and lentils had higher polyphenol contents than chickpeas. The indigestible fraction of black beans had the lowest and chickpeas the highest associated polyphenols content. Condensed tannins were retained to some extent in the indigestible fraction that exhibited significant antioxidant capacity. The total indigestible fraction of the three pulses produced short chain fatty acids (SCFA) after 24 hours of in-vitro fermentation by human colonic microflora. Indigestible fraction from black bean and lentil were the best substrates for fermentative production of butyric acid. The results showed that the indigestible fraction of pulses may be an important source of bioactive compounds.

Anticancer and Cancer Detection Activities

Studies by Faris et al. (2009) found that consumption of lentils may confer protection against colon carcinogenesis in rats and that hydrothermal treatment resulted in an improvement in the chemopreventive potential for the whole lentils. Significant reductions were found in total aberrant crypt foci number for raw soya bean (27.33), cooked whole lentils (33.44), and raw split lentils (37.00) in comparison with the control group (58.33). Hepatic glutathione-S-transferases activities rosed significantly in rats fed all treatment diets (from 51.38 to 67.94 μmol/mg/min) when compared with control diet (26.13 μmol/mg/min). Rodríguez-Juan et al. (2000) found that lectins of *Lens culinaris, Phaseolus vulgaris* and *Vicia faba* specifically triggered interleukin-8 (IL-8) production by human colon carcinoma cell line CACO-2. The IL-8 secreted may induce the extravasation of activated neutrophils and cause tissue damage.

The severity of side-effects of adjuvant hormone therapy in breast cancer patients was reduced by complementary treatment with sodium selenite, plant enzymes (bromelaine and papain) and *Lens culinaris* lectin (Uhlenbruck et al. 2010). The mean score of symptoms declined from 4.2 (before treatment) to 3.2 (after 4 weeks of treatment) to 2.7 (after 8 weeks of treatment) for arthralgia and from 3.2 (before treatment) to 2.9 (after 4 weeks of treatment) to 2.6 (after 8 weeks of treatment) for mucosal dryness. The reduction of side-effects of adjuvant hormone therapy was statistically significant after 4 and 8 weeks.

Lens culinaris agglutinin-reactive fraction of α-fetoprotein (AFP-L3), a fucosylated variation of AFP, was found not only sensitive and specific for localization of hepatocellular carcinoma (HCC) but also a prognostic factor for patients with HCC (Kusaba 1998). AFP-L3 was found to be a significant marker of poor prognosis for HCC (Yamashita et al. 1996). Sassa et al. (1999) found that the detection rate of small HCC was improved by combination assay with des-γ-carboxy prothrombin (H-DCP) and *Lens culinaris* agglutinin A-reactive α-fetoprotein (AFP-L3%). Their results indicated that the markers were complementary and useful for the diagnosis and evaluation of small HCC when measured simultaneously. Studies by Yamashiki et al. (1999) suggested that AFP-L3 was a useful indicator of distant metastasis and a poor prognosis for HCC. No significant differences were found in age, sex, and virus markers between the AFP-L3-positive and AFP-L3-negative groups. However, patients in the positive group had worse liver function and larger tumours compared to the negative group. Distant metastasis was diagnosed significantly more often in the positive group than that in the negative group. Khien et al. (2001) found AFP-L3 to be potentially a clinically useful marker for the differentiation of increased AFP levels in hepatocellular carcinoma (HCC) and chronic liver diseases. The AFP-L3 percentage was closely related to HCC differentiation. They considered the analysis of AFP-L3 to be a useful adjunct in the diagnosis of HCC. Recent studies showed that positive AFP-L3 results after treatment predicted tumour recurrence and poor clinical outcome. Song et al. (2002) found that pretreatment status of AFP-L3 could be considered a useful marker for predicting clinical outcome in patients with HCC who underwent transcatheter arterial chemoembolization (TACE). Results of studies by Tamura et al. (2010) suggested that AFP-L3 positivity (>or = 15%) may be a promising indicator for

selecting therapeutic modalities in HCC patients. AFP-L3 had different impacts on prognosis in patients with HCC who underwent percutaneous ablative therapy and hepatectomy. *Lens culinaris* lectin (LCA) was found to be a useful probe for the detection in serum of a core-fucosylated alpha-fetoprotein, called AFP-L3 fraction, a well-known marker for the diagnosis and prognosis of hepatocellular carcinoma (Tateno et al. 2009). LCA showed the highest affinity to the core-fucosylated, agalactosylated, bi-antennary N-glycan but not to their tri- and tetra-antennary branched forms, indicating that addition of the *N*-acetyl-D-glucosamine residue at the N-acetylglucosaminyltransferase IV position abolished the binding affinity.

Carr et al. (2007) found that the combination of *Lens culinaris* agglutinin-reactive fraction of α-fetoprotein (AFP-L3%) and des-γ-carboxy prothrombin (DCP) and AFP were superior for detection of HCC compared with each marker alone or to other combinations. AFP-L3% was significantly related to portal vein invasion and patient outcomes and appeared to be a useful prognostic marker for HCC. In a recent study, α-fetoprotein (AFP) or *Lens culinaris* agglutinin-reactive fraction of α-fetoprotein combined with des-γ-carboxyprothrombin (DCP) were established to diagnose hepatocellular carcinoma (HCC) (Inagaki et al. 2011). This combined testing using several tumour markers helped to increase the sensitivity of diagnosis of HCC, thus significantly increasing the clinical usefulness of DCP. Various tumour markers such as DCP had been developed for serological diagnosis of cancers, including HCC, in order to increase the survival rate of cancer patients. In a recent study of 124 patients, mean age 62 (±10.2) years, 94 (76%) males, all Child-Pugh A, the combined application of serum α fetoprotein (AFP) *Lens culinaris* agglutinin isoform 3 fraction (AFP-L3%) and des-γ-carboxy prothrombin (DCP) was found to increases the diagnostic accuracy for hepatocellular carcinoma (HCC) in patients with cirrhosis (Romeo et al. 2010). The median (25th-75th quartile) AFP, AFP-L3% and DCP values were significantly higher in HCC than in cirrhosis. The pre-treatment α-fetoprotein (AFP-L3) level was found to be a useful prognostic biomarker for survival after repeat hepatic resection for recurrent hepatocellular carcinoma (HCC) (Matsuda et al. 2011). By multivariate analysis, only AFP-L3 >15% was an independent predictor of unfavorable overall survival. The 1-, 3-, and 5-year survival rates after the second hepatic resection of 27 HCC patients with low AFP-L3 (<15%) were 100%, 100%, and 91.7%, respectively, whereas the corresponding survival rates of 8 HCC patients with high AFP-L3 (>15%) were 100%, 47.6%, and 23.8%, respectively.

Studies by Sakurai et al. (2003) showed the serum *Lens culinaris* agglutinin-A-reactive α-fetoprotein (AFP-L3) to be a possible serum marker for evaluating liver atrophy and/or liver regeneration in patients with fulminant hepatic failure (FHF). In FHF patients, the serum AFP-L3 level at the onset of encephalopathy was significantly higher in cases with mild atrophy than in those with severe atrophy. *Lens culinaris* agglutinin-reactive α-fetoprotein (AFP-L3), a variant of α-fetoprotein with α1→6 fucose appended to the reducing terminal N-acetylglucosamine was found to be an effective replacement for α-fetoprotein (AFP), in prenatal Down's syndrome screening (Yamamoto et al. 2001). The percentage of AFP-L3 in maternal serum identified 55% of Down's syndrome cases with a 5% false-positive rate.

Measurement of *Lens culinaris* agglutinin reactive thyroglobulin ratio in serum was found to be useful for distinguishing between thyroid carcinoma and benign thyroid tumour (Shimizu et al. 2007). The *Lens culinaris* agglutinin reactive thyroglobulin ratio in patients with thyroid carcinoma was significantly lower than in patients with benign thyroid tumour with serum thyroglobulin level >200 ng/ml. Among cases of thyroid carcinoma with lymph node metastasis, *Lens culinaris* agglutinin reactive thyroglobulin ratios were significantly lower than in patient with thyroid carcinoma without metastasis and those with benign tumour regardless of serum thyroglobulin concentration. Measurement of *Lens culinaris* agglutinin (LCA)-reactive thyroglobulin was able to differentiate between benign and malignant thyroid

carcinoma and may be useful for screening serum and wash samples (Kanai et al. 2009).

Mitogenic Activity

The response of mouse lymphocytes to a syngeneic stimulus after surface modification by lectins, leukoagglutinin and *Lens culinaris* lectin was characterised as cell-mediated mitogenic response (CMMR) (Ozato et al. 1977). Both lectins that induced CMMR were T-cell mitogens. CMMR was generated in all the syngeneic combinations tested and even in allogeneic combinations. No detectable cytotoxic activity towards syngeneic target cells was produced after CMMR. Moreover, CMMR in allogeneic combinations led to the suppression of the generation of specific cytotoxic lymphocytes.

Hypotriglyceridemic Activity

Compared with the casein diet, the chickpea and lentil protein diets exhibited similar cholesterolemia, but lower triglyceridemia (1.9-fold and 2.5-fold) and VLDL (Very low density lipoprotein) particle number, as measured by their reduced contents of triacylglycerols and apolipoproteins (Boualga et al. 2009). Chickpea and lentil protein diets lowered liver triacylglycerols and cholesterol by 31 and 45%, respectively compared to the casein diet. In addition, lipoprotein lipase activity in adipose tissue of rats fed chickpea or lentils was 1.6-fold lower than that of rats fed casein. There was no significant difference in heart and gastrocnemius lipoprotein lipase activities with the three proteins. In contrast, hepatic lipase activity was higher in rats fed chickpea and lentils. The results showed that the low food efficiency ratio of purified chickpea and lentil proteins related to casein was associated with reduced plasma VLDL and adipose tissue lipoprotein lipase activity. The low liver triacylglycerols concomitant with reduced triacylglycerols and apolipoproteins contents of VLDL confirmed that hypotriglyceridemia was essentially due to impaired synthesis, exportation and transport of triacylglycerols by VLDL which prevented lipid storage in adipose tissue.

Antimicrobial Activity

Red lentil seeds were found to contain an antifungal peptide, with a molecular mass of 11 kDa (Wang and Ng 2007). The antifungal peptide inhibited mycelial growth in *Mycosphaerella arachidicola* with an IC_{50} of 36 μM. It also exhibited antifungal activity against *Fusarium oxysporum*, but there was no inhibitory activity toward tumour cell lines and human immunodeficiency virus type 1 reverse transcriptase (RT).

A Bowman-Birk type trypsin-chymotrypsin inhibitor was isolated from seeds of green lentil (*Lens culinaris*) (Cheung and Ng 2007). The protease inhibitor did not exert any inhibitory effect on hepatoma (Hep G2) and breast cancer (MCF 7) cell lines. There was no suppressive action on several fungal species including *Botrytis cinerea, Fusarium oxysporum* and *Mycosphaerella arachidicola*. It slightly inhibited the activity of HIV-1 reverse transcriptase, with an IC_{50} of 30 mM. A novel 47-residue plant protein defensin termed Lc-def was purified from germinated seeds of the lentil (Finkina et al. 2008). Lc-def showed high sequence homology with legumes defensins, exhibited an activity against *Aspergillus niger*, but did not inhibit proteolytic enzymes.

Antinutritional Factors

Saskatchewan-grown lentils were found to be naturally low in phytic acid (phytic acid = 2.5–4.4 mg/g; phytic acid phosphorus = 0.7–1.2 mg/g), with concentrations lower than those reported for low phytic acid mutants of corn, wheat, common bean, and soybean (Thavarajah et al. 2009). Decortication prior to cooking further reduced total phytic acid by >50%. As lowering phytic acid intake could lead to increased mineral bioavailability, dietary inclusion of Canadian lentils may have significant benefits in regions with widespread micronutrient malnutrition.

A lentil seed trypsin inhibitor (LCTI) was isolated from *L. culinaris* var. *macrosperma* seed (Ragg et al. 2006). LCTI was found to be a 7,448 Da double-headed trypsin/chymotrypsin inhibitor and belonged to natural Bowman-Birk inhibitor family.

Thavarajah et al. (2010) found that phytic acid and zinc levels in lentil seeds were significantly higher in the increasing temperature regime (8.8 mg/g and 69 mg/kg, respectively) than in the decreasing temperature regime (6.7 mg/g and 61 mg/kg, respectively). Likewise for the iron contents (116 vs. 113 mg/kg respectively). The cooler temperatures of temperate summers might be an important factor in the production of seeds with lower phytic acid contents. Phytic acid, found in cereal and legume staple foods, is considered an anti-nutrient for iron and zinc. These results would be relevant to the development of biofortification strategies aimed at reducing the phytic acid content in staple crops.

Allergenic Activity

The mature 48-kd lentil vicilin, designated Len c 1.01, was found to be a major allergen in lentils (López-Torrejón et al. 2003). Two of its processing fragments, corresponding to subunits of 12–16 kd (previously named Len c 1) and 26 kd, were also relevant lentil IgE-binding proteins. The sequence homology of Len c 1.01 to those of major allergens from peanut, soybean, walnut, and cashew could help to study potential cross-reactions among these plant foods. Lentils are among the main plant foods causing allergic reactions in pediatric patients in the Mediterranean area and in many Asian communities.

Traditional Medicinal Uses

The seeds are mucilaginous and laxative. They are considered to be useful in the treatment of constipation and other intestinal affections; made into a paste, they are a useful cleansing application in foul and indolent ulcers.

Other Uses

Crude methanol extracts from four cultivated varieties of mature lentil seeds *(Lens culinaris*) were found to possess anti-feedant and insecticidal properties in laboratory tests with the rice weevil (*Sitophilus oryzae* L.), an insect pest of stored products (Taylor et al. 2007). The methanol extracts yielded flavonol, lysolecithin, soyasaponin, and peptide fractions. The flavonol fraction was shown to contain a mixture of kaempferol 3-O-β-glucopyranosyl(1 → 2)-O-[α-rhamnopyranosyl(1 → 6)]-β-galactopyranoside-7-O-α-rhamnopyranoside and, tentatively, kaempferol 3-O-β-glucopyranosyl(1 → 2)-O-[α-rhamnopyranosyl(1 → 6)]-β-glucopyranoside-7-O-α-rhamnopyranoside. Three lysolecithins were identical to those previously identified in pea extracts. Soyasaponin I (soyasaponin Bb) and soyasaponin VI (soyasaponin betag) were also found in Diaion HP-20 methanol extracts. An insecticidal lentil peptide with a mass of 3,881 Da, isolated from an Eston variety in small quantities was related to the cysteine-rich pea albumin 1b class of botanical insecticides. Binary mixtures of the insecticidal lentil peptide and soybean soyasaponin I were synergistic in tests with *Sitophilus oryzae.*

Comments

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Leucaena leucocephala

Scientific Name

***Leucaena leucocephala* (Lam.) de Wit**

Synonyms

Acacia glauca Willd., *Acacia leucocephala* (Lam.) Link, *Leucaena glabarta Rose, Leucaena glauca* (Willd.) Benth., *Leucaena glauca* auct., *Leucaena latisiliqua* (L.) Gillis & Stearn, *Leucaena leucocephala* subsp. *glabrata*, *Leucaena leucocephala* subsp. *leucocephala, Mimosa glauca* L., *Mimosa leucocephala* Lam.

Family

Fabaceae, also placed in Leguminosae, Mimosaceae

Common/English Names

Coffee Bush, False Koa, Hedge Acacia, Horse Tamarind, Ipil-Ipil, Jumpy Bean, Jumbie Bean, Lead Tree, Leucaena, White Babool, White Popinac, Wild Tamarind

Vernacular Names

Afrikaans: Reuse Wattel;
American Samoa: Fua Pepe, Lopa;
Amharic: Lukina;
Arabic: Leuceana;
Bahamas: Jumby Bean;
Belize: Wild Tamarind (Corozal);
Burmese: Bawzagaing;
Chamorro: Talntangan, Tangan-Tangan, Tangantangan, Tangantangan;
Chinese: Yin Ho Huan;
Cook Islands: Mara'Inu, Marainu, Nītō (Maori);
Creole: Delen, Lisina;
Cuba: Aroma Blanca;
Czech: Akácie Bělohlavá;
Danish: Vild Tamarinde;
El Salvador: Barba De Leon;
Eritea: Lucina (Tigrigna);
Fiji: Vaivai, Vaivai Dina, Vaivai Ni Vavalangi;
French: Faux Acacia, Faux Mimosa, Graines De Lin, Delin Étranger, Mimosa, Leucane, Tamarin Batard;
German: Wilde Tamarinde;
Guam: Tangantangan, Tangan Tangan, Talantayan;
Guatemala: Chalip, Guash Criollo;
Haiti: Lisina, Delen;
Hawaii: False Koa, Koa Haole, Haole Koa, Ēkoa, Lilikoa;
Honduras: Frijol Guaje;
I-Kiribati: Te Kaitetua;
India: Angouba, Chigonglei, Subabul (Bengali), Lasobaval (Gujerati), Balori, Koo Babul, Ku-Babul, Kubabul, Lamtoro, Safed Babool, Subabul, Subabul (Hindu), Subabul (Marathi), Tagarai (Tamil), Kaniti, Nagarikesari, Nattuccavundal, Ragarai,

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Rajokasundiri, Takaranniram, Toira Kadam, Vilayatibaral;
Indonesia: Lamtara, Lamtoro, Lamotorogung, Klandingan, (Javanese), Pete Cina, Kemetir, Kemlandingan, Metir, Pete, Pete Java, Petir, Selamtara, Selong, Malandingan, Keplanfingan, Palandingan;
Japanese: Ginnemu;
Khmer: Khtum Té:Hs, Krâthum' Thé:T;
Kosraean: Tuhngantuhngan, Rohbohtin;
Laotian: Kan Thin, Kathin, Kh'o:Ng Kha:W, Khaaw, Kh'oonz Koong;
Malaysia: Pete Sulong, Petai Belalang, Petai Jawa, Pete, Pete Cina, Lamtoro;
Marquesan: Atiku;
Marshall Islands: Tangantangan, Tangan Tangan, Talantayan;
Mexico: Calguaje, Dormilon, Efe, Guache, Guache Tierra Caliente, Guaje, Guaje Blanco, Guaje Verde, Guas, Guash, Guashe, Guaslim, Guaxin, Huaxin, Huaxe, Huaxim, Liliak, Uaxi, Uaxim, Uaxin, Tumbapelo, Waxim, Xaxim Guash De Castilla;
Nauruan: Bin;
Niuean: Pepe;
Palauan: Telengtungd, Telentund;
Papua New Guinea: Kunia, Lamtoro;
Philippines: Kabahero (Cebu Bisaya), Kariskis, Komkompitis (Iloko), Agho, Aghog, San Pedro (Panay Bisaya), Oyloi (Samar-Leyte Bisaya), Palo-Maria, Elena, Santa-Elena, Santaelena (Spanish), Ipel, Ipil Ipil, Kariskis (Tagalog);
Pohnpeian: Tangantangan;
Samoan: Fua Pepe, Fua Pepe, Fuapepe, Fuapepe, Lopa Samoa, Lopā Samoa, Lusina;
Spanish: Guaje, Huaxin, Uaxim, Tamarindo Silvestre, Acacia Bella Rosa, Peladera;
Swahili: Lusina, Mlusina;
Swedish: Ipilipil, Ipil-Ipil;
Thai: Kra Thin, Katin, To Bao;
Tongan: Siale Mohemohe;
Vanuatu: Cassis;
Vietnam: Keo Giau, Kay Keo Dâu, Bok Et Dai, Tao Nhan, Bo Chet, Binh Linh, Phac Can Thin (Tay), Nang Dung Diang (Dao);
Yapese: Talntangan, Ganitnityuwan Tangantan;
Zanzibar: Shak-Shak.

Origin/Distribution

Leucaena leucocephala is native to Central America and the Yucatan Peninsula of Mexico. It is now found naturalised in most tropical and subtropical countries in the Caribbean, south Asia, southeast Asia and the Pacific islands, including New guinea, Australia and Hawaii.

Agroecology

Leucaena leucocephala is strictly a tropical species requiring warm temperatures (25–30°C day temperatures) for optimum growth. At higher latitudes and at elevated tropical altitudes growth is reduced. Growth ceases at 15–16°C. The tree is not tolerant of even light frosts which cause leaf shedding and heavy frost causes death of tree. It is found naturalized from near sea level to about 800 m along roadsides, in disturbed and cultivated areas and in pastures, on dry river banks or open gravel banks in forest, often forming dense thickets. It prefers subhumid to humid climates of 650–1,500 mm rainfall and up to 3,000 mm annual rainfall. *Leucaena* is very drought tolerant even during establishment and tolerates up to 7 months dry season however growth is retarded in dry environments. It does not tolerate waterlogged soils or extended periods (>3 weeks) of flooding.

In its native range, it grows on shallow limestone soils, coastal sands and seasonally dry, self-mulching, vertisol soils of pH 7.0–8.5. It is intolerant of soils with low pH, low P, low Ca, high aluminium saturation, high salinity and water-logging but is tolerant of moderate salinity and alkalinity. *Leucaena* thrives best on deep, well-drained, neutral to calcareous soils; it is often found naturalised on the rocky coralline terraces of Pacific island countries. However, it grows on a wide variety of soil types including mildly acid soils (pH > 5.2). It is well adapted to clay soils and requires good levels of phosphorus and calcium for optimum growth.

It thrives in full sun but will grow under light shade and has been found to be productive under

mature coconuts in Vanuatu and Indonesia. In many tropical areas it has escaped as nuisance weed in waste places and is also commonly cultivated as hedge plants.

Edible Plant Parts and Uses

Young leaves, flower buds, young pods and seeds are eaten raw as *lalap* (salad) in Indonesia or as *gudangan* (mixed vegetable dish in coconut milk) with rice Also eaten as *sayor* with *sambal goreng* (fried, spicy, chilli shrimp paste). The half-ripe seeds are used in *botok* – a dish of grated coconut, fish or meat wrapped and cooked in banana leaf. Seeds of ripe pods are eaten with rice after roasting. In Indonesia, a food called '*tempe lamtoro*' is made of fermented immature leucaena seeds. The mature seeds are also used as a substitute for coffee. Unripe pods and seeds have been used by the native inhabitants of Mexico and Central America as a food since ancient times. Very young shoots and pods are used as food by villagers in Thailand. In Manipur, India, tender leaves, young pods and seeds are used raw or fried as vegetable. The seed gum is used in ice-cream.

Botany

A thornless, evergreen, branched shrub or small tree up to 8 m high with deep roots. Trunk is greyish brown. Leaves are alternate, bipinnate to 25 cm long with 12–18 pairs of small, shortly stalked, linear or linear-oblong, acute, dull greyish-green, glabrous leaflets, 10–15 mm by 3–4 mm wide, with minute stipule (Plates 1–3). Flowers are numerous, white to yellowish white, formed in axillary, cream coloured, globose heads (Plates 1–2). Flowers are bisexual, 5-merous. Calyx is campanulate with 5 triangular teeth, corolla consist of 5 spathulate, puberulous petals, 10 stamens with hairy anthers and a sparsely pubescent stipitate ovary. Fruit is a pod broadly linear (strap-shaped), thin, flat, 12–14 cm long by 1.5 cm wide, light green when immature (Plates 4–6), turns brown and dry

Plate 1 *Leucaena* with pendant pods

Plate 2 *Leucaena* immature and mature globose inflorescence heads

Plate 3 *Leucaena* a leaves on sale as vegetables in the market

Plate 4 Immature *Leucaena* pods

Plate 5 Bundles of *Leucaena* pods on sale in the market

Plate 6 *Leucaena* pods and seeds on sale in the market

when ripe and containing 15–30 seeds. Seeds ovate-oblong or elliptic, flat, 6–10 mm long, shining, green when immature (Plate 6) turning dark brown.

Nutritive/Medicinal Properties

Leucaena leucocephala leaves were found to contain 3% tannin, carotene and leucenol and to be a rich source of proteins. The leaves were also found to have flavonol glycosides such as 3-arabinosides, 3-rhamnosides and 3-glucuronides of quercetin and myricetin, and quercetin-3-rhamnosylglucoside, at a total concentration of 3–4% (Lowry et al. 1984). Leaf protein concentrate (LPC) prepared from *Leucaena leucocephala* leaf meal (LLM) gave a recovery of LPC of 7.6% and analysis showed that the LPC contained 65.91% crude protein compared with 29.15% of the LLM, ash level was 17.56% while contents of essential amino acids-lysine, histidine, arginine, isoleucine and leucine – were 5.57%, 2.34%, 5.88%, 5.42% and 10.8% on a dry matter basis, respectively (Farinu et al. 1992). The aerial vegetative parts of *L. leucocephala* contained 26.1–28.1% dry matter, 22.1–23.4% crude protein, crude fat 4.6–6.1%, crude ash 5.9–7.3%, crude fibre 14.3–16% and nitrogen free extract 43.4–51.7% (Hongo et al. 1987).

The leaves were also found to contain an antinutrient, mimosine. Mimosine was found distributed in all parts of the plant with a mean of 3.3% but the young leaves had the highest content of 8.6–9.4% (Soedarjo and Borthakur 1996). Studies found that boiling eliminated mimosine from young leaves, pods and seeds of *Leucaena* but it also reduced the quantity of soluble protein significantly. Soaking in water for 24 hours eliminated 97% of mimosine from young leaves, pods and split seeds of *Leucaena*, and up to 20% of mimosine from the whole young seeds without significantly reducing the soluble protein content.

Leucaena seeds were found to contain low content of oil (6.4%) but was rich in protein (27.6%). The oil had an iodine number of iodine value 113.5, saponification value of 188, unsaponifiable matter of 2.5 and the following fatty acid compositions: palmitic 14.2%, stearic 6.1%, oleic 20.1%, linoleic 53.8%, linolenic 1.8%, and arachidic 2.3%. The seed also contained 1.7% lignoceric acid (Chandrasekhara Rao et al. 1984).

Chen and Wang (2010a) isolated ficaprenol-11 (polyprenol), squalene, lupeol, β-sitostenone, trans-coumaric acid, cis-coumaric acid, pheophytin-a, pheophorbide a methyl ester, methyl-13²-hydroxy-(13²-S)- pheophorbide-b and aristophyll-C were isolated from the whole plants of *Leucaena leucocephala*. Four steroids, 5α,8α-epidioxy-(24ξ)-ergosta-6,22-dien-3β-ol (1), β-sitosterol (2), β-sitostenone (3), and stigmastenone (4), along with 10 known compounds were isolated from the whole plants of *Leucaena leucocephala* (Chen and Wang 2010 b). Compound 1, Lupeol (5), 1,3-dipalmitoyl-2-oleoylglycerol (6), methylparabene (8) and isovanillic acid (9) were found for the first time from *Leucaena leucocephala*.

Young pods and leaves are esteemed as food and fodder for its high protein content (up to 18%). The seeds we also reported to contain alkaloids, tannins and flavonoids (Ademola et al. 2005).

Studies reported that extracts of *Leucaena* seeds have anthelminthic, anti-cancerous, anti-inflammatory, analgesic, anti diabetic, antifibrotic, and anti-mutagenic properties.

Analgesic Activity

The chloroform soluble alkaloidal *Leucaena* seed extract was analgesic at a dose of 5 mg/20 g mouse as it showed a comparable result to mefenamic acid using the acetic acid-induced writhing method (Villaseñor et al. 1998).

Antimutagenic Activity

Results of the micronucleus test, showed that both the chloroform soluble and ethyl acetate alkaloidal *Leucaena* seed extracts were not mutagenic but instead exhibited antimutagenic activities at 0.5 mg/20 g mouse. The chloroform soluble and ethyl acetate-soluble alkaloidal extracts reduced the number of micronucleated polychromatic erythrocytes induced by tetracycline, a known mutagen, by 67.0% and 71.2%, respectively (Villaseñor et al. 1998).

Central Nervous System Activity

Preliminary pharmacological screening showed that chloroform soluble and ethyl acetate alkaloidal *Leucaena* seed extracts caused a relative depression in the central nervous system as evidenced by a decrease in respiratory rate and depth and a decrease in motor activity (Villaseñor et al. 1998).

Anticancer Activity

Gamal-Eldeen et al. (2007) reported that using a simple chemical modification such as 2,4-pentanedione treatment and additional sulphation of *L. leucocephala* polysaccharide-protein complex could provide new cancer chemo-preventive and/or anticancer properties. The study highlighted the potential to use such derivatives of *L. leucocephala* polysaccharide-protein complexes in health food industries, to provide potential cancer chemo-preventive and/or anticancer properties for high-risk populations. The studies extracted and modified the seed polysaccharides into two forms: 2,4-pentanedione-treated derivative (glycosylated form) which was further sulphated to give sulphated glycosylated form. The results revealed that the glycosylated form inhibited both cytochrome P450 1A (CYP1A) and the induction of glutathione-S-transferases (GSTs) while sulphated glycosylated form not only inhibited CYP1A, but also induced the GSTs. Both the glycosylated form and sulphated glycosylated form induced HepG2 cell death by necrosis, but not apoptosis. Seeds of *L. leucocephala* were found to have galactomannans and lectin galactomannan that constituted a glycoside (Lesniak and Liu 1981). Galactomannans from soybean have been reported to possess antitumour, hemagglutinating and anticoagulating activities (Hassan et al. 2009).

Antifibrotic Activity

Studies showed that mimosine induced antifibrotic effects on cultured adult cardiac fibroblasts and was associated with inhibition of prolyl

4-hydroxylase and diminished extracellular secretion of procollagen, despite the reactive elevation of intracellular procollagen synthesis (Ju et al. 1998). The cytotoxicity of mimosine treatment was found minimal at the concentrations used. The results indicated that specific inhibition of prolyl 4-hydroxylase may provide a novel therapeutic approach for the modulation of cardiac fibrosis.

Antiinflammatory and Fibrinolytic Activities

Studies showed that *Leucaena leucocephala* seeds had antiinflammatory activity. Two serine protease inhibitors from *Leucaena leucocephala* seeds: trypsin inhibitor 1 (LLTI-1) and trypsin inhibitor 2 (LLTI-2) were found to reduce swelling induced by collagenase in rat paw (Souza Pinto et al. 1995). LLTI-1 and LLTI-2 did not inhibit collagenase activity for one of its specific substrates. Another study reported that the serine proteinase inhibitor isolated from *Leucaena leucocephala* seeds (LlTI) inhibited plasmin, human plasma kallikrein, trypsin and chymotrypsin (Oliva et al. 2000). LlTI inhibited kinin release from high molecular weight kininogen by human plasma kallikrein in-vitro and, administered intravenously, caused a decrease in paw edema induced by carrageenin or heat in male Wistar rats. The inhibition of the fibrinolytic activity of plasmin was confirmed on the hydrolysis of fibrin plates. In addition, lower concentrations of bradykinin were found in limb perfusion fluids of LlTI-treated rats.

Antidiabetic Activity

Leucaena leucocephala seeds were found to have antidiabetic activity in alloxan-induce diabetic rats (Syamasudin et al. 2010). Methanol extract caused the greatest decrease in blood glucose level compared to n-hexane, ethyl acetate or water extracts. The bioactive compound were found to be glycoside compounds with monosaccharide galactose clusters and many other saccharides.

Anthelminthic Activity

An in-vitro test for anthelminthic activity using *Ascaris suum* showed that the chloroform soluble alkaloidal *Leucaena* seed extract gave a comparable result to mebendazole (Antiox) at a concentration of 5 mg/ml (Villaseñor et al. 1998). Seeds of *Leucaena leucocephala* are being employed as vermifuge, as it is effective against roundworms. The polyphenol fraction of an ethanol seed extract was demonstrated to kill infective larvae of the nematode *Haemonchus contortus* (Rudolphi) of sheep supporting its application in anthelmintic therapy in veterinary practice (Ademola et al. 2005).

Vehicle for Drug Dispensation

Pendyala et al. (2010) reported that their studies indicated that the swelling ability of *Leucaena leucocephala* bark gum may provide potentials for its use as a disintegrant in tablet formulation, as a hydro gel in modified release dosage forms and the rheological flow properties may also provide potential for its use as suspending and emulsifying agents owing to its pseudo plastic and thixotropic flow patterns.

Birth Defects

Mimosine had adverse effects on the biosynthesis of collagen in embryonic cartilage from chick embryos, due to inhibition of the synthesis of hydroxyproline. Studies reported that feeding pregnant rats with mimosine produced deformities in fetuses (De Wreede and Wayman 1970). Deformities were associated with perforations in the uterus between placental attachments with partial protrusion of fetuses through the uterus. Mimosine had neurotoxic effects on young rats, which developed distinct paralysis of the hind limbs on a 25% *Leucaena* diet (Ter Muelen et al. 1979). These effects were reversible with a normal control diet.

Traditional Medicinal Uses

Leucaena leucocephala have been used in traditional folk medicine. Roasted seeds are used as an emollient. The roots in decoction are used as an emmenagogue, a decoction of the bark and roots has been reported as powerful emmenagogue and is used in the West Indies as an abortifacient.

Other Uses

Leucaena leucocephala has a wide variety of uses and has been dubbed a 'miracle tree'. The tree is used in reforestation and in cropping systems in the Philippines, in Timor and Flores in Indonesia. It ha been employed in contour strip cropping for erosion control on steep slopes and as a form of alley cropping in which its foliage is mulched into the soil to enhance yields of inter-row crops as it enriches the fertility of the soil as green manure because of its high nitrogen fixing efficiency at more than 500 kg/ha/year. Previously it has been used as a reclamation species following mining, but is no longer used due to the high weed risk. On some islands of eastern Indonesia, thickets of *Leucaena* are regularly burnt prior to planting crops in an advanced form of swidden (slash-and-burn) agriculture. The low seeding varieties are used to provide shade for tea, mangosteen, cacao and coffee and natural live support for climbers such as pepper, vanilla, yams and passion fruit. *Leucaena* is grown in dense rows as living fence or hedges and are useful as windbreaks and firebreaks, the latter due to the suppression of understorey grass growth. *Leucana* flowers also provided good foraging for bees. The leaves of *Leucaena* are highly nutritious for ruminants and provide a good source of forage and fodder for cattle. However, the leaves which contain mimosine, are toxic to horses that eat them. Leaves and bark can be used for animal feed. Red, brown and black dyes are extracted from the pods, leaves and bark. Mature seeds are used for the production of bags, necklaces and leis. *Leucaena leucocephala* produces a gum similar to gum Arabic which has utilization in ice-creams, cosmetics, and in the pharmaceutical industry.

Leucaena provides a large volume of a medium-light hardwood for fuel (specific gravity of 0.5–0.75) with low moisture and a high heating value, and makes excellent charcoal, producing little ash and smoke. It can also be utilised for parquet flooring and small furniture, craft-wood as well as for paper pulp and rayon. *Leucaena* poles are useful for posts, props and frames for various climbing crops.

Studies showed that the inclusion of *L. leucocephala* leaves meal in the diet of adult indigenous Senegal chickens at 21% level, had no significant untoward effect on feed intake, average daily weight gain, feed conversion ratio and nutrients utilization (except ether extract) (Ayssiwede et al. 2010). It significantly improved the crude protein and metabolizable energy utilization in chickens fed the 7% level inclusion diet. Analyses showed that *Leuceana* leaves were relatively rich in protein (24.9% DM), ether extract (6.4% DM), crude fibre (14.2% DM) and neutral detergent fibre (22.4% DM). It contained respectively 43.1% and 11.4% DM of nitrogen free extract and ash, particularly calcium (1.8%) and potassium (1.1% DM) and 2573.8 kcal/kg DM of metabolizable energy.

Studies in Thailand showed that protein foliage from *L. leucocephala* can substitute imported feedstuff concentrates like soybean bean meal as protein supplement for goat production (Paengkoum and Paengkoum 2010). Also separate studies showed that *Leucana* bark and pangola grass hay diets can be fed to goats (Palmer et al. 2010). *Leucaena* bark had lower crude protein content than the leaf (11.7 versus 25.9), and the *Leucaena* bark+hay diet had lower dry matter and crude protein digestibility than the other diets. The calculated bark digestibility of dry matter and crude protein of 44.1% and 38.2%, respectively, were much lower than the values for the *Leucaena* leaf of 62.9% and 89.1%, respectively. The lower than expected crude protein digestibility was attributed to higher tannin levels in the bark compared to the leaves. Despite this, the bark was well accepted by the goats and was often preferred to the hay.

Comments

Two subspecies are recognized: subsp. *leucocephala* and subsp. *glabrata*.

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Lupinus albus

Scientific Name

***Lupinus albus* L.**

Synonyms

Lupinus sativus Gaertn., Lupinus termis Forssk

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Bitter White Lupin, Broad-Leaved Lupin, Broadleaf Lupin, Egyptian Lupin, European White Lupin, Mediterranean White Lupin, White Lupin, White Lupine

Vernacular Names

Afrikaans: Witlupien;
Arabic: Bâqilâ Shâmî, Turmus;
Chinese: Bai Hua Yu Shan Dou, Bai Yu Shan Dou;
Czech: Lupina Bílá, Vlčí Bob Bílý;
Danish: Hvid Bitterlupin, Hvid Lupin;
Dutch: Bittere Lupine, Lupine, Lupine Sort, Witte Lupine;
Eastonian: Valge Lupiin;
Ethiopia: Gibto;
Finnish: Valkolupiini;
French: Lupin Blanc, Lupin Blanc Amer, Lupin D'egypte;
German: Ägyptische Lupin, Weisse Lupine, Weiße Lupine, Weiße Bitterlupine, Wolfsbohne;
Hebrew: Turmus Lavan;
Italian: Lupino Bianco, Lupino Bianco Amaro, Lupino Egiziano;
Japanese: Shiro Bana Ruupin;
Korean: Paek Saek Ru P'in;
Norwegian: Hvit Lupin
Polish: Łubin Biały;
Portuguese: Tremoceiro Branco, Tremoço Branco Amargo;
Romanian: Lupin Alb
Russian: Ljupin Belyj;
Slovaščina: Bela Sladka Lupina, Beli Volčji Bob, Volčji Bob Beli;
Spanish: Altramuz, Altramuz Blanco, Altramuz Blanco Amargo, Tramuso;
Swedish: Vitlupin;
Turkish: Aci Bakla, Ak Aci Bakla, Misir Baklasi, Yahudi Bakla.

Origin/Distribution

White lupin originates from West Asia (Turkey, Palestine) and the eastern Mediterranean region of southern Europe (Balkans, Greece, Cyprus, Italy,) where domestication occurred during ancient times and wild types are found. Today

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white lupin is a traditional minor pulse crop, grown around the Mediterranean and the Black Sea, and in the Nile valley, extending to Sudan and Ethiopia. It is also cultivated elsewhere, e.g. in Kenya, Tanzania, Zimbabwe, South Africa, Mauritius, United States and South America (mainly Brazil and Chile).

Agroecology

In the wild, white lupin prefers disturbed sites and poor soils and occurs in meadows, pastures, and grassy slopes in its native range.

White lupin is usually grown at mean monthly temperatures of 15–25°C with the optimum being 18–24°C. Higher temperatures and moisture stress retard flowering and fruit setting. It is cold-tolerant, but temperatures of −6°C to −8°C are detrimental at germination, temperatures of −3°C to −5°C at flowering. For optimal yield, a of 400–1,000 mm during the growing period is required. As with all lupin species, it is drought-tolerant due to their deep roots, but are sensitive to moisture deficiency during the reproductive period.

White lupin adapts best in well-drained, mildly acid or neutral soils of light to medium texture, with pH 4.5–7.5. Growth is hindered on heavy clays and waterlogged soils. Calcareous or alkaline soils cause chlorosis and reduce growth although some cultivars are more tolerant to soil salinity and heavy soils.

Edible Plant Parts and Uses

In Italy, Greece, Spain and Portugal and some regions in Brazil, white lupin seeds are consumed as a popular snack. In the island of Crete, white lupin is much relished as a popular snack especially in the period of Lent before Easter. The seeds are soaked in sea-water for 2–3 h and consumed raw. However, the seeds are usually cooked prior to which they soaked in water to remove the bitter alkaloids. The seeds are also utilised as pickles. The seeds are used as protein rich vegetables or as meat analogues in savoury dishes. The seeds are also roasted and eaten; roasted and used as coffee substitute; or ground into flour in making bread, biscuits, pasta products and a variety of other food products. White lupin is considered to be a rich source of protein with a notable content of lysine and is being increasingly used in bakery, confectionery, snacks and pastry products due to its multifunctional properties (Guillamón et al. 2010). In addition to their utilization in bakery products, value added products such as pasta, crisps, milk and yogurt analogues, meat analogues, lupin protein isolate for the enrichment of vegetable and fruit based foods can be produced from the lupin flour after removal of the anti-nutritional factors present in the lupin seeds (Tizazu and Emire 2010).

In Ethiopia, white lupin seeds are used as roasted bean '*kolo*' and to prepare a local alcoholic drink called '*katikala*' and other food products especially in the north-western part of the country (Tizazu and Emire 2010); also a high-quality spirit ('*araki*') is distilled from fermented seeds. The seeds are roasted or soaked in river or spring water for 3–7 days to remove the bitter alkaloids before use. An edible oil is obtained from the seeds.

Botany

It is annual, erect, branched, bushy more or less pubescent herbaceous plant, 30–150 cm high (Plate 1) with taproot and nodules. Stipules are persistent, acicular, subulate, concrescent with the petioles over 1/3 of their length. Leaves are alternate, digitally compound with 5–9 leaflets (Plates 1–2). Leaflets are oblong or obovate, 2–6 cm by 0.5–2 cm, cuneate at base, rounded and mucronate at apex, glabrous above and villous below, margins ciliate. Inflorescence a terminal psuedoraceme 3–30 cm long, many-flowered, lower flowers alternate, upper ones in whorls; sessile to shortly peduncled. Flowers bisexual, zygomorphic, papilionaceous; pedicel 1–2 mm long; calyx 8–14 mm long, densely hairy outside, 5-lobed, tube 4 mm long, 2-lipped, upper lip entire, lower lip entire or slightly 3-toothed; corolla white to violet-blue, standard obovate, 15–18 mm × 8–12 mm, margins partly reflexed, wings obovate, 13–17 mm × 6–10 mm,

Plate 1 White lupin plant habit (Bevan Buirchell)

Plate 2 Inflorescence and digital compound leaves (Bevan Buirchell)

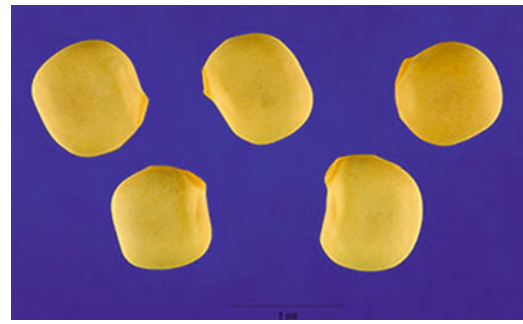

Plate 3 White lupin seeds (Steve Hurst @ USDA-NRCS PLANTS Database)

keel ladle-shaped, 12–15 mm × 4 mm, beaked; stamens 10, monadelphous, united below; ovary superior, 1-celled, style c. 7.5 mm long with a ring of small hairs below the stigma. Fruit a narrowly oblong, laterally compressed pod 6–15 cm × 1–2 cm, bulging over the seeds, shortly hairy but glabrescent, yellow, 3–6-seeded. Seeds rectangular or square with rounded corners, laterally compressed, 7–16 mm × 6–12 mm × 2–5 mm, more or less smooth, white, olive, brown, or black, seed surface mottled or patchy (Plate 3).

Nutritive/Medicinal Properties

The fatty acid composition of white lupin seed oil from a range of cultivars was reported as: total oil 9.6%, oleic acid 43.6–54.4%, linoleic acid 17.2–26.9%, linolenic acid from 6.7% to 15.2% (Green and Oram 1983). Most cultivars were deficient in sulphur containing amino acids, typical of legume proteins, with methionine and cysteine totalling only 2.2% of the protein. *Lupinus albus* differed slightly from other lupin species in amino acid composition, having higher levels of threonine, tyrosine and isoleucine, but a lower level of glutamic acid than both *L. angustifolius* and *L. luteus*. Four low-alkaloid lines of *L. albus* each had higher lysine content than the high-alkaloid line, but 'Kiev Mutant', despite earlier claims, had a lysine level no higher than the other three low-alkaloid lines. White lupin *Lupinus albus* grown in turkey were reported to contain high amounts of protein (32.2%), fibre (16.2%), oil (5.95%), and sugar

(5.82%) (Erba et al. 2005). Oil of seeds was composed of 13.5% saturated, 55.4% monounsaturated, and 31.1% polyunsaturated fatty acids. Sucrose constituted 71% of total sugar content of seeds. Lupin seeds contained 3.9 mg/kg of thiamin, 2.3 mg/kg of riboflavin and 39 mg/kg of niacin. They found that lupin is an excellent food material with a high nutritional value. The nutrient composition (dry weight basis) of white lupin grown in Ethiopia was determined by Tizazu and Emire (2010) Mean values for protein, crude fat, total carbohydrates, crude fibre, and crude ash content were 40.22, 8.92, 47.73, 10.08 and 3.15 g/100 g, respectively. The mean values of minerals such as phosphorus, iron, zinc and calcium contents were 248.90, 12.51, 4.68 and 82.56 mg/100 g, respectively.

Three main globulins designated by γ-, β- and α-conglutins were found in white lupin seeds (Melo et al. 1994). The main proteins of white lupin seed comprised four main protein families of globulins, termed α-, β-, γ- and δ-conglutins (Duranti et al. 2008). Globulins of *L. albus* seeds were found to consist of two major globulins called α-conglutin (11S and "legumin-like") and β-conglutin (7S and "vicilin-like") and another additional two globulins, γ-conglutin and δ-conglutin, which were present in lower amounts (Franco et al. 1997; Nadal et al. 2011).

Nutrient composition of raw mature lupin (*L. albus*) seeds per 100 g edible portion reported by USDA (2010) was as follows: water 10.44 g, energy 371 kcal (1,552 kJ), protein 36.17 g, fat 9.74 g, ash 3.28 g, carbohydrate 40.38 g, Ca 176 mg, Fe 4.36 mg, Mg 198 mg, P 440 mg, K 1,013 mg, Na 15 mg, Zn 4.75 mg, Cu 1.022 mg, Mn 2.382 mg, Se 8.2 μg, vitamin C 4.8 mg, thiamine 0.640 mg, riboflavin 0.22 mg, niacin 2.190 mg, panthothenic acid 0.750 mg, vitamin B-6 0.375 mg, total folate 355 μg, vitamin A (RAE) 1 μg, vitamin A 23 IU, total saturated fatty acids 3.940 g, 12:0 (lauric) 0.008 g, 14:0 (myristic) 0.013 g, 16:0 (palmitic) 0.742 g, 18:0 (stearic) 0.316 g, total monounsaturated fatty acids 3.940 g, 16:1 undifferentiated (palmitoleic) 0.034 g, 18:1 undifferentiated (oleic) 3.558 g, 20:1 (gadoleic) 0.255 g, 22:1 undifferentiated (euric) 0.093 g, total polyunsaturated fatty acids 2.439 g, 18:2 undifferentiated (linoleic) 1.995 g, 18:3 undifferentiated (linolenic) 0.446 g, tryptophan 0.289 g, threonine 1.331 g, isoleucine 1.615 g, leucine 2.743 g, lysine 1.933 g, methionine 0.255 g, cystine 0.446 g, phenylalanine 1.435 g, tyrosine 1.360 g, valine 1.510 g, arginine 3.877 g, histidines 1.030 g, alanine 1.296 g, aspartic acid 3.877 g, glutamic acid 8.686 g, glycine 1.539 g, proline 1.476 g, serine 1.869 g.

Lupinus albus seeds were found to contain a lectin-like protein (Ramos et al. 1997; Falcón et al. 2000) Free ubiquitin and ubiquitin-protein conjugates contents varied in cotyledons of white lupin during the course of seed formation, from the flower to the dry seed, and during germination and seedling growth, from the dry seed to the senescing cotyledons (Ferreira et al. 1995). In addition, during germination of *Lupinus albus* seeds, a 20-kDa polypeptide accumulated in the cotyledons of 4-d-old plants. The 20-kDa polypeptide was found to be an intermediate breakdown product of β-conglutin catabolism, the vicilin-like storage protein from *L. albus* (Ramos et al. 1997). Besides rabbit anti-ubiquitin antibodies, the 20-kDa polypeptide interacted with a variety of glycoproteins, including immunoglobulin G from several animal species, peroxidase and alkaline phosphatase, suggesting that it possessed a lectin-type activity.

The most abundant oligosaccharide in *Lupinus albus* was found to be stachyose (2.8%), followed by sucrose (1.8%) raffinose (0.4%) and verbascose (0.3%) (Mohamed and Rayas-Duarte 1995). *Lupinus albus* was reported to have a low phytic acid content (0.03%), uronic acid (12%) and total dietary fiber (34.2%). No free monosaccharides were detected, except for a trace of fructose. The total carotenoid content of the whole grain was 36 ppm.

The following isoflavones genistin, licoisoflavone A, genistein and 2´-hydroxygenistein were detected in leaf, stem, bud and root of *Lupins albus* (Von Baer et al. 2006). They found that that licoisoflavone A, lupinalbin A, 2`-hydroxygenistein, licoisoflavone B, genistein and wighteone exerted from mild to strong fungitoxic activity against *Colletotrichum lupini*. In *Lupinus albus*, the isoflavone content was higher in leaves than in stems,

and peaked before flowering, whereas it declined during maturity (D'Agostina et al. 2008). Autumn-sown plants exhibited higher isoflavone content than early spring-sown plants, especially in late vegetative and early reproductive stages. Genistein 7-O-glucoside was the major isoflavone of leaves and stems in the late vegetative stages of early spring sowing, whereas genistein was the major isoflavone under autumn sowing. No isoflavones were found in seeds. Gamma-Conglutin, a glycoprotein from *Lupinus albus* seed was found to have high structural similarity with xyloglucan-specific endo-β-1,4-glucanase inhibitor proteins (XEGIPs) and *Triticum aestivum* xylanase inhibitor (TAXI-I), which acted specifically against fungal glycosyl hydrolase belonging to families 12 and 11, respectively(Scarafoni et al. 2009). Studies showed that γ-conglutin failed to inhibit representative fungal endo-glucanases and other cell wall-degrading enzymes.

Lupinus albus protein isolate (L-ISO) was found to have adequate nutritional value and to reduce large intestinal weight in rats after restricted and ad libitum feeding (Caligari et al. 2006). Liver composition (DNA, RNA, glycogen, and fat) and plasma levels of some amino acids (histidine, threonine, alanine, proline, tyrosine, valine and methionine) were affected by diet, but no effects on plasma lipid, glucose, or uric acid were observed.

Antioxidant Activity

Studies showed that methanol extracts of lupin flour exhibited a marked antioxidant activity, higher than that of soya flour extracts (Tsaliki et al. 1999). The pronounced antioxidant activity was attributed to the presence of high levels of total phenolics and phospholipids in the lupin extracts.

Hypocholesterolemic Activity

Sirtori et al. (2004) found that white lupin, although isoflavone free, exhibited hypocholesterolemic activity similar to that of other leguminous proteins in an established animal model. In rats fed a casein-based cholesterol+cholic acid diet, a relatively low daily intake (50 mg/day by gavage for 2 week) of total lupin protein extract lowered plasma total and VLDL+LDL cholesterol concentrations by 21% and 30%, respectively. In addition, cholesterol reduction appeared to be associated with stimulation of LDL receptors by a well-defined protein component of the lupin seeds as demonstrated by in vitro studies. In in-vitro and in-vivo studies the researchers found the most active hypocholesterolemic component of soybean protein to be β-conglutin, the 7S globulin (Wait et al. 2005). At least 18 peptides derived from β-conglutin, having a percentage identity higher than 50% and a similarity percentage higher than 70% vs the α-subunit of β-conglycinin, were likely candidates to be the biologically active components of lupin protein. A fast and automated high-performance liquid chromatography/electrospray ionization tandem mass spectrometry (HPLC/ESI-MS/MS) method was developed for the detection of the hypocholesterolemic component β-conglutin (Locati et al. 2006).

Hypoglycaemic Activity

Al-Zaid et al. (1991) found that *Lupinus termis* exerted a significant hypoglycemic effect in non-diabetic and streptozotocin diabetic rats without apparent side effects.

Antinutritional Factors

Functional lupin seeds were obtained from two different cultivars of white (*Lupinus albus*) were obtained by extraction of antinutritional factors such as α-galactosides (Martínez-Villaluenga et al. 2006). In white lupin seeds, α-galactosides were effectively removed and processed seeds contained very low amounts of flatulence causing factors (about 0.5–1%). Protein, fat and starch contents exhibited high retention in processed seeds (upto 130%). Sucrose and soluble dietary fibre, however, decreased significantly as a result of processing and retentions ranged from

10% to 60%, depending on the variety studied. Vitamins B1, B2, E and C were also lowered. Trypsin inhibitor activity was not detected and inositol phosphate content was modified slightly after extraction. All in all, the functional lupin seeds, with low contents of α-galactosides, are a product of nutritional importance due to their high protein content, dietary fibre and fat contents as well as acceptable levels of thiamin, riboflavin and vitamin E. They can be incorporated as a proteic source, not only in animal feeding but also in a wide range of foods.

Allergy Problems

Lupin seed flour had been reported as a causative agent of allergic reactions, especially in patients with allergy to peanut since the risk of immunological cross-reactivity between lupin and peanut was higher than with other legumes (Guillamón et al. 2010). The two major lupin allegens were identified as 34.5 kDa allergen (Lup-1), a conglutin β (vicilin-like protein) while the 20 kDa allergen (Lup-2) corresponded to the conglutin α fraction (legumin-like protein). The high level of amino acid sequence homology of Lup-1 and Lup-2 with the major allergens of some legumes elucidated the IgE cross-reactivity and clinical cross-reactivity of lupin and other legumes.

Traditional Medicinal Uses

In traditional medicine white lupin is used for various disorders, e.g. as an vermifuge, carminative, aperient, diuretic and pectoral. Lupin meal added with honey or vinegar is used as a treatment for worms, while infusions or poultices are applied for boils and skin complaints.

Other Uses

White lupin is also used as green manure crop, as forage and as livestock feed. In southern Europe it is still a traditional green manure crop in vineyards and olive plantations. White lupin is a good honey plant and an attractive annual ornamental; its inflorescences are used in floral arrangements. Burning seeds are used as an insect repellent.

Comments

Like all lupines white lupin harbours nitrogen-fixing *Bradyrhizobium* bacteria in its root nodules and increases the nitrogen level of the soil.

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Lupinus angustifolius

Scientific Name

***Lupinus angustifolius* L.**

Synonyms

Lupinus cryptanthus Shuttlew. ex Campb., *Lupinus linifolius* Roth., *Lupinus opsianthus* Atabek. & Maissurjan, *Lupinus philistaeus* Boiss., *Lupinus reticulatus* Desv., *Lupinus sylvestris* Lam., *Lupinus varius* Savi, non L.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Australian Sweet Lupin, Blue Lupin, Blue Lupine, European Blue Lupine, Lupin, Lupine, Narrow-Leaved Lupin, Narrowleaf Lupin, New Zealand Blue Lupin, Sweet Lupin, Sweet Lupinseed

Vernacular Names

Afrikaans: Bloulupien;
Arabic: Turmus Shaytânî;
Chinese: Xia Ye Yu Shan Dou, Zhai Ye Yu Shan Dou;
Czech: Lupina Úzkolistá, Vlčí Bob Úzkolistý;
Danish: Smallbalder Lupin, Smalbladet Lupin;
Dutch: Blauwe Lupine;
Eastonian: Ahtalehine Lupiin;
Egyptian: Termis Shitani (Arabic);
Finnish: Sinilupiini;
French: Lupin À Feuilles Étroites, Lupin Bleu, Lupin Petit Bleu;
German: Bitterlupine, Blaue Lupine, Lupine, Schmalblättrige Lupine;
Hungarian: Kék Csillagfürt, Keskenylevelü Csillagfürt;
Italian: Lupino Azzurro, Lupino Selvatico;
Japanese: Ao Bana Ruupin;
Korean: Bul Ru Ru P'in, Ka Neun Ip Mi Seon Kong;
Mexico: Lupino Azul;
Norwegian: Smallupin,
Polish: Łubin Wąskolistny
Portuguese: Tremoceiro-Azul, Tremoceiro De Folha Estreita, Tremoçao Bravo, Tremoço Amargo, Tremoço Des Folhas Estreitas;
Russian: Ljupin Uzkolistnyj;
Spanish: Alberjón, Altramuz, Altramuz Amargo, Altramuz Azul, Haba De Lagarto, Titones;
Swedish: Blå Lupin;
Switzerland: Lupin À Folioles Étroites (French);
Turkish: Mavi Aci Bakla, Yabani Turmus.

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Origin/Distribution

Blue lupin is native to southern Europe, Middle East and northern Africa. It has naturalized in parts of Australia, South Africa and North America. It is widely distributed in all Mediterranean countries, from Portugal, southwest France and the Maghreb countries to the Levante and Turkey.

Agroecology

Lupinus angustifolius is a cool climate crop that thrives best in a Mediterranean or sub-temperate climatic regime. High temperatures at flowering time decreases pod set and reduces seed production and branching of *Lupinus angustifolius* (Downes and Gladstones 1984a; Downes and Gladstones 1984b; Downes and Gladstones 1984c). Plant growth is poor at day/night temperatures above 27/22°C. Temperatures about 21/16°C is most suitable for seed development. High temperature stress at flowering can substantially reduced numbers of seed-containing pods.

Generally *Lupinus angustifolius* prefers moderately acidic, well drained, friable soils of reasonable depth (Cowling and Clements 1993; French 2002; Yu et al. 2002), such as friable sandy loams and deep yellow loamy sands. It grows poorly in alkaline soils, where root development is impeded above pH 6 (Yu et al. 2002) and plants become chlorotic and stunted (Cowling and Clements 1993; French 2002). Also, deep white or grey sands are unsuitable where nutritional deficiencies and poor water holding capacities become limiting. Shallow duplex or heavy clays with poor physical structure and poor drainage are also unsuitable. In heavy or shallow soils, roots develop poorly and the plants prematurely collapse from drought in spring.

Edible Plant Parts and Uses

The immature lupin seeds have similar taste and texture to those of green peas. Lupin seeds can be fermented to produce high quality *tempe*, a traditional Indonesian food, and *miso* and *natto,* traditional Japanese foods. Lupin flour can be incorporated in proportion of 5–20% with wheat flour to improve the nutritive value of the flour and used for making bread, muffins, pasta, biscuits, cookies, cakes etc. The lupin flour addition tends to extend the shelf-life and imparts a golden colour. Other uses for lupins include as a snack food base, and in the production of dietary fibre, protein concentrates, salad dressings and fermented sauces.

Lupin sprouts can be used as a salad vegetable, in stir-fries or for pickling. The content of antinutrients such as alkaloids and phytate are further reduced by germination. Lupin sprouts are available commercially in Australia.

Studies found that the general acceptability of ASLF (Australian sweet lupin flour) chocolate chip cookies and breakfast bars was rated similarly to the wheat flour control and defatted soy flour (DFSF) variants (Hall and Johnson 2004). ASLF pasta was rated lower than control (wheat flour) but higher than DFSF pasta, whereas ASLF addition reduced the general acceptability of muffins and bread compared with the other variants. Some ASLF products appeared palatable whereas ASLF incorporation rate in others requires reduction. Blue lupin seed protein hydrolysates were found to have improved functional properties (protein solubility, oil absorption, foam capacity and stability, emulsifying activity, and emulsion stability and could be used in the elaboration of a variety of products such as breads, cakes, and salad dressings (Lqari et al. 2005).

Botany

Annual, branched, erect herbs, up to 1.5 m high (Plate 1) with a tap root and nodules. Young stems or shoots are sparsely to densely pubescent. Leaves are alternate, stipulate, petiolate, petiole 20–60 mm long and palmately compound with 5–11 leaflets (Plates 1–3). Stipules are adnate to the petiole. Leaflet 10–50 mm long, 1–6 mm wide, narrowly oblong or linear, base tapering, margins entire, apex mucronate or obtuse or retuse, pubescent. Flowers are zygomorphic, bisexual, pentamerous, papilionaceous, and borne

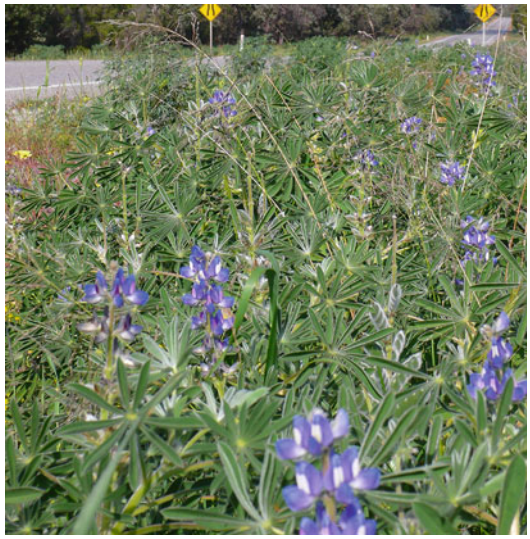

Plate 1 Erect, herbaceous habit (P. White)

Plate 2 Young terminal inflorescence bud (P. White)

in many-flowered terminal racemose inflorescences (Plates 1, 3 and 4). Flowers shortly pedicellate, pedicel 1.5–4 mm long; calyx – 5-lobed, some sepals joined, 7.5–8.5 mm long; corolla – 5 clawed petals, in shades of blue, violet, pink, or white; stamens 10, monadelphous, united below, both opposite and alternating with the corolla parts; anthers non-versatile, dehiscing via longitudinal slits; ovary monomerous, superior,

Plate 3 Terminal inflorescence and palmately digitate leaves (P. White)

Plate 4 Close-up of papilionaceous flowers (P. White)

Plate 5 Young developing, pubescent fruit (P. White)

Plate 6 Mature lupin legume (P. White)

unilocular; styles 1, simple, terete. Fruit a legume, pubescent, dehiscent, non-fleshy, 35–60 mm long, 8–16 mm wide (Plates 5 and 6), with 3–10 seeds. Seeds ovoid to rounded in outline, with smooth surface of varying colours from dark gray to brown to white, olive, or speckled or mottled (Plate 7).

Nutritive/Medicinal Properties

Nutrient composition (mean values) of Australian sweet lupin (g/kg) was reported as:dry matter 911 g, protein 320 g, fat 59 g, fibre 154 g, ash

Plate 7 Seeds of narrow-leaf lupin (P. White)

27 g, Ca 2.2 g, Mg 1.6 g, P 3 g, K 8 g, Na 0.4 g, S 2.3 g, cu 4.7 mg, Fe 68.5 mg, Mn 19 mg, Zn 34.1 mg, Mo 1.6 mg, Co 78 mg, Se 89 mg; amino acid (g/16N): arginine 11.62 g, histidine 2.57 g, isoleucine 3.91 g, leucine 6.90 g, lysine 4.75 g, methionine 0.66 g, phenylalanine 3.85 g, threonine 3.54 g, tryptophan 1.00 g, Valine 3.78 g and anti-nutritional factors: alkaloids 0.02%, oligosaccharides (raffinose, staychose, verbascose) 4.07%, phytate 0.50%, saponins 573 mg/kg, tannins (total) 0.29%, TIA 0.12 mg/kg (Petterson et al. 1997).

Blue lupin seed was found to have three globulins designated α, β and γ, conglutins which differed markedly in amino acid composition (Blagrove and Gillespie 1975). Conglutin γ differed from conglutins α and β and most other legume storage proteins in its relatively high content of cystine and methionine and lower content of arginine and glutamic acid. Two types of protein isolates were prepared from *Lupinus angustifolius* defatted flour (Lqari et al. 2002). Isolate A and B had 93.9% and 84.6% protein content, respectively, and had a balanced composition of essential amino acids, with respect to the FAO

standards except for lysine. The in-vitro protein digestibility varied between 86.3% and 93.9% for isolate A and B, respectively. Food proteins suffer losses of functional and nutritional value due to reaction with lipid peroxidation products. Lqari et al. (2003) found that on incubation with 13-hydroperoxide-11,9-octadecadienoic acid at pH 9, the seed globulins conglutin α and γ from *Lupinus angustifolius* became fragmented and polymerized. This was accompanied by losses of tryptophan, methionine, cysteine, proline, valine and leucine. It was concluded that reaction with 13-hydroperoxide-11,9-octadecadienoic acid led to a decrease in the nutritional value of the conglutins because the losses of essential amino acids were substantial. Further, fragmentation and polymerization reactions most likely had a detrimental effect in the functional properties of the conglutins. These results highlighted the deleterious effects that lipid peroxidation products could have on products such as protein concentrates, isolates and hydrolysates obtained from lipid-rich seeds.

In nutritive aspects lupin seed could be an attractive alternative to dry beans and soya beans for human consumption. Studies have shown that the high protein and oil in lupin seeds are more readily digested, there is a lower content of antinutritional factors such as phytate which can reduce the availability of dietary calcium and zinc, fewer protease inhibitors and a negligible content of lectins. Lupin seed is low in carbohydrates and with a high content of the dietary fibre component is typically associated with cholesterol-lowering and beneficial blood pressure activities.

Antioxidant Activity

Using the Rancimat and Oxidograph tests, antioxidant activity was found both in the flours and in the hulls of lupin (Lampart-Szczapa et al. 2003). Alpha-, γ- and δ-tocopherols were found in the lupin oil. Lupin tannins levels in the flours were a few times higher than in the hulls. Correlation between the antioxidant properties and the tocopherol and tannin contents (the natural lupin antioxidants) was not found. Increasing doses of irradiation lowered antioxidant effects of lupin extracts. Germination of *Lupinus angustifolius* seeds caused significant changes in flavonoids and non-flavonoid phenolic compounds (Dueñas et al. 2009). Isoflavones, flavones and dihydroflavonols in free and conjugated forms were identified. The results indicated that germination modified the quantitative and qualitative polyphenolic composition of lupin seeds during the different days of the germination process, with a significant increase of flavonoids. Concomitantly an increase in the antioxidant activity was also observed. Germination was shown to be a good process to increase the phenolic content of lupin seeds as well as their antioxidant activity.

Hypocholesterolemic/Anti-hypercholesterolemic Activity

A significant lowering effect on total plasma cholesterol was observed in growing rats fed 10 days with the sweet lupin seed meal and its fractions (aqueous fractions that were soluble [LPAD] and insoluble [LPADI] after dialysis at pH 7.0, and phosphate-citrate buffer extracted ones that were soluble [BUSOL] and insoluble [BUDI] after dialysis at pH 7.0) compared with that value obtained from the lactalbumin control (Rahman et al. 1999). The buffer-dialyzed insoluble (BUDI) fraction, which resembled γ-conglutin and was found to be in an almost pure form, decreased total plasma cholesterol by 34% compared with the value for the lactalbumin fed group. Liver lipid and cholesterol were also found to be lower in rats fed *L. angustifolius* seed meal and its fractions. The observed hypocholesterolemic effects were greater than any values previously reported for such a short feeding duration.

Three week studies in pigs showed that diet-induced hypercholesterolemia was inhibited by the blue lupin diet through a substantial reduction in plasma LDL-cholesterol (Martins et al. 2005). Blue lupin also lowered liver esterified and total cholesterol, elevated hepatic LDL receptor synthesis and HMG-CoA reductase activity, and stimulated intestinal bile acid reabsorption.

The neutral sterol output was higher in blue lupin-fed than in casein-fed pigs. The bile acid output was lower in ileorectal anastomosed than in intact pigs. These results suggested that the hypocholesterolemic effect of the blue lupin, compared with the casein, was due to impaired intestinal cholesterol absorption, probably involving enhanced bile acid reabsorption and higher levels of dietary phytosterols, both factors that decreased the micellar solubilization of cholesterol.

In a randomized crossover dietary intervention study of 38 healthy males (age 24–67 years), administration of Australian sweet lupin (*Lupinus angustifolius*) kernel fibre was found to reduce total chlosterol (TC), low-density lipoprotein cholesterol (LDL-C), TC: high-density lipoprotein cholesterol (HDL-C), and LDL-C:HDL-C compared to control (Hall et al. 2005a). No effects on HDL-C, triacylglycerols, glucose or insulin were found.

Insulinaemic/Glycaemic Activity

Studies showed that sweet lupin kernel fibre (LKF) could be formulated into palatable bread and beneficially influenced the incremental areas under curves (IAUC) for insulin (Johnson et al. 2003). A reduction of 18.8% was seen in IAUC for insulin of LKF bread compared with the control (white) bread breakfast. No significant differences were seen in the other glucose or insulin measures. In further studies. Australian sweet lupin (*Lupinus angustifolius*) flour (ASLF) addition to the breakfast was found to reduce its glycaemic index (mean ASLF bread breakfast = 74.0 standard white bread breakfast = 100), raised its insulinaemic index (ASLF bread breakfast = 127.7 standard white bread breakfast = 100), but did not affect palatability, satiety or food intake (Hall et al. 2005b). The results indicated that while ASLF addition resulted in a palatable breakfast the potential benefits of the lowered glycaemic index may be eclipsed by the elevated insulinaemic index.

Conglutin γ, a lupin seed protein, was found to bind insulin in-vitro and reduce plasma glucose levels of hyperglycemic rats (Magni et al. 2004). The binding of conglutin γ, to an insulin-immobilized matrix occurred in the pH range from 7.5 to 4.2 and was strongly affected by ionic strength, suggesting that it was driven primarily by electrostatic interactions. The in-vitro interaction between conglutin γ and insulin was specific. The effect of the oral administration of conglutin γ on the glycemic levels of rats subjected to glucose overloading was a statistically significant reduction in glycemia comparable to that of metformin, a well-known glucose lowering drug. The results presented the first molecular evidence of the possible use of a legume protein in the control of glycemia. Studies showed that lupin γ-conglutin was resistant to proteolysis at pH greater than 4.0, likely because of a compact native conformation and an acidic pH renders the protein susceptible to proteases (Capraro et al. 2009). γ-conglutin was found to undergo an "all or none" degradation pathway, regardless of the enzyme used. Using in vitro and ex vivo models, lupin γ-conglutin was found to transit through the intestinal barrier (Capraro et al. 2011). The intact protein can transit from the apical to the basolateral side of the cell monolayers. The unmodified lupin protein was also detected inside the intestinal everted sacs. In recent studies using mouse myoblasts, the antidiabetic effect of conglutin γ was postulated to be through an insulin-mimetic mechanism (Terruzzi et al. 2011). The authors concluded that conglutin-γ may regulate muscle energy metabolism, protein synthesis and MHC (major histocompatibility complex) gene transcription through the modulation of the same insulin signalling pathway. The results suggested the potential therapeutic use of this natural legume protein in the treatment of diabetes and other insulin-resistant conditions, as well as the potential conglutin-γ influence on muscle cells differentiation and regulation of muscle growth.

Cancer Risk Reduction Effect

In a single-blind, randomized, crossover study of 38 free-living, healthy men, consumption of an Australian sweet lupin (*Lupinus angustifolius*) kernel fibre (LKFibre) diet was found to improve bowel function and beneficially modify some putative faecal risk factors for colon cancer

(Johnson et al. 2006). In comparison to the control diet, the LKFibre diet enhanced frequency of defecation by 0·13 events/day, increased faecal output by 21% and raised faecal moisture content by 1·6% units, whilst reducing transit time by 17% and decreasing faecal pH by 0·26 units. Faecal butyrate level was elevated by 16%, butyrate output was enhanced by 40% and β-glucuronidase activity was reduced by 1·4 μmol/h per g wet faeces compared to the control diet.

Antiobesity/Energy Reduction Effect

In a within-subject design study of 33 healthy men (mean age 52 years BMI 27·4 kg/m^2), the effects of a full-fat sausage patty (FFP) or a reduced-fat patty containing inulin (INP) or lupin-kernel fibre (LKP) on palatability, perceptions of satiety, and food intake were investigated (Archer et al. 2004). All patties were rated above 'neither acceptable or unacceptable', however the INP rated lower for general acceptability and the LKP lower for flavour than the FFP. The LKP breakfast rated more satiating than the INP and FFP breakfasts. Total fat intake was 18 g lower on the day of the INP and 26 g lower on the day of the LKP breakfast than the FFP breakfast day. Energy intake was lower (1,521 kJ) only on the day of the INP breakfast. Both inulin and lupin-kernel fibre appeared to have potential as fat replacers in meat products and for reducing fat and energy intake in men.

Consumption of lupin kernel flour-enriched bread (LB) was found to increase satiety and reduces energy intake in humans (Lee et al. 2006). Two randomized controlled crossover trials were performed to compare the acute effects of LB with those of white bread (WB), involving 16 and 17 subjects respectively. In study 1 (16 subjects), the LB breakfast resulted in significantly higher self-reported satiety and lower energy intake (kJ) at lunch than did the WB breakfast. The LB lunch resulted in a significantly lower within-meal energy intake (kJ) at lunch than did the WB lunch. In study 2 (17 subjects), compared with the WB breakfast, the LB breakfast significantly altered the 3-hours post-meal plasma ghrelin response and resulted in significantly lower mean 3-hours plasma ghrelin concentrations.

A 16-week parallel-design randomised controlled study was performed on 88 overweight and obese men and women (74 completed the study) to determine the effects on body weight and composition and blood lipids, glucose and insulin of an ad libitum LKF-enriched diet higher in dietary protein and fibre (Hodgson et al. 2010). They found that for lupin relative to control, the net effects on body weight −0.4 kg, fat mass −0.5 kg and percentage −0.5%, plasma leptin −1.66 ng/ml and adiponectin 0.20 mg/l − as well as serum total cholesterol −0.08 mmol/l, triglycerides 0.09 mmol/l, glucose 0.10 mmol/l and insulin 0.40 mU/l were not significant. This study did not support the proposal that an ad libitum diet enriched in LKF resulting in moderate changes in both protein and fibre intakes could benefit body weight and composition or fasting blood lipids, glucose and insulin concentrations in overweight men and women with mildly elevated total cholesterol concentrations.

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Hypotensive Activity

A controlled 16-week parallel-design intervention study was performed on 88 overweight and obese men and women (74 completed the study) to ascertain the effects on blood pressure of a diet moderately higher in dietary protein and fibre achieved by substituting lupin kernel flour for wheat flour in bread (Lee et al. 2009). For lupin relative to control, the estimated mean (95% CI) net differences in protein, fiber, and carbohydrate intakes during the intervention were 13.7 g/day, 12.5 g/day and −19.9 g/day, respectively. Differences in systolic blood pressure, diastolic blood pressure, pulse pressure, and heart rate were −3.0 mm Hg, 0.6 mm Hg, −3.5 mm Hg and 0.0 beats/min. The results suggested that increasing protein and fiber in bread with lupin kernel flour may be a simple dietary approach to help reduce blood pressure and cardiovascular risk.

Bifidogenic Activity

In-vitro tests showed that oligosaccharides from lupin and pea are utilized by selected beneficial colon bacterium strains (Gulewicz et al. 2002). The in-vivo test demonstrated that α-galactosides from legume significantly influenced the growth of bifidobacteria in rats colon. α-galactosides from lupin and pea seeds were found to be essentially nontoxic. Their acute toxicity (LD_{50}) in mice was >4,000 mg/kg of body weight. α-Galactoside preparations were also not cytotoxic for mouse thymocytes in-vitro.

Allergic Protein

Conglutin β, a major storage protein, was identified by in-vitro IgE binding and mass spectrometry, to be an allergen in seeds of *Lupinus angustifolius* and *Lupinus albus* (Goggin et al. 2008). Purification of conglutin β from *L. angustifolius* flour confirmed that serum IgE bound to this protein. The *L. angustifolius* conglutin β allergen was designated Lup an 1 by the International Union of Immunological Societies (IUIS) allergen nomenclature subcommittee.

Other Uses

Blue lupin contributes distinctly to the maintenance of soil fertility and is often grown in rotation with cereals (Australia, South Africa) or maize (USA) and used as cover and green manure crop. It is used as grain and green forage crop, mainly for sheep, less so for cattle. In Australia, lupin is also utilised in production of protein-rich food rations for pigs (Gdala et al. 1996; King et al. 2000), poultry (Hughes and Kocher 1998), and as pet food. Studies demonstrated that the growth performance of pigs given diets with seeds of *L. luteus* and *L. angustifolius* was not different from that of pigs given the soybean diet, but pigs given the L. albus diet had a higher feed conversion ratio (Gdala et al. 1996). Seeds of *L. luteus* cultivar 'Cybis' and both cultivars of *L. angustifolius* were used at levels of up to 41 g/kg in diets without depression of growth performance as compared with soybean diet. Glencross et al. (2008) found that the inclusion of lupin kernel meal, at up to 30% of the diet, did not affect the ability of rainbow trout, *Oncorhynchus mykiss*, to utilize the dietary digestible protein and energy of diet in which it is included.

Comments

Currently, Western Australia has become the world's leading producer of lupin, accounting for about 80% of world production, and the only significant exporter of lupin grain.

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Mucuna pruriens

Scientific Name

***Mucuna pruriens* (L.) DC.**

Synonyms

Carpopogon atropurpureum Roxb., *Carpopogon niveum* Roxb., *Dolichos pruriens* L., *Marcanthus cochinchinensis* Lour, *Mucuna atropurpurea* sensu auct., *Mucuna axillaris* Baker, *Mucuna bernieriana* Baill., *Mucuna cochinchinensis* (Lour.) A.Chev., *Mucuna esquirolii* H. Lev., *Mucuna minima* Haines, *Mucuna nivea* (Roxb.) DC., *Mucuna prurita* Hook., *Mucuna prurita* (L.) Hook., *Stizolobium atropurpureum* (Roxb.) Kuntze, *Stizolobium pruriens* (L.) Medik., *Stizolobium pruritum* (Wight) Piper

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Banana Stock Pea, Bengal Bean, Bengal Velvet-Bean, Buffalo Bean, Cowage, Cowage Velvet-Bean, Cowhage, Cowitch, Florida Velvet Bean (USA), Lacuna Bean, Lyon Bean, Lyon's Bean, Mauritius Bean, Mauritius Velvet Bean, Velvet Bean, Yokohama Velvet Bean

Vernacular Names

Afrikaans: Fluweelboontje;
Argentina: Poroto Aterciopelado;
Chinese: Ci Mao Li Dou, Mao Dou, Gou Zhua Dou;
Danish: Fløjlsbønne, Floejlsboenne;
Dutch: Luweelboon;
Eastonian: Bengaali Rasvauba;
Finnish: Samettipapu;
French: Dolique De Floride, Haricot Veloute, Pois Velu, Pois Mascate;
German: Samtbohne;
India: Alkusi, Kaunch, Kavach, Makhmali Sem (Hindu), Nasuganni (Kannada), Atmagupta (Sanskrit), Punaikkali (Tamil), Dulagondi (Telugu), Alkushi (Urdu);
Italian: Fagiolo Vellutato, Stizolobia;
Japanese: Hasshou Mame;
Malay: Kacang Babi, Kacang Benguk, Kekara Juleh, Kara Benguk;
Mexico: Frijol Terciopelo;
Mozambique: Taingilotra (Malagasay);
Nepali: Kaocho;
Puerto Rico: Haba De Terciopelo;
Spanish: Judia Aterciopelada De Florida, Haba Terciopelo, Frijol Terciopelo, Guisante Negro, Ojo De Venado;
Thai: Cigu;
Vietnamese: Đậu Mèo.

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Origin/Distribution

Velvet bean is considered to have been domesticated in tropical Asia (eastern India) from its wild ancestral form, *Mucuna pruriens* (Tateishi 1987) and from southern China. It is now grown pan-tropically.

Agroecology

Velvet bean prefers a warm and humid climate with mean annual rainfall of 1,000–2,500 mm or more, but will in environments with an rainfall as low as 400 mm in altitudes from sea level to 1,600 m or higher. The plant exhibits better growth under warm, moist conditions and an altitude of less than 1,600 m (Buckles 1995). It thrives in the tropic and subtropics. The optimum temperature range is 19–27°C. It is susceptible to frost and moderately drought resistant and is intolerant to water-logging. It thrives best in full sun on well-drained medium to high fertility soils but can be grown successfully on sandy soils and will tolerate and be grown in a very wide soil acidity range of pH<5–8 but pH of 5–6.5 is preferred.

Edible Plant Parts and Uses

Velvet beans have been traditionally used as a food in a number of countries, viz., India, Philippines, Nigeria, Ghana, Brazil, and Malawi (Pugalenthi et al. 2005) and in Mexico and Guatemala (Buckles 1995). During the eighteenth and nineteenth centuries, Mucuna was grown widely as a green vegetable in the foothills and lower hills of the eastern Himalayas and in Mauritius (Piper and Tracy 1910; CSIR 1962). Both the green pods and the mature beans were boiled and eaten. Burkill (1966) suggested that Mucuna was eventually replaced as a vegetable in Asia by more palatable legumes, although it is still used as a famine food and as specialty food in north-eastern India (CSIR 1962). The use of *Mucuna* spp. as minor food crops has also been reported in Ghana (Osei-Bonsu et al. 1995), West Africa (Egounlety 2003), Mozambique (Infante et al. 1990), and Nigeria (Onweluzo and Eilittä 2003).

The immature pods and leaves are used as vegetables in southeast Asia; and in some parts of Asia, the seeds are roasted and eaten (Vadivel and Janardhanan 2000). In India, the North-eastern tribes and Kanikkas tribes of Kerala state consumed the beans as such or along with cereals (Siddhuraju et al. 2000; Janardhanan and Lakshmanan 1985). The Dravidian tribes in the Tirunelveli district, Tamil Nadu, have started cultivating it for use as a pulse (Janardhanan et al. 2003; Pugalenthi et al. 2005).

In Southern Ghana, the velvet beans are cultivated and consumed by the Ashanlis. To prepare a stew, Mucuna or Canavalia beans are boiled with chillies and onions (Osei-Bonsu et al. 1995). The seed coat and the water used in boiling are discarded and the remaining endosperm is ground into a fine paste along with the other ingredients. Salt and heated palm oil are then added to the paste and the dish is eaten with yam, plantain or cocoyam. Soups are also prepared by boiling mucuna or canavalia seeds with chillies and egg plants or cocoyam leaves (Osei-Bonsu et al. 1995). After discarding the seed coat of the legume and water used in boiling, a fine paste is prepared from the ingredients and dissolved in a soup made of onions, tomatoes, salt and meat or chicken. Soup in Ghana is eaten with *fufu*, a starchy food made of pounded cassava and plantain, cocoyam or yam. In Nigeria, various dishes are prepared with mature Mucuna beans such as sauce, soup, roasted snack, and gel in Enugu state and as soup, porridge, fried cake, *moi-moi, fufu* in Kogi state (Onweluzo and Eilittä 2003) In soups, the Mucuna flour is used as a thickener often mixed with or replaces *egusi*, a common thickener.

Mucuna tempe, Mucuna condiment and Mucuna-fortified weaning foods can be prepared by pre-treatment involving dehulling, soaking and boiling of the beans and fermentation with fungi or bacteria (Egounlety 2003). All the fermented products were found to contain contained very low

levels of L Dopa (often < 0.1% dry wt). Total crude protein remained fairly constant in all types of fermentations. Levels of soluble solids and soluble protein increased dramatically in fungal and basic fermentations. Non-protein nitrogen also followed the same trend.

Incorporation of defatted Mucuna seed flour at 15% replacement in wheat flour increased the protein content from 7.36 to 10.–11.26 g/100 g DM (Ezeagu et al. 2002). The overall acceptability of the mucuna biscuits were appreciable (60–62%). Level of L-Dopa in the biscuits were very low 60–63/100 g DM. Bunch (2002) added the velvet bean flour and prepared several new recipes like nutriflour, nutricafe, and nutrichocolate and noted that the people consuming these products did not have any side effect. In Latin America, Mucuna seeds have been roasted and ground to make a coffee substitute for decades and is widely known as nescafé for this reason (Buckles 1995). In Okinawa, the young pods are used as vegetables and the seeds are used to make "*kinton*" (sweet potato or yam paste with velvet bean) or "*ann*" (velvet bean jam) by soaking the seeds to remove the antinutrients and boiling.

Although velvet beans contain high levels of protein and carbohydrate, their utilization is limited due to the presence of a number of anti-nutritional/ anti-physiological compounds, phenolics, tannins, L-Dopa, lectins, protease inhibitors, etc., which may reduce the nutrient utilization (Eilittä et al. 2002; Pugalenthi et al. 2005). Another major reason for the low sustained interest in *Mucuna* is its low utilization as a food and feed and consequently, its lack of marketability for the beans although it has beneficial nutrient composition and good seed and forage yield (Eilittä et al. 2002).

Plate 1 Trifoliolate leaves and immature pods of velvet bean

Plate 2 Finely pubescent, velvety swollen, immature velvet bean pods

Botany

A vigorous twining herbaceous annual with slender pubescent stem reaching 6 m or more in length and well-nodulated flesh roots. Leaves are alternate with large, trifoliolate, rhomboid-ovate leaflets, acute-acuminate, thin, pubescent-gray below, 5–13 cm long, the lateral leaflets asymmetrical (Plate 1). Inflorescence axillary, long and pendulous, 15–35 cm, many-flowered, flowers pale purple or white, bisexual and papilionaceous. Bracts and bracteoles linear-lanceolate 6–9 mm, hairy, caducous. Calyx greyish-pubescent, calyx tube about 5 × 10 mm with deltoid lobes. Corolla deep purple or white; standard

1.6–2.5 cm, 1/2–2/3 of keel length; wings 2–4 × ca. 1.2 cm, shorter than or subequal to keel; keel 2.8–4.2(–4.5) cm. Legume linear-oblong usually more or less S-shaped, finely pubescent with white, grey to light brown soft hairs and slightly swollen around seeds or misshapen with irregular swellings around seeds, 5 to 9 × 1(–2) cm, about 5 mm thick (Plates 1-2). Pods contain up to 4–6 oblong-ellipsoid seeds, 1–1.9 cm long, 0.8–1.3 cm wide, 4–6.5 mm thick (Plates 1-2) and of variable colour (black, maroon, creamy, white, grey, beige, brown, brownish or black mottled), hilum (3–6 mm) surrounded by a prominent, cream-coloured aril.

Nutritive/Medicinal Properties

Proximate composition of *M. pruriens* var. *utilis* seeds in % was reported as follows: crude protein 31.44%, crude lipid 6.73%, crude fibre 5.16%, ash 4.11%, and crude carbohydrate 52.56% (Siddhuraju et al. 1996). Amino acid profile of *M. pruriens* var. *utilis* seeds in mg/100 g was reported by Siddhuraju et al. (1996) as: glutamic acid 17.23 mg, aspartic acid 8.16 mg, serine 4.10 mg, threonine 3.64 mg, alanine 2.2 mg, glycine 5.12 mg, valine 5.57 mg, cystine 0.84 mg, methionine 1.28 mg, isoleucine 4.12 mg, leucine 7.85 mg, tyrosine 4.76 mg, phenylalanine 3.85 mg, tryptophan 1.35 mg, lysine 6.60 mg, histidine 3.14 mg, argineine 7.16 mg; fattyacid g/100 g: total fatty acids 40.40 g, palmitic acid (16:0) 20.16 g, stearic acid (18:0) 3.84 g, arachidic acid (C20:0) 1.80 g, behenic acid (C22:0) 0.73 g, oleic acid (C18:1) 28.71 g, linoleic acid (C18:2) 37.41 g, linolenic acid (C18:3) 3.28 g.

In another study by Vadivel and Janardhanan (2000), the proximate composition of velvet bean seed (*Mucuna pruriens* var. *utilis*) was reported as follows: crude protein 20.2–29.3%, crude lipid 6.3–7.4%, total dietary fibre 8.7–10.5%, ash 3.3–5.5% and carbohydrates 49.9–61.2%. The energy level of the seed (1562–1597 kJ/100 g DM) was comparable with commonly consumed Indian pulses. Mineral profiles in mg/100 g seed flour were: sodium 43.1–150.1 mg, potassium 778.1–1846.0 mg, calcium 393.4–717.7 mg, magnesium 174.9–387.6 mg, phosphorus 98.4–592.1 mg, iron 10.8–15.0 mg, copper 0.9–2.2 mg, zinc, 5.0–10.9 mg and manganese 3.9–4.3 mg. The data on seed protein fractions revealed that the globulins constitute the major bulk of the seed protein as in most legumes. Velvet bean was found to contain relatively higher levels of all essential amino acids except threonine, leucine and lysine in black-coloured seed coat accessions and phenylalanine and tyrosine in white-coloured seed coat accession compared with the FAO/WHO requirement pattern. The in-vitro protein digestibility of the legumes under study ranged from 72.4% to 76.9%. Ravindran and Ravindran (1988) found the mature seeds of mucuna bean (*Mucuna utilis*) contained 264 g crude protein, 63 g crude fibre, 41 g crude fat, 37 g ash and 595 g carbohydrates/kg DM. The essential amino acid profile compared well with the FAO/WHO scoring pattern except for a deficiency of sulphur-containing amino acids. Mineral composition was similar to those reported for most tropical grain legumes. The in-vitro protein digestibility of raw and cooked beans were 71·5% and 80·3%, respectively.

The proximate composition of raw and differentially processed seeds of velvet bean (*Mucuna pruriens* var. *utilis)* per g/1,200 g DM was reported *by* (Vadivel and Pugalenthi 2007) as follows:

- Raw unprocessed seeds: moisture 8.4%, crude protein 27.3 g, crude lipid 6.06 g, crude fibre 9.7 g, ash 5.60 g, Nitrogen free extract 51.34%, energy 1,541 kJ;
- Soaked seeds: 6.7%, crude protein 27.0 g, crude lipid 5.71 g, crude fibre 9.6 g, ash 3.10 g, Nitrogen free extract 54.67%, energy 1,579 kJ;
- Cooked seeds: 7.10%, crude protein 27.53 g, crude lipid 6.01 g, crude fibre 9.62 g, ash 4.90 g, Nitrogen free extract 52.45%, energy 1,562 kJ;
- Autoclaved seeds: 7.90%, crude protein 28.50 g, crude lipid 6.23 g, crude fibre 9.68 g, ash 5.25 g, Nitrogen free extract 50.64%, energy 1,556 kJ;
- Roasted seeds: 7.50%, crude protein 26.50 g, crude lipid 5.92 g, crude fibre 9.64 g, ash 5.40 g, Nitrogen free extract 53.56%, energy 1,560 kJ.

The crude protein and lipid content of raw seeds (27.3% and 6%) were found to be higher when compared to certain common legumes such as *Cicer arietinum* (20.7% and 4.16%); *Vigna mungo* (23.6% and 0.45%); *Vigna radiata* (24.5% and 0.71%); *Vigna aconitifolia* (25.3% and 0.69%) and *Phaseolus vulgaris* (25.1% and 0.9%) (Bravo et al. 1999). The protein and lipid content of autoclaved seed samples (25.5% and 6.23%) were higher than the raw and other processed seeds (Siddhuraju and Becker 2005).

Mohan and Janardhanan (1995) reported that albumin and globulin fractions constituted the major bulk of seed proteins of *M. utilis*. Amino acid profiles of *M. utilis* (black seed coat sample) revealed that the seed proteins contained relatively higher levels of the sulpho-amino acid cystine. *M. utilis* also had high levels of other essential amino acids, isoleucine, tyrosine and phenylalanine and contained high concentrations of palmitic acid and linoleic acid. The antinutritional fatty acid, behenic acid, also was detected. The seeds were also high in minerals such as Na, P, Mg, Zn and Fe. Different germplasms of a white variety and black variety *Mucuna pruriens* var. *utilis* were found to have higher grain weight, density, hydration, and swelling capacity than other common legumes (Siddhuraju et al. 2000). The dehulled samples contained 303.2–335.5/g protein and 46.1–53.5 g/kg lipid, and these values were higher than the respective whole seeds. The levels of macro- and microelements in both whole and dehulled seeds were comparable to those in common pulses. All germplasms had high dietary fibre content (18–19.5%), made up of mainly insoluble dietary fibre. Seed lipids were high in unsaturated fatty acids (64.7–66.9%), specifically linoleic acid (48–49%). Whole and dehulled seeds of the white variety from Salem were particularly rich in sulfur-containing amino acids with significantly higher levels of in-vitro protein digestibility than the other two germplasms.

Vijayakumari et al. (2002) reported that the crude protein content of four different germplasm of the tribal pulse, *Mucuna utilis* viz, 'Keriparai', 'Myllaru', 'Thachanmalai' and 'Valanad' ranged from 20.21% to 29.63% and crude carbohydrates from 47.38% to 63.15%. Compared to recommended dietary allowances (RDA) the seeds of all the four germplasm contained more than adequate levels of Mg, Fe and Mn. Globulin appeared to be the predominant protein fraction in all the germplasm studied.

The heat-processed flour of velvet bean (*Mucuna pruriens* var *utilis*) was found to contain 6.8% moisture, 24.3% protein, 4.9% fat, 1.3% crude fibre, 3.5% ash and 61.2% carbohydrate (Ahenkora et al. 1999). The flour was rich in potassium (125 mg/100 g), zinc (9.8 mg/100 g) and phosphorus (361 mg/100 g). Differences in proximate and mineral composition of raw and heat-processed flours were not significant. The flours showed minimum protein solubility at pH 4.5 and formed reasonably stable emulsions and foams. Compared to raw flour, heat-processed flour had better water and fat absorption capacities, but lower protein solubility, emulsion and foam capacities. The flours showed potential for food product development.

Other Phytochemicals

Mwatseteza and Torto (2010) reported a total of 26 volatile compounds, mostly alkyl benzenes and polycyclic compounds in black, white, black–white, and yellow green *Mucuna pruriens* beans. The number of volatile compounds sampled, most notably alkylbenzenes, decreased with each hour of boiling and discarding of water extracts. As the beans approached being fully cooked, benzoic acid 2-hydroxy methyl ester was the most dominant compound in all the four types of beans.

M. pruriens seeds were found to have 5-indolic compounds, especially tryptamine and 5-hydroxytryptamine (5-HT) (Pant and Joshi 1970) and four alkaloids, mucunine, mucunadine, prurienine and prurieninine (Mehta and Majumdar 1994). The seeds of *Mucuna pruriens* afforded four 1,2,3,4 tetrahydroisoquinoline alkaloids out of which, two are new: (−)3-Carboxy-1,1-dimethyl-6,7-dihydroxy-1,2,3,4-tetrahydroisoquinoline (3), (−)3-Carboxy-1,1-dimethyl-7,8-dihydroxy-1,2,3,4-tetrahydroisoquinoline (4) (Misra and Wagner 2004).

Mucuna beans were found to also contain non-protein amino/imino acids, namely L-3,4-dihydroxyphenylalanine (L-dopa), L-3-carboxy-6,7-dihydroxy-1,2,3,4-tetrahydroisoquinoline (compound I), (−)-1-methyl-3-carboxy-6,7-dihydroxy-1,2,3,4-tetrahydroisoquinoline (compound II) and 5-hydroxytryptophan (5-HTP) (Siddhuraju and Becker 2003).

Mucuna pruriens var *utilis*, is a high value medicinal crop grown for its seeds to extract L-3,4-dihyroxy-phenylalanine (L-DOPA), a non-protein amino-acid which is used in treatment of Parkinson's disease (Mamatha et al. 2010). Evaluation of germplasm in Bangalore, India revealed that highest seed yield recorded in one line was 180.88 g/m^2 and the active principle L-DOPA contents varied from 4.11% to 6.61%. The contents of L-Dopa, L-3-carboxy-6,7-dihydroxy-1,2,3,4-tetrahydroisoquinoline and 1-methyl-3-carboxy-6,7-dihydroxy-1,2,3,4-tetrahydroisoquinoline were found to be significantly higher in whole and dehulled white variety than in the black variety of *Mucuna pruriens* var. *utilis* (Siddhuraju and Becker 2001c). Wu et al. (2009) found that the linear range of levodopa in *Mucuna pruriens* var. *utilis* was 26.45–132.25 μg/ml, and the average recovery rate of levodopa was 103.8%. Immature seeds of *Mucuna pruriens* var. *utilis* was found to contain maximum L-dopa content and mature leaves possessed maximum catalytic activity of tyrosine hydroxylase (Luthra and Singh 2010). Tyrosine hydroxylase, an iron containing tetrahydrobiopterin dependent monooxygenase (tyrosine 3-monooxygenase), catalyzes the rate-limiting step in which L-dopa is formed from the substrate L-tyrosine.

Some of the reported pharmacological properties of *Mucuna pruriens* are elaborated below.

Antioxidant Activity

The methanolic extract of mucuna beans (*Mucuna pruriens* var *utilis*) and several of its non-protein amino/imino acids, namely L-3,4-dihydroxyphenylalanine (L-dopa), L-3-carboxy-6,7-dihydroxy-1,2,3,4-tetrahydroisoquinoline (compound I), (−)-1-methyl-3-carboxy-6,7-dihydroxy-1,2,3,4-tetrahydroisoquinoline (compound II) and 5-hydroxytryptophan (5-HTP), exhibited excellent reducing power, with the highest values being recorded for L-dopa in a dose-dependent fashion (Siddhuraju and Becker 2003). Similarly, as compared with synthetic antioxidants, butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) and quercetin, all the tested compounds and the seed extract were found to be more potent in free radical-scavenging activity against α,α-diphenyl-β-picrylhydrazyl (DPPH) radicals. Hydroxyl radicals (OH) and superoxide anion radicals (O_2^-) were effectively quenched by the test compounds, with the exception that no scavenging activity of 5-HTP was observed on (O_2^-) up to a concentration of 2 mg/ml, as was also the case for BHA. Among the tested non-protein amino/imino acids and seed extract the highest peroxidation-inhibiting activity (95%) was recorded for 5-HTP. In contrast, in the linoleic acid/β-carotene-bleaching system, L-dopa, compound I and compound II acted as pro-oxidants, whereas the seed extract showed only weak antioxidant activity as in the linoleic acid emulsion system.

Tripathi and Upadhyay (2001) demonstrated the antioxidant activity of *M. pruriens* using in-vitro and in-vivo models. In-vitro study showed that *M. pruriens* possessed concentration-dependent protection against superoxide generation, hydroxyl radical production and $FeSO_4$-induced lipid peroxidation. In-vivo study showed significant inhibition in lipid peroxidation induced by alloxan and immobilized stress. They also showed that the alcoholic seed extract had an antilipid peroxidation property, which was mediated through the removal of superoxides and hydroxyl radicals (Tripathi and Upadhyay 2002). An in-vivo study on albino rats for 30 days showed no toxic effect up to a dose of 600 mg/kg body weight, on oral administration. There was no change in the level of TBA (thiobarbituric acid)-reactive substances, reduced glutathione content and superoxide dismutase (SOD) activity in the liver. The activity of serum glutamic-oxaloacetic transaminase (GOT),

glutamic-pyruvic transaminase (GPT) and alkaline phosphatase was also unchanged.

Rajeshwar et al. (2005b) found the methanol extract of *Mucuna pruriens* (MEMP) to have significant antioxidant activity. A 100 μg/ml of MEMP and BHT exhibited 90.16 and 93.98% inhibition, respectively, and the IC_{50} values were found to be 38.5 μg and 15 μg/ml for the extract and BHT respectively as measured by 1,1-diphenyl-2-picryl-hydrazyl (DPPH) radical. The effect of the extract on reducing power was studied according to the reaction of Fe^{3+} to Fe^{2+}. The reducing power of the extract increased with the increasing amount of the concentration. It was found that the extract contained 33.04 mg/g total polyphenolic content, which was significant when compared to gallic acid. The extract inhibited dose-dependently the nitric oxide (NO) and super oxide (SO) anions and hydrogen peroxide (H_2O_2) radical at IC_{50} values of 50 μg/ml, 210 μg/ml and 237.25 μg/ml against the corresponding standards curcumine (IC_{50} = 2.5 μg/ml), quercetin (IC_{50} = 155 μg/ml) and α-tocopherol (IC_{50} = 115 μg/ml).

Hypoglycaemic/Antidiabetic Activity

Mucuna pruriens seeds were shown to possess hypoglycaemic activity (Akhtar et al. 1990). Powdered seeds significantly lowered blood glucose level in normal and alloxan-diabetic rabbits at concentration of 0.5–2 g/kg and 1–2 g/kg respectively. The reference drug, acetohexamide in 500 mg/kg dose significantly reduced the blood glucose levels but in normal rabbits only. Grover et al. (2002) reported that *M. pruriens* was one of many plants that exhibited varying degree of hypoglycemic and anti-hyperglycemic activity. Grover et al. (2001) reported that treatment with *M. pruriens* significantly prevented the rise in urinary albumin levels from day 0 to 40 in comparison to diabetic controls but failed to modify renal hypertrophy. Maximum antihyperglycaemic effect was observed at week 6 with an alcohol extract of *M. pruriens* (MP) at a dose of 200 mg/kg/day (Rathi et al. 2002a). In chronic alloxan-diabetic rats, MP exhibited a decline of 40.71%, 45.63%, 50.33% and 51.01% in plasma glucose levels at 1, 2, 3 and 4 months, respectively. In chronic streptozotocin diabetic mice, MP exerted no significant effect. Rathi et al. (2002b) reported the protective effect of *Mucuna pruriens* in the prevention of murine alloxan diabetic cataract. Lyophilized aqueous extract of *M. pruriens* (200 mg/kg p.o.) decreased (40.17%) the incidence rate of cataract in treated groups along with a significant reduction in plasma glucose level. Herbal plant extract of *M. pruriens* was found to have blood glucose lowering effect within 2 weeks in alloxan diabetic albino rats (Kar et al. 2003). The presence of antidiabetic oligocyclitols, D-chiro-inositol and its two galacto-derivatives was demonstrated in *Mucuna pruriens* seeds (Donati et al. 2005). The quantities detected elucidated the well-established antiglycaemic effect of *Mucuna pruriens* seeds.

Bhaskar et al. (2008) demonstrated that in normal rats, the aqueous seed extract of *Mucuna pruriens* (100 and 200 mg/kg body weight) significantly reduced the blood glucose levels after an oral glucose load from 127.5 to 75.64.8 mg% 2 h after oral administration of the seed extract. It also significantly lowered the blood glucose in STZ diabetic rats from 240.5 to 90.6 mg% after 21 days of daily oral administration of the extract.

Dyskinesia Protective Activity

Ethanolic extract of *Mucuna pruriens* var. *utilis* at the dose level of 400 mg/kg was found to exert significant protective effect against haloperidol induced tardive dyskinesia as evaluated by vacuous chewing movements, tongue protrusions, transfer latency in elevated plus maze (Dhanasekaran et al. 2010). Significant elevation of antioxidant enzymes levels (SOD, CAT, GSH) was observed. The protective action of the extract was postulated to be due to its ability to increase the levels of antioxidant enzymes and to suppress lipid peroxidation. Haloperidol, a widely used neuroleptic for the treatment of psychosis was found to be limited by its tendency to produce a range of extrapyramidal movement disorders like

tardive dyskinesia (TD), akathisia, dystonia and Parkinsonism (Kane and Smith 1982). Studies showed that the methanolic extract of *M. pruriens* seeds prevented neuroleptic-induced tardive dyskinesia by virtue of its free radical scavenging activity (Pathan et al. 2010). The extract at 100 and 200 mg/kg inhibited haloperidol-induced vacuous chewing movements, orofacial bursts and biochemical changes. The extract also inhibited hydroxyl radical generation and DPPH.

Antiparkinsonian Activity

Traditionally, *M. pruriens* has been used as a nerve tonic for nervous system disorders including Parkinson's disease. Because of the high concentration of L-DOPA in the seeds, it had been studied for its possible use in Parkinson's disease in rats and humans (Vaidya et al. 1978a). The powdered seeds of *M. pruriens* with its high concentration of L-DOPA, had been reported to be clinically used for the management of Parkinson's disease and hyperprolactinaemia (Vaidya et al. 1978b). Hussain and Manyam (1997) found that dose for dose, *Mucuna pruriens* seeds (MPE) was more effective than L-DOPA in Parkinson's disease in rats. MPE showed twice the antiparkinsonian activity compared with synthetic L-DOPA in inducing contralateral rotation in the parkinsonian animal model. The results suggested that MPE may contain unidentified antiparkinsonian compounds in addition to L-DOPA, or it may have adjuvants that enhance the efficacy of L-DOPA. In later studies, eight Parkinson's disease patients with a short duration L-DOPA response and on period dyskinesias completed a randomised, controlled, double blind crossover trial wherein the patients were challenged with single doses of 200/50 mg LD/CD, and 15 and 30 g of Mucuna preparation in randomised order at weekly intervals (Katzenschlager et al. 2004). Compared with standard L-DOPA/carbidopa (LD/CD), the 30 g Mucuna preparation generated a considerably faster onset of effect (34.6 v 68.5 min), reflected in shorter latencies to peak L-DOPA plasma concentrations. The rapid onset of action and longer on time without concomitant increase in dyskinesias on Mucuna seed powder formulation suggested that this natural source of L-DOPA might possess advantages over conventional L-DOPA preparations in the long term.

An antiparkinson drug , HP-200, containing *Mucuna pruriens* endocarp, was shown to be more effective in the treatment of Parkinson's disease compared to synthetic levodopa in an animal model of Parkinson's disease (Manyam et al. 2004a). Oral administration of HP-200 had a significant effect on dopamine content in the cortex with no significant effect on levodopa, norepinephrine or dopamine, serotonin, and their metabolites – HVA, DOPAC and 5-HIAA in the nigrostriatal tract of the rat brain. The failure of *Mucuna pruriens* endocarp to significantly affect dopamine metabolism in the striatonigral tract along with its ability to improve Parkinsonian symptoms in the 6-hydorxydopamine animal model and humans may suggest that its antiparkinson effect may be due to components other than levodopa or that it had a levodopa enhancing effect. In another paper, *Mucuna pruriens* was found to possess significantly higher antiparkinson activity compared with levodopa in the 6-hydroxydopamine (6-OHDA) lesioned rat model of Parkinson's disease (Manyam et al. 2004b*). Mucuna pruriens* cotyledon powder significantly increased the brain mitochondrial complex-I activity but did not affect the total monoamine oxidase activity (in-vitro). Unlike synthetic levodopa treatment, *Mucuna pruriens* cotyledon powder treatment significantly restored the endogenous levodopa, dopamine, norepinephrine and serotonin content in the substantia nigra. Nicotine adenine dinucleotide (NADH) and coenzyme Q-10, that had been shown to have a therapeutic benefit in Parkinson's disease, were detected in the *Mucuna pruriens* cotyledon powder. Earlier studies showed that *Mucuna pruriens* treatment controlled the symptoms of Parkinson's disease. This additional finding of a neurorestorative benefit by *Mucuna pruriens* cotyledon powder on the degenerating dopaminergic neurons in the substantia nigra may be due to increased complex-I activity and the presence of NADH and coenzyme Q-10. Further studies suggested that the neuroprotective and neurorestorative effect of *Mucuna pruriens* might be related to its antioxidant activity independent of the symptomatic effect (Dhanasekaran et al. 2008). The antioxidant

activity of *Mucuna pruriens* was demonstrated by its ability to scavenge DPPH radicals, ABTS radicals and reactive oxygen species. *Mucuna pruriens* significantly inhibited the oxidation of lipids and deoxyribose sugar. *Mucuna pruriens* exhibited divalent iron chelating activity and did not show any genotoxic/mutagenic effect on the plasmid DNA indicating it to be therapeutically safe in the treatment of patients with Parkinson's disease.

The L-DOPA from *M. pruriens* seeds could be obtained in good yield on extraction with EtOH-H2O mixture (1:1) using ascorbic acid as protector (Misra and Wagner 2007). Interestingly, n-propanol extract, which contained negligible amount of L-DOPA, had shown significant neuroprotective activity, suggesting that some components, other than L-DOPA, might also be responsible for anti-Parkinson property of seeds. The extract (MW-0100) containing mainly amino acids and water-ethanol extract (1:1) (MWEL-1299) showed promising antioxidant activity (EC_{50} = 2.5 μg) against DPPH radicals. MWEL-1299 also exhibited encouraging results against 1-methyl-4-phenylpyridinium ion (MPP+) toxicity. A water extract of *Mucuna pruriens* was found to provide long-term amelioration of parkinsonism with reduced risk for dyskinesias (Lieu et al. 2010). Studies suggested that *M. pruriens* contained water-soluble ingredients that either had an intrinsic dopa-decarboxylase inhibitor (DDCI)-like activity or mitigated the need for an add-on DDCI to ameliorate parkinsonism. These unique long-term anti-parkinsonian effects of a parenterally administered water extract of *M. pruriens seed* powder may provide a platform for future drug discoveries and novel treatment strategies in PD.

The results of studies by Kasture et al., (2009) confirmed the antiparkinsonian effects of an extract of *Mucnua prureins* seeds known to contain, among other components, 12.5% L: -dihydroxyphenylalanine (L-DOPA), supporting traditional medicinal use of the plant in the treatment of Parkinson's disease. The results obtained revealed how an acute administration of *Mucuna pruriens* seed extract at a dose of 16 mg/kg (containing 2 mg/kg of L-DOPA) consistently antagonized the deficit in latency of step initiation and adjusting step. *Mucuna pruriens* significantly improved the placement of the forelimb in vibrissae-evoked forelimb placing, suggesting a significant antagonistic activity on both motor and sensory-motor deficits. *Mucuna pruriens* extract acutely induced a significantly higher contralateral turning behavior than L-DOPA (6 mg/kg) On subchronic administration, both *Mucuna pruriens* extract (48 mg/kg) and L-DOPA (6 mg/kg) induced sensitization of contralateral turning behavior; however, L-DOPA alone induced a concomitant sensitization in abnormal involuntary movements (AIMs) suggesting that the dyskinetic potential of *Mucuna pruriens* was lower than that of L -DOPA. *Mucuna pruriens* (48 mg/kg) was also effective in antagonizing tremulous jaw movements induced by tacrine, a validated test reproducing parkinsonian tremor.

Analgesic, Antipyretic and Antiinflammatory Activities

Alcohol extracts of leaf and fruit trichome of *Mucuna pruriens* were found to have analgesic and antipyretic activity (Iauk et al. 1993). The extracts when administered to rats by gavage increased the pain threshold and decrease body temperature, when pyrexia was induced by injecting a yeast suspension. The extracts also showed antiinflammatory activity, as they were able to inhibit carrageenin-induced edema. Hishikar et al. (1981) reported that the seeds of *M. pruriens* had antiinflammatory activity.

Antimicrobial Activity

The methanol extract of *Mucuna pruriens* seeds was found to have broad spectrum of antimicrobial activity against all the tested microorganisms except *Staphylococcus aureus* and *Vibrio cholera* (Rajeshwar et al. 2005b).

Sexual Behaviour Activity

The seeds of *M. pruriens* are widely used for treating male sexual dysfunction in Tibb-e-Unani (Unani Medicine), the traditional system of

medicine of Indo-Pakistani sub-continent (Amin et al. 1996). Amin et al. (1996), found that *M. pruriens* powdered seeds produced a striking and sustained increase of sexual activity in normal male rats which was observed by increase in mounting frequency, intromission frequency and ejaculation latency. The seeds of *M. pruriens* had been reported to contain L-dopamin; Guiliano and Allard (2001) reported that dopamine, a key neurotransmitter in the control of sexual function, could trigger penile erection by acting on oxytocinergic neurons located in the paraventricular nucleus of the hypothalamus, and perhaps on the pro-erectile sacral parasympathetic nucleus within the spinal cord. However, Rajendran et al. (1997) found that *M. pruriens* caused a decrease in sexual function in female rats. Treatment with *M. pruriens* seed powder was found to increase sperm concentration and motility in all the infertile men study groups (Ahmad et al. 2008). Oligozoospermic patients recovered sperm concentration significantly, but sperm motility was not restored to normal levels in asthenozoospermic men. Furthermore, in the seminal plasma of all the infertile groups, the levels of lipids, antioxidant vitamins, and corrected fructose were recovered after a decrease in lipid peroxides after treatment.

Treatment with *M. pruriens* seed powder was found to regulate steroidogenesis and improved semen quality in infertile men (Shukla et al. 2009). Decreased sperm count and motility, serum T (testosterone) and LH (luteinising hormone) levels, as well as seminal plasma and blood levels of dopamine, adrenaline, and noradrenaline were found to decrease in all groups of infertile men. This was accompanied by significantly increased serum FSH (follicle stimulating hormone) and prolactin levels in oligozoospermic subjects. Treatment with *M. pruriens* significantly improved T, LH, dopamine, adrenaline, and noradrenaline levels in infertile men and reduced levels of FSH and prolactin. Sperm count and motility were significantly recovered in infertile men after treatment. More recently, Shukla et al. (2010) found that treatment with *M. pruriens* significantly ameliorated psychological stress and seminal plasma lipid peroxide levels along with improved sperm count and motility. Treatment also restored the concentrations of SOD (superoxide dismutase), catalase, GSH (glutathione) and ascorbic acid in seminal plasma of infertile men. They concluded that *M. pruriens* not only reactivated the anti-oxidant defense system of infertile men but it also helped in the management of stress and improved semen quality.

The ethanolic extracts of *Mucuna pruriens* seeds produced a significant and sustained increase in the sexual activity of normal male rats at a particular dose (200 mg/kg) (Suresh et al. 2009). The extract administered per os significantly increased the mounting frequency, intromission frequency and ejaculation latency, and decreased the mounting latency, intromission latency, post-ejaculatory interval and inter-intromission interval. The potency test significantly increased erections, quick flips, long flips and total reflex. Suresh et al. (2009) reported that aged animals showed significant reduction in sperm count, viability and motility, increased morphological damage and an increase in the number of sperm with cytoplasmic remnant, and these alterations were significantly reversed in *M. pruriens* treated group. Supplementation of *M. pruriens* significantly reduced ROS and LPO production and significant increase in both enzymatic and non-enzymatic antioxidant levels. There were significant DNA damage, loss of chromosomal integrity and increase in mitochondrial membrane permeability in aged rat sperm. This was significantly reduced by *M. pruriens* treatment. The results indicated that *M. prureins* possessed antioxidant enhancing property, free radical quenching ability and spermatogenic efficacy. Collectively, sperm damage in ageing was significantly reduced by quenching ROS, improving antioxidant defence system and mitochondrial function. In more recent studies, Suresh and Prakash (2010) revealed the potential efficacy of ethanolic seed extract of *M. pruriens* to improve male sexual behavior with androgenic and antidiabetic effects in the streptozocin-induced diabetic male rats. Daily sperm production and levels of follicular stimulating hormone, luteinizing hormone, and testosterone were significantly reduced in streptozocin -induced dia-

betic rats, whereas the animals with diabetes administered with seed extract of *M. pruriens* showed significant improvement in sexual behavior, libido and potency, sperm parameters, daily sperm production and hormonal levels. This study supported the usage of *M. pruriens* in the Indian system of traditional medicine as sexual invigorator in diabetic condition.

Anticancer Activity

Gupta et al. (1997) reported the anti-neoplastic activity (60% protection) of methanol extract of *Mucuna pruriens* root in tumour bearing mice. In subsequent studies, the methanol extract of *Mucuna pruriens* seeds (MEMP) was found to exhibit significant antitumour and antioxidant effects in Ehrlich ascitic carcinoma (EAC) bearing mice (Rajeshwar et al. 2005a). Treatment with MEMP at a dose of 125 and 250 mg/kg increased the mean survival time to 29.5 and 34 days respectively. The extract also decreased the body weight of the EAC tumour bearing mice, significantly decreased RBC and increased WBC counts. MEMP treatment restored haemoglobin content to near normal levels and decreased the levels of lipid peroxidation and increased the levels of glutathione, superoxide dismutase and catalase.

Cognitive Behaviour Activity

Powdered seeds of *Mucuna pruriens* was found to have significant activity on learning skills and memory retrieval in Wistar male rats (Poornachandra et al. 2005). Results on memory retrieval, assessed on 17th day suggested an increase of 15% and 35% memory retrieval in animals that received extract only in memory retrieval session and animals that received extract during both in training and memory retrieval sessions respectively.

Antinutritional Factors

Two different germplasms of a white variety and one germplasm of a black variety of were evaluated for their physicochemical properties as well as their nutritional and anti-nutritional characteristics. Different germplasms of a white variety and black variety *Mucuna pruriens* var. *utilis* were found to have high levels of total phenols and phytate, trypsin, and chymotrypsin inhibitor activities, but were low in tannins, saponins, and α-amylase inhibitor activity (Siddhuraju et al. 2000). Only weak hemagglutinating activity against cow erythrocytes and no hemagglutinating activity against human erythrocytes (O) was observed in all the samples. Dehulled seeds were higher in total starch, including resistant starch and oligosaccharides (with verbascose as the major fraction) than the respective whole seeds. Both whole and dehulled samples of the white variety of Salem germplasm showed significantly lower concentrations of L-DOPA, nonmethylated, and methylated tetrahydroisoquinolines than the respective whole and dehulled samples of other germplasms. Vijayakumari et al. (2002) reported that the level of tannins was found to be negligible in the three germplasm of the tribal pulse, *Mucuna utilis* viz, 'Keriparai', 'Myllaru', 'Thachanmalai', and absent in 'Valanad' germplasm. Except 'Myllaru' germplasm, all the other germplasm strongly agglutinated the human erythrocytes from A, B and O groups without any specificity. In 'Thachanmalai' germplasm, albumin protein specifically agglutinated B and O blood groups erythrocytes. All the four different germplasm of *M. utilis* in the present study exhibited higher in-vitro protein digestibility (IVPD) than some of the commonly cultivated pulse crops.

Evaluation of five different accessions of *Mucuna pruriens* var. *utilis* revealed that the accession "Thachenmalai (black)" contained the highest levels of the anti-nutrients, total free phenolics, tannins, trypsin and chymotrypsin inhibitors, phytohaemagglutinins (lectins) (Gurumoorthi et al. 2003). Lower levels of phytohaemagglutinating activity for human erythrocytes of 'O' blood group than for 'A' and 'B' blood groups were found in all accessions. In-vitro protein digestibility (IVPD) ranged between 72.41% and 76.92%. IVPD of both the blackcoloured accessions (Thachenmalai and Valanad) registered lower values of 72.41% and 72.86%, respectively.

Raw mucuna (*Mucuna utilis*) seed samples were found to contain moderately high levels of anti-tryptic activity (2,170 trypsin units inhibited/g DM) (Ravindran and Ravindran 1988), but this was completely destroyed by cooking. They asserted that other antinutritional factors (phytate, cyanide and tannins) were probably of little nutritional significance provided that the beans were properly processed. In view of the high L-DOPA contents reported in some mucuna cultivars, they cautioned the overconsumption of mucuna beans unless suitable processing methods were developed. Vadivel and Janardhanan (2000), also found antinutritional substances like total free phenolics, tannins, L-DOPA, trypsin inhibitor activity and phytohaemagglutinating activity in velvet bean seed (*Mucuna pruriens* var. *utilis*). They asserted that the detected antinutritional factors probably had little nutritional significance if the beans were properly processed.

Soaking, cooking and autoclaving of *Mucuna pruriens* were found to affect the levels of certain antinutritional factors (Vijayakumari et al. 1996). The amount of reduction of total free phenolics was found to be greater in sodium bicarbonate solution (56%) compared to distilled water (47%); subjected to cooking and autoclaving these were further reduced to 49%. Autoclaving (45 min) significantly reduced the tannin content (71%). Insignificant reduction in content of L-DOPA was observed in all the processes. Distilled water soaking was found to be ineffective in eliminating lectin activity; whereas very significant reduction was noticed against all the human blood groups ABO without any specificity in samples subjected to cooking and autoclaving. Soaking in distilled water was more effective (27% reduction) than sodium bicarbonate solution (17% reduction) in lowering the contents of phytic acid. Cooking for 90 minutes and autoclaving for 45 minutes resulted in eliminating phytic acid to the extent of 18% and 44%, respectively. Loss of HCN was greater under autoclaving (75%) than the other processes studied. Of the three oligosaccharides analysed, soaking effected maximum reduction in the level of stachyose followed by verbascose and raffinose. Autoclaving effected greater reduction (59–81%) compared to ordinary cooking (40–60% reduction). Of all the different treatments studied, autoclaving seemed to be the best method in eliminating the investigated antinutrients more efficiently except L-DOPA. In *Mucuna pruriens*, verbascose has been considered as the main oligosaccharide responsible for flatus.

Cooking or autoclaving of both raw seeds and presoaked seeds of *Mucuna pruriens* var. *utilis* in different solutions (water, tamarind extract, sodium bicarbonate, and citric acid) were found to significantly reduce the content of total phenolics, phytic acid, trypsin inhibitor and chymotrypsin inhibitor activities, and L-DOPA compared to soaking or dry heating techniques (Siddhuraju and Becker 2001a). The germination processes (24 and 48 hours) were also effective in the reduction of various antinutrients, although this reduction appeared to be more pronounced in a prolonged period of germination (72 hours). Water soaking followed by dehusking was found to be ineffective in the reduction of trypsin and chymotrypsin inhibitor activities. All of the treatments were effective in significantly reducing the resistant starch content. Cooking as well as autoclaving brought about a more significant improvement in the digestibility of protein and starch compared to germination and dry heat treatment. Moreover, among the different processing techniques, soaking in sodium bicarbonate solution followed by cooking (29.6–34.8%) or autoclaving (33.0–37.2%) seemed to be the best method for improving starch digestibility. The various treatments also had varying effects on the levels of mono- and disaccharides and α-galactosides in two varieties of *Mucuna pruriens* var *utilis* (Siddhuraju and Becker 2001b). The levels of raffinose, stachyose and verbascose decreased under various treatments. Among the different soaking and cooking/autoclaving treatments, tamarind pulp extract soaking and sodium bicarbonate solution soaking followed by autoclaving procedures were the most effective for removing α-galactosides (68.4–70.9 and 68.5–68.9% respectively). The lowest reduction of α-galactosides (8.4–17.2%) was observed in dry-heated samples. Germination for more than

72 hours resulted in the highest reduction of total α-galactosides (93.6% and 89.6% in white and black varieties respectively). During the germination process, glucose, fructose and sucrose concentrations increased significantly.

Janardhanan et al. (2003) found that repeated boiling *M. pruriens* var. *utilis* seeds in water (seven times) resulted in the greatest reduction of L-DOPA and phytic acid (by 56–60% and 36–38%, respectively). Both autoclaving and crude α-galactosidase treatments were the most effective methods in reducing the levels of raffinose (reduction of 40–43%; 79–85%, respectively), stachyose (53–57% and 95–98%, respectively), and verbascose (52–54% and 82–83%, respectively).

Siddhuraju and Becker (2005) found that soaking *Mucuna pruriens* var. *utilis* seeds in different solutions, water, 0.07% sodium bicarbonate, 0.1% ascorbic acid and 3% Moringa leaf powder in water, followed by autoclaving, did not affect the proximate composition on gross energy value, but they significantly reduced the levels of various antinutrients, such as total phenolics, tannins, phytates, saponins, L-dopa, trypsin inhibitor (TI), chymotrypsin inhibitor (CI) and lectin activities of the respective samples. Nonetheless, all the processing methods improved the total protein digestibility and individual amino acid availabilities, particularly those of methionine, tyrosine, lysine and arginine, without affecting the protein quality. When compared to the raw seed sample, all the hydrothermal processing increased the total (TS) and digestible (DS) starch content (351–361 and 303–315 g/ kg, respectively) and decreased the resistant starch (RS) content (46.1–48.1 g/kg) significantly. The values of starch hydrolysis index (HI) and glycemic index (GI) were comparable to that of similarly processed legumes such as moth bean and black gram.

Various processing methods, namely soaking, cooking, autoclaving and roasting, all reduced the contents of antinutritional compounds (g/100 g DM) in *Mucuna pruriens* var. *utilis* seeds (Vadivel and Pugalenthi 2007) as follows:

Raw unprocessed seeds: total free phenolics 4.90 g, tannins 0.07 g, L-DOPA 6.33 g, phytic acid 0.93 g, raffinose 0.93 g, stachyose 1.20 g, verbascose 4.18 g, haemagglutinating activity 17.36 haemagglutinating unit (HU)/g sample, trypsin inhibitor activity 94 TIU/g sample, amylase inhibitors activity 5.10 AIU/g sample;

Soaked seeds: total free phenolics 3.53 g, tannins 0.05 g, L-DOPA 5.13 g, phytic acid 0.85 g, raffinose 0.82 g, stachyose 1.14 g, verbascose 3.18 g, haemagglutinating activity 15.36 haemagglutinating unit (HU)/g sample, trypsin inhibitor activity 76 TIU/g sample, amylase inhibitors activity 4.50 AIU/g sample;

Cooked seeds: total free phenolics 2.21 g, tannins 0.03 g, L-DOPA 3.87 g, phytic acid 0.45 g, raffinose 0.44 g, stachyose 0.64 g, verbascose 2.72 g, haemagglutinating activity 9.56 haemagglutinating unit (HU)/g sample, trypsin inhibitor activity 46 TIU/g sample, amylase inhibitors activity 2.20 AIU/g sample;

Autoclaved seeds: total free phenolics 0.92 g, tannins 0.01 g, L-DOPA 1.31 g, phytic acid 0.21 g, raffinose 0.21 g, stachyose 0.32 g, verbascose 1.03 g, haemagglutinating activity 5.36 haemagglutinating unit (HU)/g sample, trypsin inhibitor activity 26 TIU/g sample, amylase inhibitors activity 1.10 AIU/g sample;

Roasted seeds: total free phenolics 2.34 g, tannins 0.03 g, L-DOPA 3.15 g, phytic acid 0.81 g, raffinose 0.61 g, stachyose 0.85 g, verbascose 3.64 g, haemagglutinating activity 14.58 haemagglutinating unit (HU)/g sample, trypsin inhibitor activity 71 TIU/g sample, amylase inhibitors activity 2.90 AIU/g sample. Among the various processing methods employed, the autoclaving was found to significantly reduce the maximum levels of various antinutritional substances such as total free phenolics (81%), tannins (76%), L-DOPA (79%), phytic acid (77%), oligosaccharides like raffinose (77%), stachyose (73%) and verbascose (75%), haemagglutinating activity (69%), trypsin inhibitor activity (72%) and amylase inhibitor activity (78%) (Vadivel and Pugalenthi 2007).

Diallo and Berhe (2003) reported that recipes of *Mucuna* food had lower concentrations of L-DOPA (<1%) as a result of was removal by

soaking the seeds for a minimum of 48 h with a change of fresh water every 12 h and that they were used in conjunction with other food ingredients. They recommended two ways for reducing the level of L-DOPA in Mucuna beans: (1) cracking the seeds and soaking them in running water (from a faucet) for 36 h and (2) putting Mucuna beans in a cloth bag and leaving them immersed in a flowing river for 3 days. Velvet bean (*Mucuna pruriens* var *utilis*) was pretreated and subjected to fungal or bacterial fermentation to produce three foods, namely Mucuna tempe, Mucuna condiment and Mucuna-fortified weaning foods (Egounlety 2003). Total crude protein remained fairly constant in all types of fermentations. Levels of soluble solids and soluble protein increased dramatically in fungal and basic fermentations. Non-protein nitrogen followed the same trend. pH increased in mould and basic fermentations while it decreased in lactic acid fermentation. Pretreatment of the bean before fermentation was found to provide the most effective means of reducing L-DOPA in velvet bean. In the treatment that reduced about 90% (89.95%) of L-DOPA, the beans were boiled for 45 min, dehulled, soaked for 12 or 24 hours with removal and replacement of water after 12 hours, and then boiled in fresh water for an additional 45 minutes. Further reduction was obtained during fungal fermentation, suggesting the production of an L-DOPA-degrading enzyme. All the fermented products contained low levels of LDopa (often <0.1% dry wt). Production of Mucuna tempe and Mucuna-fortified weaning foods was recommended at household level as a way to alleviate protein-energy malnutrition.

Soaking velvet beans in 0.2% sodium bicarbonate solution plus autoclaving treatment caused a substantial reduction on the levels of various antinutritional compounds such as tannins (84%), L: -Dopa (79%), phytic acid (87%), raffinose (93%), stachyose (83%), verbascose (73%), haemagglutinating activity (84%), trypsin inhibitor activity (77%), and α-amylase inhibitor activity (78%) without affecting the nutritional quality (Vadivel and Pugalenthi 2010). Velvet beans was found to contain appreciable levels of crude protein (273.2 g/kg DM), lipid (60.61 g/kg DM), neutral detergent fiber (84.3 g/kg DM), and ash content (56.04 g/kg DM).

Antivenom Activity

Aqueous leaf extract *Mucuna pruriens* var. *utilis* was found to exhibit a dose related ability to prolong the time taken to clot for blood treated with a standardised dose of the venom of the snake, *Echis carinatus* (Houghton ad Skari 1994). The anti-venom activity had been studied extensively by Guerranti et al. (2001, 2002, 2004, 2008). *Echis carinatus* venom (EV) was found to contain a mixture of proteins that affected the coagulative cascade, causing severe bleeding and haemorrhage. *M. pruriens* seed extract was found to significantly inhibit the lethal venom induced myotoxic, cytotoxic and coagulation activities in experimental animals. An increase in procoagulant activity was found with the extract in prothrombin activation by EV in-vitro by clotting and chromogenic assay The antivenom property of water extract of *M. pruriens* seeds was assessed in-vivo in mice and tested for its immunological properties. Two proteins of *Echis carinatus* venom with apparent molecular masses of 25 and 16 kDa were detected. Of the immunoreactive venom proteins, phospholipase A(2,) the most toxic enzyme of snake venom, was identified. The results demonstrated that the observed antivenin activity had an immune mechanism. Antibodies of mice treated with non-lethal doses of venom reacted against some proteins of *M. pruriens* extract (MPE). The antisnake venom properties of a *Mucuna pruriens* seed extract (MPE) were tested its in vivo efficacy against *Echis carinatus* venom (EV) in short- (1 injection) and long-term (three weekly injections) treatments. The most significant changes with the treatment were: albumin, haptoglobin, fibrinogen, serum amyloid A and serum amyloid P. Most of these changes were explained by EV effects on coagulation, inflammation and haemolysis. The plasma of challenged mice showed substantial

proteomic modifications. This suggested the mechanism of MPE protection involved the activation of counterbalancing processes to compensate for the imbalances caused by the snake venom.

Tan et al. (2009) found that rats pre-treated with *Mucuna pruriens* seed extract (MPE) conferred effective protection against lethality of *Naja sputatrix* venom and moderate protection against *Calloselasma rhodostoma* venom. Indirect ELISA and immunoblotting studies showed that there were extensive cross-reactions between anti-MPE IgG and venoms from many different genera of poisonous snakes, suggesting the involvement of immunological neutralization in the protective effect of MPE pre-treatment against snake venom poisoning. In vitro neutralization experiments showed that the anti-MPE antibodies effectively neutralized the lethalities of Asiatic cobra (Naja) venoms, but were not very effective against other venoms tested. Results of studies by Fung et al. (2009) suggested that *M. pruriens* seed extract pre-treatment protected rat heart and liver blood vessels against *Naja sputatrix* (Malayan cobra) venom-induced damages.

Hallucinogenic Activity

The presence of hallucinogenic indoles (e.g. *N*-*N*-dimethyltryptamine, bufotenine, serotonin), the major antinutritional compounds in *Mucuna* apart from L-DOPA had been reported in all parts of *Mucuna pruriens* (pods, seeds, leaves and roots) (Ghosal et al. 1971). As such, it could potentially have psychedelic effects; it had purportedly been used in ayahuasca (psychoactive) preparations.

Antidepressant Activity

Mucuna pruriens seeds have also been found to have antidepressant properties in cases of depressive neurosis when consumed. Studies in India reported that the herb increased the level of dopamine, serotonin and other catecholamines in the brain and body to the extent that it induced mood elevation and relieved depression (Khare 2004).

Pruritic and Nociceptive Activity

The trichomes (spicules) of a pod of cowhage (*Mucuna pruriens*) are known to elicit a histamine-independent itch that is mediated by a cysteine protease (LaMotte et al. 2009). They reported that the tip of a single spicule applied to the forearm of 45 subjects typically evoked (1) itch associated with nociceptive sensations of pricking/stinging and, less commonly, burning, and (2) one or more areas of cutaneous dysesthesia marked by hyperknesis (enhanced itch to pricking) with or without alloknesis (itch to stroking) and/or hyperalgesia (enhanced pricking pain). They postulated that there may be separate neural coding mechanisms for itch, nociceptive sensations, and each type of dysesthesia.

Traditional Medicinal Uses

Various parts of *M. pruriens* have been used in traditional medicine (CSIR 1962; Burkill 1966; Nadkarni 2001; Khare 2004; Sathiyanarayanan and Arulmozhi 2007). Seeds are astringent, laxative, anthelmintic, aphrodisiac, alexipharmic and tonic. In Indian Ayurvedic medicine, the seeds have been used as a vermifuge, snake bite, dysentery, diarrhea, cough, dysmenorrhea, diabetes, tuberculosis, sexual debility, impotence, rheumatic disorders, muscular pain, gonorrhea, sterility, gout, delirium, general debility, vitiated conditions of vata and cancer. In Ayurvedic system of medicine, *M. utilis* has been used for the management of male infertility and nervous disorders. Seed powder being high in levodopa has been employed for Parkinson disease. In India boiled seeds have been used as an aphrodisiac, nerve tonic, diuretic, emmenagogue, uterine stimulant, and blood purifier. In Brazil, the seeds have been used internally for Parkinson's disease, edema, impotence, intestinal gas, and worms. Externally it is applied to ulcers.

The trichomes on the pods and flowers have been used as vermifuge. The leaves are also used as aphrodisiac, anthelmintic, tonic and are useful in general debility, ulcers, inflammation and cephalalgia. The root is bitter, emmenagogue, anthelmintic, febrifuge, thermogenic, emolient, stimulant, purgative, aphrodisiac, diuretic and tonic. They are useful in vitiated conditions of vata and pitta in Ayurveda. Decoctions of roots are used in Ayurverdic for constipation, strangury, dysmenorrhoea, nephropathy, elephantiasis, dropsy, neuropathy, amenorrhoea, consumption, ulcers, fever and delirium.

Other Uses

M. pruriens is used as a green manure, fodder fallow crop and cover crop. In Eastern and southern Africa, it is being used as a green manure and fodder in cut-and-carry systems. In Vietnam and Benin in Africa, it is being used as a cover crop to control *Imperata cylindrica.* In Central America, it is being used as a really-sown fallow crop 45 days after maize. There are also successful examples of zero-tillage maize- planting into dead Mucuna cover. The plant is also being used as forage, silage and hay and the seeds used for concentrate feed. Recently, velvet beans are exploited as a protein source in the diets of fish, poultry, pig, and cattle after subjected to appropriate processing methods to remove anti-nutritional factors (Pugalenti et al. 2005).

Studies showed that replacement of soybean meal protein up to 40% level, corresponding to the inclusion of processed velvet bean meal up to 15.7% and 11% in the starter and finisher phase poultry feeds, respectively, elicited better growth performance of broiler birds without any adverse effects (Vadivel and Pugalenthi 2010). Velvet bean was processed by soaking in sodium bicarbonate and autoclaving to remove anti-nutrients.

Comments

The hairs inside the legume pods and the small spicules on the leaves can cause severe itching when touch.

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Parkia speciosa

Scientific Name

***Parkia speciosa* Hassk.**

Synonyms

Inga pyriformis Jungh., *Mimosa pedunculata* Hunter, *Parkia biglobosa* sensu auct., *Parkia brunonis* R. Grah. ex Wall., *Parkia harbesonii* Elmer, *Parkia macrocarpa* Miq., *Parkia roxburghii* G. Don (Mansf), *Parkia speciosa* hort. ex Hassk.

Family

Fabaceae, also placed in Leguminosae, Mimosaceae

Common/English Names

Bitter Bean, Petai Bean, Stink Bean, Twisted Cluster Bean

Vernacular Names

Dutch: Stinkboon;
India: Yongchak (Manipur);
Indonesia: Petai Papan, Pete, Sindutan (Javanese), Kundai, Patak (Dyak, Tinggalan, Kalimantan), Petah (Busang, Kenya, Kalimantan), petai (Katingan, Sampit, Kalimantan), Nuep (Kalimantan), Petai, Pete (Malay), Petteh (Madurese), Petej , Petej Pare, Petej gede, Sigobang (Sundanese);
Japanese: Nejire Fusamame, Nejire Fusa Mame No Ki;
Malaysia: Chou Dou (Cantonese), Nyiring, Patag, Patai, Petah, Petai;
Thailand: Nitta, Sator, Sator Dan, Sator Kow, To Dan, To Khao;
Philippines: U'pang (Tagalog).

Origin/Distribution

Petai is native to the Malayan Peninsula, Indonesia, and Borneo (Sarawak); growing wild in lowland forests, often cultivated in Malay kampongs.

Agroecology

The tree occurs wild in scattered lowland primary rainforests and sometimes also in tall secondary forest, on sandy, loamy and podzolic soils and on riverbanks from near sea-level to 1,400 m elevation. It also grow in waterlogged locations such as freshwater swamp forest but thrives best on well-drained loamy or clay-loam soils in areas with mean annual temperature of about 24°C and mean annual rainfall of 1,000–2,000 mm evenly distributed throughout the year.

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Edible Plant Parts and Uses

Petai is popularly eaten in Myanmar, Thailand, Malaysia, Indonesia and north-eastern India. Part of the sprouts and of the thickened inflorescence stalks, young feathery leaves, young fruit pods and seeds are eaten raw or roasted and cooked as vegetable as well. The seeds are eaten raw, blanched and sometimes mix with ingredients like dried shrimps, garlic, chilli and belacan in a dish called *sambal petai* or used in stir-fries, salad, soup, curry (e.g. Thai green duck curry) and in other hot spicy dishes. Seeds have a pungent garlic odour. They taste good in a sweet-and-sour stir-fry. In North-eastern India, the seeds or the bean as a whole are eaten in a local delicacy call *Iromba* (dish made from fermented fish) or *Yongchak singju* (type of vegetable salad). In Thailand, the seeds are also sometimes roasted and eaten with *Nam Prik* (a type of spicy paste), they are also fried with currypaste mixed with shrimp or pork or are made into pickles. Seeds are also dried and seasoned for later consumption. When dried the seeds turn black. Petai seeds are exported to other countries in cans or bottle jars, pickled in brine. Young flat fruit pods with undeveloped seeds can be eaten raw, fried or pickled. Half-ripe pods are usually pickled in salt.

Plate 1 Developing inflorescence heads of Petai

Plate 2 Compound leaves and pendulous inflorescence head

Botany

The tree is erect and evergreen growing up to 15–40 m in height with a 50–100 cm diameter stem. Branchlets are pubescent. Leaves are alternate, bipinnate on 2–6 cm long stalks with gland above the stalk base. Pinnae 10–19 pairs, 5–9 cm long, each with 31–38 pairs of opposite, linear pinnules, 5–9 mm long and about 2 mm wide, with rounded tip and small pointed asymmetric lobe at the base (Plate 2). Flowers numerous, small and creamy white to brown-yellow, are found in densely crowded pear-shaped, pendulous inflorescence heads – asexual or male at the base and female at the apex (Plates 1–3). The calyx and corolla are tubular and 5 lobed, stamens (staminodes) are 10 with filaments united at the base into a tube. The flowers produce a great deal of nectar and have a strong, somewhat sickly smell. They are pollinated by bats and only the apical flowers develop fruits. Pods are large, 35–55 cm long and 3–5 cm wide, straight

Plate 3 Close-up of inflorescence head of Petai

Plate 4 Pendulous bunch of twisted Petai pods

Plate 5 Petai pods on sale in the local market

or more commonly twisted; hanging in small bundles of 6–10, green becoming black when they ripen (Plates 4–6). Each pod contains 10–18 large, soft-testa, green, broadly ovoid seeds (Plate 6).

Plate 6 Petai pods and seeds

Nutritive/Medicinal Properties

Proximate composition of raw seeds of *Parkia speciosa* (per 100 g edible portion) (Tee et al. 1997) was reported as follows: moisture 69%, energy 124 kcal, carbohydrates 16.9 g, fat 1.8 g, protein 10 g, fibre 1 g, ash 1.3 g, Ca 126 mg, P 3 mg, Fe3.4 mg, Na 11 mg, K 376 mg, carotene 151ug, vitamin B1, 0.15 mg, vitamin B2 0.2 mg, niacin 0.5 mg, and vitamin C 32.7 mg.

Petai is very rich in plant protein and minerals especially K, Na, Fe and Ca. It also has a good amount of vitamin C.

Other Phytochemicals

Seventy-seven chemical compounds were found in fresh petai seeds/beans and the constituents were dominated by hydrogen sulfide, ethanol and 1,2,4-trithiolane, propanoic acid and 3, 3′-thiobis – didodecyl ester (Salman et al. 2006). Other major compounds included linoleic acid chloride, palmitic acid, linoleic acid, myristic acid, arachidonic acid, undecanoic acid and 2-Hexyl-1-decanol. Terpenoids compounds of ß-sitosterol and squalene and others such as stigmasterol, lupeol and campesterol were also indentified. Cyclic polysulphides were the major components of cooked petai (Frerot et al. 2008). New sulphur minor compounds 1,3-dithiabutane, 2,4-dithiapentane, 2,3,5-trithiahexane and 2,4,6-trithiaheptane were also identified. These linear

polysulphides were found to have an important contribution to the flavour of cooked petai beans. The main constituents of petai volatile oil were found to be 1,2,4-trithiolane, 1,3,5- trithiane and 3,5-dimethyl-1,2,4-trithiolane (Osman et al. 2000). Peati contained low levels of antinutrients such as tannins, trypsin inhibitors and hemagglutin (Suhaila et al. 1987).

Some reported pharmacological properties of petai are elaborated below.

Antioxidant Activity

Using response surface methodology, a high alcohol insoluble polysaccharide (AIPS) yield of 17–18% with high uronic acid content (97–99 mg/g) and antioxidant property (48–50% DPPH) was obtained from *Parkia speciosa* pods (Gan et al. 2010). Gan and Latiff (2011) also found the pods to have high total phenolic and flavonoid contents and high antioxidant activities. Response surface methodology yielded total phenolic contents of 664–668 mg gallic acid equivalents/100 g, total flavonoid contents of 47.4–49.6 mg pyrocatechol equivalents/100 g, $DPPH_{sc}$ of 81.2–82.1%, $ABTS_{sc}$ of 78.2–79.8% and FRAP values of 3.2–3.3 mM. In separate studies, Razab and Abdul-Aziz (2010) found that the shoots and fruits had high polyphenolic contents (>150 μg gallic acid equivalents/mg dried plant) and high antioxidant activities when measured using the ferric reducing antioxidant power (FRAP) (>1.2 mM) and Trolox equivalent antioxidant capacity (TEAC) assays (>2.4 mM). A strong correlation was observed between the two antioxidant assays (FRAP versus TEAC) implying that the plant could both scavenge free radicals and reduce oxidants. There was also a strong correlation between the antioxidant activities and polyphenolic content.

Mitogenic and Anti-proliferative Activity

Petai seed also contained lectins which exhibited mitogenic and anti-proliferative activity (Kaur et al. 2005). The mitogenic activity of the lectin was comparable to those of known T-cell mitogens (concanavalin A, phytohaemagglutinin, pokeweed mitogen). The petai seed lectins showed anti-proliferative effect on two murine macrophage cancer cell lines i.e. P 388DI (50%) and J774 (70%). Additionally, petai lectin also inhibited proliferation of HB98 (65.47%), a B-cell hybridoma cell line.

The lectin from *Parkia speciosa* seeds displayed mitogenic activity (Suvachittanont and Jaranchavanapet 2000). The lectin enhanced the incorporation of [3H]thymidine into DNA of human lymphocytes. The activity of the lectin increased as its concentration was increased and then declined once the concentration passed an optimum point. The mitogenic activity of the lectin was comparable to those of the known T-cell mitogens, such as concanavalin A, phytohaemagglutinin, and pokeweed mitogen. Only slightly less responsiveness was observed in the case of lymphocytes from esophageal cancer compared to lymphocytes from normal donors. The seeds also contained thioproline, an effective nitrite-trapping agent in the human body (Suvachittanont et al. 1996). Thioproline levels in petai seeds increased after cooking. Uncooked petai seeds contained substantial amounts of formaldehyde and thiol compounds and the amounts decreased after boiling.

Hypoglycaemic Activity

Administration of protein extracts of *Parkia speciosa* seeds to alloxan induced diabetic rats daily for 2 weeks decreased blood glucose level compared to unfed animals (Suvachittanont and Pothiruckit 1988). Laxative effect of the seeds was also evident. Firstly, rats fed with homogenized seeds had softer stool than those of control. Secondly, proteins extracted from the seeds stimulated rat duodenum contraction in-vitro. The oral administration of the chloroform extract of *Parkia speciosa* seeds to alloxan-induced diabetic rats produced a significant decrease in blood glucose levels (Fathaiyajamal and Suhaila 1993). The hypoglycemic activity of the extract reached a maximum 2–5 hours

after oral administration of the extract and lasted for at least 24 hours. Separate studies showed that the hypoglycaemic (reducing blood sugar level) effect of *Parkia speciosa* seeds were due to the synergistic action of β-sitosterol and stigmasterol (Jamaluddin et al. 1994). Oral administration of the chloroform extracts of petai seeds to alloxan-induced diabetic rats produced a significant decrease in blood glucose levels. The minimum effective dose which produced statistically significant hypoglycaemic effect was 25 mg seeds/kg BW. When tested individually β-sitosterol and stigmasterol showed no hypoglycaemic effects, indicating that synergism between β-sitosterol and stigmasterol was necessary to effectuate the hypoglycaemic activity.

Haemagglutinating Activity

Proteins extracted from *Parkia speciosa* seeds were found to have haemagglutinating activity (Chankhamjon et al. 2010) The protein Gj, which was identified as a protein similar to putative aristolochene synthase, 3′-partial from *Oryza sativa* (Poaceae), had haemagglutinating activity of 0.39 μg/μl. Another protein fraction C2 had haemagglutinating activity of 1.17 μg/μl. Using gel electrophoresis, two proteins C2a and C2b were separated, having molecular weights of 45 kDa and 23 kDa, respectively. C2a was found to be similar to the hypothetical protein B1342F01.11 from *Oryza sativa*, and C2b was similar to the hypothetical protein At1g51560 from *Arabidopsis thaliana* (Brassicaceae).

Antimicrobial Activity

Five polysulphides 1,2,4-trithiolane; 1,2,4,6-tetrathiepane; 1,2,3,5,6-pentathiepane (lenthionine); 1,2,4,5,7,8-hexathionane and 1,2,4,6,7- or 1,2,4,5,7-pentathiocane were isolated from *Parkia speciosa* and found to have antimicrobial activity (Gmelin et al. 1981) . Dichrostachinic acid, djenkolic acid and thiozolidine4-carboxylic acid were also identified (Holzman et al. 1982).

Adverse Effects

Petai seeds contain djenkolic acid which has been known to cause blockage of the urinary tubules due to its low solubility, resulting in pain, haematuria and even death (Suhaila et al. 1987). *P. speciosa* seeds also contain significant minerals, vitamins, protein and fat, while having a lower antinutrient content compared to soya bean (Suhaila et al. 1987). The use of moist heat to reduce the amount of trypsin inhibitor and hemagglutinin was more effective than dry heat, and germination of seeds was more effective than fermentation with *Rhizopus oligosporus.* The magnitude of reduction in trypsin inhibitor activity and hemagglutinin depended on the time and temperature of treatment.

Traditional Medicinal Uses

In southeast Asia, the seeds have been employed traditionally for the treatment of diabetes, scabies, oedema, high blood pressure, inflammation of kidneys, cancer, hepatalgia, nephritis, colic, cholera and as an anthelmintic to expel worms. The seeds are also applied externally to wounds. The seeds are also valued as a carminative.

Other Uses

The wood is used in the manufacture of paper. The tree yields a usually lightweight, occasionally medium-weight hardwood which is used in the manufacture of cabinet work and boxes. It is sometimes planted as a shade tree, for example, for coffee plantations and in nurseries.

Comments

Petai is propagated from seeds and removal of the seed coat will hasten and improve germination.

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Phaseolus lunatus

Scientific Name

***Phaseolus lunatus* L.**

Synonyms

Phaseolus amazonicus Benth., *Phaseolus bipunctatus* Jacq., *Phaseolus derasus* Schrank, *Phaseolus falcatus* Benth. ex Hemsl., nom. nud., *Phaseolus foecundus* Macf., *Phaseolus ilocanus* Blanco, *Phaseolus inamoenus* L., *Phaseolus latisiliquus* Macf., *Phaseolus limensis* Macfad., *Phaseolus lunatus* L. (Gran Lima Group), *Phaseolus lunatus* L. (cultigroup Big Lima), *Phaseolus lunatus* var. *macrocarpus* Benth.

Phaseolus lunatus var. *lunatus, Phaseolus lunatus* var. *macrocarpus* (Moench) Benth., *Phaseolus lunatus* var. *silvester* Baudet, *Phaseolus macrocarpus* Moench, *Phaseolus maximus* Roxb., *Phaseolus parviflorus* Stokes, *Phaseolus platyspermus* Haberle ex Steud., *Phaseolus puberulus* H.B.K., *Phaseolus rufus* Jacq., *Phaseolus saccharatus* Macf., *Phaseolus saccharatus* Stokes, *Phaseolus tunkinensis* Lour., *Phaseolus vexillatus* Blanco, *Phaseolus viridis* Piper, *Phaseolus xuarezii* Zucc.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Burma Bean, Butter Bean, Civet Bean, Duffin Bean, Guffin Bean, Haba, Haricot Bean, Hibbert Bean, Java Bean, Large Lima Bean, Large White Bean, Lima Bean, Madagascar Bean, Pallar Bean, Prolific Bean, Rangoon Bean, Sieva Bean, Sugar Bean

Vernacular Names

Argentina: Frijol De Lima, Frijol De Luna, Frijol Lima, Frijol Manteca, Poroto Manteca;
Bolivia: Palato;
Brazil: Fava-Belém, Feijão-Fava;
Burmese: Htawbat Pe, Kal Beir Kan, Kawl Be, Pe Bra, Pe Byu Gyi, Pe Gya, Santagu Pe, Tim Sin, Tunoran;
Chinese: Cai Dou, Choi Dáu, Da Li Cai Dou, Jin Dou, Li Ma Dou, Ling Dou, Long Ya Dou, Mian Dou, Xue Dou, Yu Dou;
Columbia: Torta;
Czech: Fazol Barmský, Fazol Měsíční;
Danish: Limabřnne, Månebønne, Mĺnebřnne, Sukkerbřnne;
Dutch: Indische Maanboon, Lima-Boon;
Eastonian: Liima Aeduba;
Ecuador: Garrofó, Haba Pallar;
Fijian: Pini;
French: Fève Créole, Haricot De Lima, Haricot Du Cap, Haricot Lima Ŕ Gros Grains, Haricot De Madagascar, Haricot Lima Ŕ Gros Grains,

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Haricot De Madagascar, Pois De Sept Ans, Pois De Java, Pois Du Cap, Pois Souche;
Gambia: Sσso (Manding-Maninka);
German: Indische Mondbohne, Limabohne, Mondbohne;
Guinea: Sσso, Tubabu Sσso (Manding-Maninka), Togué (Susu);
Guinea-Bissau: Fidjom Faba (Crioulo);
Honduras: Alubia De Lima, Chilipuca, Chilipuco, Fríjol Chilipuca, Frijol Mantequilla, Fríjol Reina, Frijol Viterra, Judía De Lima, Judía De Manteca, Judía Limeńa;
India: Sem (Hindu);
Indonesia: Kacang Kara, Kara, Kekara, Kratok (Java), Kacang Mas, Roway (Sundanese);
Italian: Fagiolo Del Capo, Fagiolo Detto Di Lima, Fagiolo Di Lima;
Japanese: Aoi Mame, Lai-Mame;
Korean: La I Ma K'ong;
Madagascar: Haricot De Madagascar, Kabaro, Kalamaka, Konoka, Maimbolany (Malagasy);
Malaysia: Kacang China, Kacang Jawa, Kacang Serendeng, Kekara Keratok;
Peru: Lima, Layo, Pallar;
Philippines: Buni (Baguio), Patani (Bikol), Patani (Bisaya), Kilkilang, Kopani, Kutakut (Bontok), Gulipatan (Ibanag), Puida (Igorot), Palpadi, Parda, Patani, Perkoles (Iloko), Haba, Habichuela, Zabache (Spanish), Bulai-Patani, Buriñgi, Butiñgi, Patani (Tagalog);
Portuguese: Feijão Carolino De Lima, Feijão De Lima, Feijão Favona, Feijão Espadinho;
Russian: Fasol' Lima, Fasol' Limskaia, Fasol' Lunoobraznaia, Fasol' Lunovidnaia Lima, Limskaia Fasol', Limskii Fasol';
Senegal: Kissi Soso, (Manding-Bambara), Tubabu Soso (Maninka);
Spanish: Frijol Caballero, Frijol De Pallar, Frijol De Luna, Guaracaro Frijol Comba, Haba De Lima, Haba Lima, Judía De Lima, Frijol De Pallar, Pallar, Palma De Coco, Poroto De Lima, Poroto De Manteca;
Slovencina: Fazuľa Mesiacovitá;
Swahili: Mfiwi;
Swedish: Limaböna;
Thai: Thua Rachamat;
Tongan: Piini 'Ae Puaka;
Vietnamese: Đấu Ngư, Đậu Bạch Biển, Đấu Điểm.

Origin/Distribution

Lima bean is native to tropical America with at least two centres of domestication: Mesoamerican in Mexico and Guatemala for the small-seeded types and Andean in Peru and Ecuador for the large-seeded types. The Mesoamerican wild types have a wide distribution extending from Mexico to Argentina, while the Andean wild types are restricted to its native range. Recent studies indicated there could be 3 centres of genetic diversity: centres of genetic diversity cum centres of domestication in Central America and in the western slopes of the Andes in southern Ecuador and northern Peru; and a new centre of genetic diversity in the region covering northern Peru, northern Colombia, northern Ecuador and western Venezuela.

The Spaniards introduced lima bean throughout the Americas and also to the Philippines from where it spread to Indonesia, Myanmar and the Mauritius. Today lima bean is cultivated worldwide in the tropical and subtropical regions including Africa, south Asia and the Pacific. It has naturalised in many areas.

Agroecology

Lima bean is adapted to a humid tropical climatic regimes but can be grown in the subhumid subtropical, warm temperate, semi-arid and arid areas. Lima bean is grown from sea level to above 2,000 m elevation. Optimum temperature for growth and production is 16–27°C and it is frost intolerant. Excessive heat or cold will slow germination as well as early growth. Lima bean has cultivars that differ in their degree of photoperiodism, some will flower in day-lengths up to 18 hours while the short day types will flower with day-lengths of 11–12.5 hours. An ideal mean annual rainfall is 900–1,500 mm but once established the crop will survive in areas with as little as 500–600 mm. Lima bean withstand heat and drought better than other legumes but abhors water-logged conditions. Lima bean likes a well-drained, well aerated fertile soil with pH from 5.5 to 6.8. Some cultivars will tolerate pH as low as 4.4.

Edible Plant Parts and Uses

The immature lima bean seeds, dry mature seeds, young pods, sprouts and young leaves are eaten as vegetables (Plates 1–5). Immature seeds are used like peas in soups, broths, porridge, stews, stir-fries, etc. The dried seed can be ground into a powder then used as a thickener in soups or can be mixed with cereal flours when making bread. The mature seeds are also fermented and processed into *tempeh*. In tropical Africa, the seeds are usually eaten boiled, fried in oil or baked. In Nigeria they are also cooked with maize, rice or yam and used in various kinds of soup and stew. The seeds are processed for preparing porridge, puddings and cakes by the Yoruba people. In Japan, the dry seeds are cooked as "*nimame*" (boiled bean sweetened with sugar). In Ghana and Malawi, the leaves and young pods are eaten; the leaves have a bitter taste. In Java the young pods are eaten cooked or steamed, often as a side dish with rice. The ripe mature seeds are boiled after dehulling and eaten. The leaves are used in the form of a pulp to colour puddings green. The young sprouted seedlings are

Plate 1 Young lima bean pods and leaves

Plate 2 Ripe and young lima bean pods

Plate 3 Lima bean pods

Plate 4 Green pink mottled lima beans

Plate 5 White-pink mottled lima beans

eaten cooked in many Asian countries and often used in Chinese dishes.

Recent studies showed that octenylsuccinylation improved the properties of lima bean starch and allows its use in products such as beverages, salad dressings and soups where the use of this starch is limited because lack of diversity in their functional properties necessaries in the alimentary industry (Segura-Campos et al. 2010). The improved properties of the *Phaseolus lunatus* octenyl succinic anhydride (OSA) starch make it potentially useful in processes requiring a thickening agent that must gel at lower temperatures. The OSA starch can also serve to lower energy consumption during cooking processes or like thickening or emulsifying agent or make it potentially useful as an additive in candies and jellies to provide brightness.

Botany

Climbing or small bushy annual or perennial herb, with pubescent or glabrous stem up to 4 m long. Leaves, alternate, trifoliolate; stipules triangular, 2–3.5 mm, petioles 1.5–19 cm long. Leaflet ovate to rhomboid or lanceolate, usually 5–12 × 3–9 cm, acute to acuminate, base rounded or broadly cuneate, sparsely pilose to glabrous, lateral ones often oblique (Plate 1). Inflorescences axillary racemes with few to many flowered. Flowers bisexual, papilionaceous; pedicel 5–10 mm long, bracteoles elliptic, shorter than calyx tube., calyx campanulate, 2–3 mm, pubescent, corolla white, yellowish, or reddish; standard 7–10 × 5–8.5 mm, apex emarginate; wings obovate; keel apex twisted; stamens 10, 9 fused and 1 free; ovary superior and pubescent, style with a terminal coil, with collar of hairs below the stigma. Fruit an oblong or falcate-oblong compressed pod (Plates 1–3), 5–10.5 cm long, 1.2–2.5 cm broad, glabrous or pilose, 2-(4) –5 seeded. Seed subrhombic or reniform, 12–13 × 8.5–9.5 mm white, green, yellow, brown, pink, red, purple, black or variously speckled or mottled, often with transverse lines radiating from the hilum (Plates 4 and 5).

Nutritive/Medicinal Properties

Raw, immature lima been seeds had been reported to have the following nutrient composition per 100 g value (USDA 2010): water 70.24 g, energy 113 kcal (473 kJ), protein 6.84 g, total lipid 0.86 g, ash 1.89 g, carbohydrates 20.17 g, total dietary fibre 4.9 g, sugars 1.48 g, Ca 34 mg, Fe 3.14 mg, Mg 58 mg, P 136 mg, K 467 mg, Na 8 mg, Zn 0.78 mg, Cu 0.318 mg, Mn 1.215 mg, Se 1.8 μg, vitamin C 23.4 mg, thiamine 0.217 mg, riboflavin 0.103 mg, niacin 1.474 mg, pantothenic acid 0.247 mg, vitamin B-6 0.204 mg, total folate 34 μg, total choline 40 mg, vitamin E (α-tocopehrol) 0.32 mg, vitamin K (phylloquinone) 5.6 μg, vitamin A 209 IU, β-carotene 126 μg, total saturated fatty acids 0.198 g, 14:0 (myristic acid) 0.002 g, 16:0 (palmitic acid) 0.173 g, 18:0 (stearic acid) 0.022 g; total monounsaturated fatty acids 0.0.050 g, 18:1 undifferentiated (oleic acid) 0.050 g; total polyunsaturated fatty acids 0.419 g, 18:2 undifferentiated (linoleic acid) 0.283 g, 18:3 undifferentiated (linolenic acid) 0.136 g; tryptophan 0.090 g, threonine 0.290 g, isoleucine 0.440 g, leucine 0.538 g, lysine 0.452 g, methionine 0.068 g, cystine 0.083 g, phenylalanine 0.337 g, tyrosine 0.220 g, valine 0.427 g, arginine 0.458 g, histidine 0.232 g, alanine 0.260 g, aspartic acid 0.735 g, glutamic acid 0.881 g, glycine 0.274 g, proline 0.102 g and serine 0.427 g.

Raw, large, mature lima bean (*Phaseolus lunatus*) seeds had been reported to have the following nutrient composition per 100 g value (USDA 2010): water 10.17 g, energy 338 kcal (1,414 kJ), protein 21.46 g, total lipid 0.69 g, ash 4.30 g, carbohydrates 63.38 g, total dietary fibre 19.0 g, sugars 8.50 g, Ca 81 mg, Fe 7.51 mg, Mg 224 mg, P 385 mg, K 1,724 mg, Na 18 mg, Zn 2.83 mg, Cu 0.740 mg, Mn 1.672 mg, Se 7.2 μg, vitamin C 0 mg, thiamine 0.507 mg, riboflavin 0.202 mg, niacin 1.537 mg, pantothenic acid 1.355 mg, vitamin B-6 0.512 mg, total folate 395 μg, vitamin E (α-tocopehrol) 0.72 mg, vitamin K (phylloquinone) 6 μg, total saturated fatty acids 0.161 g, 14:0 (myristic acid) 0.002 g, 16:0 (palmitic acid) 0.118 g, 18:0 (stearic acid) 0.032 g; total monounsaturated fatty acids 0.062 g, 16:1 (palmitoleic

acid) 0.004 g, 18:1 undifferentiated (oleic acid) 0.052 g, 22:1undiferentiated (behenic acid) 0.004 g; total polyunsaturated fatty acids 0.309 g, 18:2 undifferentiated (linoleic acid) 0.215 g, 18:3 undifferentiated (linolenic acid) 0.095 g; tryptophan 0.254 g, threonine 0.927 g, isoleucine 1.129 g, leucine 1.850 g, lysine 1.438 g, methionine 0.271 g, cystine 0.237 g, phenylalanine 1.236 g, tyrosine 0.759 g, valine 1.291 g, arginine 1.315 g, histidine 0.656 g, alanine 1.095 g, aspartic acid 2.767 g, glutamic acid 3.038 g, glycine 0.906 g, proline 0.975 g and serine 1.428 g.

Raw, thin seeded (baby) mature lima bean (*Phaseolus lunatus*) seeds had been reported to have the following nutrient composition per 100 g value (USDA 2010): water 12.07 g, energy 335 kcal (1,402 kJ), protein 20.62 g, total lipid 0.93 g, ash 3.55 g, carbohydrates 62.83 g, total dietary fibre 20.6 g, sugars 8.32 g, Ca 81 mg, Fe 6.19 mg, Mg 188 mg, P 370 mg, K 1,403 mg, Na 13 mg, Zn 2.60 mg, Cu 0.665 mg, Mn 1.686 mg, Se 7.0 μg, vitamin C 0 mg, thiamine 0.574 mg, riboflavin 0.218 mg, niacin 1.712 mg, pantothenic acid 1.265 mg, vitamin B-6 0.327 mg, vitamin E (α-tocopherol) 0.70 mg, vitamin K (phylloquinone) 5.9 μg, total folate 400 μg, total saturated fatty acids 0.219 g, 14:0 (myristic acid) 0.003 g, 16:0 (palmitic acid) 0.161 g, 18:0 (stearic acid) 0.043 g; total monounsaturated fatty acids 0.084 g, 16:1 (palmitoleic acid) 0.006 g, 18:1 undifferentiated (oleic acid) 0.071 g, 22:1 undiferentiated (behenic acid) 0.006 g; total polyunsaturated fatty acids 0.420 g, 18:2 undifferentiated (linoleic acid) 0.292 g, 18:3 undifferentiated (linolenic acid) 0.129 g; tryptophan 0.244 g, threonine 0.891 g, isoleucine 1.085 g, leucine 1.778 g, lysine 1.382 g, methionine 0.261 g, cystine 0.228 g, phenylalanine 1.188 g, tyrosine 0.729 g, valine 1.240 g, arginine 1.264 g, histidine 0.630 g, alanine 1.052 g, aspartic acid 2.659 g, glutamic acid 2.920, glycine 0.871 g, proline 0.937 g and serine 1.372 g.

Phaseolin, a vicilin-like 7S storage globulin, was found to be the most abundant storage protein of lima bean seeds (Sparvoli et al. 1996); mainly in the cotyledons and testa (Moraes et al. 2000). Phaseolin was found to consist of four major oligomers containing two subunit classes. Polypeptides of one class showed a molecular mass ranging from 38.5 to 32 kDa, while the molecular mass of polypeptides belonging to the other class varied from 27 to 21 kDa. Chel-Guerrero et al., (2007) found that lima bean seeds contained 2 globulin species, I and II, which were later identified as 11S and 7S globulins, respectively. Species II, 7S globulin had a molecular mass of 72 kDa and was constituted by polypeptides of 34–36, 25–27 and 16–18 kDa without intermolecular disulfide bonds. This protein exhibited some particular features, including a lower molecular mass and higher thermal stability than typical vicilins. Species I, with a molecular mass of 336 kDa, was constituted by subunits of 53–55 and 40–41 kDa formed by smaller polypeptides (around 30 and 20 kDa) linked by disulfide bonds. These features, together with the existence of basic and acid polypeptides in the molecule, confirmed that species I is a globulin of the legumins, 11S globulins or α-conglutin family.

Twenty-five isoflavonoids were isolated from *Phaseolus lunatus* seedlings: kievitone, isoferreirin, 5-deoxykievitone, kievitone hydrate, cyclokievitone, cyclokievitone hydrate, daidzein, 2′-hydroxydaidzein, genistein, 2′-hydroxygenistein, 2,3-dehydrokievitone, luteone, phaseollidin,2-(γ,γ-dimethylallyl)-phaseollidin,coumestrol, psoralidin, 7,8,2′,4′-tetrahydroxyisoflavone, 5,7,8,2′,4′-penta hydroxyisoflavone, 2,3-dehydrokievitol, lunatone, 5-deoxykievitol, kievitol, 3′-(γ,γ-dimethylallyl)-kievitone, 4-(γ,γ-dimethylallyl)-phaseollidin and 2-(γ,γ)-dimethylallyl-6a-hydroxy-phaseollidin (O'Neill et al. 1986).

P. lunatus was found to have a crude fibre of 12.8%, total dietary fibre, 29.4% and insoluble dietary fibre, 28.6% (Betancur-Ancona et al. 2004). Water-holding capacity (26.5%) in the legume fibrous residue was higher than the oil-holding capacity (18%). *P. lunatus* residue had low emulsifying activity (8.6%) but higher emulsifying stability (100%). The fibrous residue was not capable of bonding calcium ions, but did bind iron ions (28.4%). Antioxidant activity value of 35.6% was obtained for the lima bean residue.

The percentage protein of three varieties (white, brown and dark brown) of lima bean varied from 21.8 to 26.2 depending on the variety

and dehulling (Apata and Ologhobo 1994). The ash and fat contents did not vary considerably while the fibre varied with variety and dehulling. Zinc, calcium and potassium were more concentrated in the hull, phosphorus more so in the cotyledon while iron was evenly distributed in the hull and cotyledon. The least gelation concentrations for the beans were found to vary from 8% in the brown sample to 12% in the dark brown sample. The water absorption capacities varied from 130% for the white whole seed sample to 142% in the dark brown dehulled sample. The oil absorption capacities varied from 82% to 91.5% depending on whether the sample was dehulled or not. The bean flour formed a reasonably stable emulsion while foaming capacities varied from 22.9% to 29.1% and did not collapse completely until after 36 h. The protein solubility of the three varieties showed minimum solubility at about pH 4 and 4.5 for whole and dehulled samples respectively.

Rats fed diets with raw and cooked *Phaseolus vulgaris* and *P. lunatus* beans did not develop toxicity but all rats fed with raw common beans died (Benshimol et al. 1985). Protein and phosphorus contents were greater in common bean than in lima bean seeds. The chemical score and availability of lysine were better in lima bean. Protein efficiency was better with cooked lima beans.

The yield of starch from large-seeded lima beans was 22% on a whole seed basis (Hoover et al. 1991). The shape of the starch granules was round to oval to elliptical, with granules 15–36 μm diameter. Gelatinization temperature range was 70–75–80°C and amylose content was 34.5%. The starch exhibited high single stage swelling and moderate solubility in water. The native starch granules were very resistant to attack by porcine pancreatic α-amylase. The gel showed poor stability towards refrigerated storage and freeze-thaw cycling. The starch granules were highly resistant to acidic hydrolysis. Starch is widely consumed by humans as an inexpensive and stable available carbohydrate and protein source. Lima bean starch was changed by pyrodextrinization to lower available starch (AS) content (Campechano-Carrera et al. 2007). Compared to the *P. lunatus* native starch, the pyrodextrinized starch exhibited enhanced paste clarity (58%T), solubility (80%), a higher gelatinization temperature range (76–88°C), lower viscosity and swelling power (9.8 g water/g starch). This pyrodextrinization process appeared to be a promising strategy for producing resistant starch from legumes.

The incorporation of octenylsuccinate groups into lima bean starch was found to produce a derivative with more versatility as a food additive providing new and improved functional properties (Segura-campos et al. 2010). Octenylsuccinylation increased emulsifying capacity from 0.47 ml oil/ml sample in the native starch to 0.53 ml oil/ml sample in the octenyl succinic anhydride (OSA) starch. Starch gel clarity (transmittance percentage) increased from 23.8% to 37.3%. Viscosity increased from 700 to 1,000 BU. Gel firmness decreased from 0.3401 kgf for gel rupture in the native starch to 0.0314 kgf for rupture in the OSA starch. Gelatinization temperature decreased from 75.3 to 64.6°C and gel enthalpy decreased from 10.7 to 9.7 J/g. octenylsuccinylation did not evoke significant changes in solubility, swelling power and water absorption capacity. OSA starch stability was lower under refrigerated conditions.

Antimicrobial and Antiviral Activity

An anti-fungal peptide designated as lunatusin, with a molecular mass around 7 kDa, was purified from the seeds of lima bean (*Phaseolus lunatus*) (Wong and Ng 2005). Lunatusin exerted an anti-fungal activity toward fungal species such as *Fusarium oxysporum, Mycosphaerella arachidicola* and *Botrytis cinerea*, and an antibacterial action on *Bacillus megaterium, Bacillus subtilis, Proteus vulgaris* and *Mycobacterium phlei*. Lunatusin reduced the activity of HIV-1 reverse transcriptase and it also inhibited translation in a cell-free rabbit reticulocyte lysate system. Its anti-fungal activity was retained after incubation with trypsin. Lunatusin elicited a mitogenic response from mouse splenocytes. Trypsin inhibitors from *Phaseolus lunatus* were reported to inhibit HIV-1 reverse transcriptase (Wang and Ng 2001).

Anticancer Activity

Lunatusin purified from the seeds of lima bean, inhibited proliferation in the breast cancer cell line MCF-7 (Wong and Ng 2005). Ethanol extract of lima bean exhibited estrogen-like activities on the human breast cancer cell line MCF-7/BOS (Zhao et al. 2007). Both mRNA and protein levels of progesterone receptor (PR) in the cell line increased after 48 hours treatment with the extract compared with those in the control. Lima bean extract altered the estrogen receptor intracellular distribution in the same way as estradiol in which the estrogen receptor almost disappeared in the nucleus and mainly occurred in the cytoplasm.

Antihypertensive and Antioxidant Activities

Protein hydrolysate from *Phaseolus lunatus* seeds hydrolyzed with the enzymes Alcalase® and Flavourzyme® exhibited angiotensin-I converting enzyme (ACE-I) inhibitory and antioxidant activities (Torruco-Uco et al. 2009). With Alcalase®, the highest degree of hydrolysis in *P. lunatus* was 37.94% at 45 minutes, and with Flavourzyme®, the highest degree of hydrolysis was 22.03% at 90 minutes. ACE-I inhibitory activity in the Alcalase® hydrolysates was IC_{50} = 0.056 mg/ml for *P. lunatus* at 90 min and in the Flavourzyme® hydrolysates this activity was IC_{50} = 0.0069 mg/ml. Antioxidant activity was 11.55 mmol/l TEAC/mg protein for *P. lunatus* with Flavourzyme® at 90 minutes.

Antihypercholestrolemic Activity

Studies showed that there was a significant reduction in the concentration of serum lipids in rats fed the lima beans legume diet and saponin diet when compared to the control and hypercholestrolemic diet (25% coconut oil and 1% cholesterol). (Oboh and Omofoma 2008) The consumption of lima beans could be recommended to also lower cholesterol and promote cardiovascular health due to the presence of saponin in the legume.

Antinutritional Factors

Lima bean seeds were found to contain antinutritional factors that included protease inhibitors, lectins, trypsin inhibitors, phytohemagglutinin, polyphenols (Egbe and Akinyele 1990) raffinose oligosaccharide (Korytnyk and Metzler 1962; Oboh et al. 2000) and cyanogenic glucosides: linamarin or phaseolunatin (Dunstan et al. 1907,), linamarin and loaustralin (Frehner et al. 1990). The latter was accompanied by an enzyme, linamarase, which could hydrolyse the glucosides into a sugar and an aglycone, and finally into acetone and hydrogen cyanide (HCN) (Dunstan et al. 1907). Hydrolysis occurred rapidly when the soaked seeds were cooked in water; most of the HCN then evaporated. The raw samples of lima beans, cooked samples and cooking water were found to contain various levels of the antinutritional factors such as trypsin inhibitors, tannins, phytohemagglutinin, polyphenols and cyanogenic glucosides (Egbe and Akinyele 1990). Cooked samples had significantly lower levels than raw samples for all parameters analysed. The level of tannins in raw beans was found to decrease with increase in cooking time. Total polyphenol content of lima beans decreased from 122 to 55 mg/g when boiled for 60 minutes and as boiling time increased further significant decrease was observed.

Lima beans seed was found to contain the seed lectin (LBL) (Galbraith and Goldstein 1972; Sikder et al. 1986) and two lectin-related proteins AIL (α-amylase inhibitor-like) and ARL (arcelin-like) (Sparvoli et al. 1998; 2001). Lectins were reported as plant defence proteins (Sparvoli et al. 1998; 2001). ARL and AIL polypeptides contained 239 and 233 amino acids, respectively (Sparvoli et al. 1998). Each occurred in the mature protein as two glycoforms. ARL subunits (43 and 46 kDa) comprised oligomers of about 125–130 kDa whereas AIL subunits (40 and 42 kDa) oligomerised in dimers of about 88–100 kDa. Lima bean lectin (LBL) was found to agglutinate only type A red blood cells (Galbraith and Goldstein 1970) and was therefore blood group A-specific (Sikder et al. 1986). By inhibition of precipitation of LBL with A1 blood

group substance, the lectin was found to be most specific for fucose-containing oligosaccharides having the A trisaccharide, DGalNAc α 1-3[L-Fuc α 1-2]DGal determinant.

Lima bean seeds were also found to contain oligosaccharides: raffinose, stachyose and verbascose and sucrose (Korytnyk and Metzler 1962; Oboh et al. 2000). Stachyose was predominant in lima beans. The total α-galactoside contents of the seeds in white lima beans was 3.62 mg/100 mg and in red lima beans 3.37 mg/100 mg. Cooking unsoaked seeds evoked a greater reduction in the total α-galactoside content than soaking for 9 hours. The removal of oligosaccharides was higher in legumes cooked in alkaline solution than in water. Germination quantitatively reduced raffinose, stachyose and verbascose while sucrose was increased except in red lima beans.

Frehner et al. (1990) reported that the cyanide potential of lima bean fruit increased shortly after anthesis and stopped before fruit maturity. At all time of its development, the lima bean fruit contained the monoglucosides linamarin and loaustralin. Linamarin was also found in leaves. Linamarin together with the related enzyme hydroxynitrile lyase, was found inside the cells of lima bean leaves while the linamarin B-glucosidase, linamarase was confined to the apoplast (Frehner and Conn. 1987). This compartmentation prevented cyanogenesis from occurring in intact tissue, and suggested that linamarin had to be protected during any translocation across the linamarase rich apoplast.

Ihimire et al. (2004) found that there were 96.82%, 99.78% and 99.62% reductions in cyanide content of the red lima bean cultivar after boiling in water, dilute HCl and dilute H_2SO_4 respectively for 30 minures. The corresponding values for the white cultivar were 96.39%, 99.59% and 94.77% respectively. Dehydrocyanation was more effective in enzyme-incubated samples when they were parboiled in dilute mineral acids. The residual cyanide content in enzyme-incubated samples was below tolerable limits after 30 minutes of treatment. However, the longer the parboiling time, the higher was the trytophan loss. Therefore parboiling for 30 minutes in dilute HCl would produce the desired result of insignificant residual cyanide content and minimal tryptophan loss in all samples.

Germination of lima bean seeds resulted in a decrease in the raffinose content; this was significant after 5 days of germination (Dibofori et al. 1994). In contrast, sucrose, glucose and galactose increased significantly by the 5th day of germination. There was a highly significant decrease in the cyanide content of the cotyledons when the seeds were germinated for 5 days. The shoot which appeared on the 4th day contained 11·7 mg/kg of cyanide and this increased to 50·9 mg/kg on the 5th day. Germination resulted in an increase in protein content, and a significant decrease in the lipid content.

The trypsin inhibitor purified from lima bean seeds exhibited high trypsin-inhibiting activity and contained high sulfur (5.5%) and cystine (16%) contents (Fraenkel-Conrat et al. 1952). The inhibitor was relatively resistant to denaturing conditions. It was not attacked by pepsin or papain. The inhibitor was not inactivated by extensive esterification of its carboxyl groups, or by iodination and coupling of its phenolic and imidazole groups. Blocking of part of the amino and amide or guanidyl groups, sulfation of the hydroxyl groups, or extensive reduction of the disulfide bonds destroyed its activity. Sakura and Timasheff, (1973) also reported three purified proteinase inhibitors (fraction I, II and IV) from lima bean with trypsin inhibiting activity.

Lima beans also contained cysteine proteinase inhibitor (CPI) (Lawrence and Nielsen 2001). This CPI was found to have molecular weight of 20 kDa with an N-terminal sequence homologous to other members of the cystatins. It exhibited high inhibitory activity against papain activity. The protein was relatively heat labile suggesting it could be inactivated with normal cooking.

Raw lima bean contained cyanide, trypsin inhibitor, lectin, phytin and tannin (Adeparusi 2001). Phytate phosphorus was estimated to be 28.2% of total phosphorus. There was no significantly different in the crude protein content of raw and processed flour. There was significant difference in the values of the macro- and micro- elements. Soaking, autoclaving and toasting completely eliminated trypsin inhibitor and lectin

while it significantly lowere the concentrations of phytin, tannin and cyanide. Autoclaving lima beans for 20 minutes eliminated all the anti-nutrients except for tannins.

The protein content of the raw lima beans was decreased like calcium, magnesium and potassium, with the soaking and cooking processes (Granito et al. 2007). Drum drying decreased anti-nutritional factors like trypsin inhibitors (66.09%) and cyanhydric acid (50.36%). Similarly, soluble fibre, available starch, total starch, and soluble sugars diminished, while total and insoluble fibre and resistant starch increased. The content of total polyphenols, tannins and antioxidant capacity decreased with thermal processing. Drum drying process exibited least diminished antioxidant capacity. Likewise, the water absorption index was increased by 85% and 161.5% with processing.

Allergy

Results of oral food challenges demonstrated that clinically important cross-reactivity to legumes (peanut, soybean, green bean, pea, and lima bean) in children was very rare (Bernhisel-Broadbent and Sampson 1989). Clinical hypersensitivity to one legume does not warrant dietary elimination of all legumes. Results of prick skin tests should not be used to determine prolonged food restriction diets.

Immunoglobulin E (IgE)-mediated food allergy can develop as a consequence of allergic sensitisation to pollen proteins. Recently, cross-reactivity was demonstrated between Mesquite tree pollen (*Prosopis juliflora*) and Lima bean as a food, both being members of the family Leguminosae (*Fabaceae)* (Dhyani et al. 2007). In a study of 110 patients with asthma and/or rhinitis, of whom 20 showed marked positive reactions with *Prosopis* pollen extract, 12 patients showed elevated IgE antibody level to *Prosopis* pollen extract alone and 4 to both *Phaseolus* and pollen extract. *P. lunatus* extract could inhibit IgE binding to *P. juliflora* in a dose-dependent fashion. The presence of 20, 26, 35, 66 and 72 kDa proteins as shared IgE binding components between the 2 extracts was demonstrated.

Traditional Medicinal Uses

In traditional Asian medicine the seeds and leaves are valued for their astringent qualities and used as a diet against fever. The plant is used for stomach ache in small children and as a poultice smeared over the abdomen in Java. Sap from the leaves is used in nasal instillations against headache and as eardrops against otitis in Senegal and Democratic Republic of Congo. In Nigeria, the seeds are pulverized and applied into small cuts on tumours and abscesses to promote suppuration.

Other Uses

The seeds are sometimes used as fodder, but may lead to hydrogen cyanide poisoning when used raw. The leaves and stems may be turned into hay or silage. Lima bean has been grown as a cover crop and for green manure.

Lima bean (*Phaseolus lunatus*) seed coat phaseolin has insecticidal properties, it is detrimental to the cowpea weevil (*Callosobruchus maculatus*) (Moraes et al. 2000).

Comments

Lima beans are readily propagated from seeds that also store well without loss of viability when properly dried.

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Phaseolus vulgaris

Scientific Name

***Phaseolus vulgaris* L.**

Synonyms

Phaseolus aborigineus Burkart, *Phaseolus aborigineus* var. *hondurensis* Burkart, *Phaseolus amoenus* Fingerh., *Phaseolus angulosus* Schübl. & Mart., *Phaseolus asparagoides* Schur, *Phaseolus compressus* DC., *Phaesolus communis* Pritz., *Phaseolus cruentus* hort. ex Schur, *Phaseolus dimidiatus* Haberle ex Schübl. & Martens, *Phaseolus esculentus* Salisb., *Phaseolus gonospermus* Savi, *Phaseolus haematocarpus* Savi, *Phaseolus ionocarpus* Fingerh., *Phaseolus lilac* Zucc., *Phaseolus lupinoides* Fingerh., *Phaseolus melanospermus* Fingerh., *Phaseolus mexicanus* Mart., *Phaseolus nanus* Juslen., *Phaseolus nigerrimus* Juss. ex Zucc., *Phaseolus nigricans* Haberle ex Schübl. & Martens, *Phaseolus oblongus* Savi, *Phaseolus ovalispermus* Fingerh., *Phaseolus pictus* Cav. ex Steud., *Phaseolus praecox* Fingerh., *Phaseolus romanus* Savi, *Phaseolus saponaceus* Savi, *Phaseolus sinensis* hort. ex Schur, *Phaseolus sphaericus* Savi, *Phaseolus subglobosus* Fingerh., *Phaseolus triangularis* Fingerh., *Phaseolus tumidus* Savi, *Phaseolus vulgaris* subsp. *aborigineus* (Burkart) Burkart & H. Bruecher, *Phaseolus vulgaris* var. *aborigineus* (Burkart) Baudet, *Phaseolus vexillatus* Blanco, *Phaseolus zebra* Fingerh.

Family

Fabaceae also placed in Leguminosae, Papilionaceae

Common/English Names

Borletti Bean, Bush Bean, Climbing Bean, Common Bean, Dry Bean , Dwarf Bean, French Bean, Field Bean, Flageolet Bean, Garden Bean, Green Bean, Haricot, Haricot Bean, Kidney Bean, Mange-Tout, Navy Bean, Pea Bean, Pole Bean, Pop Bean, Popping Bean, Rose Family Dry Bean, Runner Bean, Snap Bean, String Bean, Wax Beans, Runner beans.

Bean, Common Bean, Common Bean;bean, Common Haricot, Dry Bean, Dwarf Bean, Frash Bean, French Bean, Frijol, Garden Bean, Green Bean, Habichuela, Haricot Bean, Haricot Commun, Haricot Francais, Haricots Carapatte, Haricots De Bourbon, Haricots Pales, Haricots Panaches, Haricots Tachetes, Haricots Varies, Haricots Violets, Kidney Bean, Runner Bean, Snap Bean, String Bean, Wax Bean

Vernacular Names

Angola: Otchipoke (Umubumbu), Feijoeiro Ordinario (Portuguese);
Argentina: Chicharo, Chaucha, Poroto;

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Armenian: Lobi Sovorakan;
Azerbaijan: Adi Lobya;
Belarusan: Fasolya Zvychainaya, Khvasolya, Pasolya;
Bolivia: Chicharo, Judía, Judía Común, Frejol, Poroto, Vainita;
Brazil: Feijão, Feijão–Vagem, Feijoeiro;
Burmese: Bo Sa Pè, Hto Pe Ton, Mete Beir, Pè-Bya-Galè, Pè-Gya(ni), Pra Say Taut, Ta La Pe, To Tok;
Chile: Chicharo, Judía, Judía Común, Frejol, Poroto, Tabla, Vainita;
Chinese: Bai Fan Dou, Ban Wen Dou, Cai Dou, Man Cai Dou, Man Sheng, Cai Dou, Qing Dou, Shi Jia Cai Dou, Si Ji Dou, Yun Dou;
Chuvash: Shalsa Parsi;
Columbia: Alubia, Fríjol, Frísol;
Costa Rica: Frijol;
Cuba: Frijol;
Czech: Fazol Obecný, Fazole Zahradní;
Danish: Almindelig Bŕnne, Bønne, Buskbŕnne, Buskbŕnnen, Grøn Bønne, Have-Bønne, Stangbŕnne, Stang Bŕnner;
Democratic Republic of Congo: Cishimbo (Shi);
Dominican Republic: Habichuela:
Dutch: Boon, Bruine Boon, Gewone Boon, Staakboon, Stokboon, Witte Boon;
Eastonian: Harilik Aeduba, Turgi Uba;
Ecuador: Fréjol, Vainita;
El Salvador: Frijol;
Finnish: Salkopapu, Tarhapapu, Torapapu;
French: Haricot Commun, Haricot Grimpant, Haricot Mangetout, Haricot Ŕ Rame(S), Haricot Vert;
Gabon: Modjangi, Maliko (Apindji), Butsangi (Baduma), Bésangé (Bakélé), Mutsangi, Mariko (Balumbu), Botsangi, Mariko (Banzabi), Butsangi, Mariku (Bapunu), Butsangi, Mariku (Bavarama), Butsangi, Mariko (Bavili), Butsangi, Mariku (Bavungu), Uhangé (Benga), Usangé (Béséki), Butsangi, Mariku (Eshira), Osangé, Ariko (Galoa), Ésanga, Mariki, Eriki (Mindumu), Mdjangi, Madiko (Mitsogo), Osangé, Ariko (Mpongwè), Mutsangi, Mariko (Ngowé), Osangé, Ariko (Nkomi), Osangé, Ariko (Orungu);
Georgian: Lobio;
German: Bohne, Fisole, Garten-Bohne, Kletterbohne, Stangenbohne;
Greek: Fasiolos Koinos, Fasolaki Anarihetiko;
Guatemala: Frijol;
Hawaian: Bakla, Loba, Lobia, Rajmah, Vilayti Sem;
Honduras: Frijol;
Hungarian: Bab, Paszuly, Veteménybab;
India: Bakla, Biins, Rajmah (Hindu), Binns (Urdu);
Indonesia: Boncis, Buncis;
Italian: Fagiolo, Fagiuolo Commune, Fagiolo Da Sgranare, Fagiolo Rampicante, Fagiolino Rampicante (General), Fascinale (Abruzzi), Suriaca, Vasuli (Calabria), Fasol, Fasulein (Emilia), Fagiolo, Faxoe, Faisoe (Liguria), Cornett (Lombardia), Fasoel (Piemonte), Fasoleddu, Basolu, Pisu (Sardegna), Fasolu, Trujaca (Sicilia), Fasciolo (Umbria), Fasioi, Fasoler (Veneto);
Japanese: Ingen Mame, Sasage;
Kampuchean: Sândaèk Barang;
Korean: Gang Nang K'ong;
Laos: Mak Thaoua Khek, Mak Thaoua Frang, Thwàx Fàlangx;
Latvian: Parastas Pupinas;
Lithuanian: Darzines Pupeles;
Malaysia: Kacang Buncis, Kacang Merah, Kacang Pendek;
Moldavian: Fasole Urketoare;
Mong: Chichees Buurtzag, Egel Shosh;
Mali: Nii;
Mexico: Ejote, Frijol;
Nepali: Dolo Simi;
Nicaragua: Frijol;
Norwegian: Hagebønne;
Pakistan: Loba Fasoulia;
Panama: Chicharo, Frijol, Poroto:
Paraguay: Habilla;
Peru: Chicharo, Judía, Judía Común, Frejol, Frijol, Poroto, Vainita;
Philippines: Sitao, Sitaw (Tagalog);
Polish: Fasola Zwyczajna, Fasola Zwykła, Feijao, Feijoeiro;
Portuguese: Feijão, Feijão-De-Trepar, Feijão-Vagem, Feijoeiro, Feijoeiro-De-Trepar;
Puerto Rico: Habicuela;
Quechuan: Purutu:

Russian: Fasol' Obyknovennaia, Fasol' Ovoshchnaia, Fasole Comun, Lubiyo;
Slovašcina: Fižol Navadni, Navadni Fižol, Nizki Fiol, Visoki Fiol;
Slovencina: Fazuľa Obyčajná, Fazua Záhradná;
Spanish: Alubia, Alubias, Bajoca, Caraotas, Chícharos, Ejote, Fabas, Frejoles, Frijol, Fríjol De Guía, Frijoles, Granos, Habichuela Enana, Habichuela Verde, Habichuelas, Judía, Judía Alta De Enrame, Judía Común, Judía De Enrame, Judía Trepadora, Judías, Nuña, Ñuñas, Pochas, Porotos, Vainita;
Swahili: Mharagwe;
Swedish: Böna, Stĺngböna, Störböna, Trädgårdsböna;
Swiss: Bruna Bonor, Storbona;
Taiwan: Pan Wen Tou;
Thai: Thua Khaek, Thua Phum;
Turkish: Fasulye;
Uganda: Mattu Wanyambi (Bugisu), Ngaingai, Teiko (Kakwa), Habichuela, Ebijanjaalo, Ebisobooza, Ebisobyo, Ebikanga (Luganda), Ebihimba (Runyankore), Ebihimba (Rutooro), Ebihimba (Runyora);
Ubzek: Loviya;
Ukranian: Kvasolya Zvichaina;
Uruguay: Chicharo, Poroto;
Venezuela: Caraota;
Vietnamese: Đậu Ve.

Origin/Distribution

Phaseolus vulgaris is generally believed to have originated in the Americas, with two centres of domestication (Gepts and Dpbouk 1991; Smartt 1990). The small seed varieties were proposed to have domesticated from small-seede wild type (*P. vulgaris* var.*aborigineus* (Burk.) Baudet) in Central America and the large-seeded varities from large-seeded type (*P. vulgaris* var. *aborigineus*) in the Andean region of South America. Europe is regarded as a secondary diversification center for *P. vulgaris* germplasm (Angioi et al. 2010). A high proportion of the European bean landracess (about 44%) was derived from hybridization between the Andean and Mesoamerican gene pools. The commercial production of beans is well-distributed worldwide with countries in Asia, Africa, Europe, Oceania, South and North America all among the top bean growers. Brazil and India are the leading global producers of dry beans and the largest producer of green beans.

Agroecology

In the tropics, *Phaseolus vulgaris* grows in high altitudes of 1,200–2,200 m with mean temperatures of 15–25°C in the growing season. The plant can tolerate occasional diurnal temperatures of 35°C, but this often causes flower abortion. Growth is halted below 10°C and the plant is devastated by frosts. At latitudes of 10 or more from the equator, the crop is grown at low altitudes during the cooler months, usually with irrigation. The crop is usually grown in areas with mean annual rainfall of 250–400 mm during the growing season. Occasional water deficits reduce yield, but too wet or humid conditions during the growing period promote diseases that damage the crop. *P. vulgaris* germplasm vary in photoperiod sensitivity (short day to day neutral). The Andean genotypes are more sensitive to photoperiodism than the mesoAmerican genotypes.

Soil-wise, *P. vulgaris* prefers medium-textured, organic rich, well-drained soils over 0.5 m deep. It is intolerant of high soil acidity and the associated aluminium and manganese toxicities. Optimum pH hovers from 5.5 to 7.5.

Edible Plant Parts and Uses

The different cultivars of *Phaseolus vulgaris* are primarily grown for their immature edible pods and for the dry ripe seeds. In Latin America and parts of tropical Africa, they are grown mainly for the dried pulse. In Europe, the United States and other temperate countries, they are grown for the green immature pods which are eaten as a vegetable and are also canned and frozen. The leaves are also used as vegetables in southeast Asia and Papua New Guinea.

Three types of green beans are commonly cultivated for its pods: string or runner beans, stringless or French beans (depending on whether the pod has a tough, fibrous "string" running along its length), and snap beans, with a thin flat pod that requires less cooking time.

Snap beans (both green and yellow) or green beans or French beans, string or stringless beans, runner beans are popularly eaten as immature pods. The immature pods are often steamed, boiled, stir-fried, or baked in casseroles. The pods are eaten mixed with other vegetables like carrots, corn and peas; or in stir fries with various types of meat. Some pods are battered and fried and in Japan, green beans are used in tempura. In USA, green bean casserole comprising green beans, cream of mushroom soup, and French fried onion is commonly eaten especially at Thanksgiving.

Navy beans also called haricot or pea bean are small, creamy-white to white, pea-sized beans (Plate 20). They are mild-flavoured beans that are dense and smooth. In Britain and USA, they are popularly used in baked beans, pies and soups. Other white beans include Cannellini, a fairly popular variety in Central and Southern Italy which is related to the kidney bean (Plate 23). Cannellini are often the bean of choice used in Tuscan cooking, most prominently in *Fagioli all'Uccelletto*, where boiled cannellini beans are sautéed in olive oil, tomatoes and sage.

Pinto beans are mottled or painted beans (Plate 16). The "Alavese pinto bean is a red variety of pinto beans, originated from Álava province in the Basque Country of northern Spain. Pinto bean is the most common bean in the United States and north-western Mexico. The bean is used whole in broth or mashed and refried and is used as filling for burritos. Pinto beans are also used in chili con carne, a spicy meat stew.

Black turtle beans are also known as black Spanish beans, Tampico beans and Venezuelan beans (Plate 21). They are small, glossy, with a dense meaty flavour liken to that of mushrooms and are nutritionally rich especially in antioxidants. These black beans are traditionally used in Mexican, Caribbean and Latin American recipes. They are featured in Cajun and Creole cuisines of South Louisiana and Hispanic cuisines in USA. Black beans are widely used in the vegetarian Mexican-American black bean burrito. It is used in *feijoada* (stew of beans, beef and pork), the national Portuguese dish in Brazil. Black bean is the primary ingredient in the famous Cuban dish or rice and beans; in *Gallo pinto*, the traditional dish of Nicaragua and Costa Rica and *Pabellón criollo* is a traditional Venezuelan dish, comprising plate of rice, shredded beef and stewed black beans. The black turtle bean is also very popular for making into soups, which are often eaten with Cuban crackers.

Cranberry beans originated in Colombia as the *cargamanto* variety are also called shelled beans (Plate 18). The bean is a medium large tan or hazelnut-coloured bean, splashed with red/black to magenta streaks or mottles. One recipe suggests simmering the beans in olive oil or a little chopped pancetta, chopped garlic and fresh sage leaves.

Borlotti beans, also known as roman beans or *Romano b*eans are a variety of cranberry bean bred in Italy. They have distinctive creamy-coloured pods, flecked with bright crimson-red (Plate 19). Inside, the beans are a reddish-brown mottled colour and have a thicker skin. Borlotti beans are very popular in Italian, Portuguese and Turkish cuisine.

Kidney beans also called chilli beans are kidney-shaped and have a bright red or maroon skin (Plate 22). Red kidney beans are solely used in New Orleans and much of southern Louisiana for the classic Monday Creole dish of red beans and rice. Kidney beans are also used in *chilli con carne.* In Punjab, northwest India, kidney bean is an integral part of the Punjabi cuisine. Small kidney beans used in stews in La Rioja, Spain, are called *Caparrones*.

Yellow beans also called canary beans are small, oval, yellow colour beans with a thin skin and creamy texture. *Peruano* beans, a type of canary beans is the top-selling beans in Mexico city.

Pink beans are small oval-shaped, pale-pinked coloured beans. In Spanish they are called *Habichuelas Rosadas*. Pinks beans are tasty and go well with rice.

Botany

Annual, climbing or sub-erect herbaceous bush with 2–3 m long pubescent stem, glabrescent when old (Plates 1–5). Leaf trifoliolate, alternate on 4–9 cm long petiole (Plates 6–7). Leaflets 4–16 cm cm long, 2.5–11 cm broadly ovate to ovate-rhombic, acuminate, apex, rounded to broadly cuneate base, entire margin; lateral leaflets oblique; petiolule 1.5–2.5 mm long; stipules, deltoid 2–4 mm long. Inflorescence 1-3-flowered. Bracteoles, ovate and persistent. Flower papilionaceous, bisexual. Calyx cup-shaped, pubescent, tube 2–3 mm long, teeth 1 mm long, upper 2 joined to form an emarginate lip. Corolla white, yellow, purple or pale-pink, standard 9–12 mm long and glabrous, wings obovate, keel 10–12 mm long, spirally incurved.

Plate 1 Green pole beans

Plate 2 Cranberry bean pods

Plate 3 Bush beans

Plate 4 Large podded pole beans

Ovary pubescent. Fruit, 8–20 cm long by 1–2.5 cm wide, linear-oblong legume, green, yellow, black, purple, pink, white-pink mottled in colour, slightly curved to broadly undulating, turgid, glabrous, beaked (Plates 1–5 and 8–15). Seeds (beans) 4–10, white, brown, pink, red, black, mottled or variegated in 2 colours, plump, oblong, kidney-shaped or ensiform, 1–2×0.5–1.3 cm (Plates 15–23).

Nutritive/Medicinal Properties

Phaseolus vulgaris pods, seeds and sprouts are rich in proteins, carbohydrates (starch), dietary fibre, minerals, folate, vitamins (especially Bs) and antioxidant phytochemicals. The nutrient profile and level of nutrients in *P. vulgaris* varies considerably according to cultivars.

Plate 5 Close-up large podded pole beans

Plate 6 Trifoliolate leaves and flowers

Proximate nutrient composition of raw, green snap beans (*P. vulgaris*) per 100 g edible portion was reported as: water 90.32 g, energy 31 kcal (131 kJ), protein 1.83 g, total lipid 0.22 g, ash 0.66 g, carbohydrate 6.97 g, total dietary fibre 2.7 g, total sugars 3.26 g, sucrose 0.36 g, glucose 1.51 g, fructose 1.39 g, starch 0.88 g, Ca 37 mg, Fe 1.03 mg, Mg 25 mg, P 38 mg, K 211 mg, Na

Plate 7 Young leaves sold as vegetables

Plate 8 Cranberry (Borlotti) bean pods

Plate 9 Pink-podded beans

Plate 10 Yellow podded beans

Plate 13 Large podded beans

Plate 11 Purple-podded beans

Plate 14 String beans

Plate 12 Snap (French) beans

Plate 15 White seeds of large podded beans

Plate 16 Pinto beans

Plate 19 Borlotti beans

Plate 17 Small red beans

Plate 20 White, small Navy beans

Plate 18 Cranberry beans

Plate 21 Black turtle beans

Plate 22 Large red kidney beans

Plate 23 White Cannellini beans

6 mg, Zn 0.24 mg, Cu 0.699 mg, Mn 0.216 mg, F 19 μg, Se 0.6 μg, vitamin C 12.2 mg, thiamine 0.082 mg, riboflavin 0.104 mg, niacin 0.734 mg, pantothenic acid 0.225 mg, vitamin B-6 0.141 mg, total folate 33 μg, choline 15.3 mg, vitamin A 35 μg RAE, vitamin A 690 IU, β-carotene 379 μg, α-carotene 69 μg, lutein + zeaxanthin 640 μg, vitamin E (α-tocopherol) 0.41 mg, vitamin K (phylloquinone) 14.4 μg, total saturated fatty acids 0.050 g, 16:0 (palmitic) 0.042 g, 18:0 (stearic) 0.008 g, total monounsaturated fatty acids 0.010 g, 18:1 undifferentiated (oleic) 0.008 g, total polyunsaturated fatty acids 0.113 g, 18:2 undifferentiated (linoleic) 0.044 g, 18:3 undifferentiated (linolenic) 0.069 g, tryptophan 0.019 g, threonine 0.079 g, isoleucine 0.066 g, leucine 0.112 g, lysine 0.088 g, methionine 0.022 g, cystine 0.018 g, phenylalanine 0.067 g, tyrosine 0.042 g, valine 0.090 g, arginine 0.073 g, histidine 0.034 g, alanine 0.084 g, aspartic acid 0.255 g, glutamic acid 0.187 g, glycine 0.065 g, proline 0.068 g and serine 0.099 g (USDA 2010).

Proximate nutrient composition of raw, yellow snap beans (*P. vulgaris*) per 100 g edible portion was reported as: water 90.27 g, energy 31 kcal (129 kJ), protein 1.82 g, total lipid 0.12 g, ash 0.66 g, carbohydrate 7.13 g, total dietary fibre 3.4 g, Ca 37 mg, Fe 1.04 mg, Mg 25 mg, P 38 mg, K 209 mg, Na 6 mg, Zn 0.24 mg, Cu 0.069 mg, Mn 0.214 mg, Se 0.6 μg, vitamin C 16.3 mg, thiamine 0.084 mg, riboflavin 0.105 mg, niacin 0.752 mg, pantothenic acid 0.094 mg, vitamin B-6 0.074 mg, total folate 37 μg, vitamin A 5 μg RAE, vitamin A 108 IU, total saturated fatty acids 0.026 g, 16:0 (palmitic) 0.022 g, 18:0 (stearic) 0.004 g, total monounsaturated fatty acids 0.005 g, 18:1 undifferentiated (oleic) 0.005 g, total polyunsaturated fatty acids 0.059 g, 18:2 undifferentiated (linoleic) 0.023 g, 18:3 undifferentiated (linolenic) 0.036 g, tryptophan 0.019 g, threonine 0.079 g, isoleucine 0.066 g, leucine 0.112 g, lysine 0.088 g, methionine 0.022 g, cystine 0.018 g, phenylalanine 0.067 g, tyrosine 0.042 g, valine 0.090 g, arginine 0.073 g, histidine 0.034 g, alanine 0.084 g, aspartic acid 0.255 g, glutamic acid 0.187 g, glycine 0.065 g, proline 0.068 g and serine 0.099 g (USDA 2010).

Proximate nutrient composition of raw, mature red kidney bean (*P. vulgaris*) seeds per 100 g edible portion was reported as: water 11.75 g, energy 337 kcal (1408 kJ), protein 22.53 g, total lipid 1.06 g, ash 3.37 g, carbohydrate 61.29 g, total dietary fibre 15.2 g, total sugars 2.10 g, Ca 83 mg, Fe 6.69 mg, Mg 138 mg, P 406 mg, K 1,359 mg, Na 12 mg, Zn 2.79 mg, Cu 0.699 mg, Mn 1.111 mg, F 2.2 μg, Se 3.2 μg, vitamin C 4.5 mg, thiamine 0.608 mg, riboflavin 0.215 mg, niacin 2.110 mg, pantothenic acid 0.780 mg, vitamin B-6 0.397 mg, total folate 394 μg, choline 65.9 mg, vitamin E (α-tocopherol) 0.21 mg, vitamin K (phylloquinone) 5.6 μg, total saturated fatty acids 0.154 g, 16:0 (palmitic) 0.136 g, 18:0 (stearic) 0.018 g, , total monounsaturated fatty acids 0.082 g, 18:1 undifferentiated (oleic)

0.082 g, total polyunsaturated fatty acids 0.586 g, 18:2 undifferentiated (linoleic) 0.228 g, 18:3 undifferentiated (linolenic) 0.358 g, tryptophan 0.267 g, threonine 0.948 g, isoleucine 0.995 g, leucine 1.799 g, lysine 1.547 g, methionine 0.339 g, cystine 0.245 g, phenylalanine 1.218 g, tyrosine 0.634 g, valine 1.179 g, arginine 1.395 g, histidine 0.627 g, alanine 0.945 g, aspartic acid 2.725 g, glutamic acid 3.436 g, glycine 0.880 g, proline 0.955 g and serine 1.226 g (USDA 2010).

Proximate nutrient composition of raw, mature French bean (*P. vulgaris*) seeds per 100 g edible portion was reported as: water 10.77 g, energy 343 kcal (1,435 kJ), protein 18.81 g, total lipid 2.02 g, ash 4.30 g, carbohydrate 64.11 g, total dietary fibre 25.2 g, Ca 186 mg, Fe 3.40 mg, Mg 188 mg, P 304 mg, K 1,316 mg, Na 18 mg, Zn 1.90 mg, Cu 0.440 mg, Mn 1.20 mg, Se 12.9 μg, vitamin C 4.6 mg, thiamine 0.535 mg, riboflavin 0.221 mg, niacin 2.083 mg, pantothenic acid 0.789 mg, vitamin B-6 0.401 mg, total folate 399 μg, total saturated fatty acids 0.221 g, (myristic) 0.005 g, 16:0 (palmitic) 0.186 g, 18:0 (stearic) 0.023 g, , total monounsaturated fatty acids 0.138 g, 16:1 undifferentiated (palmitoleic) 0.003 g, 18:1 undifferentiated (oleic) 0.135 g, total polyunsaturated fatty acids 1.207 g, 18:2 undifferentiated (linoleic) 0.442 g, 18:3 undifferentiated (linolenic) 0.765 g, tryptophan 0.223 g, threonine 0.792 g, isoleucine 0.831 g, leucine 1.502 g, lysine 1.291 g, methionine 0.283 g, cystine 0.205 g, phenylalanine 1.017 g, tyrosine 0.530 g, valine 0.984 g, arginine 1.165 g, histidine 0.524 g, alanine 0.789 g, aspartic acid 2.276 g, glutamic acid 2.869 g, glycine 0.734 g, proline 0.798 g and serine 1.023 g (USDA 2010).

Proximate nutrient composition of raw, mature navy bean (*P. vulgaris*) seeds per 100 g edible portion was reported as: water 12.10 g, energy 337 kcal (1,411 kJ), protein 22.33 g, total lipid 1.50 g, ash 3.32 g, carbohydrate 60.75 g, total dietary fibre 24.4 g, total sugars 3.88 g, sucrose 3.33 g, glucose 0.21 g, galactose 0.34 g, starch 32.90 g, Ca 147 mg, Fe 5.49 mg, Mg 175 mg, P 407 mg, K 1,185 mg, Na 5 mg, Zn 3.65 mg, Cu 0.834 mg, Mn 1.418 mg, Se 11.0 μg, thiamine 0.775 mg, riboflavin 0.164 mg, niacin 2.188 mg, pantothenic acid 0.744 mg, vitamin B-6 0.428 mg, total folate 364 μg, choline 87.4 mg, betaine 0.1 mg, vitamin E (α-tocopherol) 0.02 mg, γ-tocopherol 2.10 mg, δ-tocopherol 0.17 mg, vitamin K (phylloquinone) 2.5 μg, total saturated fatty acids 0.170 g, 14:0 (myristic) 0.002 g, 15:0 (pentadecanoic) 0.001 g, 16:0 (palmitic) 0.135 g, 17:0 (margaric) 0.002 g, 18:0 (stearic) 0.023 g, 20:0 (arachidic) 0.006 g, total monounsaturated fatty acids 0.245 g, 16:1 undifferentiated (palmitoleic) 0.002 g, 18:1 undifferentiated (oleic) 0.117 g, 18:1 c 0.117 g, total polyunsaturated fatty acids 1.411 g, 18:2 undifferentiated (linoleic) 0.335 g, 18:3 undifferentiated (linolenic) 0.538 g, tryptophan 0.247 g, threonine 0.711 g, isoleucine 0. 0.952 g, leucine 1.723 g, lysine 1.280 g, methionine 0.273 g, cystine 0.187 g, phenylalanine 1.158 g, tyrosine 0.484 g, valine 1.241 g, arginine 1.020 g, histidine 0.507 g, alanine 0.908 g, aspartic acid 2.598 g, glutamic acid 3.098 g, glycine 0.801 g, proline 1.117 g and serine 1.180 g (USDA 2010).

Proximate nutrient composition of raw, mature pinto bean (*P. vulgaris*) seeds per 100 g edible portion was reported as: water 11.33 g, energy 347 kcal (1,452 kJ), protein 21.42 g, total lipid 1.23 g, ash 3.46 g, carbohydrate 62.55 g, total dietary fibre 15.5 g, total sugars 2.11 g, sucrose 1.98 g, glucose 0.13 g, starch 34.17 g, Ca 113 mg, Fe 5.07 mg, Mg 176 mg, P 411 mg, K 1,393 mg, Na 12 mg, Zn 2.28 mg, Cu 0.893 mg, Mn 1.148 mg, Se 27.9 μg, vitamin C 6.3 mg, thiamine 0.713 mg, riboflavin 0.212 mg, niacin 1.174 mg, pantothenic acid 0.785 mg, vitamin B-6 0.474 mg, total folate 525 μg, choline 66.2 mg, betaine 0.4 mg, vitamin E (α-tocopherol) 0.21 mg, vitamin K (phylloquinone) 5.6 μg, total saturated fatty acids 0.235 g, 14:0 (myristic) 0.001 g, 16:0 (palmitic) 0.229 g, 18:0 (stearic) 0.005 g, total monounsaturated fatty acids 0.229 g, 18:1 undifferentiated (oleic) 0.229 g, total polyunsaturated fatty acids 0.407 g, 18:2 undifferentiated (linoleic) 0.170 g, 18:3 undifferentiated (linolenic) 0.237 g, tryptophan 0.237 g, threonine 0.810 g, isoleucine 0.871 g, leucine 1.558 g, lysine 1.356 g, methionine 0.259 g, cystine 0.187 g, phenylalanine 1.095 g, tyrosine 0.427 g, valine 0.998 g, arginine 1.096 g, histidine 0.556 g, alanine 0.872 g,

aspartic acid 2.268 g, glutamic acid 3.027 g, glycine 0.796 g, proline 1.072 g and serine 1.171 g (USDA 2010).

Proximate nutrient composition of raw, mature black bean (*P. vulgaris*) seeds per 100 g edible portion was reported as: water 11.02 g, energy 341 kcal (1,425 kJ), protein 21.60 g, total lipid 1.42 g, ash 3.60 g, carbohydrate 62.36 g, total dietary fibre 15.2 g, total sugars 2.12 g, Ca 123 mg, Fe 5.02 mg, Mg 171 mg, P 352 mg, K 1,483 mg, Na 5 mg, Zn 3.65 mg, Cu 0.841 mg, Mn 1.060 mg, Se 3.2 µg,vitamin C 0.0 mg, thiamine 0.900 mg, riboflavin 0.193 mg, niacin 1.955 mg, pantothenic acid 0.899 mg, vitamin B-6 0.286 mg, total folate 444 µg, choline 66.4 mg, vitamin E (α-tocopherol) 0.21 mg, vitamin K (phylloquinone) 5.6 µg, total saturated fatty acids 0.366 g, 14:0 (myristic) 0.001 g, 16:0 (palmitic) 0.343 g, 18:0 (stearic) 0.022 g, total monounsaturated fatty acids 0.123 g, 18:1 undifferentiated (oleic) 0.123 g, total polyunsaturated fatty acids 0.610 g, 18:2 undifferentiated (linoleic) 0.332 g, 18:3 undifferentiated (linolenic) 0.278 g, tryptophan 0.256 g, threonine 0.909 g, isoleucine 0.954 g, leucine 1.725 g, lysine 1.483 g, methionine 0.325 g, cystine 0.235 g, phenylalanine 1.168 g, tyrosine 0.608 g, valine 1.130 g, arginine 1.337 g, histidine 0.601 g, alanine 0.905 g, aspartic acid 2.613 g, glutamic acid 3.294 g, glycine 0.843 g, proline 0.916 g and serine 1.175 g (USDA 2010).

Proximate nutrient composition of raw, mature white bean (*P. vulgaris*) seeds per 100 g edible portion was reported as: water 11.32 g, energy 333 kcal (1,393 kJ), protein 23.36 g, total lipid 0.85 g, ash 4.20 g, carbohydrate 60.27 g, total dietary fibre 15.2 g, total sugars 2.11 g, Ca 240 mg, Fe 10.44 mg, Mg 190 mg, P 301 mg, K 1,795 mg, Na 16 mg, Zn 3.67 mg, Cu 0.984 mg, Mn 1.796 mg, Se 12.8 µg,vitamin C 0.0 mg, thiamine 0.437 mg, riboflavin 0.146 mg, niacin 0.479 mg, pantothenic acid 0.732 mg, vitamin B-6 0.318 mg, total folate 388 µg, choline 66.2 mg, vitamin E (α-tocopherol) 0.21 mg, vitamin K (phylloquinone) 5.6 µg, total saturated fatty acids 0.219 g, 14:0 (myristic) 0.001 g, 16:0 (palmitic) 0.205 g, 18:0 (stearic) 0.013 g, total monounsaturated fatty acids 0.074 g, 18:1 undifferentiated (oleic) 0.074 g, total polyunsaturated fatty acids 0.364 g, 18:2 undifferentiated (linoleic) 0.198 g, 18:3 undifferentiated (linolenic) 0.166 g, tryptophan 0.277 g, threonine 0.983 g, isoleucine 1.031 g, leucine 1.865 g, lysine 1.603 g, methionine 0.351 g, cystine 0.254 g, phenylalanine 1.263 g, tyrosine 0.658 g, valine 1.222 g, arginine 1.446 g, histidine 0.650 g, alanine 0.979 g, aspartic acid 2.825 g, glutamic acid 3.561 g, glycine 0.912 g, proline 0.990 g and serine 1.271 g (USDA, 2010).

Proximate nutrient composition of raw, mature yellowbean (*P. vulgaris*) seeds per 100 g edible portion was reported as: water 11.10 g, energy 345 kcal (1,443 kJ), protein 22.00 g, total lipid 2.60 g, ash 3.60 g, carbohydrate 60.70 g, total dietary fibre 25.1 g, Ca 166 mg, Fe 7.01 mg, Mg 222 mg, P 488 mg, K 1,042 mg, Na 12 mg, Zn 2.83 mg, Cu 0.636 mg, Mn 1.286 mg, Se 12.8 µg,vitamin C 0.0 mg, thiamine 0.690 mg, riboflavin 0.330 mg, niacin 2.430 mg, pantothenic acid 0.734 mg, vitamin B-6 0.442 mg, total folate 389 µg, total saturated fatty acids 0.671 g, 14:0 (myristic) 0.002 g, 16:0 (palmitic) 0.629 g, 18:0 (stearic) 0.040 g, total monounsaturated fatty acids 0.226 g, 18:1 undifferentiated (oleic) 0.22 + g, total polyunsaturated fatty acids 1.118 g, 18:2 undifferentiated (linoleic) 0.609 g, 18:3 undifferentiated (linolenic) 0.510 g, tryptophan 0.260 g, threonine 0.926 g, isoleucine 0.972 g, leucine 1.756 g, lysine 1.510 g, methionine 0.331 g, cystine 0.239 g, phenylalanine 1.190 g, tyrosine 0.620 g, valine 1.151 g, arginine 1.362 g, histidine 0.612 g, alanine 0.922 g, aspartic acid 2.661 g, glutamic acid 3.355 g, glycine 0.859 g, proline 0.993 g and serine 1.197 g (USDA, 2010).

Proximate nutrient composition of raw, sprouted mature kidney bean (*P. vulgaris*) seeds per 100 g edible portion was reported as: water 90.70 g, energy 29 kcal (121 kJ), protein 4.20 g, total lipid 0.5 g, ash 0.5 g, carbohydrate 4.10 g, Ca 17 mg, Fe 0.81 mg, Mg 21 mg, P 37 mg, K 187 mg, Na 6 mg, Zn 0.40 mg, Cu 0.159 mg, Mn 0.182 mg, Se 0.6 µg, vitamin C 38.7 mg, thiamine 0.370 mg, riboflavin 0.250 mg, niacin 2.920 mg, pantothenic acid 0.368 mg, vitamin B-6 0.085 mg, total folate 59 µg, vitamin A 2 IU,

total saturated fatty acids 0.072 g, 16:0 (palmitic) 0.064 g, 18:0 (stearic) 0.009 g, total monounsaturated fatty acids 0.039 g, 18:1 undifferentiated (oleic) 0.039 g, total polyunsaturated fatty acids 0.276 g, 18:2 undifferentiated (linoleic) 0.107 g, 18:3 undifferentiated (linolenic) 0.169 g, tryptophan 0.044 g, threonine 0.176 g, isoleucine 0.186 g, leucine 0.302 g, lysine 0.239 g, methionine 0.044 g, cystine 0.048 g, phenylalanine 0.212 g, tyrosine 0.144 g, valine 0.216 g, arginine 0.228 g, histidine 0.524 g, alanine 0.174 g, aspartic acid 0.546 g, glutamic acid 0.512 g, glycine 0.144 g, proline 0.169 g and serine 0.224 g (USDA 2010).

Proximate nutrient composition of raw, sprouted navy bean (*P. vulgaris*) mature seeds per 100 g edible portion was reported as: water 79.15 g, energy 67 kcal (280 kJ), protein 6.15 g, total lipid 0.7 g, ash 0.95 g, carbohydrate 13.05 g, Ca 15 mg, Fe 1.93 mg, Mg 101 mg, P 100 mg, K 307 mg, Na 13 mg, Zn 0.89 mg, Cu 0.356 mg, Mn 0.408 mg, Se 0.6 μg, vitamin C 18.8 mg, thiamine 0.390 mg, riboflavin 0.215 mg, niacin 1.220 mg, pantothenic acid 0.825 mg, vitamin B-6 0.191 mg, total folate 132 μg, vitamin A 4 IU, total saturated fatty acids 0.085 g, 16:0 (palmitic) 0.076 g, 18:0 (stearic) 0.009 g, total monounsaturated fatty acids 0.052 g, 18:1 undifferentiated (oleic) 0.052 g, total polyunsaturated fatty acids 0.407 g, 18:2 undifferentiated (linoleic) 0.147 g, 18:3 undifferentiated (linolenic) 0.260 g, tryptophan 0.064 g, threonine 0.258 g, isoleucine 0.273 g, leucine 0.442 g, lysine 0.350 g, methionine 0.064 g, cystine 0.070 g, phenylalanine 0.310 g, tyrosine 0.212 g, valine 0.316 g, arginine 0.335 g, histidine 0.172 g, alanine 0.255 g, aspartic acid 0.799 g, glutamic acid 0.750 g, glycine 0.212 g, proline 0.248 g and serine 0.329 g (USDA 2010).

Proximate nutrient composition of raw, sprouted pinto bean (*P. vulgaris*) mature seeds per 100 g edible portion was reported as: water 81.30 g, energy 62 kcal (259 kJ), protein 5.25 g, total lipid 0.9 g, ash 0.95 g, carbohydrate 11.60 g, Ca 43 mg, Fe 1.97 mg, Mg 53 mg, P 94 mg, K 307 mg, Na 153 mg, Zn 0.50 mg, Cu 0.320 mg, Mn 0.366 mg, Se 0.6 μg, vitamin C 21.7 mg, thiamine 0.230 mg, riboflavin 0.175 mg, niacin 2.280 mg, pantothenic acid 0.740 mg, vitamin B-6 0.171 mg, total folate 118 μg, vitamin A 2 IU, total saturated fatty acids 0.109 g, 16:0 (palmitic) 0.097 g, 18:0 (stearic) 0.012 g, total monounsaturated fatty acids 0.067 g, 18:1 undifferentiated (oleic) 0.067 g, total polyunsaturated fatty acids 0.523 g, 18:2 undifferentiated (linoleic) 0.189 g, 18:3 undifferentiated (linolenic) 0.334 g, tryptophan 0.055 g, threonine 0.220 g, isoleucine 0.233 g, leucine 0.377 g, lysine 0.299 g, methionine 0.064 g, cystine 0.060 g, phenylalanine 0.265 g, tyrosine 0.181 g, valine 0.270 g, arginine 0.286 g, histidine 0.147 g, alanine 0.218 g, aspartic acid 0.682 g, glutamic acid 0.640 g, glycine 0.181 g, proline 0.212 g and serine 0.281 g (USDA 2010).

Compared to cultivated *P. vulgaris* beans, wild beans contained less fat (0.56% vs. 0.89%) and carbohydrates (61.64% vs. 68.05%) and more protein (21.7% vs. 25.5%), ash (4.15% vs. 5.15%), crude fibre (5.04% vs. 7.08%) (Sotelo et al. 1995). Sulfur amino acids were found to be limiting in both groups of bean however, the cultivated beans had a higher content of the limiting amino acids. Therefore, the cultivated beans possessed a better amino acid profile than the wild beans. Toxic factors were not found in either type of bean.

Kalogeropoulos et al. (2010) evaluated the bioactive micronutrients of cooked broad beans, chickpeas, two split peas varieties, two lentils varieties, pinto beans, black-eyed beans, five white beans varieties and white lupines. Crude protein was found to range from 6.1% to 11.5%, crude fibre 3.6% to 11.7%, and energy content 103 to 155 kcal/100 g. Phytosterols contents varied from 13.5 to 53.6 mg/100 g. Tocopherols and squalene ranged from 0.26 to 1.78 and 0.12 to1.74 mg/100 g, respectively. Legumes' lipids were rich in α-linolenic acid which comprised 2.5–41.7% of fatty acids. Total phenolic content of the cooked legumes ranged from 11.8 to 25.9 mg gallic acid equivalents/100 g, simple polyphenols ranged between 0.32 and 2.4 mg/100 g and triterpenic acids between 0.34 and 8.5 mg/100 g. Among the simple polyphenols determined, flavonoids – mainly catechins-predominated in lentils and chickpeas, and phenolic acids in the rest of legumes.

Other Phytochemicals

Phaseolus vulgaris seeds were found to contain bioactive components such as alkaloids, anthocyanin, carbohydrate, catechin, fibres, flavonoids, phasine, phytic acid, quercetin, saponins, steroids, tannins and terpenoids and trypsin inhibitors (Ocho-Anin Atchibri et al. 2010b). The seeds contained per100g dried seeds: 62.9 g carbohydrates, 22.4 g proteins, 44.12 g resistant starch, 6.9 g fibre, 61 mg catechins, 56 mg saponins, 45 mg anthocyanins, quercetin 31 mg, trypsin inhibitors 7 mg, phasine 4 mg, phytic acid 3 mg. Besides being a good dietary source, *Phaseolus vulgaris* seeds have a rich and diverse array of bioactive compounds which impart potential health benefits though biological activities such as enhancement of the bifidogenic effect (da S Queiroz-Monici et al. 2005); antioxidant (Heimler et al. 2005); anticarcinogenic (Hangen and Bennink 2002), antihypercholesterolemic (Shutler et al. 1989; Winham and Hutchins 2007), antidiabetic and antihyperglycemic activity activities (Carai et al. 2009; Tormo et al. 2004; Ocho-Anin Atchibri et al. 2010a). It has also been reported earlier that terpenoids (Murakami et al. 1993), we are precise bioactive components responsible for the antidiabetic activity of *P. vulgaris* seeds. The consumption of *P. vulgaris* seeds had been reported to be associated with a decrease risk for a wide variety of chronic and degenerative diseases such as cancer, obesity, cardiovascular diseases and diabetes as discussed below.

The seed colour of beans was reported to be determined by the occurrence and concentration of flavonol glycosides, anthocyanins, and tannins (Beninger and Hosfield 2003; Aparicio-Fernandez et al. 2005; Choung et al. 2003). Five major anthocyanins were isolated, from seed coats of 16 kidney beans (*Phaseolus vulgaris*) cultivated in Korea (Choung et al. 2003). The structures of these five anthocyanins were elucidated as cyanidin 3,5-diglucoside, delphinidin 3-glucoside, cyanidin 3-glucoside, petunidin 3-glucoside, and pelargonidin 3-glucoside. The contents and composition of anthocyanins in speckled seed were found to depend on the classes of speckle colour. An abundance of pelargonidin 3-glucoside and delphinidin 3-glucoside were observed in red and black kidney beans, respectively. The concentrations of cyanidin 3,5-diglucoside, delphinidin 3-glucoside, cyanidin 3-glucoside, petunidin 3-glucoside, pelargonidin 3-glucoside, and total anthocyanins were in the ranges of 0–0.04, 0–2.61, 0–0.12, 0–0.17, 0–0.59 and 0–2.78 mg/g of dried seed coats, respectively. Anthocyanins, flavanol monomers, and heterogeneous flavanol oligomers up to hexamers were detected in the seed coat of Black Jamapa (*P. vulgaris*) bean (Aparicio-Fernandez et al. 2005). This represented the first report that myricetin glycoside and proanthocyanidin oligomers containing (epi)-gallocatechin had been reported in the black bean. Gu et al. (2003b) identified heterogeneous B-type proanthocyanidins containing (epi)afzelechin as subunits in pinto beans by using electrospray ionization (ESI) mass spectrometry high-performance liquid chromatography. Propelargonidins, A-type proanthocyanidins were identified in pinto beans by a normal-phase HPLC-MS/MS (Gu et al. 2003a). Deng et al. (2010) purified ferritin from black bean seed. Ferritin possessed an apparent molecular mass of approximately 560 kDa and shared close homology in amino acid sequence to soybean seed ferritin (SSF).

The main flavonoids identified in yellow and green French beans were 3-*O*-glucuronides and 3-*O*-rutinosides of quercetin and kaempferol (Hempel and Bohm 1996) The total content of quercetin-3-*O*-glycosides ranged from 19.1 to 183.5 μg/g and that of kaempferol-3-*O*-glycosides from 5.6 to 14.8 μg/g of fresh bean. Kaempferol 3-O-β-D-glucoside (astragalin) was isolated as the main flavonoid monomer present in three dry bean (*Phaseolus vulgaris*) genotypes differing in seedcoat colour, mineral brown, yellow brown, and pale greenish yellow (Beninger et al. 1999). Flavonoid polymers (condensed tannins) were also detected but not anthocyanins. Astragalin was present at similar levels in pale greenish yellow and mineral brown genotypes, but was significantly lower in yellow brown. Subtle differences in colour between these genotypes may be due to the amount and type of

tannins which had secondarily polymerized with phenolics and flavonoid monomers. Three flavonol glycosides were isolated and identified from the commercial dark red kidney bean (*Phaseolus vulgaris*) cultivar Montcalm (Beninger and Hosfield 1999). In descending concentration, these compounds were 3‘,4‘,5,7-tetrahydroxyflavonol 3-*O*-β-D-glucopyranosyl (2→1) *O*-β-D-xylopyranoside, quercetin 3-*O*-β-D-glucopyranoside, and kaempferol 3-*O*-β-D-glucopyranoside. These three flavonol glycosides were Being yellow compounds the three flavonol glycosides did not contribute to the garnet red colour of Montcalm seed coats. Red-coloured compounds which tested positive for proanthocyanidins were most likely responsible for the red seed coat colour of cultivar Montcalm. The overall average (5) of condensed tannins found in common bean seed coats was 20.04% (Diaz et al. 2010). Soluble tannins ranged from 8% to 27.9%, insoluble tannins varied from 1.5% to 5.4% and total tannins 10.7–30.9%. Condensed tannins in the genotypes were mainly composed of catechin (60.3%), gallocatechin (25%), and afzelechin (14.7%) as monomeric units. Anthocyanins in seed coats averaged 0.08% (0.013–0.21% range) expressed as delphinidin-3-glucoside equivalents.

Phaseolin (also named G1 globulin) accounting for 50 g/kg of total storage protein in kidney bean seed was compared with a kidney bean protein isolate (KPI) in functional properties (Yin et al. 2010). Compared with kidney bean protein isolate (KPI), the acid-extracted phaseolin-rich protein product (PRP) had much lower protein recovery of 320 g/kg (dry weight basis) but higher phaseolin purity (over 950 g/kg). PRP exhibited much better protein solubility, emulsifying activity index, and gel-forming ability than KPI. The results presented here suggest the potential for acid-extracted PRP to be applied in food formulations, in view of its functional properties. The relatively poor functional properties of KPI may be associated with protein denaturation/unfolding, with subsequent protein aggregation. Phaseolin was confirmed to be a 7 S globulin, devoid of inter-polypeptide disulfide bonds (Yin et al. 2011). Hydrophobic and electrostatic interactions and hydrogen bonding contributed to the conformational stability of phaseolin.

A total of 62 volatiles consisting of aromatic hydrocarbons, aldehydes, alkanes, alcohols and ketones were determined in uncooked dry bean (*Phaseolus vulgaris*) cultivars representing three market classes (black, dark red kidney and pinto beans) (Oomah et al. 2007). Bean cultivars differed in abundance and profile of volatiles. The combination of 18 compounds comprising a common profile elucidated 79% of the variance among cultivars.

All 24 common bean samples representing 17 varieties were found to contain the same hydroxycinnaminic acid derivatives, but the glycosylated flavonoid components showed distinct dissimilarities (Lin et al. 2008). Black beans contained primarily the 3-O-glucosides of delphinidin, petunidin and malvidin. Pinto beans contained kaempferol and its 3-O-glycosides. Light red kidney beans contained trace amounts of quercetin 3-O-glucoside and its malonates. Pink and dark red kidney beans contained the diglycosides of quercetin and kaempferol. Small red beans (also known as red Mexican) contained mainly kaempferol 3-O-glucoside and pelargonidin 3-O-glucoside. Alubia, cranberry, great northern, and navy beans had no detectable amounts of flavonoids. This represented the first report of the isolation of quercetin 3-O-pentosylhexoside and flavonoid glucoside malonates, and the first detailed detection of hydroxycinnamates, in common beans.

Soaked, cooked and soaked-cooked common beans exhibited a decrease in ash, most minerals, vitamins, and some essential amino acids (Barampama and Simard 1995). Soaking decreased soluble sugar (9.8%) but increased starch (7.3%) and soluble fibber (16.9%) compared to untreated beans. In cooked beans, an increase in soluble sugar (1.5%), and a decrease in thiamine (81.7%), starch (24.6%) and soluble fibber (16.6%) and nitrogen (2.9%) concentrations were observed. Crude fibber (6.9%) and starch (10.0%) increased while fat (17.6%), fatty acids (linoleic: 10.7%; linolenic: 14.3%) and soluble sugars (25.4%) and nitrogen (14.4%) decreased in soaked-cooked beans. Fermentation

elevated potassium (11.6%), soluble fibber (18.9%), and some amino acids but lowered fatty acids (linoleic: 13.5%; linolenic: 19.9%), soluble sugar (75.2%) and vitamin (riboflavin: 41.0%; niacin: 24.5%) concentrations in common beans. However, the in-vitro starch digestibility was appreciably improved (12.3%) by cooking while it decreased in soaked beans (29.2%). Soaking-cooking and fermentation did not have any significant effect on the digestibility of common bean starch. Among the five treatments applied to common beans, only fermentation showed a significant improvement (8.3%) on the protein nutritive value of this legume.

Polysaccharide and soluble fibre contents of *P. vulgaris* increased upon cooking with stachyose as the major oligosaccharide (Campos-Vega et al. 2009). Cooked bean of cultivar Bayo Madero had the highest yield of polysaccharides (55%) and resistant starch (37%), followed by those of Negro 8,025 (48% and 32%, respectively). Acetate was the most abundant short-chain fatty acids (SCFAs) found in all bean varieties. The concentration of SCFAs was cultivar-dependent; Bayo Madero and Negro 8,025 displayed the highest concentration of butyrate (15 mmol/l), while Azufrado Higuera had the lowest and highest concentrations of acetate (39 mmol/l) and propionate (14 mmol/l), respectively. The results illustrated the common bean to be an excellent source of polysaccharides that could be fermented in the colon to produce SCFAs, compounds previously reported to exert health benefits. Studies by Gallegos-Infante et al. (2010) showed that pasta with 30% and 45% of common bean flour showed higher values of protein. Composite spaghetti samples with increasing common bean flour showed decreasing levels of total starch but an important increase in the resistant starch (RS) content and indigestible insoluble fraction levels. Plain pasta made with semolina experienced the highest enzymatic hydrolysis rate, which decreased when common bean flour was added to the spaghetti. Spaghetti with a higher level of common bean flour was more slowly available, which may have positive implications for human health.

Studies had indicated iron bioavailability in white beans to be significantly higher compared to that in the coloured beans (Lung'aho and Glahn 2010). The white beans had a significantly greater content of ferritin formation (13.54 ng/mg) when compared to all other porridge ingredients including the red beans (2.3 ng/mg) The results suggested that substitution of complementary food ingredients with high anti-nutrient concentrations with those with lower anti-nutrient levels may enhance iron bioavailability from complementary food home-recipes.

Dry beans are endowed with nutrients which make them well-suited to meet two major dietary requirements for good health – increased intake of starches and complex carbohydrates and decreased intake of fat (Geil and Anderson 1994). Dry beans provide protein, complex carbohydrate, fibre, essential vitamins and minerals to the diet, yet are low in fat and sodium and contain no cholesterol. Both prophylactic and therapeutic effects of bean consumption have been documented. Incorporating dry beans in a health-promoting diet is especially essential in meeting the major dietary recommendations to reduce risk for chronic diseases such as coronary heart disease, diabetes mellitus, obesity and cancer (Geil and Anderson 1994). Black bean (*Phaseolus vulgaris)* plays an important role in the normal Guatemalan diet; 70 g per capita of black beans are consumed daily (Serrano and Goñi 2004). Besides being important sources of protein and energy, they contained "lente" digestion carbohydrates and a high amount of non-digested carbohydrates that may be fermented in the large intestine. These types of carbohydrates are linked to a low glycemic response, low serum cholesterol levels, and a decrease of colon cancer risk factors.

Numerous pharmacological properties of *P. vulgaris* have been scientifically studied and are elaborated below.

Antioxidant Activity

Using the oxygen radical absorbance capacity (ORAC) assay with fluorescein as the fluorescent probe and 2,2′-azobis(2-amidinopropane) dihydrochloride as a peroxyl radical generator, the lipophilic and hydrophilic antioxidant capacities of over 100 common food items and vegetables

were examined, and among these, coloured beans (black, navy, pinto, red kidney and small red) showed a high antioxidant capacity (Wu et al. 2004). The EC_{50} values of the antiradical activity of dry beans of four Italian landraces (12 samples) were found to vary from 39 to 2,810 mg sample/mg 1,1-diphenyl-2-picrylhydrazil radical (Heimler et al. 2005). The phenolic content of expressed as gallic acid equivalents was ranged from 1.17 to 4.40 mg/g. The flavonoid content, expressed as mg of (+)-catechin per g of dry seeds, ranged from 0.24 to 1.43 mg/g. Tsuda et al. (1994) isolated the seed coat pigments, RPO (cyanidin 3-O β-D-glucoside) and RP1 (pelargonidin 3-O-/β-D-glucoside) from red bean and BP1 (delphinidin 3-O-β-D-glucoside) from black bean. RPO exhibited strong antioxidative activity in the linoleic acid system at neutral condition (pH 7.0), while RP1 and BP1 displayed no antioxidative activity at pH 7.0. In acidic conditions (pH 3.0 and 5.0), RP1 and BP1 exhibited strong antioxidative activity.

The seed coat methanol extracts, tannin fractions, and pure flavonoids isolated from ten different seed coat colour genotypes of *Phaseolus vulgaris* all exhibited antioxidant activity in a fluorescence-based liposome assay (Beninger and Hosfield 2003). The relatively high activity of the condensed tannin (proanthocyanidin) fractions indicated that these may play a major role in the overall activity of the extracts. This activity also indicated that although these polyphenols could cause problems in digestibility, they may be important dietary supplements with beneficial health effects. The pure anthocyanins delphinidin 3-O-glucoside (1), petunidin 3-O-glucoside (2), and malvidin 3-O-glucoside (3) and the flavonol quercetin 3-O-glucoside (4) isolated from seed coats also displayed significantly higher antioxidant activity than the Fe^{2+} control. The activity of kaempferol 3-O-glucoside (5) was not different from that of the Fe^{2+}control. These findings suggested that variously coloured dry beans may be an important source of dietary antioxidants. In 25 Brazilian and three Peruvian bean cultivars, condensed tannins, anthocyanins, and flavonols such as kaempferol and quercetin glycosides were mostly found in seed coats (Ranilla et al. 2007). Cotyledons were rich in phenolic acids, such as ferulic, sinapic, chlorogenic, and other hydroxycinnamic acids. Generally, the seed coat colour pattern and the type of cultivar impacted on the variability of phenolic profiles and levels, respectively. Total phenolics and antioxidant capacity assessed by the DPPH method were higher in seed coats than in cotyledons. The antioxidant capacity had a significant correlation with condensed tannins for all samples and with total anthocyanins in black and red seed coats, whereas in cotyledons, it was more related to the total phenolic content.

Golam Masum Akond et al. (2011) found the following variations of seed colour in 29 common bean accessions: white, cream, purple, red and black, with variations being striped, rhomboid spotted and circular mottled. Bean genotypes displayed distinct dissimilarities in anthocyanin and total polyphenol content and antioxidant activities. Anthocyanin content differed significantly among genotypes and market classes, ranging from 0.05 to 0.47 mg/g. The bean genotypes with total polyphenol content ranging from 5.87 to 14.14 mg of gallic acid equiv/g and the sample also exhibited significant variation in antioxidant activity (17.09–36.96%). Generally bean genotypes with high anthocyanin and polyphenol content exhibited high antioxidant activity.

Total phenolics (mg/g dwb) expressed as gallic acid equivalents (GAE), total flavonoids (mg/g dwb) as catechin equivalents (CE) and proanthocyanidin expressed as leucocyanidin equivalent (mg LE/g) in selected dry beans (red kidney beans, black-eyed peas, pinto beans and soy beans) were found to range from 3.42 to 7.21, 0.61 to 0.84 and 0.51 to 3.13 in raw beans; 3.58–6.94, 0.19–0.99 and 0.43–3.13 in soaked beans and 4.55–9.52, 0.23–1.00 and 0.20–3.25 in toasted beans, respectively (Boateng et al. 2008). FRAP (ferric reducing antioxidant potential in μg/g) in raw, soaked and toasted dry beans ranged from 0.00097 to 0.00424 while DPPH (2,2-diphenyl-1-picrylhydrazyl.) (T30) (%) ranged from 43.9 to 62.61. The results indicated that processing methods (soaking and roasting) influenced total phenolic, flavonoid and antioxidant contents (DPPH, FRAP) in selected dry beans.

Black Jamapa bean (*P. vulgaris*) was found to be rich in condensed tannins, anthocyanins and flavonols (Aparicio-Fernández et al. 2008). Jamapa bean methanolic extract (BME) and some of the proanthocyanidin-rich fractions derived from it was found to have potent antiradical activity. A strong correlation between proanthocyanidin concentration in BME and antiradical capacity was observed, suggesting that these compounds contributed significantly to antiradical activity. BME was a better radical scavenger than butylated hydroxytoluene (45.6% and 33.9% antiradical capacity at 400 μM, respectively). Two proanthocyanidin-rich fractions obtained after a preliminary separation of the BME using Toyopearl (TP4 and TP6) exhibited a higher antiradical activity than the parent extract. Studies on the effect of BME on apoptosis of HeLa cells and earlier studies (Aparicio-Fernández et al. 2006) suggested that black Jamapa bean could be an important source of polyphenolic compounds with potential biological use as antioxidant and anticancer agents.

Total phenolic content and antioxidant activity of *P. vulgaris* bean hulls, were 6-8-times those of corresponding whole beans as measured using oxygen radical absorbance capacity (ORAC) values (Oomah et al. 2010). Aqueous acetone (70%) extracted more than twice the quantity of total phenolics from hulls that displayed significantly higher antioxidant and stronger inhibitory effect on both cyclooxygenases, COX-1 and COX-2, than water. Acetone extract of black bean hull displayed strong COX-1 (IC_{50} = 1.2 μg/ml) and COX-2 (IC_{50} = 38 μg/ml) inhibitory effects, even outperforming aspirin. However, bean hull water extracts were more potent inhibitors of lipoxygenase, 15-LOX, than corresponding acetone extracts. Anti-inflammatory activity of bean hulls was dependent on their phenolic content and antioxidant activity that were significantly affected by cultivar and extracting solvent.

The pearled common bean material, also referred to as milled samples, exhibited antioxidant activity that correlated with phenolic content and inhibited DPPH significantly in a dose-dependent manner as evaluated using the β-carotene-linoleate and the 1,1-diphenyl-2-picrylhydrazyl (DPPH) in vitro model systems (Cardador-Martínez et al. 2002a). Fractions extracted with ethyl acetate/acetone and acetone displayed antioxidant activity, which implied potent free radical scavenging activity with antimutagenic activity. Ranilla et al. (2009) found that cooking of beans (*P. vulgaris*) either at 100°C or 12°C without a soaking stage and keeping the cooking water to be best for retaining antioxidant phenolic compounds and enhancing antioxidant capacity.

All processed beans (soaked, boiled, steamed) exhibited significantly lower antioxidant activities than raw beans in total phenolic content (TPC), DPPH free radical scavenging activity (DPPH), and oxygen radical absorbing capacity (ORAC) (Xu and Chang 2008). Steaming processes resulted in a higher retention of TPC and ORAC values than the boiling processes. Pressure boiling shortened processing time compared to regular boiling, resulted in insignificant differences in TPC, but significantly enhanced ORAC value as compared to the regular boiling method. Pressure steaming resulted in significant reductions in TPC, DPPH, while significantly enhanced ORAC compared to regular steaming. Greater TPC, DPPH, and ORAC values were achieved in boiling water than in the soaking and steaming water. Mass balance analysis disclosed that boiling caused more dry solid loss than steaming. All the data indicated that processing methods significantly changed contents and activities of antioxidant components of black beans. Steam processing afforded several advantages in appearance and texture of the cooked product, shortening processing time, and in better retention of TPC and antioxidant activities. Steam processing may be used to develop high-quality health-promoting black bean products. In a subsequent study they found that compared to the original raw beans, all processing methods caused significant reductions in total phenolic content (TPC), total flavonoid content (TFC), condensed tannin content (CTC), monomeric anthocyanin content (MAC), DPPH free-radical scavenging activity (DPPH), ferric-reducing antioxidant power (FRAP), and oxygen radical absorbing capacity (ORAC) values in both pinto and black beans (Xu and Chang 2009). Steaming processing resulted in a greater retention of TPC, DPPH, FRAP, and

ORAC values than the boiling processes in both pinto and black beans. All thermal processing significantly affected individual phenolic acids, anthocyanins, flavan-3-ols, and flavonols, significantly reduced total phenolic acid contents in both pinto and black beans and total flavonol contents in pinto beans, and dramatically reduced anthocyanin contents in black beans. Phenolic acids and flavonols may play important roles on the overall antioxidant activities of pinto beans, while anthocyanins, flavan-3-ols, and flavonols may play important roles on the overall antioxidant activities of black beans.

Antihypertensive and Antioxidant Activities

Protein hydrolysate from *Phaseolus vulgaris* hydrolysed with the enzymes Alcalase® and Flavourzyme exhibited angiotensin-I converting enzyme (ACE-I) inhibitory and antioxidant activities (Torruco-Uco et al. 2009). With Alcalase®, the highest degree of hydrolysis in *P. vulgaris* was 49.48% at 30 min, and with Flavourzyme®, the highest degree of hydrolysis was 26.05% at 90 min. ACE-I inhibitory activity in the Alcalase® hydrolysates was IC_{50} = 0.061 mg/ml for *P. vulgaris* at 90 min and in the Flavourzyme® hydrolysates this activity was IC_{50} = 0.127 mg/ml at 45 min. Antioxidant activity was 10.09 mmol/l TEAC/mg protein for *P. vulgaris* with Alcalase® at 60 min.

Antihypercholesterolemic Activity

Shutler et al. (1989) reported that consumption of beans (for 14 days) and spaghetti (for 14 days after a 14 day washout) by normo-cholesterolaemic male students led to a significant decrease in the amount of fat eaten daily. Bean consumption also resulted in significant enhancement in protein, fibre and sugar intakes. During the bean-eating period the mean total plasma cholesterol concentration of the students fell significantly from 5.1 to 4.5 mmol/l. No reduction in plasma cholesterol occurred during the spaghetti-eating period. High-density lipoprotein (HDL)-cholesterol levels declined significantly during both periods, but HDL:total cholesterol ratio was significantly reduced only during the spaghetti-eating period. Neither beans nor spaghetti affected triacylglycerol, insulin or C-peptide levels. In a separate randomized, crossover, 2 × 2 block design of 8-week duration, baked bean consumption was found to reduce serum cholesterol in free-living hypercholesterolemic adults (Winham and Hutchins 2007). A significant absolute reduction in total cholesterol levels after 8 weeks was observed with the vegetarian baked bean treatment in contrast to the control. Mean percentage change of serum total cholesterol for baked beans was −5.6% in contrast to 0.5% for the control. Mean percentage change of serum LDL-C was −5.4% and 1.0% respectively. No significant differences were found with the other blood concentrations. These findings indicated that vegetarian baked bean consumption could reduce serum total cholesterol in hypercholesterolemic adults. Separate studies showed that bean consumption can improve lipid profiles (colonic short chain fatty acids formation) associated with cardiovascular disease, but does not clearly confer health benefits related to colon cancer risk (Finley et al. 2007). Bean intake decreased faecal production of isovaleric and isobutyric acids from cornstarch by as much as 50% in all volunteers. Of the bacterial populations studied, only *Eubacterium limosum* was affected by bean consumption and was approximately 50% lower than in those consuming soup. Beans lowered serum total cholesterol by approximately 8% in the controls and 4% in the premetabolic syndrome group. Bean consumption lowered serum HDL-cholesterol and LDL-cholesterol in both groups without affecting serum triglycerides, VLDL cholesterol, or glucose.

In untreated streptozotocin (STZ) diabetic rats there was a significant increase in tissue cholesterol, triglycerides, free fatty acids, and phospholipids (Venkateswaran et al. 2002; Pari and Venkateswaran 2004). There was also a significant increase in the concentrations of palmitic acid (16:1), stearic acid (18:0), and oleic acid (18:1) in liver, kidney, and brain, whereas the

concentrations of linolenic acid (18:3) and arachidonic acid (20:4) were significantly decreased. Oral administration of the aqueous extract of *P. vulgaris* pods (200 mg/kg of body weight) for 45 days to STZ diabetic rats significantly reduced the elevated blood glucose, serum triglycerides, free fatty acids, phospholipids, total cholesterol, very-low-density lipoprotein cholesterol, and low-density lipoprotein cholesterol. The extract also caused a significant decrease in plasma thiobarbituric acid-reactive substances (TBARS), hydroperoxides, vitamin E, and ceruloplasmin. The extract also decreased fatty acids, viz., palmitic, stearic, and oleic acids, whereas linolenic and arachidonic acids were elevated. Similarly, the administration of *P. vulgaris* pod extract to normal animals resulted in a significant hypolipidemic effect. These results suggested that *P. vulgaris* extract exhibited hypoglycaemic, hypolipidemic and antioxidant effects in STZ diabetic rats. It also prevented the fatty acid changes produced during diabetes. The effect of the extract at 200 mg/kg of body weight was better than that of glibenclamide.

Antidiabetic Activity

Phaseolus vulgaris α-amylase inhibitor isoform 1 (α-AI1) starch blockers were assessed to have potential as a widely used therapy against obesity and diabetes (Obiro et al. 2008). Ingestion of the α-amylase inhibitor was reported to cause marginal intraluminal α-amylase activity facilitated by the inhibitor's appropriate structural, physico-chemical and functional properties. As a consequence postprandial plasma hyperglycaemia and insulin levels decreased, resistance of starch to digestion and activity of colorectal bacteria increased. The authors assessed the extracts to be potential ingredients in foods for increased carbohydrate tolerance in diabetics, decreased energy intake for reducing obesity and for increased resistant starch. Porcine pancreatic α-amylase (PPA) was inhibited by the red kidney bean (*Phaseolus vulgaris*) inhibitor α-AI1 (Koukiekolo et al. 1999; Santimone et al. 2004). In particular, with α-AI1, the inhibition takes place only when porcine pancreatic α-amylase and α-AI were preincubated together before adding the substrate. This indicated that the abortive PPA-αAI1 complex was formed during the preincubation period. Also it was found the hydrolysis of α-AI1 that accounted for the inhibitory activity. An α-amylase inhibitor (α-AI) was isolated from white kidney beans (*Phaseolus vulgaris*) was found to have good hypoglycemic effect on alloxan induced diabetic rats and may have high potential pharmaceutical value as a regulative digestive-starch degradation in patients suffering from diabetes (Zhang et al. 2007). Continuous oral administration of the α-AI at 150 mg/kg/day for 7 days lowered fasting blood glucose and 300 mg/kg/day for 7 days improved the sugar tolerance on alloxan-dependent diabetic model rats.

Tormo et al. (2004) demonstrated that the prolonged oral administration (21 days) of an α-amylase inhibitor isolated and purified from an extract of white kidney beans (*Phaseolus vulgaris*) reduced blood glucose levels and body-weight gain in Wistar rats without modifying the plasma concentration of insulin. A significant anorexigenic action of the inhibitor was observed; there was reduced food intake, reduced weight gain as well as changes in the activity of some intestinal enzymes such as maltase. Oral administration of α-AI, a purified pancreatic α-amylase inhibitor from white beans (*Phaseolus vulgaris*) significantly reduced glycaemia in both the non-diabetic and type 2 neonatal diabetic animals (Tormo et al. 2006). The inhibitor reduced the intake of food and water, and normalized the elevated disaccharidase, sucrose and maltase levels of the diabetic rats. Administration of doses of *P. vulgaris* dry extract devoid of any behavioural toxicity dose-dependently decreased food intake (irrespective of the diet), body weight gain, and glycemia in rats (Fantini et al. 2009). Pretreatment with lorglumide, the colecistokinin (CCK) receptor antagonist blocked the reducing effect of *P. vulgaris* dry extract on food intake. The ability of *P. vulgaris* dry extract to reduce food intake, body weight, and glycemia in rats were postulated to be attributed to (a) inhibition of α-amylase, (b) stimulation of CCK release from

the intestinal brush border cells, and/or (c) interference with the central mechanism(s) regulating appetite, food intake, and food palatability.

Seeds of *P. vulgaris* at a concentration of 300 g/kg body weight exhibited maximal blood glucose lowering effect in diabetic rats 3 hours after administration (Ocho-Anin Atchibri et al. 2010a). Combination of *P. vulgaris* (300 mg/kg bw) and glibenclamide (0.20 g/kg bw) was found to be safe and exhibited hypoglycemic as well as antihyperglycemic activities without creating severe hypoglycemia in normal rats.

Carai et al. (2009), in their review of preclinical data on extracts of and preparations derived from beans of *Phaseolus vulgaris,* found that increasing evidence suggested that acute and chronic administration of *P. vulgaris* derivatives reduced food intake (including highly palatable foods), body weight, lipid deposit, and glycemia in rats exposed to multiple experimental procedures. Two possible lectin-mediated mechanisms of action were proposed: (a) inhibition of α-amylase, resulting in lower carbohydrate metabolism and absorption; (b) phytohemoagglutininduced regulation of the activity of cholecystokinin and glucagon-like peptides, resulting in a reduced appetite. They asserted that if these initial clinical data be confirmed by future surveys, *P. vulgaris* derivatives might constitute novel remedies for the management of obesity and metabolic syndrome.

In an open-label 6-arm crossover study with 13 randomized subjects, standardized GI testing was performed on white bread with and without the addition of Phase 2, a dietary supplement derived from the common white kidney bean (*Phaseolus vulgaris*) in capsule and powder form, each in dosages of 1,500, 2,000, and 3,000 mg (Udani et al. 2009). Only the powder formulation of 3,000 mg exerted a significant reduction in effective Glycemic Index (GI). It was concluded that Phase 2 white bean extract appeared to be a novel and potentially effective method for reducing the GI of existing foods without modifying their ingredient profile.

Fairly high doses of aqueous *Phaseolus* extracts need to be given to be effective in phytopharmaceutical treatment of diabetes (Helmstädter 2010). Because of their fibre content and an α-amylase inhibitory effect, beans might be more useful as food components in preventing or ameliorating type 2 diabetes.

Anticancer Activity

Hughes et al. (1997) found that carcinogen azoxymethane (AOM)-treated rats fed a bean diet had significantly fewer colon adenocarcinomas and colonic tumours than rats fed the casein diet. Tumour proliferation was also significantly lower for the bean-fed rats, and significantly fewer tumours per tumour-bearing rat were observed in bean-fed rats than in casein-fed rats. The study demonstrated that dry beans contain anticarcinogenic compounds capable of inhibiting AOM-induced colon cancer in rats. Similar results were obtained by Hangen and Bennick (2002) who found that azoxymethane treated rats consuming black beans and navy beans had significantly lower colon cancer incidence and multiplicity. The 44–75% reduction in colon carcinogenesis in rats fed beans was attributed to (1) more controlled appetites, leading to significantly less body fat, and (2) much greater concentrations of butyrate in the distal colon.

Henningson et al. 2001 found that with diets such as red kidney bean flours containing high amounts of non-digested carbohydrates reaching the colon include mainly resistant starch (RS), soluble and insoluble dietary fibre, and non digestible oligosaccharides (NDO) resistant starch, the butyric acid concentration was significantly higher in the distal colon than in the proximal colon. This is of great importance, because the majority of colonic cancer tumours occur in the distal part of the colon in both human subjects and experimentally induced rodent cancer models. In tumour cell lines, butyrate causes cellular growth arrest by two mechanisms, one involving histone hyperacetylation and p21 induction and the other related to impaired EGF-responsiveness (Archer et al. 1998). Butyrate also induced apoptosis in colorectal tumour cell lines (Hague and Paraskeva 1995) and in human colon cancer RKO cells

through activation of JNK MAP kinase pathway (Zhang et al. 2010). It modulated expression of proteins involved in cellular differentiation (Siavoshian et al. 2000) and potentiated the transforming growth factor (TGF-β) signalling and its tumour suppressor activity (Nguyen et al. 2006).

Korean kidney bean husk extract exhibited a series of antitumour effects such as cell death and apoptotic body appearance in colon cancer cells (Lee et al. 2009). These antitumour effects were accompanied by the increase in intracellular signalling cascades of AMP-activated protein kinase (AMPK) and p-Acc as well as antitumour proteins p53 and p21. The authors exerted that the ability of carcinogenesis control by Korean kidney bean husk extract with high potency suggested its value as an antitumour agent in colon cancer therapy.

Data from food frequency questionnaires given to 90,630 women in the Nurses Health Study II in 1991 and 1995 were computed for the association of flavonol intake with breast cancer risk in premenopausal women who were between 26 and 46 years at baseline in 1991 (Adebamowo et al. 2005). During 8 years of follow-up, 710 cases of invasive breast cancer were documented. No associations were obtained between consumption of individual flavonols such as kaempferol, quercetin or myricetin and breast cancer risk. The multivariate relative risks, comparing highest to lowest quintiles of cumulative average flavonol intake, was 0.94 for sum of flavonol-rich foods. Among the major food sources of flavonols, the researchers found a significant inverse association of breast cancer with intake of beans and lentils but not with tea, onions, apples, string beans, broccoli, green pepper or blueberries. Dry beans in the animal diet reduced mammary cancer incidence (no. of animals with cancerous tumour) from 95% in the standard diet to 67% (Thompson et al. 2009). The number of cancer tumours per animal was reduced from 3.23 to 1.46, respectively. Cancer multiplicity differed by dry bean type (white kidney vs. navy, 1.05 vs. 1.87 tumours per animal). However, anticancer activity was not associated with bean antioxidant capacity, phenolic or flavonoid content, or seed coat colour (dark beans had 10 times or greater phenolic and flavonoid content than white beans).

Twenty-four bioactive compounds including 12 triterpenoids, seven flavonoids, and five other phytochemicals were isolated from black bean (*Phaseolus vulgaris*) seed coats and their antiproliferative properties were evaluated (Dong et al. 2007). Antiproliferative activities of isolated compounds against human colon cancer cells, human liver cancer cells, and human breast cancer cells were evaluated. Among the compounds isolated, 11 compounds 1, 2, 6, 7, 8, 13, 14, 15, 16, 19, and 20 exhibited potent inhibitory activities against the proliferation of HepG2 human liver cancer cells. Fourteen compounds 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 14, 15, 19, and 20 showed potent antiproliferative activities against Caco-2 human cancer cell growth. Seven compounds 5, 7, 8, 9, 11, 19, 20 showed potent antiproliferative activities against MCF-7 breast cancer cell growth in a dose-dependent manner. Six flavonoids (compounds 14–19) displayed potent antioxidant activity. The data indicated black bean seed coats to have potent antioxidant and antiproliferative characteristics.

Water-soluble black bean condensed tannins at 0.24–24 μM did not affect the growth of normal human fibroblast lung cells, but dose-dependently triggered cancer cell death by apoptosis as evidenced by a dose-dependent decrease in ATP and cell gross morphology (Bawadi et al. 2005). After 24 hours of exposure to Caco-2 colon cancer, MCF-7 breast cancer, Hs578T breast cancer, and DU 145 human prostatic cancer cells, water-soluble black bean condensed tannins at 24 μM inhibited foetal bovine serum stimulated cell migration, the secretion of matrix metalloproteinase-2, matrix metalloproteinase-9, and vascular endothelial growth factor VEGF(165) receptor expression by the cancer cells in the conditioned substrate.

Studies on rats with cancer induced by the carcinogen 1-methyl-1-nitrosourea showed that cancer- rats consuming dry red bean (*P. vulgaris*) consumption exhibited lower mammary cancer incidence, cancer multiplicity, and tumour burden in a concentration-dependent manner compared to rats in the control group devoid of red beans (Thompson et al. 2008). Dry bean consumption was also found to be associated with

concentration-dependent decreases in blood levels of glucose, insulin, insulin-like growth factor-1, C-reactive protein, and interleukin-6 in food-deprived rats. Analysis of the mammary adenocarcinomas indicated that induction of apoptosis via the mitochondrial pathway was the dominant mechanism accounting for reduced tumour burden.

The results of studies by Bobe et al. (2008) suggested that both the soluble and the insoluble fraction of the cooked navy beans extract contributed to the cancer-protective effect of cooked navy beans. Mice fed cooked navy beans (whole beans), the insoluble fraction (bean residue) or soluble fraction of the 60% (vol:vol) ethanol extract of cooked navy beans (bean extract), had lower incidence of dysplasia, adenomas, or adenocarcinomas and any type of colon lesions, including focal hyperplasia in comparison to control mice fed a modified AIN-93 G diet (16.6% fat including 12.9% lard).

Aparicio-Fernández et al. (2006) found that black Jamapa beans (*Phaseolus vulgaris*) could be a source of polyphenolic compounds, which exhibited inhibitory effect toward HeLa human cervical cancer cells but were less disruptive on HaCaT human premalignant keratinocytes. The IC_{50} values showed that the 100% methanol crude extract seed coats of black Jamapa beans was the most effective inhibitor of HeLa cell proliferation [34.5 μM equiv of (+)-catechin] even when it was dissolved in dimethylsulfoxide (DMSO) [97.7 μM equiv of (+)-catechin]. The 100% methanol crude extract (35 μg of dry material/ml) reduced the number of HeLa cells in the G0/G1 phase from 68.9% (for control cells) to 51.4% (for treated cells) and enhanced apoptosis (2.9% and 21.2% for control and treated cells, respectively). The Toyopearl 5 (TP5) fraction and silica gel 2 (SG2) fraction of the extracts suppressed 60% of the HeLa cell proliferation. The IC_{50} was 154 μM equiv of (+)-catechin of the 100% methanol crude extract on HaCaT cells. Toyopearl fractions TP4 and TP6 significantly inhibited HaCaT cell proliferation, but the silica gel fractions did not have a significant effect. The treatment of HeLa cells with 35 μg the methanol extract/ml/24 h increased the expression of Bax and Caspase-3, pro-apoptotic proteins (6.13 and 1.2 times for Caspase-3 and Bax, respectively) (Aparicio-Fernández et al. 2008).

The growth of a transplantable murine non-Hodgkin lymphoma tumour, developing either intraperitoneally as an ascites tumour or subcutaneously as a solid tumour, had been shown to be appreciably reduced by incorporating phytohaemagglutinin (PHA), a lectin present in raw kidney bean (*Phaseolus vulgaris*) in the animal diet (Pryme et al. 1994; 1999a,b). In NMRI mice fed PHA within the range 0.45–7.0 mg/g diet, tumours which developed during a 10 day period after subcutaneous injection of cells were about 35% of the dry weight of those in lactalbumin-fed (control) animals. The decreased rate of growth occurred in a concentration-dependent manner within the range 0.45–3.5 mg/g diet. Similarly, dietary PHA reduced the proliferation of a mouse plasmacytoma (MPC-11) tumour in Balb/c mic indicating that the effect of PHA was not restricted to a single tumour system (Pryme et al. 1996a; 1998). The reduction in growth caused by the PHA appeared to occur in a dose-dependent fashion but the values did not reach significance before PHA was at a concentration of 7.0 mg/g diet. A lypolytic effect of PHA occurred at high concentration. The observations suggested that PHA itself did not exert a direct effect on the tumour cells, but an inter-relationship between gut hyperplasia and decreased tumour growth was implicated.

Further studies suggested that PHA exerted a competitive effect between the gut tissue undergoing hyperplasia and tumour development for nutrients (including polyamines) from a common body pool (Pryme et al. 1996a,b; 1998; 1999a, b; Pryme and Bardocz 2001). The role of polyamines on tumour development was demonstrated by Bardocz et al. (1997), where the number of Krebs II tumour cells recovered from ascitic fluid of mice fed with PHA diet was three times lower than the control animals. Additionally, there was an apparently inverse relationship between the total tumour cells count and the intracellular content of putrescine, spermidine and spermine. Hyperplastic growth of the small intestine would appear to compete with tumour cells for

polyamines from a common body pool. Gut hyperplasia also occurred in animals which were fed non-protein diet supplemented with PHA, indicating the strength of PHA as a growth signal. The authors postulated that this 'normal' growth was able to compete with the tumour for important growth factors and nutrients, including polyamines, effectively starving the tumour for these molecules and resulting in its decreased rate of proliferation. The series of studies suggested that lectins like PHA, which exhibited growth-promoting effects on the gut, may have interesting applications in the formulation of new approaches with respect to cancer treatment.

Antimutagenic Activity

Phenolic compounds in beans (*P. vulgaris*) imparted antimutagenic properties (de Meija et al. 1999; Cardador-Martínez et al. 2002a). The inhibitory effect was shown using *Salmonella typhimurium* tester strain YG1024 on 1-NP and B[a]P mutagenicity with a dose of 300 μg/plate of ellagic acid as the antimutagenic control (de Meija et al. 1999). The percentages of inhibition produced against B[a]P (2 μg/plate) using 300 μg/plate of ellagic acid and for the extracts 500 μg equivalent catechin/plate were 82%, 83%, 81% and 83% for ellagic acid , water extract, water/methanol extract and methanol extract, respectively. However, for 1-NP mutagenicity, only the methanolic extract from beans showed an inhibitory effect. The ellagic acid and bean extracts were not toxic to the bacteria at the concentrations tested. Cardador-Martínez et al. (2002a) used *Salmonella typhimurium* tester strains TA98 and TA100 to examine the antimutagenic effect of phenolic compounds extracted from the common bean (*Phaseolus vulgaris*) (PE) against mutagenicity induced by aflatoxin B1 (AFB1). The inhibitory effect of PE against AFB1 mutagenicity was dose-dependent at the lower concentrations tested (2.5, 5, 10, 12.5, 15 and 25 μg-equivalent (+)-catechin/tube for TA98; 0.5, 1, 1.5, 2.5, 5, 10 and 25 μg-equivalent (+)-catechin/ tube for TA100). The AFB1 and phenolic extract (PE) were not toxic to the bacteria at concentrations tested.

Osteoprotective Activity

Oral administration of the methanolic extract of *P. vulgaris* seeds (MPV) to ovariectomized (OVX) adult Sprague–Dawley rats significantly decreased serum alkaline phosphatase and reduced serum tartarate resistant acid phosphatase and urinary Ca levels compared to OVX control (Shirke et al. 2009). It caused an increase in bone density, ash density, and bone mechanical strength and significantly increased bone Ca. No increase in weight of atrophic uterus in OVX animals was observed with MPV treatment. The results suggested that treatment with MPV prevented estrogen deficiency-induced osteopenia without affecting the uterine mass.

Antibacterial Activity

Tannin constituents from *P. vulgaris* exhibited antibacterial activity against *Listeria monocytogenes* (Amarowicz et al. 2008).

Mucin Modulating Activity

Montoya et al. (2010) demonstrated that unheated phaseolin from *Phaseolus vulgaris* bean was resistant to digestion and enhanced gut endogenous protein losses. Unheated phaseolin increased nitrogen flow in ileum, colon and faeces, and reduced apparent nitrogen digestibility linearly. Heat treatment reversed all these changes except mucin flow. Colonic mucin flow decreased linearly with increasing dietary level of unheated phaseolin. The gene expressions of Muc mRNA in gut tissues were influenced by dietary phaseolin level and thermal treatment. The results indicated that phaseolin modulated mucin flow and Muc gene expression along the intestines differentially.

Lectins, Peptides and Associated Biological Activities

Lectins are sugar-binding proteins that are highly specific for their sugar moieties that

agglutinate cells and/or precipitate glycoconjugates. They play a role in biological recognition phenomena involving cells and proteins. Besides haemagglutinating properties, they have been reported to have mitogenic, anti-fungal, antiviral and antiproliferative activities on cancer cells.

Of the lectins from *Phaseolus vulgaris, Momordica charantia, Ricinus communis* and its constituent chains, and *Agaricus bisporus, P. vulgaris* lectin and *A. bisporus* lectin were the most potent in inhibiting HIV-1 reverse transcriptase (Wang and Ng 2001). The aforementioned lectins had only weak or no inhibitory effects on the glycohydrolases (α-glucosidase, β-glucosidase and β-glucuronidase). A 67-kDa hemagglutinin composed of two identical subunits was purified from *Phaseolus vulgaris* cv. 'Dark Red Kidney Bean' (Xia and Ng 2006). The hemagglutinating activity was stable between 25°C and 70°C degrees C and between pH 4 and pH 11, and in the presence of a variety of divalent metal chlorides at 500 mM concentration. Although the hemagglutinin exhibited mitogenic activity toward murine splenocytes, it exhibited no inhibitory activity on HIV-1 reverse transcriptase or mycelial growth in the fungi *Botrytis cinerea, Fusarium oxysporum* and *Mycosphaerella arachidicola*. It exhibited an antiproliferative activity on leukaemia L1210 cells. A protein with antifungal and hemagglutinating activities was isolated from dried flageolet beans (*Phaseolus vulgaris*) (Xia and Ng 2005). The protein exhibited antifungal activity against *Mycophaerella arachidicola* with an IC_{50} of 9.8 μM, but was inactive toward *Fusarium oxysporum* and *Botrytis cinerea*. Its hemagglutinating activity could not be inhibited by a variety of the sugars tested. The hemagglutinating activity was stable in the presence of a variety of monovalent, divalent and trivalent chlorides, and also when the ambient pH varied from 3 to 12. It did not exhibited any mitogenic activity on mouse splenocytes in-vitro nor inhibit HIV-1 reverse transcriptase. It inhibited [3 H-methyl]-thymidine incorporation into leukaemia L1210 cells with an IC_{50} of about 4 μM.

An antifungal peptide with a defensin-like sequence and exhibiting a molecular mass of 7.3 kDa was purified from dried seeds of *Phaseolus vulgaris* 'Cloud Bean' (Wu et al. 2011) The antifungal peptide exhibited antifungal activity *against Mycosphaerella arachidicola* with an IC_{50} value of 1.8 μM. It was also active against *Fusarium oxysporum* with an IC_{50}value of 2.2 μM. It had no inhibitory effect on HIV-1 reverse transcriptase when tested up to 100 μM. Proliferation of L1210 mouse leukaemia cells and MBL2 lymphoma cells was suppressed by the antifungal peptide with an IC_{50} of 10 and 40 μM, respectively. Earlier, a similar 7.3-kDa antifungal peptide with a defensin –like homology was isolated *Phaseolus vulgaris* cv. 'Spotted Bean' (Wang and Ng 2007). It exerted an antifungal action on *Fusarium oxysporum and Mycosphaerella arachidicola*. It suppressed proliferation of leukaemia L1210 cells and MBL2 cells with an IC_{50} value of 4.0 and 9.0 μM, respectively, but was inactive on HIV-1 reverse transcriptase activity when the peptide was tested up to 0.1 mM.

A galactose-specific dimeric lectin purified from pinto beans had a molecular mass of 62 kDa with two subunits of 31 kDa (Wong et al. 2006). The hemagglutinating activity of pinto bean lectin was stable within the pH range of 3–12 and the temperature range of 0–70°C. By using the [3 H-methyl]-thymidine incorporation assay, it was shown that the lectin had the ability to evoke a mitogenic response from murine splenocytes but it did not inhibit proliferation of L1210 leukaemia cells. The pinto bean lectin inhibited HIV-1 reverse transcriptase with an IC_{50} of 3 μM. French bean thaumatin-like protein expressed low HIV- I protease inhibitory activity and red kidney bean lectin inhibited HIV- I integrase by only a very small extent (Ng et al. 2002). Antifungal proteins from the field bean and mung bean had an intermediate potency in inhibitory HIV-1 protease and integrase (Ng et al. 2002).

Two trypsin inhibitors were isolated from *Phaseolus vulgaris* cv "White Cloud Bean" (Sun et al. 2010). Both trypsin inhibitors exhibited a molecular mass of 16 kDa and reduced the activity of trypsin with an IC_{50} value of about 0.6 μM. Both trypsin isoinhibitors inhibited leukaemia L1210 cells with an IC_{50} value of 28.8

and 21.5 μM, respectively. They were inactive toward lymphoma MBL2 cells, HIV-1 reverse transcriptase and fungal growth when tested up to 100 μM. A haemagglutinin purified from Japanese Hokkaido red beans (*Phaseolus vulgaris* cv. Hokkaido red bean) was found to possess potent anti-proliferative effect against HepG2 (human hepatoma) cells (Wong et al. 2010). The haemagglutinin exhibited a weak mitogenic activity toward mouse splenocytes, a stronger anti-proliferative activity than Con A toward HepG2 (human hepatoma) cells and inhibited >80% of HIV-1 reverse transcriptase inhibitory activity at 3.3 μmol/l. It was devoid of anti-fungal activity. A lectin isolated from seeds of the *Phaseolus vulgaris* cv. "Anasazi beans" was found to have two 30-kDa subunits with substantial N-terminal sequence similarity to other *Phaseolus* lectins (Sharma et al. 2009). The hemagglutinating activity of the lectin was stable within the pH range of 1–14 and the temperature range of 0–80°C. The lectin potently inhibited proliferation of MCF-7 (breast cancer) cells with an IC_{50} of 1.3 μM, and inhibited the activity of HIV-1 reverse transcriptase with an IC_{50} of 7.6 μM. It evoked a mitogenic response from murine splenocytes. The lectin had no antifungal activity and did not stimulate nitric oxide production by murine peritoneal macrophages. Chemical modification results indicated that tryptophan was crucial for the hemagglutinating activity of the lectin.

A 5,443 Da peptide with sequence homology to defensins was purified from purple pole beans (*Phaseolus vulgaris* cv. 'Extra-long Purple Pole bean') (Lin et al. 2009). The peptide inhibited mycelial growth in *Mycosphaerella arachidicola, Helminthosporium maydis, Fusarium oxysporum, Verticillium dahliae, Rhizoctonia solani, Candida albicans* and *Setosphaeria turcica* with an IC_{50} of 0.8, 0.9, 2.3, 3.2, 4.3, 4.8 and 9.8 μM respectively. Its antifungal potency was higher than that of the plant defensin coccinin (IC_{50} > 50 μM). The peptide suppressed the proliferation of hepatoma (HepG2), breast cancer (MCF7), colon cancer (HT29) and cervical cancer (SiHa) cells but not that of human embryonic liver (WRL68) cells. Its anti-HepG2 activity (IC_{50} = 4.1 μM) was higher than that of another plant defensin, gymnin (IC_{50} > 50 μM). Its anti-MCF7 activity (IC_{50} = 8.3 μM) was similar to that of other plant defensins. It reduced the activity of HIV-1 reverse transcriptase with an IC_{50} of 0.5 μM, much more potently than other plant defensins (IC_{50} > 40 μM).

Two defense proteins including a 6-kDa defensin-like antifungal peptide and a 60-kDa dimeric hemagglutinin were isolated from seeds of the French bean (*Phaseolus vulgaris*) (Leung et al. 2008). The antifungal activity of the antifungal peptide was stable from 0–90°C, from pH 4–10, and after exposure to trypsin (1 mg/ml) at 37°C for 1 h. The hemagglutinin was stable from 10–80°C, from pH 1 to 12, and after treatment with trypsin at 37°C for 2 h. The hemagglutinin inhibited [methyl-(3)H]thymidine incorporation into breast cancer (MCF-7), leukaemia (L1210), hepatoma (HepG2) and human embryonic liver (WRL68) cells with an IC_{50} of 6.6, 7, 13 and 15 μM, respectively. It elicited maximal mitogenic response from mouse splenocytes at 1 μM concentration. It suppressed HIV-1 reverse transcriptase activity with an IC_{50} of 1.9 μM, but was devoid of antifungal activity.

A 60-kDa lectin from *Phaseolus vulgaris* cv. Extralong Autumn Purple Bean (EAPL) was found to be galactose-specific (Fang et al. 2010). It exerted hemagglutinating activity toward erythrocytes of rabbit, rat, mouse, and human ABO blood types. The lectin manifested anti-HIV-1-RT activity, and it could inhibit the proliferation of human tumour cells by inducing the production of apoptotic bodies. The nitric oxide-inducing activity of the lectin may find application in tumour therapy.

Yoon et al. (2010) found that binding of *Phaseolus vulgaris*-L lectin (PHA-L), defining the GlcNAcβ6Manα6Man side chain present in tri- or tetra-antennary N-linked glycans, to β-haptoglobin was higher for prostate cancer cases and high-grade prostate intraepithelial neoplasia than for benign diseases. Many other lectins and antibodies showed no binding to β-haptoglobin, or showed no significant difference between cancers vs. benign diseases. Thus, binding of PHA-L to affinity-purified β-haptoglobin from sera of

patients could lead to development of useful tools for differential diagnosis of prostate cancer vs. benign prostate diseases.

A lectin specific for glucuronic acid and galacturonic acid was isolated from French bean *Phaseolus vulgaris* seeds (Sharma et al. 2010). The hemagglutinating activity of the lectin was stable within the pH range of 1–13 and the temperature range of 10–60°C. The lectin did not exhibit any antiproliferative activity against tumour cells nor stimulated nitric oxide production by murine peritoneal macrophages at doses as high as 1 mM. It failed to evoke any mitogenic response from murine splenocytes and had neither HIV-1 reverse transcriptase inhibitory activity nor any antifungal activity. A dimeric 64 kDa haemagglutinin was isolated from dried *Phaseolus vulgaris* cultivar 'French bean number 35′ seeds (Lam and Ng 2010a, b). The yield was exceptionally high (1.1 g hemagglutinin per 100 g seed), which was 10–85 times higher than other *Phaseolus* cultivars. Its hemagglutinating activity was stable in the pH range 6–8, and in the temperature range 0 –50°C. It suppressed HIV-1 reverse transcriptase with an IC_{50} of 2 μM and mycelial growth of *Valsa mali* with an IC_{50} of 10 μM. It inhibited the proliferation of hepatoma HepG2 cells and breast cancer MCF-7 cells with an IC_{50} of 100 and 2 μM respectively. It exerted no antiproliferative effect on normal embryonic liver WRL68 cells.

Lectin purified from red kidney beans (*P. vulgaris*) exhibited good mitogenic activity comparable to that of commercial phytohemagglutinin (extracted from *P. vulgaris*) (Hou et la. 2010). The red kidney bean lectin was found to notably stimulate splenic lymphocyte proliferation at concentrations from 6.5 to 200 μg/ml. Mitogenic properties of the lectin were enhanced when four Chinese herbal polysaccharides (*Astragalus mongholicus*, *Poria cocos*, indigowood root and *Angelica sinensis)* were applied concurrently, among which 50 μg/ml *Astragalus mongholicus* polysaccharides (APS) with 12.5 μg/ml red kidney bean lectin yielded the highest mitogenic activity. 100 mg/kg/bw of APS with 12.5 mg/kg/bw red kidney bean lectin elevated mouse nonspecific immunity. APS augmented the phagocytic activity of macrophages, which increased 9.07% when APS and red kidney bean lectin were applied concurrently.

Antiobesity Activity

The results of a randomized, double-blinded, placebo controlled study of 60 slightly overweight volunteers, indicated that *Phaseolus vulgaris* extract produced significant reductions in body weight and reductions in fat mass and maintained lean body mass. (Celleno et al. 2007) After 30 days, subjects receiving *Phaseolus vulgaris* extract with a carbohydrate rich, 2,000-to 2,200-calorie diet had significantly greater reduction of body weight, BMI, fat mass, adipose tissue thickness, and waist/hip/ thigh circumferences while maintaining lean body mass compared to subjects receiving placebo.

Udani and Singh (2007) conducted A 4-week randomized, double-blind, placebo-controlled clinical trial of 25 healthy subjects consuming 1,000 mg of a proprietary fractioned white bean extract or an identical placebo twice a day before meals in conjunction with a multi-component weight-loss program, including diet, exercise, and behavioural intervention. Subjects who adhered to a program including dietary modification, exercise, and behavioural intervention significantly reduced their weight and waist size in a brief period. It was found that the tertile of subjects who consumed the most carbohydrates experienced a significant reduction in both weight and waist size with the addition of the white bean extract compared to the placebo group of the same tertile of carbohydrate consumption.

Bifidogenic Activity

Leguminous containing diets including the common beans (*P. vulgaris*) were found to have a bifidogenic effect on the intestinal microbiota of rats (da S Queiroz-Monici et al. 2005). The common bean diet exhibited the highest content of dietary fibre (17.0 g/100 g), which was

significantly different from the chickpea (*Cicer arietinum*), and lentil (*Lens culinaris*), and a control diet (casein + microcrystalline cellulose). Resistant starch content was similar for all diets. The leguminous-containing diets produced a larger mass of caecal material that was statistically different from the control group. The pea group presented the highest count of *Bifidobacterium* (9.4 log colony-forming units per gram of raw material), which was significantly different from the others, and the *Lactobacillus* count was similar for all groups. Animals fed leguminous-containing diets showed lower counts of *Enterobacter* and *Bacteroides* than did the control group and no statistical difference was found between groups with respect to counts of *Clostridium* and total anaerobes.

Six diets prepared from red kidney bean flours yielded a total concentration of indigestible carbohydrates of 90 or 120 g/kg (dry weight basis) (Henningson et al. 2001). The total fermentability of the indigestible carbohydrates was high with all diets (80–87%). Raw and physically-inaccessible starch was more readily fermented than retrograded starch (97–99% v. 86–95%). Non-starch glucans were fermented to a lesser extent than resistant starch, but the fermentability was higher in the case of autoclaved (50–54%) than boiled beans (37–41%). The distribution between acetic, propionic and butyric acid in the caecum was similar for all diets, with a comparatively high percentage of butyric acid (approximately 18). However, with diets containing the high amounts of resistant starch, the butyric acid concentration was significantly higher in the distal colon than in the proximal colon.

Pancreatic Growth Stimulation

Phytohaemagglutinin, a red kidney bean lectin was found in vivo- and in-vitro to be a potent stimulus for cholecystokinin release in rats, inducing pancreatic growth (Herzig et al. 1997). However, intestinal growth was stimulated by a cholecystokinin independent mechanism.

Antinutritional Factors

Both wild and cultivated beans contained antinutritional factors such as hemagglutinins (lectins) and trypsin inhibitors (Sotelo et al. 1995). The wild beans exhibited a higher content of trypsin inhibitors (28 TUI per mg) and lectins (9.6) than the cultivated beans did (21 TUI per mg and 7 respectively). Black beans *Phaseolus vulgaris* were reported to contain several antinutritional compounds (enzymatic inhibitors, haemaglutenins, saponins and phytic acid, etc.), some of them thermolabiles that were partially eliminated during culinary processes and may modify the nutritional quality of beans (Serrano and Goñi 2004). No differences in stachyose and raffinose content were found between the two bean types, anasazi and pinto beans of *P. vulgaris* (Weder et al. 1997). Verbascose was not detected at all. Anasazi beans contained less (soluble and bound condensed tannins compared to pinto beans. Significant differences in lectin content were observed between anasazi and pinto bean. The lectins of anasazi beans were classified as non toxic and those of the pinto beans as toxic types. No differences in inhibitor activity against human and bovine trypsin and chymotrypsin were found between the two bean types. Both fresh and hard-to-cook beans were found to contain nutritionally significant amounts of lectins, trypsin, and α-amylase inhibitors, which were mostly inactivated by extrusion (Martín-Cabrejas et al. 1999). The extrudate bulk density and water solubility index decreased with increasing temperature, whereas the water absorption index increased due to the higher proportion of gelatinized starch in the extruded samples. Extrusion also evoked a considerable redistribution of insoluble dietary fibre to soluble, although the total dietary fibre content was not altered. Alterations in solubility involved pectic polysaccharides, arabinose and uronic acids being the main sugars involved. Stored beans subjected to extrusion cooking exhibited physical and chemical characteristics similar to those of extrudates from fresh beans.

The antinutrient (raffinose oligosaccharides, tannins, phytic acid and trypsin inhibitors)

composition and in vitro protein digestibility of eight improved varieties of *Phaseolus vulgaris* grown in Ethiopia were investigated by Shimelis and Rakshit (2005). Stachyose was the predominant α-galactosides in all haricot bean samples. Raffinose was also present in significant quantities but verbascose, glucose and fructose were not detected in the samples. The concentrations observed for the protein digestibility and anti-nutritional factors, varied significantly among varieties. Mean values for protein digestibility varied from 80.66% (in Roba variety) to 65.64% (in Beshbesh variety). Mean values for raffinose, stachyose, sucrose, trypsin inhibitors, tannins and phytic acid were 3.14 mg/g, 14.86 mg/g, 24.22 mg/g, 20.68 TUIx10(3)/g, 17.44 mg, catechin equivalents/g and 20.54 mg/g respectively. Statistical analyses of data revealed that anti-nutritional factors and protein digestibility were Relationships between anti-nutritional factors and protein digestibility were also observed and was found to be influenced by varietal genotype.

Nine novel polypeptides identified, from the crude extract of bean *Phaseolus vulgaris* seeds showed trypsin inhibitor activity (Alves et al. 2010). One of these polypeptide inhibitors yielded no homology in the UniProt database, indicating it to be a new protein with unique TI properties. Three of the remaining polypeptides showed additional high homology with lectins, likely indicating that they have lectin properties. The other five showed high homology with α-amylase inhibitors, indicating that they probably have a dual inhibitory effect against trypsin and the α-amylase enzyme.

Soaking of common beans was found to decrease the phytate content of the beans (85%) (De Oliveira et al. 2001). Cooking also decreased (84%) the tannin content. In the freeze-dried cooked bean without the non-absorbed soaking water (FCSAM) treatment a decrease in the raffinose (25.0%), stachyose (24.8%), verbascose (41.7%) and starch (26.8%) contents was observed. The freeze-dried cooked unsoaked bean (FCSM) showed the higher digestibility (74.3%) among the bean treatments in wistar rats. The reduction of the phytates, tannin, starch contents and flatulence factors in the common bean was most effective when the soaking water not absorbed (FCSAM) was discarded. Extrusion cooking of kidney beans was found to reduce phytic acid, condensed tannins, and trypsin, chymotrypsin, and α-amylase inhibitory activities (Marzo et al. 2002). In addition, hemagglutinating activity was eliminated by extrusion treatment. Protein content was not altered by this thermal treatment. Rats fed raw kidney bean lost body weight rapidly and the majority died by the ninth day. In contrast, pre-treatment of the beans by extrusion cooking improved food intake and utilization by the rats and they gained body weight. Supplementation of extruded kidney bean with methionine further enhanced food conversion efficiency and growth. Separate studies concluded that soaking of common beans in diets offered to male Wistar rats did not interfere with the net protein ratio of the experimental diets containing the common bean as protein source, nor did it reduce the tannin content (Helbig et al. 2003). However soaking was capable of reducing the phytate levels in the common bean. Additionally, soaking was unable to increase the protein digestibility of the common bean, since the treatment of freeze dried bean cooked without soaking showed the highest value for digestibility. Sayeed and Njaa (1985) showed that the Bangladeshi home cooking of common beans (*Phaseolus vulgaris* white navy pea, black turtle and Michigan small varieties) reduced the TUI/mg dry bean, whereas the mean percent inhibition was 23.4 (range from 52.1 to 4.7 in white navy pea beans and black turtle beans, respectively). After cooking, the highest values were reduced to 7.1 and 3.5, respectively. The effect of cooking was greater when the original inhibition was high than when it was low.

All the processing treatments (lactic acid and natural fermentation, autoclaving) significantly decreased the soluble dietary fibre content, and insignificant changes were observed in the insoluble dietary fibre content of processed beans (*P. vulgaris*) (Martín-Cabrejas et al. 2004). Total dietary fibre content ranged from 24.5% dry matter (DM) in the raw to 25.2% DM in the processed beans. Cellulose content of all samples

was reduced by the processing treatments. Higher amounts of resistant starch was observed in the processed beans, except in the lactic acid fermented ones. However, the levels of pectic polysaccharides and Klason lignin were higher in the samples fermented by *Lactobacillus plantarum*. The action of microorganisms was essential for the different degradation of the bean cell wall, disrupting the protein-carbohydrate integration, thus reducing the solubility of dietary fibre.

Two hard-to-cook common bean cultivars (*Phaseolus vulgaris*) were milled and extruded to flours (Batista et al. 2010). Results indicated that the extrusion significantly decreased antinutrients such as phytic acid, lectin, α-amylase, and trypsin inhibitors, reduced the emulsifying capacity and eliminated the foaming capacity in both cultivars. Further, the water solubility, water absorption index, and in-vitro protein and starch digestibility were improved by the extrusion process. These results indicate that it was possible to produce new extruded products with good functional and biochemical properties from these common bean cultivars

Acylation treatment of red kidney beans at various anhydride-to-protein ratios (0.05–1 g/g) improved appreciably the protein solubility and emulsifying activity index at neutral pH, but the improvement by succinylation was much better than that by acetylation (Yin et al. 2009). Succinylation resulted in a distinct decrease in mechanical moduli of heat-induced gels of kidney bean protein isolate, whereas the mechanical moduli were increased by acetylation. Further, in-vitro trypsin digestibility was improved by the acylation in an anhydride-type and level-dependent manner. The results suggested that the functional properties of kidney bean protein isolate could be altered by the chemical acylation treatment, using succinic or acetic anhydride at appropriate anhydride-to-protein ratios.

Allergy Problem

Pastorello et al. (2010) characterised the allergen from green beans (*P. vulgaris*) after five patients reported adverse reactions upon consumption of cooked green beans. The allergen corresponded to a lipid transfer protein with the following amino acid sequence: Ala-Ile-Ser-X-Gly-Qln-Val-Thr-Ser-Ser-Leu-Ala. Prick + prick tests with raw and cooked green beans were positive for all of the patients. IgE immunoblotting showed that all of the patients reacted toward a unique IgE-binding protein at about 9 kDa.

Traditional Medicinal Uses

Bean pods (*Phaseolus vulgaris*) are among the most widely used traditional remedies against diabetes mellitus (Helmstädter 2010).

Other Uses

Studies reported purified active protein coagulant from common bean (*Phaseolus vulgaris*) to have potential application as a natural coagulant in water turbidity removal (Antov et al. 2010). Partially purified coagulant at initial turbidity of 35 NTU (nephelometric turbidity units) expressed the highest value of coagulation activity, 72.3%, which was almost 22 times higher than those obtained by crude extract at applied dosages. Further, the increase in organic matter that remained in water after coagulation with purified protein coagulant was more than 16 times lower than those with crude extract.

Comments

Green beans are found in two major groups, bush beans and pole beans. Bush beans are short plants, growing to approximately two feet in height, without requiring supports. They generally reach maturity and produce all of their fruit in a relatively short period of time, then cease to produce. Gardeners may grow more than one crop of bush beans in a season. Pod colour can be green, golden, purple, red, or streaked. Shapes range from thin "fillet" types to wide "Romano" types

and more common types in between. French Haricots verts (green beans) are bred for flavourful pods.

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Pisum sativum

Scientific Name

***Pisum sativum* L.**

Synonyms

Lathyrus oleraceus Lam., *Pisum arvense* L., *Pisum biflorum* Stokes, *Pisum commune* Clav. excl. var. *variegatum, Pisum gullosum* Risso ex Alef., *Pisum humile* Mill., *Pisum leptolobum* Rchb., *Pisum macrocarpum* Ser. ex Schur, *Pisum pachylobum* Dierb. ex Alef., *Pisum quadratum* Rchb., *Pisum ramulare* Rchb., *Pisum saccharatum* Ser., *Pisum sativum* Alef. excl. var. *elatius,* var. *jomardi*e, *Pisum sativum* subsp. *arvense* Asch. and Graebn., *Pisum sativum* subsp. *commune* (Clav.) Govorov, *Pisum sativum* subsp. *hortense* Asch. and Graebn., *Pisum speciosum* Dierb. ex Alef., *Pisum tetragonum* Hort. ex Pasqu., *Pisum umbellatum* Mill., *Pisum umbellatum* Rchb., *Pisum uniflorum* Moench , *Pisum vulgare* Fingerh. non Jundz., *Pisum vulgare* Jundz.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Chinese Pea, Chinese Pea Pod, Chinese Snow Pea, Dry Pea, Edible-Podded Pea, Edible Pod Pea, Field Pea, Garden Pea, Green Pea, Honey Pea, Pea, Peas, Podded Pea, Round-Podded Snow Pea, Round-Podded Sugar Pea, Shelling Pea, Snap Pea, Snow Pea, Sugar Pea, Sugar Snap Pea, Stringless Snowpea, Sweet Pea

Vernacular Names

Afrikaans: Ertjie;
Albanian: Bizele;
Arabic: Basella;
Aragones: Bisalto;
Armenian: Volor Tzanovi;
Asturian: Arbeyu;
Azerbaijan: Ekin Koi Nokhud;
Azeri: Noxud;
Basque: Ilar;
Belarusan: Garokh Pasyaouny;
Bergamasco: Roàia;
Bolognese: Arvajja;
Brazil: Ervilha;
Bresciano: Roaiot;
Breton: Pizenn;
Bulgarian: Rpax;
Burmese: Sadaw-Pè;
Byelorussian: Rapox;
Calabrese: Pisiddru, Prisedda, Pisullu;
Catalan: Pèsol;
Catanese: Pusedda;
Caterisano: Poseda;
Chuvash: Parsa;
Chinese: Jia Wan Dou, O Laan Tau, Nen Wan Dou, Wan Dou (Pod); Dau Miu, Dou Mui, Wen Dou Mui (Leafy Shoot Tips);
Croatian: Grašak;

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Czech: Hrách Peluška, Hrách Rolní, Hrách Setý, Hrách Setý Pravý;
Danish: Ært, Ærter, Almindelig Ært, Haveært;
Dutch: Doperwten, Erwt, Erwten, Tuinerwt, Tuinerwt Sort;
Dzorâtai: Pâi;
Eastonian: Harilik Hernes, Söögihernes;
Esperanto: Pizo, Verdaj Pizoj;
Ethiopia: Ater;
Faeroese: Ertur;
Ferrarese: Ruviè;
Finnish: Herne, Kylvoherne, Tarhaherne;
Flemish: Erwt;
French: Petiti Pois, Pois, Pois À Écosser, Pois Cultivee, Pois De Jardin, Pois Des Champs, Pois Des Jardins, Pois Mange-Tout À Cosse Ronde, Pois Potager;
Frisian: Dopeart;
Furlan: Cesaron, Bîsi;
Galician: Chicharo, Ervella, Perico;
Georgian: Barda;
German: Erbse, Erbsen, Feld-Erbse, Futter-Erbse, Gartenerbse, Gemueseerbse, Palerbsen, Pflueckererbsen, Rollerbsen, Saaterbse, Schalerbsen, Speiseerbse, Trockenerbsen, Trockenspeiseerbsen, Zuckererbse;
Greek: Arakas;
Guarani: Kumanda'i, Kumandachu;
Hebrew: Afun Tarbuti;
Hawaiian: Batra, Matar;
H'Mong: Taum Mog;
Hungarian: Borsó, Takarmany Borso, Zöldborsó;
Icelandic: Ertur, Gráertur;
India: Katar (Bengali), Vatana (Gujarati), Katar (Hindu), Batani (Kannada), Kara (Kashimiri), Pattani (Malayalam), Vatana (Marathi), Matara (Oriya), Kabli Chole (Punjabi), Pattani (Tamil), Batani (Telugu);
Indonesia: Kacang Ercis, Kacang Polong, Kapri;
Irish: Pis;
Italian: Piselli, Piselli Da Sgranare, Pisello, Pisello Da Sgranare, Pisello Dei Campi,Pisello Dolce, Pisello Mangiatutto, Taccola;
Japanese: Endo, Endô, Endou, Piisu, Saya Endou, Tohbyo (Shoot);
Khmer: Sândaèk Muul;
Korean: Wandu;
Korni: Anikytsh;
Kurdish Kurmanji: Polik;
Ladin: Arbëia;
Laotian: Mak Thoua Nyat;
Latvian: Sejas Zirni;
Leonese: Arbeyu;
Limburgian: Ert;
Lithuanian: Sejamasis Zirnis;
Lombaro Occidentale: Erbion;
Malaysia: Kacang Manis, Kacang Wangi;
Mantuan: Ravion;
Mapunzugun: Allfid;
Mirandolese: Piśel;
Moldavian: Mazere De-Semena;
Mong: Tarimal Bandui;
Mudnès: Pisèe;
Nepal: Kerau;
Norwegian: Ert;
Occitan: Pòis;
Pakistan: Matar;
Philippines: Citzaro (Tagalog);
Polish: Ervilha, Ervilheira, Groch, Groch Zwycrajny;
Portuguese: Ervilha, Ervilha Torta, Ervilhas;
Quecha: Alwuirja;
Reggiano: Arviot;
Rogmagnolo: Fisaril;
Romanian: Mazăre;
Russian: Gorach, Goroch, Gorokh Posevnoi, Mazare;
Saami: Earta;
Samoan: Pī;
Sardinian: Pisu;
Setswana: Lethodi, Nawa;
Slovaščina: Grah Navadna, Navadni Grah;
Slovencina: Hrach Siaty Roľný;
Spanish: Aroeja, Alverja, Arveja, Chicharo, Guisante, Guisante Azucarado, Guisante Cultivado, Guisantes, Pésol, Tirabeque;
Swahili: Njengere, Njegere;
Swedish: Ärt, Ärter, Foderärt, Gråärt, Sockerärt, Trädgårdsärt;
Swiss: Gra Art, Spritart;
Thai: Thua Lan Tao, Yur Tuah (Shoot);
Tibetan: Sran;
Triestino: Biso;
Turkish: Bezelye;

Ukranian: Gorokh Posivnyi, Ropox;
Valencian: Pesol;
Venetian: Biso;
Vietnamese: Dau Hoà Lan (Pod), Dot Dau Ho Lan (Shoots);
Welsh: Pys;
Yakut: Yhllar;
Zeneize: Poiscio.

Origin/Distribution

The origin and progenitors of *Pisum sativum* are still unclear. It is generally held that pea originated in south-western Asia, possibly north-western India, Pakistan or adjacent areas of former USSR (now Tajikistan, Uzbekistan, Turkmenistan and Krgystan) and Afghanistan and thereafter spread to the temperate zones of Europe (Kay 1979; Makasheva 1983). According to Gritton (1980), four centers of origins, namely, Central Asia, the Near East, Abyssinia and the Mediterranean have been recognized based on genetic diversity. Recently FAO designated Ethiopia and western Asia as centres of diversity, with secondary centres in southern Asia and the Mediterranean region. At present, *Pisum sativum* is cultivated in all temperate countries, as a cool season crop in the subtropics and in most tropical highlands. Pea was introduced into the Americas soon after Columbus. Pea was taken to China in the first century (Makasheva 1983). Main producers of dry seeds are the former USSR, China, India and the USA, for green seeds the USA, United Kingdom, France and former USSR. Dry seeds are used as pulse for food and feed, cooked, roasted and ground to flour. Green immature seeds became a major vegetable, they are canned and frozen.

Agroecology

Pea requires a relatively cool and humid climate, with average temperatures between 7°C and 24°C, for optimum growth, development and yield. Optimum day and night temperature for vegetative growth were reported to be 21°C and 16°C and optimum day and night temperature for reproductive growth at 16°C and 10°C (Slinkard et al. 1994). Temperatures above 27°C shorten the growing period and adversely affect pollination. A hot spell is more damaging to peas than a light frost. Winter hardy peas can withstand light frost to −10°C. Young plants can withstand frost to −2°C if progressively hardened by lowering temperatures. Frost during flowering can cause heavy pod losses. Peas are adapted to moderate humidity or cool humid climate. In the tropics, peas can be grown at elevations above 1,000 m near the equator, or at lower elevations (even in coastal areas) during the cool season at latitudes between 15°C and 20°C. Pea is slightly sensitive to daylength, with long days promoting flowering. In most tropical circumstances it can be considered day-neutral. Peas can be grown in areas with an annual rainfall as low as 400 mm, but the optimum is 800–1,000 mm per annum. Pea grows on a wide range of soil types with moderate fertility levels provided they are well drained and with pH 5.5–7.0, although some cultivars tolerate a pH up to 7.5. Pea prefers well-drained sandy loam, clay loam or silt loams. It is adversely affected by soil acidity, aluminium toxicity and water-logging. Excessive nitrogen and potassium injure the roots or cause excessive vegetative growth.

Edible Plant Parts and Uses

Three main types of pea cultivars can be distinguished: field pea, grown for the dry seeds; garden pea, grown for the immature green seeds; and edible-podded peas (snow peas (*Pisum sativum* var. *saccharatum*), snap peas, sugar snap peas) grown for the immature pods. Snap peas or sugar snap peas (*Pisum sativum* var. *macrocarpon* Ser.), are a group of edible-podded peas differing from snow peas in their round instead of flat pod shapes. The French name *mangetout* refers to both snap peas and snow peas. The ordinary garden (English) pea, has a thin, tough membrane inside that contracts as the pod ripens and dries, causing the pod to open, twist, and expel its seeds. In contrast, edible-podded peas do not have the membrane

and do not open when ripe and is less fibrous. Snap peas may be frozen but should not be canned since high temperatures destroy the structure of the pods. In cooking they should be briefly steamed or quickly stir-fried in oil to retain crispness. Overcooking the pods will make them come apart. Snap peas may be used in a salad, omelette, soup, or stew, or on its own eaten as a substitute for French fries, stuffed, or batter-fried.

Fresh green pea seeds, dried seeds, tender, immature pods, leafy shoots and sprouts are eaten cooked as vegetables. Peas are also eaten raw as they are sweet when fresh off the plant. Green peas are marketed fresh, canned, or frozen while ripe dried peas are used whole, split, or made into flour. In many parts of the world, dried peas are consumed split as dahl, roasted, parched or boiled. The roasted pea seed is also used as a coffee substitute. The mature pea, which dries naturally in the field, is known as the marrowfat pea. Marrowfat peas are mainly grown in Britain and exported to the Far east especially Japan where it is popularly called *Maro*. Fresh peas are often eaten boiled and flavoured with butter and/or spearmint as a side dish vegetable. Fresh peas are also used in pot pies, salads and casseroles.

Pea is being used in a booming snack market. One snack recipe involves soaking the peas overnight and frying them in palm oil or coating them with other food items such as rice flour before frying. Another product is prepared by finely grinding the peas and extruding them under pressure to create different shapes. The different shapes are then fried, seasoned and packaged (Jambunathan et al. 1994). The extruder powder is also used to enrich the protein content of wheat flour when making bread. Boiled peas are sometimes sold dried and coated with wasabi as an eye-watering snack. In Japan, China, Taiwan and other Southeast Asian countries including Thailand and Malaysia, the peas are roasted and salted, and eaten as snacks. In Ethiopia, peas snacks include '*eshet*' (fresh green pea seeds either eaten raw or roasted), '*nifro*' (boiled dry or fresh green pea seeds) and '*endushdus*h' (seeds soaked first and then roasted). Some common pea dishes in Ethiopia include '*shiro wot*' (split pea seeds ground, mixed with spices into stew) and '*kik wo*t' (split pea seeds boiled and made into stew).

In Britain, dried, rehydrated and mashed marrowfat peas are used as accompaniment to fish and chips or meat pies. In India, fresh peas are used in various recipes such as *aloo matar* (curried potatoes with peas) or *matar paneer* (paneer cheese with peas). Dried peas are often made into a soup or simply eaten on their own. In the UK, dried yellow split peas are used to make a traditional dish, *pease* pudding (or "*pease* porridge"). In North America a similarly traditional dish is split pea soup. In Sweden, a traditional pea soup called *Ärtsoppa* used to be eaten on a Thursday, because this was an off-day for the maids and the soup was easy to prepare and also because Friday was a fasting day. This dish when made with pork and a little onion, is known as *Ärtsoppa och fläsk*. It is usually served with a little mustard on the side and is then followed by thin pancakes called *Pannkakor* and a sweet, hot liquor called *Punsch.* In Cyprus, Greece, Turkey, and other parts of the Mediterranean, peas are used in a stew with meat and potatoes. In Greek this stew is called *arakas*, whilst in Cyprus and Turkey it is called *mpizeli* or *mpizelia*.

The leafy shoots are used as a pot herb in parts of Asia and Africa. The tender leafy shots are also used in salads. In Chinese cuisine, pea sprouts called *dòu miáo* are popularly relished in the relatively high-priced stir-fries. Pea leaves are often considered a delicacy as well.

Studies showed that pea protein isolate exhibited significantly higher emulsion and foam forming properties than soybean protein isolate and that pea starch could be used to augment the quality of soybean protein isolate-stabilized food emulsions (Aluko et al. 2009). Incorporation of pea starch into soybean protein isolate I emulsions produced a synergistic effect that led to significant enhancement in emulsification capacity (reduced emulsion oil droplet size) when compared to soybean protein isolate or starch alone. Pea flour (*Pisum sativum*) is a relatively cheap protein source and studies showed that heat inactivated pea flour can be used for bread

making (Alasino et al. 2008). The sensory evaluation panel found that pea flour at a level of 5% could be successfully utilised. Pea flour provides a good source to improve the amino acidic profile.

Botany

Annual, climbing or bushy, glabrous usually glaucous, self-pollinated herb with well developed tap root and lateral roots, slender, terete stem 30–150 cm long with no or few basal branches. Leaves are alternate, pinnate with 2–3 pairs of leaflets and the rachis ending in a terminal branched tendril (Plates 1-3). Leaflets are ovate or elliptic, with entire or dentate margin; stipules 1.5–8 cm long, obliquely ovate, toothed at least below, semi-amplexicaul at the base. Inflorescence an axillary, 1–3-flowered raceme. Flowers bisexual, papilionaceous, white to reddish-purple; calyx with 4–8 mm long tube, lobes subequal, as long or longer than tube; corolla white, pink to purple, standard 16–30 mm × 25–45 mm, wings a little shorter than standard, keel much shorter; stamens 10, 9 united and 1 free; ovary superior, 1-celled, style curved, longitudinally grooved. Fruit an oblong-ovate pod 3.5–11 cm × 1–2.5 cm, straight or slightly curved, swollen or compressed, short-stalked, pendant, dehiscent, 3–11-seeded (Plates 1, 4-7). Seeds globose or angled, exalbuminous, smooth or wrinkled, 5–8 mm in diameter, varying in colour from whitish, cream-white, gray, yellow, brown, green to purple or spotted (Plates 8-10).

Nutritive/Medicinal Properties

The nutrient composition of green peas exclude pods (*Pisum sativum*) was reported by USDA(2010) as: water 78.86 g, energy 339 kJ (81 kcal), protein 5.42 g, fat 0.4 g, ash 0.87 g, carbohydrate 14.45 g, fibre 5.1 g, total sugars 5.67 g, sucrose 4.99 g, glucose 0.12 g, fructose 0.39 g, maltose 0.17 g, Ca 25 mg, Mg 33 mg, K 244 mg, Na 5 mg, P 108 mg, Fe 1.47 mg, Zn 1.24 mg, Cu 0.176 mg, Mn 0.410 mg, Se 1.8 µg, vitamin C 40 mg, thiamine 0.266 mg, riboflavin 0.132 mg, niacin 2.090 mg, pantothenic acid 0.104 mg, vitamin B-6 0.169 mg, folate 65 µg, total choline 28.4 mg, betaine 0.2 mg, vitamin A 765 IU, Vitamin A, RAE 38 µg, vitamin E (α-tocopherol) 0.13 mg, γ–tocopherol 0.95 mg, δ-tocopherol 0.02 mg, vitamin K (phylloquinone) 24.8 µg, total saturated fatty acids 0.071 g, 16:0 (palmitic) 0.064 g, 18:0 (stearic) 0.007 g, total monounsaturated fatty acids 0.035 g, 18:1 (oleic) 0.035 g; total polyunsaturated fatty acids 0.187 g, 18:2 undifferentiated (linoleic) 0.152 g, 18:3 undifferentiated (linolenic) 0.035 g; tryptophan 0.037 g, threonine 0.203 g, isoleucine 0.195 g, leucine 0.323 g, lysine 0.317 g, methionine 0.082 g, cystine 0.032 g, phenylalanine 0.200 g, tyrosine 0.114 g, valine 0.235 g, arginine 0.428 g, histidine 0.107 g, alanine 0.240 g, aspartic acid 0.496 g, glutamic acid 0.741 g, glycine 0.184 g, proline 0.173 g, serine 0.181 g, β-carotene 449 µg, α-carotene 21 µg, lutein + zeaxanthin 2,477 µg.

The nutrient composition of raw, edible-podded pea (snowpea, sugar snap pea) minus 6% ends and strings (*Pisum sativum*) was reported by USDA(2010) as: water 88.9 g, energy 176 kJ (42 kcal), protein 2.80 g, fat 0.2 g, ash 0.56 g, carbohydrate 7.55 g, fibre 2.6 g, total sugars 4.00 g, Ca 43 mg, Mg 24 mg, K 200 mg, Na 4 mg, P 53 mg, Fe 2.08 mg, Zn 0.27 mg, Cu 0.079 mg, Mn 0.244 mg, Se 0.7 µg, vitamin C 60 mg, thiamine 0.150 mg, riboflavin 0.080 mg, niacin 0.600 mg, pantothenic acid 0.750 mg, vitamin B-6 0.160 mg, folate 42 µg, total choline 17.4 mg, vitamin A 1,087 IU, Vitamin A, RAE 54 µg, vitamin E (α-tocopherol) 0.39 mg, vitamin K (phylloquinone) 25.0 µg, total saturated fatty acids 0.039 g, 16:0 (palmitic) 0.033 g, 18:0 (stearic) 0.003 g, total monounsaturated fatty acids 0.021 g, 18:1 (oleic) 0.021 g; total polyunsaturated fatty acids 0.089 g, 18:2 undifferentiated (linoleic) 0.075 g, 18:3 undifferentiated (linolenic) 0.013 g; tryptophan 0.027 g, threonine 0.099 g, isoleucine 0.161 g, leucine 0.228 g, lysine 0.202 g, methionine 0.011 g, cystine 0.032 g, phenylalanine 0.090 g, tyrosine 0.099 g, valine 0.273 g, arginine 0.134 g, histidine 0.017 g, alanine 0.058 g, aspartic acid 0.228 g, glutamic acid 0.448 g, glycine 0.072 g, proline 0.063 g,

Plate 1 Fruiting and flowering pea plant

Plate 2 Pea leaves and young shoots eaten as vegetables

Plate 3 Pea sprouts "*dòu miáo*"

Plate 4 Sweet peas

Plate 5 Snow peas

Plate 6 Sugar snap peas

Plate 7 Podded snap peas

Plate 9 Shelled shrunken peas

Plate 8 Shelled English peas

Plate 10 Shelled field peas

serine 0.125 g, β-carotene 630 μg, α-carotene 44 μg, lutein + zeaxanthin 740 μg.

The nutrient composition of raw sprouted pea seeds was reported by USDA (2010) as: water 62.27 g, energy 124 kcal (519 kJ), protein 8.80 g, fat 0.68 g, ash 1.14 g, carbohydrate 27.11 g, Ca 36 mg, Mg 56 mg, K 381 mg, Na 20 mg, P 165 mg, Fe 2.26 mg, Zn 1.05 mg, Cu 0.272 mg, Mn 0.438 mg, Se 0.6 μg, vitamin C 10.4 mg, thiamine 0.225 mg, riboflavin 0.155 mg, niacin 3.088 mg, pantothenic acid 1.029 mg, vitamin B-6 0.265 mg, folate 144 μg, vitamin A 166 IU, total saturated fatty acids 0.124 g, 16:0 (palmitic) 0.112 g, 18:0 (stearic) 0.012 g, total monounsaturated fatty acids 0.061 g, 18:1 (oleic) 0.061 g; total polyunsaturated fatty acids 0.326 g, 18:2 undifferentiated (linoleic) 0.265 g, 18:3 undifferentiated (linolenic) 0.061 g; threonine 0.186 isoleucine 0.171 g, leucine 0.365 g, lysine 0.384 g, methionine 0.069 g, cystine 0.155 g, phenylalanine 0.251 g, tyrosine 0.127 g, valine 0.220 g, arginine 0.484 g, histidine 0.167 g, alanine 0.245 g, aspartic acid 0.656 g, glutamic acid 1.017 g, glycine 0.208 g, proline 0.277 g and serine 0.299 g.

The protein concentration of peas was found to range from 15.5 to 39.7% (Davies et al. 1985; Bressani and Elias 1988). Fresh green peas contained per 100 g: 44 cal, 75.6% water, 6.2 g protein, 0.4 g fat, 16.9 g carbohydrate, 2.4 g crude fibre, 0.9 g ash, 32 mg Ca, 102 mg P, 1.2 mg Fe, 6 mg Na, 350 mg K, 405 μg β-carotene equivalent, 0.28 mg thiamine, 0.11 mg riboflavin, 2.8 mg niacin, and 27 mg ascorbic acid, while dried peas contain: 10.9% water, 22.9% protein, 1.4% fat,

60.7% carbohydrate, 1.4% crude fibre, and 2.7% ash (Duke 1981; Hulse 1994). Pea flour contained: 343 cal, 10.9% moisture, 22.8 g protein, 1.2 g fat, 62.3 g total carbohydrate, 4.2 g fibre, 2.8 g ash, 72 mg Ca, 338 mg P, 11.3 mg Fe, 0.86 mg thiamine, 0.18 mg riboflavin, and 2.8 mg niacin (Duke 1981). An average amino acid composition, reported in terms of grams per 100 g of protein was reported as: 6.9–8.2 lysine, 1.4–2.7 methionine + cystine, 3.9 threonine, 0.9 tryptophan, 0.8–1.7 cystine (Bressani and Elias 1988). Methionine and cystine were the main limiting amino acids. The largest chemical component in peas as in other legumes was carbohydrate which constituted about 56.6% of seed weight (Bressani and Elias 1988). The most abundant pea carbohydrate was starch, 36.9–48.6%, while amylose was about 34% of seed weight (Bressani and Elias 1988). Nutrient composition of milled and polished peas as measured per 100 g of edible portion of dried matured whole seeds were reported as: 1.4 g oil, 6 g crude fibre, 16.7 g dietary fibre, 54.1% starch, 8.1% sugars, 4.4 mg iron, 0.77 mg thiamin, 0.18 mg riboflavin, 3.1 mg niacin and 330 kcal energy (Newman et al. 1988). Fertilizing peas with sulfur increased their methionine content from 1.3 to 2.2 g per 100 g protein. Pea hay (at 88.6% DM) contained (zero moisture basis): 10.7–21.6% crude protein, 1.5–3.7% fat, 16.8–36.1% crude fibre, 6.0–9.3% ash, and 41.9–50.6% N-free extract (Duke 1981).

Crude protein and true protein content of pea varieties were found to vary from 19.5% to 20.6% and 18.7–9.8%, respectively (Saharan and Khetarpaul 1994). Non-protein nitrogen constituted only 3.94–4.84% of total nitrogen. Globulins were the major components followed by albumins and glutelins. All the four varieties of peas had similar methionine and tryptophan content. Lysine content of the four pea varieties ranged from 7.56 to 9.65 g per 16 g of N**.** Cooking of peas produced an increase of 10% in in-vitro protein digestibility. Some dissimilarities were found in banding patterns of globulin and albumin of all four varieties, suggesting that composition of protein of pea varieties differed. Wang and Daun (2004) found that crude protein content overall varied from 20.2% to 26.7%. Analysis of variance showed that both variety and environmental conditions had a significant effect on starch, acid detergent fibre (ADF), neutral detergent fibre (NDF) and fat content, but ash content was only affected by variety. Significant varietal and environmental differences in potassium, manganese and phosphorus were observed. Calcium and copper showed significant varietal differences, while iron, magnesium and zinc exhibited significant environmental differences. Environmental conditions showed significant effects on alanine, glycine, isoleucine, lysine and threonine levels. Variety had a significant effect on sucrose, raffinose and phytic acid content, whereas environmental conditions had an influence on trypsin inhibitor activity (TIA). The major pea components protein and starch were inversely correlated. ADF, NDF, Fe, Mg, Zn and the amino acid arginine were positively correlated with protein content. The amino acids glycine, histidine, isoleucine, lysine and threonine were negatively correlated with protein content. It was found that tryptophan was the most deficient amino acid and the sulphur-containing amino acids were the second limiting amino acids in peas. Raffinose was positively correlated with sucrose but negatively correlated with verbascose.

Other Phytochemicals

Pea seed also contained phenolic compounds. High concentrations of glycosides of quercetin, luteolin and apigenin were found in the seed coat of two dark varieties of peas (Duenas et al. 2004). Minor concentrations of monomers and dimers of proanthocyanidins were identified. The cotyledon was found to mainly contain hydroxybenzoic and hydroxycinnamic compounds and some of the flavone and flavonol glycosides were detected in the seed coat. Two conjugated compounds with malic acid, trans pcoumaroyl-malic acid and p-hydroxybenzoyl-malic acid were identified in the cotyledon and in the seed coat, and the stilbene, trans-resveratrol-3-glucoside, only in the seed coat. A phytoferritin, pea apoferritin, with a molecular weight of 480 000 was isolated from the seeds of pea (Crichton et al. 1978). Pea apoferritin was found to have the potential to 1.2–1.4 times as much iron as mammalian ferritins.

A mitogenic lectin with a molecular weight of 49,000, comprising two pairs of non-covalently linked polypeptide subunits was isolated from garden peas (Trowbridge 1974). The pea lectin had two binding sites for mannose and methyl α-d-glucoside.

The differences of flavonoid contents in individual pea varieties were found to be not significant (Timoracká and Vollmannová 2010). The values of flavonoids in green peas were: daidzein 1.746–2.688 mg/kg, genistein 0.412–0.706 mg/kg, kaempferol 0.621–1.484 mg/kg, apigenin 0.261–0.479 mg/kg. Yellow varieties of pea contained between 0.375–0.779 mg/kg daidzein, 0.115–0.158 mg/kg genistein, kaempferol 0.742–1.314 mg/kg, apigenin 0.462–0.698 mg/kg. All the flavonoids decreased in dry pea materials after 7 months storage under natural conditions.

The use of macroporous resins was found to be effective in the enrichment and separation of flavonoids, genistein and apigenin from extracts of pigeon pea roots (Liu et al. 2010). ADS-5 resin showed the maximum effectiveness among the tested resins. After one run treatment with ADS-5 resin, the contents of genistein and apigenin in the product were 9.36-fold and 11.09-fold increased with recovery yields of 89.78% and 93.41%, respectively. The process provided a promising basis for large-scale preparation of genistein and apigenin from pigeon pea or other plants extracts.

Singh et al. (2010) found significant variation in seed and flour qualities amongst the 71 field pea lines. There was diverse variability in seed weight (4.25–25.65 g/100 seeds), seed density (0.55–2.01 g/ml) hydration capacity (0.05–0.31 g/seed), swelling capacity (0.02–0.76 ml/seed) and cooking time (45–81 min). Amylose content of starch ranged between 21.4% and 58.3%. Variability also occurred in pasting temperature (73.5–81.5°C), peak viscosity, breakdown, final viscosity and final viscosity and setback of flours from different lines.

Antioxidant Activity

Six fractions (I–VI) separated from the crude pea seed extract were found to contain flavonoids, and not phenolic acids, as the main phenolic compounds (Amarowicz et al. 2001). The antioxidant activities as evaluated by a β-carotene-linoleate assay of separated fractions correlated with their content of total phenolic compounds. They decreased in the order of IV = VI > V > III > I > II. The antioxidant activity of fractions IV and VI was very strong as compared with that of butylated hydroxyanisole (BHA). Troszynska et al. (2002) observed strong anti-oxidative properties for pea seed coat extract and its five fractions as measured by the oxidation of phosphatidylcholine to hydroxyperoxide-phosphatidylcholine in a liposome model. The extract and fractions I, IV and V also showed scavenging effects of superoxide radical anion in the xanthine-xanthine oxidase system. A statistically significant correlation was found between the inhibition of phosphatidylcholine oxidation in the system tested and contents of either total phenols or tannins. However, no statistically significant correlation was found between O_2^- scavenging effect and contents of either total phenols or tannins. The HPLC analysis of phenolic compounds of extract and active fractions showed the presence of some phenolic acids (benzoic and cinnamic acids, and cinnamic acid derivatives), flavone and flavonol glycoside.

Several peptide fractions, F3-F5, of a pea protein hydrolysate exhibited strong radical scavenging and metal chelating activities; however, hydrophobic character did not seem to contribute to reducing power of the peptides (Pownall et al. 2010). In comparison to glutathione, the peptide fractions exhibited significantly higher ability to inhibit linoleic acid oxidation and chelate metals. In contrast, glutathione exerted significantly higher free radical scavenging properties than the peptide fractions.

Hypocholesterolemic Activity

Feeding studies in rats showed that food intake and growth were greatly reduced in animals fed unsupplemented raw pea (RP) or extruded pea (EP) (Alonso et al. 2001a). Both parameters were improved by addition of amino acids to the diets. Growth, apparent N digestibility, biological value and net protein utilisation values for supplemented

(SRP) raw peas were however inferior to those for controls whilst with supplemented (SEP) extruded peas the values were similar to control levels. SRP and SEP also greatly reduced serum total cholesterol, LDL (VLDL) and cholesterol/HDL ratio. This may have been linked to the lower plasma lysine:arginine ratio. SRP and SEP increased kidney and adrenal weights and reduced liver weight. SRP stimulated pancreatic growth but SEP did not. Extrusion treatment of peas improved their nutritional quality but did not reduce their hypocholesterolemic properties.

Feeding pigs with raw pea seed (RP) was found to lower plasma total cholesterol through a significant decrease in LDL cholesterol (Martins et al. 2004). The RP diet also lowered the hepatic concentration of esterified cholesterol and enhanced 3-hydroxy-3-methylglutaryl CoA reductase activity and LDL receptor synthesis. The biliary total cholesterol and bile acid concentrations were greater in RP-fed than in casein fed pigs. Further, faecal bile acid output was higher in RP-fed pigs. The caecum-colon by-pass inhibited cholesterol and ß-sitosterol microbial transformation, lowered the bile acid output, and increased the primary to secondary bile acid output ratio, but its influence on cholesterolemia was negligible. The results suggested a hypocholesterolemic effect of the raw pea diet probably due to increased faecal bile acid output and an increased biliary bile acid concentration.

Boiled or extruded legumes (peas and chickpeas) significantly increased body weight gain (BWG) of rats but not protein efficiency ratio (PER) when compared with raw legumes (Wang and McIntosh 1996). Rats fed processed chickpeas and those fed casein had similar BWG, and both groups had greater BWG than rats fed peas. Extruded wheat combined with peas or chickpeas increased sulfur amino acid (SAA) levels in the diets and significantly enhanced BWG and PER of rats compared with those fed sucrose as an energy source. There was a linear correlation between the SAA to dietary protein ratio and BWG of rats indicating that SAA were the limiting amino acids in legumes. Plasma cholesterol concentrations were lower in rats fed legumes than in those fed casein. Cholesterol-lowering ability was affected by processing method, with extrusion being most effective for peas; boiling and extrusion were equally effective for chickpeas. Raw legume feeding resulted in greater pancreatic and small intestine weight relative to body weight. Chickpea fed rats had lower spleen, thymus and liver relative weights and higher caecum and colon relative weights than rats fed casein. There were no differences in growth, PER, organ relative weight or plasma cholesterol concentration between rats fed extruded legumes and those fed boiled legumes, suggesting that extrusion improves nutritional value of these legumes to the same extent as the traditional boiling method.

Concentrations of triacylglycerols in liver, plasma and lipoproteins did not differ between both groups of rats fed with either 200 g/kg of casein or purified pea protein for 16 days (Spielmann et al. 2008). However, rats fed the pea protein diet had a lower concentration of total cholesterol in the liver and the very low density lipoproteins (VLDL) fraction than rats fed the casein diet. Cholesterol level in plasma, low density lipoproteins (LDL) and high density lipoproteins (HDL) did not differ between both groups. Rats fed pea protein moreover had an increased mRNA concentration of cholesterol-7α-hydroxylase in the liver and an increased amount of bile acids excreted via faeces compared with rats fed casein. Concomitantly, mRNA concentrations of sterol regulatory element-binding protein (SREBP)-2 and its target genes 3-hydroxy-3-methylglutaryl coenzyme A (HMG-CoA) reductase and LDL receptor in the liver were enhanced in rats fed pea protein. The data suggested that pea protein stimulated formation and excretion of bile acids, leading to a reduced hepatic cholesterol concentration and a reduced secretion of cholesterol via VLDL. An increased gene expression of SREBP-2 and its target genes HMG-CoA reductase and LDL receptor may be a means to compensate for the increased loss of cholesterol for bile acid synthesis.

Recent studies by Rigamonti et al. (2010) showed that after 14 and 28 days of hypercholesterolemic dietary treatment, rats fed pea protein

isolate from *Pisum sativum* had distinctly lower plasma cholesterol and triglyceride levels than rats fed casein. Pea protein-fed rats exhibited higher hepatic mRNA levels of LDL receptor versus those fed casein. Hepatic mRNA concentration of genes involved in fatty acids synthesis, such as fatty acid synthase and stearoyl-CoA desaturase, was lower in pea protein-fed rats than in rats fed casein. The study demonstrated a marked cholesterol and triglyceride-lowering activity of pea proteins in rats. Moreover, pea proteins appeared to affect cellular lipid homeostasis by upregulating genes involved in hepatic cholesterol uptake and by downregulating fatty acid synthesis genes.

Calcium/Calmodulin Kinase Modulation Activity

Studies by Li and Aluko (2005) suggested that it may be possible to use pea protein-derived cationic peptides to modulate calcium/calmodulin-dependent protein kinase II (CaMKII) activities. Two peptide fractions were found to inhibit CaMKII activity mostly in a competitive manner. CaMKII was found to catalyze the phosphorylation of various cellular proteins and excessive activities had been implicated in the pathogenesis of various chronic diseases.

Anticancer Activity

Pea seed was found to contain protease inhibitors, homologous to the anti-carcinogenic Bowman-Birk inhibitor (BBI) from soybean but differing most significantly in amino acid sequences at the two independent sites of protease inhibition (Clemente et al. 2004). The two recombinant protease inhibitors differed from BBI in trypsin and chymotrypsin specific inhibitory activities. The two variant recombinant pea seed protease inhibitors designated rTI1B and rTI2B, exhibited inhibitory activity on the growth of human colorectal adenocarcinoma HT29 cells in vitro (Clemente et al. 2005). A significant and dose-dependent decrease in the growth of HT29 cells was observed using all protease inhibitors, with rTI1B showing the largest decrease (IC_{50} = 46 μM).

Antimicrobial Activity

The skin and seeds of *P. sativum*, were found to exhibit good antibacterial activity against 56 isolates belonging to 11 different species of Gram-negative bacilli: *Escherichia coli* (19), *Klebsiella pneumoniae* (11), *Pseudomonas aeruginosa* (9), *Salmonella typhi* (3), *Salmonella paratyphi* A (1), *Salmonella paratyphi* B (1), *Proteus mirabilis* (5), *Proteus vulgaris* (1), *Enterobacter aerogenes* (4), *Shigella dysenteriae* (1), and *Yersinia enterocolitica* (1) (Saeed and Tariq 2005). An antifungal protein with a molecular mass of 11 kDa and a lysine-rich N-terminal sequence was isolated from the seeds of the pea, *Pisum sativum* var. *arvense* (Wang and Ng 2006). It exerted antifungal activity against *Physalospora piricola* with an IC_{50} of 0.62 μM, and also antifungal activity against *Fusarium oxysporum* and *Mycosphaerella arachidicola*. It inhibited human immunodeficiency virus type one reverse transcriptase with an IC_{50} of 4.7 μM. A recombinant plant defensin designated rPsd, was isolated from *Pisum sativum* (Cabral et al. 2003). It exhibited high antifungal activity as expressed against the yeast, *Pichia pastries* and was also fully active against *Aspergillus niger*. Plant defensins are small cysteine-rich proteins that present high activity against fungi and bacteria and inhibition of insect proteases and α-amylases. Recent studies by Niehues et al. 2010) showed that bioactive peptides from pea protein could be applied as functional ingredients for protecting infants and children against infections such as *Helicobacter pylori*. From two highly active fractions (F3, F3.3) of *Pisum sativum* seed proteins two anti-adhesive peptides (S3, S5) were identified Neither F3 nor S3 or S5 exerted any cytotoxic effect against *Helicobacter pylori*. However it was found that F3 interacted specifically with *H. pylori* adhesins BabA, SabA, HpaA and a fibronectin-binding adhesin, while S3 and S5 inhibited only BabA.

Antiobesity Activity and Protein Metabolism

The inclusion of peas as the source of protein in the diet of growing rats generated a reduction in growth rate as well as the impairment in the liver, muscle and spleen weights as compared with casein fed controls (Martinez et al. 1995). Also, a decrease in plasma glucose, triglycerides and protein was found in the legume fed animals, while no changes in cholesterol levels were found. Further, the rats fed on the diet containing peas exhibited lower contents of plasma insulin, corticosterone, IGF-I (insulin-like growth factor −1) and T4 (thyroxine) as compared with casein controls. Liver and muscle total protein (mg) and total DNA (mg) were markedly reduced in the legume fed animals, but DNA/g, protein/DNA and RNA/protein ratios were similar in both dietary groups. Likewise, liver and muscle fractional synthesis rates were similar in the casein and legume groups, while the whole body protein synthesis appeared to be lower in the legume fed animals due to differences in body weights. It was concluded that animals fed on a diet containing peas as the only source of protein showed less adverse effects than those found with other legumes such as *Vicia faba* or *Phaseolus vulgaris*, in which protein quality, antinutritional factors and nutrient availability could be involved.

Alonso et al. (2002) reported that body weight gain, liver and gastrocnemius muscle weights and protein contents were reduced and some key hormones altered when rats were fed un-supplemented raw pea diets. This could be attributed to amino acid deficiencies in the diet, the action of antinutritional factors and the refractory nature of the reserve proteins and other seed components. After supplementation, extruded peas supported much higher rates of growth and skeletal muscle deposition than did supplemented raw peas. Protein synthesis and degradation rates in skeletal muscles and total protein contents were similar to control values. The lower growth rate did not appear to be due to diminished deposition of skeletal muscle. Deposition of other body components, possibly lipids, may have been lowered by supplemented extruded pea diets. Liver protein levels were reduced in rats fed supplemented raw peas and blood corticosterone was elevated. It was concluded that extrusion treatment of peas in combination with amino acid supplementation appeared to eradicate the negative effects of peas on skeletal muscle deposition.

Studies with human volunteers found that ingestion of a mixed meal of 30 g of raw purified pea protein either as [15N]-globulins (G) or as a mix of [15N]-globulins and [15N]-albumins (GA) in their natural proportions (22:8) differed in postprandial protein utilization (Mariotti et al. 2001). The pea albumin fraction exhibited the following effects: (1) significantly decreased the real ileal digestibility of pea protein (94% for G vs. 89.9% for GA), probably due to a direct effect of trypsin inhibitors; (2) did not exalt acute intestinal losses of endogenous nitrogen; and (3) did not significantly ameliorate the postprandial biological value of pea protein (76.5% for G vs. 78.7% for GA), despite the fact that it rectified the globulin deficiency in sulfur amino acids. The researchers concluded that both G and GA were of good nutritional value for humans and showed that cysteine-rich albumins had a far more modest impact on the efficiency of postprandial dietary protein utilization than would be expected from the amino acid scores.

Using a cross-over design, whole pea flour (WPF) and fractionated yellow pea flours (FPF) were found to reduce fasting insulin and insulin resistance in hypercholesterolaemic and overweight human subjects compared to wheat flour (WF) (Marinangeli and Jones 2011). Insulin homeostasis modelling assessment demonstrated that ingestation of WPF and FPF decreased estimates of insulin resistance compared with WF. Android:gynoid fat ratios in women participants were lower in the WPF group compared with the WF group. Urinary enterolactone levels tended to be higher in WPF compared with WF. Neither treatment altered circulating fasting lipids or glucose concentrations. It was concluded that under a controlled diet paradigm, a daily consumption of whole and fractionated yellow pea flours at doses equivalent to half a cup of yellow peas daily reduced insulin resistance, while whole pea flour reduced android adiposity in women.

Cardioprotective Activity

A plant copper amine oxidase (Cu-AO, histaminase) purified from pea seedlings was reported to play a role in the modulation of IgE-mediated allergic reactions, and in the prevention of cardiac and splachnic postischemic reperfusion damage (Masini et al. 2007). Amine oxidases (AOs) are ubiquitous enzymes involved in the metabolism of biogenic amines such as putrescine, cadaverine, and histamine.

Diabetic Management

Pea albumin 1 F (PA1F), a plant peptide isolated from pea seeds, was found to dramatically increase blood glucose concentration by subcutaneous injection with a dosage of 5 or 10 μg/g (body weight) in normal and type II diabetic mice (KK/upj-Ay) (Dun et al. 2008). The voltage-dependent anion channel 1 (VDAC-1) was identified as the PA1F binding protein from mice pancreatic cell membrane, which may be involved in the regulation of enhancing blood glucose. Studies by Marinangeli et al. (2009) showed that whole yellow-pea flour (WYPF) can be used to produce low-glycemic functional foods possessing sensory attributes that were comparable to identical food products containing whole wheat flour (WWF). WYPF banana bread (97.9 mmol × in/l) and biscotti (83 mmol × in/l), as well as BYP (112.3 mmol × min/l), reduced glycemic responses compared to white bread (WB) (218.1 mmol × min/l). The glycemic response of WYPF pasta (160.7 mmol × min/l) was comparable to WB. WYPF biscotti produced a lower postprandial glycemic response compared to WWF biscotti (117.2 mmol × min/l). Hedonic responses between corresponding foods were similar except for the WYPF pasta (2.9) which possessed a lower sensory score for smell compared to WWF pasta (3.6).

Antifertility Effect

Pea seed oil was reported to have antisex hormonic effects; produced sterility and antagonized effect of male hormone (Sanyal 1950; Duke 1981) Injection of pea seed oil into male or female member of mated pairs of rats caused sterility, which in the males was prolonged or even permanent. Injections of the oil into immature rats of either sex caused a reduction in the size attained by the sex organs, but the effect was negated when large doses of vitamin E were simultaneously administered.

Antinutritional Factors

Studies in Poland found that pea cultivars with higher trypsin inhibitor activity contained significantly less flavanols and αgalactosides (Zdunczyk et al. 1997). The varieties with higher seed content of dietary fibre contained the highest amount of α-galactosides. The content of dietary fibre ranged from 161.5 to 209.9 g/kg with a mean of 187.9 g/kg. The mean gross energy of seeds was 18.1 MJ/kg. Amino acid composition of all the cultivars was similar, which was indicated by a similar index of essential amino acids (EAAI) of about 69.7. Trypsin inhibitor content in seeds was from 2.83 to 7.32 TIU/mg and the content of phytates ranged from 6.32 to 13.36 mg/g DM. The mean content of polyphenols and flavanols in analysed pea cultivars was 0.92 and 0.46 mg/g, respectively. In the seeds of most cultivars little or no pyrimidine glucosides, i.e. vicine and convicine, were found. The overall mean oligosaccharide content was 64.3 g/kg, of which α-galactosides were 46.8 g/kg. The antinutritional factor content was not significantly correlated with protein content.

Alonso et al. (2001b) reported on the effects of extrusion cooking on chemical composition, contents of minerals, carbohydrates and antinutritional factors (inositol phosphates, condensed tannins and lectins) in pea (*Pisum sativum*) and kidney bean (*Phaseolus vulgaris*) Moisture content decreased and iron increased in extruded compared with non-treated legume seed meals. Starch and non-starch polysaccharides were reduced in both pea and kidney bean seed meals. Raffinose, stachyose and verbascose also declined in kidney bean meal after extrusion, but only stachyose was reduced by thermal treatment in

pea flours. Inositol hexaphosphate was partially hydrolysed to penta- and tetraphosphates by extrusion, which also lowered tannin and lectin level. The apparent absorption of Fe, Ca and P from unsupplemented pea-based diets significantly increased in extruded compared with raw seed meals. With amino acid supplemented pea diets, extrusion significantly increased Ca, Mg, Fe, Cu and P apparent (faecal) absorption in rats. Extrusion enhanced Ca, Mg, Zn, Cu and P apparent (faecal) absorption in rats fed with both unsupplemented and supplemented kidney bean-based diets.

Cooking was found to reduced phytic acid and tannin contents in peas (Habiba 2002). Ordinary cooking, which took longer time, was most effective in reducing phytic acid (47.9%), while microwaving gave the greatest reduction (25.7%) in pea tannins. Trypsin inhibitor and lectins were readily removed by the test methods (microwave, ordinary and pressure cooking). In-vitro protein digestibility of raw peas was 73.5% and it was improved upon cooking. Pressure cooking resulted in most the improvement (6.43%). Solubilities of proteins and amino acids were greatly decreased (about 50%) by cooking due to thermal modification and loss of fractions soluble in cooking water. In addition, HCl-extractable ash and phosphorus (as a measure of availability) were enhanced as cooking time increased. Pressure cooking showed the highest percentages of both extractable ash (94.93%) and phosphorus (4.36%).

The results of studies by Pastuszewska et al. (2004) suggested that colour-flowered pea (*Pisum sativum* ssp. *arvense*) may be considered as an interesting dietary alternative to white-flowered pea (*Pisum sativum* ssp. *hortense*) since cooking removed trypsin inhibitor activity (TIA), decreased tannins, and increased dietary fibre contents. The colour-flowered (CF) had a greater proportion of hulls and higher acid detergent fibre (ADF) content than white-flowered (WF) pea seeds (10.7 vs. 8.2% and 92.2 vs. 84.5 g/kg dry matter (DM), respectively). Three out of six CF varieties had a significantly greater amount of protein bound to neutral detergent fibre (NDF) than WF peas. The tannin content was higher in CF than in WF peas (8.46 vs. 0.37 g/kg DM). In-vitro protein and amino acid digestibility was about 8% higher in WF than in CF varieties. Cooking decreased the tannin content in CF peas (8.46 vs. 5.51 g/kg DM) but had no effect on in-vitro protein digestibility. Heat treatment reduced significantly trypsin inhibitor activity and amount of protein bound to NDF in CF and WF varieties. However, the protein bound to NDF content in pea DM increased in CF and decreased in WF varieties. Cooking resulted in an increased NDF content over two times in both CF and WF pea seeds (from 122 to 259 and from 120 to 262 g/kg DM, respectively).

Wang et al. (2008) reported on the effect of variety and processing (soaking, cooking and dehulling) on nutrients and anti-nutrients in field peas (*Pisum sativum)*. Analysis of variance revealed that variety had a significant effect on crude protein, starch, ash, soluble dietary fibre (SDF), insoluble dietary fibre (IDF), total dietary fibre (TDF), trypsin inhibitor activity (TIA), minerals, phytic acid, sucrose and oligosaccharides. Soaking and cooking increased protein content, IDF, TDF, Ca, Cu, Mn and P in peas whereas ash content, Fe, K, Mg, Zn, sucrose and oligosaccharides were reduced. TIA was increased by soaking but reduced by cooking. Cooking was more effective than soaking in reducing oligosaccharides. Dehulling increased crude protein, starch, K, P, phytic acid, stachyose and verbascose content but reduced SDF, IDF, TDF, Ca, Cu, Fe, Mg and Mn.

Peas were found to provide an excellent plant protein source (157.3–272.7 g/kg) for human diets, but their proteins were less readily digestible than animal proteins (Park et al. 2010). The proportion of albumins based on total seed protein content decreased from 229 to 147 g/kg as seed protein content increased from 157.3 to 272.7 g/kg, while the proportion of globulins increased from 483 to 590 g/kg. The in-vitro protein digestibility (IVPD) of eight raw pea variety seeds were 79.9–83.5%, with significant varietal variations, and those were improved to 85.9–86.8% by cooking. Albumins, including (pea albumins 2) PA2, trypsin inhibitor, lectin and lipoxygenase, were identified as proteolytic

resistant proteins. Globulins were mostly digested by protease treatment after heating. Smart (1990) reported that there are no significant amounts of toxicity or anti-metabolites in peas.

A Czech patented technology referred as V-O was developed to reduce antinutritional factors in pea seeds (Dvořák et al. 2005). The technology was based on exposing coarsely extracted pea seeds to moist heat, organic acids and selected oxides in a reactor. The V-O technology was compared with modified V-I and V-II variations. The V-I technology was defined by an exposure to the temperature of 80–90°C in the reactor for 30 min, the duration of ageing being 40 min. The V-II technology was characterized by an exposure to the temperature of 80–90°C in the reactor for as long as 50 min, the ageing interval being 60 min. After treatment with technologies V-0, V-I, and V-II the trypsin inhibitor activity fell by 83.8%, 80.5% and 83.8%, respectively from 15.4TIU. The lectin content felled by 70.3%, 35.7% and 73.2% respectively after treatment from a pretreatment titre of 717. The content of tannins measured by the amount of gallic acid in native pea seeds was 49.1 mg per kg. It dropped by 41.4%, 32.0% and 46.2% respectively after treatment The content of indigestible oligosaccharides causing flatulence was less affected by the treatments. The pre-treatment content of raffinose was 9.5 g/kg. The drop associated with the treatment was 9.5%, 6.3% and 10.5%, respectively. The pre-treatment content of stachyose was 21.4 g/kg and after treatment with technologies V-0 and V-II it felled by 7.0% and by 16.4%, respectively. The application of technology V-I did not result in a decline in the content of stachyose. The content of verbascose in native pea seeds was 16.1 g/kg and the treatment with technologies V-0; V-I and V-II resulted in a fall by 7.5%, 5.6% and 20.5%, respectively. As for the detected phenolic acids, with the exception of caffeic acid, not a decline, but an elevation in their content was recorded. Isoflavone oestrogens such as daidzein and genistein also recorded a slight increase in their content. The scientists concluded that the above-described methods of pea seed treatment, especially the V-II variant, proved to be useful for practical use.

Bifidogenic Effect

The native starches of beans and peas and micro-waved preparations were found to impact on nitrogen utilisation, biochemical indices in blood serum and caecal ecosystem state (Krupa-Kozak et al. 2010). The native pea starch contained more resistant starch compared with its bean counterpart (31 v. 17%). However, processing lowered these amounts to 25 v. 10%. Nitrogen digestibility was found to decrease appreciably in all preparations. An appreciable fall was observed in glucose and total cholesterol level in rat blood serum as a result of feeding both dietary legume starch preparations under microwave treatment. Further, both dietary bean starches significantly stimulated the formation of SCFA (short chain fatty acids) in the caecal digesta. As compared with the control group, a significant decrease in the pH of caecal and colonic digesta was demonstrated for both bean starch preparations. In comparison with the diet with native pea starch, its micro-waved preparation reduced the concentrations of acetic, butyric and propionic acids among caecal SCFA and increased the pH of caecal and colonic digesta. The atherogenic index was significantly lower in rats fed micro-waved pea starch. All investigated starch preparations increased the population of *Bifidobacterium* spp. in caecal digesta, but were also good substrates for opportunistic *Enterococcus* or *Escherichia coli.*

Traditional Medicinal Uses

Pea seeds are thought to cause dysentery when eaten raw. In Spain, flour is considered emollient and resolvent, applied as a cataplasm. The seed is regarded as contraceptive, fungistatic and spermacidal. The dried and pulverised seed has been used as a poultice on the skin to treat many types of skin complaints including acne. The oil from the seed, administered once a month to women, has shown promise in preventing pregnancy by interfering with the activity of progesterone.

Other Uses

Cosmetic face masks made from crushed seeds are used to treat acne and wrinkled skins. Pea seeds are also used as animal feed. The plants can be used for hay, forage, silage, green manure and pasture.

Pea starch, was reported to have inherently good gel strength, and could be used as the source material for manufacturing a biodegradable and bioactive packaging material (Nam et al. 2007). Extrudates containing 99% pea starch and 1% lysozyme were produced under various extrusion conditions. Up to 48% of the initial lysozyme activity was recovered from the extruded pea starch matrix. The lysozyme released from pea starch extrudates showed an inhibition zone against *Brochotrix thermosphacta* B2 (Nam et al. 2007). Extruded pea starch matrix containing lysozyme was shown to have potential application as an edible and biodegradable packaging material with antimicrobial activity.

Comments

The variation of flower, pod, seed, leaf and stem characters in *Pisum sativum* is extensive and there are various attempts to classify the infraspecific diversity (e.g. Govorov 1937, Makašheva 1983, Lehmann and Blixt 1984). Lehmann and Blixt, (1984) divided *P. sativum* into 3 subspecies: *asiaticum* Gov., *trasncausicum* Gov. and *sativu*m. They further divided *P. sativum* subsp. *sativum* into 5 convarieties and 101 varieties. Many convarieties and botanical varieties had been described. Hanelt (2001) listed the following: *Pisum sativum* convar. *Axiphium, Pisum sativum* convar. *Medullare, Pisum sativum* convar. *Sativum, Pisum sativum* convar. *speciosum, Pisum sativum* subsp. *abyssinicum, Pisum sativum* subsp. *asiaticum, Pisum sativum* subsp. *elatius, Pisum sativum* subsp. *sativum, Pisum sativum* subsp. *syriacum, Pisum sativum* subsp. *transcaucasicum, Pisum sativum* var. *ponderosum and Pisum sativum* var. *ponderosum.* USDA GRIN Taxonomy listed 11 subspecies *Pisum sativum* subsp. *abyssinicum*, *Pisum sativum* subsp. *asiaticum, Pisum sativum* subsp. *elatius*, *Pisum sativum* subsp. *elatius* var. *brevipedunculatum, Pisum sativum* subsp. *elatius* var. *elatius, Pisum sativum* subsp. *elatius* var. *pumilio*, *Pisum sativum* subsp. *sativum, Pisum sativum* subsp. *sativum* var. *arvense*, *Pisum sativum* subsp. *sativum* var. *macrocarpon, Pisum sativum* subsp. *sativum* var. *sativum, Pisum sativum* subsp. *transcaucasicum*.

Another pea classification is based on end-uses. Cultivated forms of *P. sativum* L. are comprised of morphologically distinct intraspecific types, which were created for different end-uses (fodder, food and feed peas) (Baranger et al. 2004). Different types are commonly utilized for livestock feeding as above ground mass (field pea, var. *arvense* (L.) Poir.) or seed (dry pea, ssp. *sativum*), and for human consumption as immaturet pods or seed (garden pea, var. *hortense* (Neilr.).

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Psophocarpus tetragonolobus

Scientific Name

***Psophocarpus tetragonolobus* (L.) DC**

Synonyms

Botor tetragonobolus (L.) Kuntze, *Dolichos ovatus* Grah., *Dolichos tetragonolobus* L.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Asparagus Bean, Asparagus Pea, Princess Bean, Princess-Pea, Four-Angled Bean, Goa Bean, Manila Bean, Supermarket Bean, Short Day Asparagus Pea, Winged Bean

Vernacular Names

Burmese: Hto-Pong, Ku-Bemya, Pe-Saungya;
Chinese: Si Jiao Dou, Sie Kok Tau, Si Leng Dou;
Cuba: Calamismis;
Czech: Prskavec Ledencový;
Danish: Goabønne, Goaboenne;
Dutch: Ketjipir;
Finnish: Goanpapu;
French: Haricot Ailé, Pois Ailé, Pois Asperge, Pois Carré;
German: Flügelbohne, Goabohne;
India: Charkoni Sem (Hindu), Chathura Payar (Malayalam), Sirahu Avarai (Tamil);
Indonesia: Kelongkang (Bali), Kecipir, Cipir, Cicipir (Javanese), Kacang Embing, Kacang Belingbing (Sumatran), Jaat (Sundanese);
Italian: Fagiolo Quadrato;
Japanese: Sikaku Mame, Tousai, Urizun;
Khmer: Prapiey;
Laos: Thwax Ph'uu;
Malaysia: Kacang Belimbing, Kacang Botor, Kacang Kelisah;
Papua New Guinea: Asbin, Bin;
Philippines: Kabey, Kalamismis (Bisaya), Calamismis (Spanish), Segidilla, Seguidilla, Sigarilya, Sigarillas (Tagalog);
Portuguese: Fava De Cavalo;
Russian: Psofokarpus Chetyrekhkylyi;
Spanish: Calamismis, Dólico De Goa, Frijol Alado, Judia Careta;
Sri Lanka: Dambala, Dara Dambala, Darambulla (Sinhalese);
Swedish: Vingböna;
Thai: Thua-Phu;
Vietnamese: Đậu Rồng.

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Origin/Distribution

The genus *Psophocarpus* contains nine species, eight of which are wild and one, winged bean is only known in cultivation. The wild species have been collected only in Africa, Madagascar and the Mascarene island, winged bean has an Asiatic distribution from Mauritius to New Guinea. New Guinea and southeast Asia especially Indonesia have many varieties and strains that point to them being the centre of diversity for winged bean. Some researchers assert that it could have an African ancestry.

Winged bean is widely cultivated in the tropics, especially in Myanmar, India, Malaysia, Indonesia, Thailand, Vietnam, Sri Lanka, Bangladesh, West Africa, New Guinea, the West Indies, South America and even South Florida.

Agroecology

Winged bean thrives in the hot, humid equatorial zone and humid tropics with day temperatures of 25–32°C and night temperatures above 18°C and with mean annual rainfall of 1,500–3,000 mm. It grows from sea level to 2,200 mm elevation but is frost sensitive. Winged bean is a quantitative short-day plant, flower induction requiring a critical day-length of around 12 h. The response to day-length varies with genotype, temperature and light intensity; some cultivars are day neutral. Winged bean thrives on a range of well-drained, friable soil types with a pH above 5.5. It is intolerant of water logging.

Edible Plant Parts and Uses

All the plant parts, viz., seeds, tender, immature pods, young leaves, flowers and tubers are edible and consumed as food.

The tuberous roots are eaten both cooked and raw in Papua New Guinea and Myanmar. The tubers are exceedingly rich in protein >10%, are white fleshed, firm and have a pleasant nutty flavour. Young pods at the 10–15 cm stage are eaten raw and cooked. In Indonesia, young leaves and shoots and young pods are eaten raw or steamed as *lalab* and in *sayor*, in a side dish with rice called *trantjam ketjepir* made up of sliced young tender pods mixed with similarly sliced cucumber and *sambal*. Young leaves are cooked and eaten as greens. In Malaysia, the young tender pods are eaten raw as *ulam* (vegetable salad) usually with *sambal belachan*. Also the young pods are sliced and fried with sambal and pounded dried shrimps. Ripe seeds are eaten as delicacy in *pindang* or eaten roasted. Flowers and flower buds eaten as *petjel* in Java. Flowers are also used to colour rice and pastries. In Madura, ripe seeds are fried as like *kacang goreng*. The seeds are also rich in proteins and has similar uses to that of soya beans – edible oil, milk, tofu, bean curd, tempeh, miso etc. Winged bean flour can be employed as protein supplement in bread making.

Botany

A climbing, twining perennial vine, 2–4 m long with ridged, glabrous stem and fleshy, fusiform, tuberous roots (Plate 6). Leaves are trifoliolate on long petioles (up to 12 cm long) grooved on the upper side and with a pulvinus at the base (Plate 5). Stipules are short, lanceolate and spurred. The leaflets are more or less triangular or rhomboid, tapering to an acute point, base obtuse 8–15 by 4–12 cm entire and light green. Inflorescence consists of 2–12 flowered axillary raceme, 15 cm long. Flowers are bisexual, papilionaceous and of varying colours pale sky blue, some are white (Plates 4 and 5), and others are reddish brown depending on cultivars. Bracteoles are ovate and persistent. Calyx is tubular with 5 short blunt teeth, corolla variously coloured with a distinct, reflex, emarginate standard petal, incurved keel petal and shorter wings, 9 stamens and 1 superior, oblong, 1-celled ovary on a short stalk, with a long, bent style and hairy globose stigma. The fruit (pod) is oblong linear, straight, curved to long and flexuous, 15–30 cm long and 2.5–3.5 cm wide, with four longitudinal serrate-dentate or sinuous leafy wings (Plates 1–3). In

Plate 1 (**a**–**d**) Different varieties of winged bean

Plate 2 (**a** and **b**) Short and long, flexous immature winged beans on sale in local markets

Plate 3 Close-up of young winged bean pod

Plate 4 Winged bean flowers and trifololiate leaves

cross section, the pod is square with the four corners tapering out into the thin wings. They are variously coloured depending on variety from green, yellow-green or purple or green with purplish-red wings (Plates 1–3). When fully ripe they turn brown and split open, often with a loud popping noise. The seeds 5–20 per pod are

Plate 5 Close-up of winged bean papilionaceous flower

Plate 6 Winged bean fusiform, tuberous roots

subglobose about 0.5–1 cm across, white, yellow, brown or black, or mottled with a small aril and non-endospermous.

Nutritive/Medicinal Properties

Analysis carried out in Malaysia (Tee et al. 1997) reported the raw, young pods of winged beans to have the following nutrient composition per 100 g edible portion: water 92 g, protein 2 g, fat 0.2 g, carbohydrate 3.1 g, dietary fibre 2.1 g, Ca 36 mg, P 31 mg, Fe 0.8 mg, K 91 mg, Na 2 mg, carotene 293 μg, thiamine 0.06 mg, riboflavin 0.12 mg, niacin 0.5 mg, vitamin C 11.3 mg.

The raw, mature winged bean seeds were reported to have the following nutrient composition (per 100 g value): water 8.34 g, energy 409 kcal (1,711 kJ), protein 29.65 g, total lipid 16.32 g, ash 3.98 g, carbohydrates 41.71 g, Ca 440 mg, Fe 13.44 mg, Mg 179 mg, P 451 mg, K 977 mg, Na 38 mg, Zn 4.48 mg, Cu 2.88 mg, Mn 3.721 mg, Se 8.2 μg, vitamin C 0 mg, thiamine 1.030 mg, riboflavin 0.450 mg, niacin 3.09 mg, pantothenic acid 0.795 mg, vitamin B-6 0.175 mg, total folate 45 μg, vitamin A 0 IU, total saturated fatty acids 2.303 g, 14:0 (myristic) 0.028 g, 16:0 (palmitic) 0.031 g, 18:0 (stearic) 0.745 g; total monounsaturated fatty acids 6.021 g, 16:1 undifferentiated (palmitoleic) 0.055 g, 18:1 undifferentiated (oleic) 5.654 g; total polyunsaturated fatty acids 4.330 g, 18:2 undifferentiated (linoleic) 4.068 g, 18:3 undifferentiated (linolenic) 0.262 g; tryptophan 0.762 g, threonine 1.179 g, isoleucine 1.468 g, leucine 2.497 g, lysine 2.136 g, methionine 0.356 g, cystine 0.545 g, phenylalanine 1.429 g, tyrosine 1.357 g, valine 1.530 g, arginine 1.886 g, histidine 0.790 g, alanine 1.040 g, aspartic acid 3.187 g, glutamic acid 4.010 g, glycine 1.140 g, proline 1.924 g and serine 1.235 g (USDA 2010).

Fresh winged bean leaves were reported to have the following nutrient composition (per 100 g value): water 76.85 g, energy 74 kcal (310 kJ), protein 5.85 g, total lipid 1.10 g, ash 2.10 g, carbohydrates 14.10 g, Ca 224 mg, Fe 4.00 mg, Mg 8 mg, P 63 mg, K 176 mg, Na 9 mg, Zn 1.28 mg, Cu 0.456 mg, Mn 1.367 mg, Se 0.9 μg, vitamin C 45 mg, thiamine 0.833 mg, riboflavin 0.602 mg, niacin 3.472 mg, pantothenic acid 0.136 mg, vitamin B-6 0.232 mg, total folate 16 μg, vitamin A RAE 405 μg, vitamin A 8090 IU, total saturated fatty acids 0.272 g, 14:0 (myristic) 0.001 g, 16:0 (palmitic) 0.076 g, 18:0 (stearic) 0.044 g; total monounsaturated fatty acids 0.285 g, 18:1 undifferentiated (oleic) 0.284 g, 22:1 undifferentiated 0.002 g; total polyunsaturated fatty acids 0.213 g, 18:2 undifferentiated (linoleic) 0.187 g, 18:3 undifferentiated (linolenic) 0.026 g; tryptophan 0.116 g, threonine 0.182 g, isoleucine 0.204 g, leucine 0.395 g, lysine 0.228 g, methionine 0.064 g, cystine 0.075 g, phenylalanine 0.188 g, tyrosine 0.126 g, valine 0.245 g, arginine 0.178 g, histidine 0.082 g, alanine 0.172 g, aspartic acid 0.517 g, glutamic acid 0.389 g, glycine 0.149 g, proline 0.168 g and serine 0.149 g (USDA 2010).

Raw, winged bean tubers were reported to have the following nutrient composition (per 100 g value): water 57.40 g, energy 148 kcal (619 kJ), protein 11.60 g, total lipid 0.90 g, ash 2.00 g, carbohydrates 28.10 g, Ca 30 mg, Fe 2.00 mg, Mg 24 mg, P 45 mg, K 586 mg, Na 35 mg, Zn 1.39 mg, Cu 1.386 mg, Mn 0.532 mg, Se 0.7 μg, vitamin C 0 mg, thiamine 0.379 mg, riboflavin 0.149 mg, niacin 1.640 mg, pantothenic acid 0.116 mg, vitamin B-6 0.075 mg, total folate 19 μg, total saturated fatty acids 0.222 g, 16:0 (palmitic) 0.062 g, 18:0 (stearic) 0.036 g; total monounsaturated fatty acids 0.234 g, 18:1 undifferentiated (oleic) 0.232 g, 22:1 undifferentiated (erucic acid) 0.002 g; total polyunsaturated fatty acids 0.174 g, 18:2 undifferentiated (linoleic) 0.153 g, 18:3 undifferentiated (linolenic) 0.021 g; tryptophan 0.252 g, threonine 0.451 g, isoleucine 0.435 g, leucine 0.640 g, lysine 0.592 g, methionine 0.143 g, cystine 0.197 g, phenylalanine 0.451 g, tyrosine 0.353 g, valine 0.599 g, arginine 0.412 g, histidine 0.241 g, alanine 0.397 g, aspartic acid 1.735 g, glutamic acid 0.800 g, glycine 0.390 g, proline 0.679 g and serine 0.464 g (USDA 2010).

As shown from the above, immature young pods are rich in protein (1–3%) and rich in calcium, iron, vitamin A. Leaves are also nutritious with 5–7% protein and vitamin A and C. The seeds are also rich in protein amino acids lysine, leucine and dietary minerals like calcium and zinc, vitamins thiamine and riboflavin. Tubers are rich in protein 10%, calcium and phosphorus. Ibuki et al (1983) reported that winged bean seeds had a high level of protein (27.8–36.6%) and fat (14.8–17.9%), which were similar to soybeans. The seeds contained high phosphorus, calcium and magnesium. The leaf was highest in protein content (33.7%) of all the parts studied except for the seeds. The protein and fat content of pods decreased as pods ripened. The calcium content in the leaf was much higher than in the other parts. The NaCl extract showed the highest range of protein concentration (60.2–77.6%). Contents

of lysine, aspartic acid, glutamic acid and leucine were high, while the sulfur-amino acid content was low.

Winged bean seed was found to contain 29–37% proteins, 15–18% oil and fairly good amounts of phosphorus, iron, and vitamin B (Kadam and Salunkhe 1984). Essential amino acid composition of winged bean was found to be very similar to that of soybean and very much comparable to groundnut.

Among the tocopherols, γ–tocopherol was found to be the dominant form in winged bean seed oil with traces of α-, β- and δ-tocopherols (De Lumen and Fiad 1982). The concentration found ranged from a low of 8 mg and high of 130 mg of γ–tocopherol/100 g of oil, most samples fell in the range of 23–44 mg/100 g of oil. The tocopherol to polyunsaturated fatty acids ratio was calculated to be 0.2 mg of δ-α tocopherol equivalent/g of polyunsaturated fatty acids, a value similar to soyabean.

Winged bean seeds (*Psophocarpus tetragonolobus*) were shown to contain 14.4% of oil on a dry weight basis (Murugiswamy et al. 1983). Fractionation of this oil yielded 72.7% neutral lipids, 2.8% of glycolipids and 24.5% of phospholipids. Fatty acid composition of total lipid, neutral and glycolipid showed palmitic acid (12.2–14.0%), stearic acid (3.5–4.3%), oleic acid (36–39%) and linoleic acid (39–42%) as major fatty acids. The phospholipid fraction was slightly different from the rest in containing higher palmitic and lower oleic and linoleic acids. Homma et al (1983) found that glyceride was the dominant lipid accounting for 89.6% of the total, followed by an unknown lipid 4%, free fatty acid of 2.3%, 1,3-diglyceride, 1,2-diglyceride and steryl ester of 1% each and finally a polar lipid of 0.2%. The results showed that winged bean oil should be suitable for edible purposes. Triglycerides showed a similar profile of fatty acids to those of whole lipid: the major fatty acids were palmitic (10.9%), stearic (4.5%), oleic (37.1%), linoleic (19.0%), eicosenoic (3.6%), behenic (18.5%) and lignoceric (4.2%) acids. Compared to soybean oil, winged bean oil contained long chain fatty acids and a fairly small amount of linolenic acid which was favorable regarding oil stability against autoxidation. The major triacylglycerols found in winged beans were behenoyl-linoleoyl-oleoylglycerol (21.3%), trioleoylglycerol (10.5%) and behenoyl-dioleoylglycerol (15.6%) (Omachi et al. 1987). Winged bean oil was found to contain triacylglycerols of larger ECN (equivalent carbon number) than soybean oil.

Oleic and linoleic acids were found to be the main unsaturated fatty acids in winged bean seed oil (Higuchi et al. 1982). Long chain saturated fatty acids, such as behenic and lignoceric acids, were detected in relatively high levels as compared with other edible seed oils. The fatty acids that could not be separated by gas liquid chromatography were identified as linolenic acid and arachidic acid. Parinaric acid, was not detected and this supposed fraction was found to contain eiconsenoic acid. Erucic acid, suspected of having an adverse effect on myocardial lesions in rats, was detected but only in low level. From these findings, winged bean seed oil could be suggested as being a food source of favourable quality. In another study, the oil content of 19 genetically improved cultivars of winged bean seeds was found to vary from 14.5% to 22.7% (Singh et al. 1995). Oleic acid (41.4%) and linoleic acid (29.7%) were the major constituents and contributed above 70%, however, the total unsaturated fatty acid varied from 66.8% to 78.9% (73.9%). Palmitic (10.9%), behenic (6.7%) and stearic (3.5%) acids were the major saturated fatty acids. Parinaric acid, a toxic fatty acid was absent in seed oil of all the varieties. The oil was found to store for longer period being low in hnolenic acid (0.9%).

All varieties of winged bean seeds exhibited a high protein concentration (34.3–40.7% on dry basis) and high oil content (16.4–21.3% on dry basis) (Gross 1983). Amino acid analysis showed that winged bean contained all amino acids in sufficient quantity, with the exception of the sulphur-containing amino acids. The amino acid content of immature pods was generally lower, and the non-protein nitrogen content higher. The seed showed a high content of hemagglutinins. The in-vivo digestibility was relatively low (71%) compared with other legumes. Protein quality for the non-supplemented winged bean protein,

measured by Protein Efficiency Ratio (PER), gave an intermediate value (1.73 vs. casein 3.07) compared with other legumes. The apparent digestibility gave the lowest value (72.8%) compared with other legumes. In another study of several legumes (winged beans, soyabean, green gram, bambarra nuts, pigeon peas, field beans, cow peas), winged bean seeds were found to contain the highest concentration of lysine (7.5 g/16 g N) and threonine (4.3 g/16 g N), but the level of methionine and cystine was low (Mnembuka and Eggum 1995). Protein digestibility was above 80% but utilizable protein was lower (23.4%) compared to soyabean (28.8%). Energy digestibility was about 80%, with soyabean having the highest value of 85.8%.

The amino acid composition of winged bean seed meal was found to be similar to that of soybean but their storage globulins were quite different (Gillespie and Blagrove 1978). Three globulin fractions were identified and named psophocarpins A, B, and C. Psophocarpin A was found to be comparatively rich in sulfur-containing amino acids while the other fractions were composed of a number of related components which had not been separated. Winged bean seeds was also found to contain albumin, winged bean albumin-1 (WBA) the predominant seed albumin (Mc Coy and Kortt 1997). WBA had sequence similarity with the STI-Kunitz trypsin inhibitors, but did not inhibit trypsin.

Two major classes of protease were shown to occur in germinating winged-bean (Usha and Singh 1996). An acidic protease designated WbAP was purified to apparent homogeneity. WbAP was found to be a monomeric thiol protease with a molecular mass of 35 kDa and a optimum pH of 6.0 and did not belong to the papain family. Besides gelatin and casein, it hydrolysed a 29 kDa winged-bean protein, indicating a prospective physiological role for it in storage-protein mobilization.

Volatiles formed by the decomposition of hydroperoxides generated by lipoxygenase-catalysed oxidation of linoleic acid were found to contribute a beany flavour to legumes (Mtebe and Gordon 1987). 11 volatiles were identified after treatment of linoleic acid by lipoxygenase extracted from winged bean seeds. Five of these volatiles; hexanal, 2-heptanone, 2-pentyl furan, undecane and tridecane, were detected in the headspace of a sample of winged bean flour after storage. Moisture levels <10% appeared to inhibit lipoxygenase activity. Incubation of a lipoxygenase extract with linoleic acid gave rise to a larger concentration of volatiles at pH 9 than at pH 6.5 due to the increased lipoxygenase activity at the higher pH.

Antioxidant Activity

The crude extract of stem leaf, root and pod (fruit) of *Psophocarpus tetragonolobus* were found to have antioxidant properties including radical scavenging and reducing power (Latha et al. 2005). The antioxidative activities correlated with the total phenol. The pod extract was more effective than the other plant parts.

In another study, winged bean seed was found to exhibit antioxidant activity; it exhibited a catalase activity of 310 U/g, superoxide dismutase (SOD) of 40 U/g and IC_{50} of 23.21 mg, and a glutathione peroxidise (GSH-Px) activity of 37.96 U/g (Said 2009). The seed coat had the highest total polyphenol content of 67.31%, followed by the pod 33.79% and the cotyledon with only 7.86%. The seeds had low anti-tyrosinase activity with an IC_{50} of 252.37 mg.

Antimicrobial Activity

Winged bean pod extract was found to be most inhibitory against all of the tested organisms (11 bacterial pathogens, four yeasts, and four moulds), followed by the stem, root, and leaf extracts (Sasidharan et al. 2008b). The ethanol fraction showed the most significant antimicrobial activity against all of the tests among three soluble fractions of extract, followed by the ethyl acetate and chloroform fractions. The minimum inhibitory concentrations (MICs) of extracts determined by the broth dilution method ranged from 1.25 to 10.0 mg/ml. The MIC of ethanol fraction of pod extracts was the lowest when compared with the other two extracts. The MIC for fungi was at or below 2.5 mg/ml and for bacteria was at or above

2.5 mg/ml. In another study, the extract of the *Psophocarpus tetragonolobus* pods exhibited antimicrobial activity against eight human pathogenic bacteria and two human pathogenic yeasts (Latha et al. 2007). The inhibitory effect increased with increase of the extract concentration from 10 to 20 µl. Gram-positive *Staphylococcus aureus* was the most susceptible strain with the widest inhibition zones (28–34 mm). The crude extract also exhibited high antimicrobial activity against *Bacillus subtilis* and *B. cereus*. Gram-negative strains displayed variable degree of sensitivity to the extract. Maximum activity was observed against *Proteus mirabilis* (inhibition zone of 22–24 mm), followed by *Escherichia coli* (18–21 mm), *Salmonella typhi* (16–19 mm), and *Klebsiella pneumoniae* (14–17 mm). Gram-negative bacteria, *Pseudomonas aeruginosa* exhibited weak inhibition zones (7–12 mm). The antimicrobial activity of this extract was also observed on the yeasts *Candida albicans* (24–36 mm) and *Rhodotorula rubra* (17–20 mm). In the brine shrimp lethality test, the ethanolic extract exhibited no significant toxicity (LC_{50} = 1.88 mg/ml) against *Artemia salina*, whereas sheep erythrocyte test showed significant toxicity. The *P. tetragonolobus* extract with high LC_{50} value indicated the plant to be not toxic to humans. The methanol extract of *Psophocarpus tetragonolobus* root showed strong antimicrobial activity against *C. albicans* with a minimum inhibitory concentration (MIC) value of 3.13 mg/ml (Sasidharan et al. 2008b). SEM studies showed alterations in morphology and complete collapse of the yeast cells after 36 h of exposure to the extract. In an acute toxicity study using rats, death was not observed, so the acute minimum fatal dose of the extract was greater than 2000 mg/kg. No pathologic changes was observed in macroscopic examination by necropsy of rats treated with extract indicating that the extract may be safely used as an antimicrobial agent.

Antinutritional Factors

On the downside, winged bean was found to contain relatively high amounts of behenic acid and parinaric acid (Kadam and Salunkhe 1984). The trypsin inhibitor in winged bean was shown to be heat resistant. Other toxic factors such as hemagglutinins and cyanide were also reported. Winged bean seeds were hard to cook. Soaking of seeds in the Rockland's soak solution containing sodium bicarbonate, sodium carbonate, sodium chloride, and sodium pyrophosphate was found to reduce cooking time significantly. Trypsin and chymotrypsin inhibitory activities of 2% NaCl extract from winged bean seeds were determined, and chymotrypsin inhibitory activity was higher than trypsin (Ibuki et al. 1983).

Winged bean was found to contain anti-nutritional factors such as tannin, phytic acid, trypsin inhibitor, chymotrypsin inhibitor, α-amylase inhibitor and lectin (Kotaru et al. 1987), psophocarpin B1, behenic acid and other protease inhibitors. Tannin contents ranged from 1.35 to 6.75 mg/g of bean (Kotaru et al. 1987), phytic acid contents ranged from 7.77 to 12.03 mg/g of bean and phytate-phosphorus represented a considerable percentage of the total phosphorus (44.3–54.8%). Chymotrypsin inhibitory activities were about two times higher than trypsin inhibitory activities. α-amylase inhibitory activities could not be detected in any of the winged bean varieties used in this study. Hemagglutinating activities were observed with respect to all types of trypsinized human erythrocytes (A, B and O). However these activities disappeared completely after heating in a boiling water bath for 10 minutes.

De Lumen and Salamat (1980) found that winged bean had the highest trypsin inhibition activity (TIA) of all selected beans examined. Most of the TIA could be inactivated by heat, residual tannin in the cooked bean accounted for the residual heat resistant TIA which amounted to 1% of the original. Soaking in NaOH (IN) was most effective in decreasing the tannin content in cooked beans. Winged bean was found also to have a chymotrypsin inhibitor which was extremely heat resistant (Tan et al. 1984). Prolonged boiling for 60 minutes was required to destroy the inhibitory activity and autoclaving for 20 minutes at 120°C and pressure of 1.05 kg/cm^2 was more effective, destroying 90% of the chymotrypsin inhibitory activity. Chan and DeLumn

(1982) found that raw winged bean diet was toxic to rats, it caused spleen and liver atrophy and mortality after 12 days of feeding. Autoclaved winged bean diet was not toxic but growth was inhibited, the casein plus isolated winged bean trypsin diet also caused pancreatic and spleen hypertrophy and slight growth inhibition. It was concluded that trypsin inhibitor in winged bean was not primarily responsible for toxicity of raw winged bean.

Psophocarpin B1, a major storage protein of winged bean (*Psophocarpus tetragonolobus*) seeds was found to inhibit the activity of bovine pancreatic chymotrypsin (Roy and Singh 1988). This inhibitory activity was abolished by heat treatment above 70°. In germinating seeds total chymotrypsin inhibitory activity (CIA) declined steadily as germination proceeds. It was demonstrated that both psophocarpin B1 and CIA disappeared concurrently during germination.

Seven proteinase inhibitors were isolated from winged bean seeds (Shibata et al. 1986). These inhibitors had molecular weights of around 20,000, included four half-cystine residues, and were Kunitz-type inhibitors. Two (WTI-2 and 3) inhibited bovine trypsin strongly and four (WCI-1, 2, 3, and 4) inhibited bovine α-chymotrypsin, but in different ways. All four chymotrypsin inhibitors cross-reacted with rabbit anti-WCI-3 serum, while the other inhibitors did not.

Twelve winged bean cultivars were investigated for variation of anti-nutritional behenic acid among the cultivars. The anti-nutritional behenic acid content varied between 0.58 mg/g (8.22%) and 0.96 mg/g (13.6%) dry weight in 12 winged bean cultivars (Fernando and Bean 1985). The highest amount of behenic acid was detected in all Nigeria selections (TPt) cultivars and the lowest was recorded in Sri Lanka selection (SLS)-1 cultivar. All University of Papua New Guinea selection (UPS) cultivars recorded second highest amounts of behenic acid, while Indonesia selection (LBNC) cultivars had moderate levels.

Pueppke (1979) purified a lectin from seeds of the winged bean. The lectin had specificity for receptors containing D-galactose and agglutinates trypsinized human red blood cells of all three ABO types. Of the tested inhibitors of hemagglutination caused by winged bean lectin, *p*-nitrophenyl–β-*D*-galctose was the most potent. Lactose was the most active oligosaccharide tested, and other oligosaccharides containing α-linked *D*-galactose were much less inhibitory. Kort (1984, 1985) found that the seeds of winged bean, contained a group of acidic lectins (pI approximately equal to 5.5) and a group of basic lectins (pI greater than 9.5) characterised by different erythrocyte hemagglutinating specificities and isoelectric points. Three basic lectins were separated and purified. These lectins were found to be glycoproteins with relative molecular mass of 58,000. The total carbohydrate content of the major lectins, B2 and B3, was 5% and comprised of mannose, N-acetylglucosamine, fucose and xylose in amounts corresponding to 9, 8, 8 and 3 mol/58,000 g, respectively, for both lectins. The basic lectins agglutinated trypsinized rabbit and trypsinized human (type A and B) erythrocytes but not trypsinized human (type O) erythrocytes. The lectins were inhibited by N-acetylgalactosamine, D-galactose and D-galactose containing disaccharides and trisaccharides. The specificity appeared to be directed to glycosides having non-reducing (terminal) α-D-galactopyranosyl groups, β-D-Galactosides, such as lactose, which were poor inhibitors.

Three acidic lectins (I, II, and III) (pI approximately 5.5) were also purified (Kortt 1985). These lectins were found to be glycoproteins with relative molecular mass of 54,000. The total carbohydrate concentration of the acidic lectins was 7% and was comprised of mannose, N-acetylglucosamine, fucose, and xylose in amounts corresponding to 9.2, 4.8, 1.6, and 7.0 mol/54,000 g, respectively. They contained essentially no half-cystine, 1–2 methionine residues, and were rich in acidic and hydroxy amino acids. The acidic lectins agglutinated trypsinized human (type A, B, AB, and O) erythrocytes but not trypsinized rabbit erythrocytes. They were inhibited by various D-galactose derivatives and D-galactose-containing disaccharides and trisaccharides. N-Acetylgalactosamine was the best inhibitor, and the specificity appeared to be directed to β-D-galactosides. However, compared with winged bean basic lectins and soybean

lectin, the winged bean acidic lectins showed a low affinity for the inhibitory sugars.

The fraction containing high hemagglutinating activity from raw winged bean tubers when orally administered to growing rats was found to decrease food intake and body weights (Shet et al. 1989). The decrease was greater as the level of lectin increased. Significant lectin activity was detected in the faeces extracted from these rats which was anti-genically similar to the native lectin preparation. Microscopic examination revealed morphological changes in the intestinal epithelial cells. The binding action of the lectin to the mucosal epithelia of the gastrointestinal tract was indicative of the damaging effects caused by the winged bean tuber, lectin.

Two isolectins which differed from each other in terms of their immunological properties, hemagglutinating activities, sugar inhibition patterns, and amino acid compositions were isolated from leaves of winged bean (Yagi et al. 1994). Both lectins were acidic and one of them (L-I), which was inactive toward trypsinized human type O erythrocytes, was similar to one of green shell lectins (WGS-1) resembling basic seed lectin in its immunological properties. The amino-terminal sequence of L-I was homologous to that of WGS-1. The amino acid composition of L-I was similar to that of basic seed lectin, but the extent of the homology between amino-terminal sequences was low when L-I and basic seed lectin were compared. Examination by ELISA revealed that L-I and WGS-1 were distinct from the basic lectins of seeds and tuberous roots. L-I exhibited high hemagglutinating activity toward human type A erythrocytes, as compared to its activity toward other erythrocytes. By contrast, the properties of a second acidic lectin from winged bean leaves (L-II) were very similar to those of acidic lectins from seeds and tuberous roots, and the similarities extended as far as the immunological properties.

The accumulation of aluminium (Al) in the edible parts of the winged bean plant i.e. the leaves, pods, seeds and tubers on acidic tropical soils and the implication of Al to human health problems further justified the inclusion of Al in nutritional analysis (Harder 1994). His studies showed that all edible portions of the winged bean plant accumulated Al from high to very high levels when compared to an average of usually less than 300 ppm in other crop plants. Aluminum accumulation was generally highest in the youngest tissues particularly in the young roots with levels recorded as high as 25,000 ppm and these contents are as high as levels for recognised 'Al accumulators' such as the leaves of *Pinus* and tea.

Traditional Medicinal Uses

In Peninsular Malaysia the leaves were used in a compound lotion for small pox and the root as poultice to cure vertigo in Myanmar (Burkill 1966). In New Guinea, the pods and the edible tubers are considered roborant (tonic) (Stopp 1962). Leaves and seed are eaten to cure skin sores such as boils and ulcers (Perry 1980).

Other Uses

Winged bean is sometimes planted as an ornamental because of its attractive flowers. The whole plant as well as processed seeds is good animal feed. The cake left after extraction of oil from the seeds can be used for stock-feed.

Laboratory studies by Gupta et al. (2008) found that winged bean proteinase inhibitors inhibited the growth and development of *Helicoverpa armigera* (Hubner) and *Spodoptera litura* (Fab). The proteinase inhibitors affected the larval and pupal survival and adult emergence in a dose-dependent manner.

Comments

Winged beans are propagated by seeds.

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Tamarindus indica

Scientific Name

***Tamarindus indica* L.**

Synonyms

Tamarindus erythraea Mattei, *Tamarindus occidentalis* Gaertn., *Tamarindus officinalis* Hook, *Tamarindus umbrosa* Salisb.

Family

Fabaceae, also placed in Leguminosae, Caesalpiniaceae

Common/English Names

Indian Date, Indian Tamarind, Kilytree, Tamarind

Vernacular Names

Afrikaans: Tamarinde;
Algeria: Tamr Hindi, Havmar (Arabic), Aganat (Berber), Tamarin, Tamarinier (French);
Angola: Tamarindeiro (Portuguese);
Arabic: Aradeib, Ardeib, Dar-Al-Sida Hhawmar, Humar, Sabara, Sbar, Tamar El Hindi, Tamare-Hindi, Tamr Hindī, Umbli;
Bangladesh: Tetul;
Benin: Djévivi (Adja), Mokoso, Mosos, Mossosso (Bariba), Pisiklé (Berba), Bobosé (Dendi), Djévivi, Djêvivitin, Bokosso, Moupin (Fon), Tamarinier (French), Djévivi (Goun), Tsamia (Haoussa), Adjagbon (Magot), Diagpi, Djammi (Peuhl), Dipi, Mousoso (Somba), Pousika Poussouka (Waama);
Brazil: Tâmara-Da-Índia, Tamarinda, Tamarindo-Do-Egito, Tamarino, Tamarindo (Portuguese);
Brazzaville: Tomi (Bambara), Tamarinier (French);
Burkina Faso: Domi, Ntomi, Tombi (Bambara), Feri-Go (Bissa), Tamarinier (French), Puaga, Pusga (Mooré);
Burmese: Ma Gyi,Ma Gi, Ma Gyee, Ma Jee, Ma Jee Pen, Ma Gyi Thi;
Burundi: Umushishi (Kirundi);
Cameroon: Tombi;
Central African Republic: Wasa (Banda), Zende (Gbaya), Zinde, Polo (Manja), M'béré (North Centrafique), Lende;
Chad: Hidjilit;
Chamorro: Camalindo, Kalamendó, Kalamendo, Kalamendok, Kamalendo, Kamalindo;
Chinese: Luo-Wang, Lo-Wang-Tzu, Luo Huang Zi, Da Ma Lin, Suan-Jiao, Suan-Chiao, Suan Dou;
Columbia: Tamarindo;
Comoros: Maniya Nihajou (Anjouan Island), Tamarinier (French); Mhajou (Great Comoros);
Cook Islands: Kavakava, Tāmerēni (Maori);
Croatian: Indijska Datula, Indijska Urma, Tamarind;

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Czech: Tamarind;
Danish: Tamarind;
Dutch: Tamarinde, Assem, Indische Dadel, Tamarinde, Tamarindeboom, Tamarindesoort Tamarijn;
Eastonian: Tamarindipuu, Tamarind;
Egypt: Tamr Hindi, Havmar (Arabic), Aganat (Berber), Tamarin;
Ethiopia: Roka (Afaan), Homorra (Afar), Hommar (Amarinya), Homär, Roqa (Amharique), Tamarind-Hendi (Arabic), Ragay (Dizi), Roka (Galinya), Rogo'ota (Konsogna), Roka (Oromo), Ragai (Soddu), Ragay (Suri), Koria (Wolayetgna);
Fijian: Tamarini, Tamalina;
Finnish: Tamarindi;
French: Tamarin, Tamarinier, Tamarinier Des Indes, Tamarin Des Bas, Tamarindier;
German: Indische Dattel, Sauerdattel, Tamarinde, Tamarindenbaum;
Ghana: Tamrisi;
Greek: Tamarin;
Guinea Conakry: Dia Be (Foula Du Fouta-Djalon), Tombi (Malinke), Tömbinyi Toumbingui (Soussou);
Hungarian: Indiai Datolya, Tamarindusz, Tamarindusz Gyümölcs;
Hebrew: Ambli, Imli, Tamar Hindi;
India: Teteli, Tetuli, Tentul, Ttali (Assamese), Ambli, Amli, Nuli, Tentul, Tentuli, Tetai, Tintiri, Tintil, Tinturi (Bengali), Khen Thiri (Garo), Ambla, Amli (Gujerati), Ambli, Amili, Amli, Amlica, Amlyaum, Ampli, Anbli, Chinch, Hunase, Imali, Imli, Katara, Nuli, Tamrulhindi, Teter, Sadad (Hindu), Aamla, Amblairo, Amla, Amli, Amlike, Asam, Gotimli Hunase Hannu, Gotu, Huli, Huli Hunise, Hulise, Hunashe-Hannu, Hunasemara, Hunacey, Hunachi, Hunase Huli, Hunase Mara, Hunise, Hunasa, Hunase, Hunasi, Hunishe, Hunisi, Hunse, Imli, Kamal, Karangi, Nerala, Punke, Unana, Unara, Unsi, Hunuse Mara, (Kannada), Chinch (Konkani), Amlam, Amlika, Balam-Pulli, Balampoolie, Balampulli, Cinca, Chinoh, Chitz, Cukram, Kamlam, Kolpuli, Machurapuli, Madhurappuli, Puli, Puliyam-Pazham, Singa, Sukram, Tindudam, Tintrini, Valampuli, Valanpuli, (Malayalam), Mangge (Manipuri), Aambali, Aamli, Ambali, Amli, Chicha, Chinch, Chincha, Chintz, Chitz, Rojiacha-Phulchinch, (Marathi), Tengere, Tengtere, Teng-Te-Re (Mizoram), Koina, Konya, Omlika, Telul, Tentuli, Tengere, Tengtere, Thenthuli Gatch Ainya, (Oriya), Imbli, Imlii (Punjabi), Abdika, Ambia, Amilam, Amla, Amlavraksha, Amli, Amlika, Atyamba, Bhukta, Charitra, Chincha, Chinchika, Chuk Yamadutika, Chukra, Chukrika, Chukru, Cinca, Cincini, Dantashatha, Gurupatra, Panktipatra, Pichhila, Ra, Sarvamda, Sarvamla, Shakachukrika, Suchakrika, Sukta, Sutintidi, Tentrani, Tindidika, Tintidi, Tintiddii Tintidika, Tintili, Tintilivija, Tintiri, Tintrani, Tintrini, Tintuli, Tittidi, Tittidika, Umblee, Vrksamla (Sanskrit), Alaiyaticcan, Alikaraittan, Amalakam, Amalapalam, Amalavirutcam, Ambilam, Ambiram, Amilam, Amiligai, Amilikai, Amiram, Amiratam, Ammalikai, Ammilam, Ammilam, Ammilavirutcam, Ammmilavirukkam, Ampalam, Ampili, Ampiram, Anippu, Anucutaimaram, Attivancam, Cacukkilam, Cancivakarani, Cancivaki, Cancivakimaram, Cancivi, Cantan, Carittirai, Carittiri, Cincakam, Cincam, Cincari, Cincarikam, Cincarikam, Cincati, Cinciram, Cincuram, Cinnilucati, Cintam, Cintikam, Cintu, Cinturam, Cinturamaram, Ciri, Cirivirukkam, Cirivirutcam, Ciriyam, Cirukam, Cukkarikai, Cukkilai, Cukkilaimaram, Cukkilam, Cukkirai, Cukkiraimaram, Egin, Eginam, Ekin, Etala, Etalari, Etalarimaram, Etilai, Indam, Ilatakam, Ilatakamaram, Ilatam, Ilatam, Intam, Intu, Ittam, Iyacaviyam, Iyacaviyamaram, Iyavacam, Kinjam, Kunkumavarni, Kunkumavarnimaram, Kurupattiram, Kutarati, Malai, Mayamam, Mugini, Mukini, Nattuppuli, Odimam, Puli, Puli Amailam, Pulia Maram, Puliyam-Pazham, Sanjivagarani, Puliyamaram, Tinturuni, Poollie, Poollium Vereikincam, Otimam, Pacavviyam, Pulimaram, Putavirutcam, Tintilikam, Tintiri, Tintitam, Tintiti, Tintitikai, Tintitikam, Tintitikamaram, Tinturunimaram, Tintutikam, Ukilati, Uranki, Urankimaram, Vacunarai, Vaicani, Valanti, Vatamatu, Virutcamalam, (Tamil), Aamlika,Amlaki, Amlika, Chewka, Chincha, Cinca, Chinta, Chinta-Pandu, Cinta,Cintacettu, Cintapandu, Chintha Chettu, Chintha Pendu, Chintha, Shenta, Sinja, Sinta,

Sintha, Tintrini, Tintrinikamu, Thintrini, Thintrinikamu (Telugu), Imli Imli Muqqashar, Maghz Tukhm Imli, Maghz Tukhm Tamar Hindi, Tamar Hindi, (Urdu);
Indonesia: Asem, Asem Jawa, Asam Kuning, Kemal, Wit Asem (Java), Achem, Chelo, Chelok (Madurese), Asam Jawa, Kayu Asem (Malay), Asem, Tambaring, Tangkal Asem, Tangkal Hasöm (Sundanese);
Iran: Anbalah, Tamar-I-Hindi Tamre Hendi (Persian);
Italian: Tamarandizio, Tamarindo, Tamarindo Dolce;
Ivory Coast: Toumbi (Bambara), Diko (Baoulé) Poulé (Dagari), Ntomi, Tombi, Toumi (Dioula), Bosaïe (Djerma), Boupouguibou (Gourmantché), Samanga (Guimini), Tsamia (Haoussa), Tamarin (Local French), Ntomi, Tombi, Toumi, (Malinké), Koussanga, Pousiga (Mossi), Kassama (Senoufo), Haa (Tagouana), Bochocho;
Japanese: Tamarindo;
Kenya: Ukwaju (Bajun), Mkwadju (Digo), Rogei (Dorobo), Muthithi (Embu), Mkwaja (Lamu Msisi), Chwa, Ochwaa (Luo), Muthithu (Meru), Oron (North Region), Mkwayu (Pokomo), Raka (Sanya), Hamar (Somali), Rogei (Suiei), Mkwaja (Swahili), Arwa (Tugen);
Khmer: 'Âm'puul, Ampil, Ampil Khui, Ampil Tum Khoua Me;
Korean: Ta Ma Rin Du;
Laotian: Khaam, Kok Mak Kham, Mak Kham, Naam Maak Khaam;
Lesser Antilles: Tamarijn (Papiamiento);
Libya: Tamr Hindi, Havmar (Arabic), Aganat (Berber), Tamarin;
Madagascar: Kili, Madiro, Voamatory, Voamadilo;
Malaysia: Asam, Asam Java (Malay) Swee Boey (Hokien);
Mali: Domi, N'tomi (Bambara), Taw (Bobo-Fing), So'o (Bwa), Somee, Omolo, Omulu, Omogon (Dogonland), Ntomi, Tombi, Tomi (Malinke), Kataanga, Kuntaanga (Minyanka), Shoshianga, Kataanga (Senoufo);
Mauritius: Tamarinier;
Mexico: Tamarindo;
Morocco: Tamr Hindi, Havmar (Arabic), Aganat (Berber) Tamarin, Tamarinier (French);
Nepalese: Amilii, Titrii;
Niger: Tamsugwu (Beriberi), Tsamiya (Gwandara), Tsamia (Hausa), Djammi (Peuhl), Bochocho (Tamacheck), Bôsey (Zarma);
Nigeria: Tsamia, Ajagbon (Huasa), Icheku Oyibo (Ibo), Ajagbon (Yoruba);
Niuean: Fitihetau, Tamaleni;
Papiamento: Tamarein;
Philippines: Sambak, Sambalagi, Samabalagi (Bikol), Kalamagi, Sambi, Sambagi (Bisaya), Sambag (Cebuano), Kalamagi (Ibanag), Salamagi, Salomagi (Iloko), Sambag (Panay Bisaya), Kalamagi, Kamalagui, Salomagi, Salunagi, Sampalok (Tagalog);
Polish: Tamarynd;
Portuguese: Tamarindo, Tamarindeiro, Tambarina;
Puerto Rico: Tamarindo;
Republic of Guinea: Ton'be (Manika), Dyabbhè (Pular), Tamarindi (Soso);
Reunion: Tamarin, Tamarin Des Bas, Tamarin Pays;
Rodrigues Island: Tamarin;
Russian: Finik Indiiskii, Indiyskiy Finik, Tamarind, Tamarind Indiiskii;
Samoan: Tamaligi;
Senegal: Tombi, Ntomi, Tumi (Bambara), Bufalat (Diola), Isobe, Ichob, Inénef (Niominka), Dabé, Dadmi, Dam, Diami, Djammi (Peuhl), Dabé, Dadmi (Tocolor), Dakhar, Diakar (Ouolof);
Serbian: Demirindi, Indijska Urma, Tamarinda;
Seychelles: Tamarinier;
Sierra Leone: Sour Tumbla (Krio), Sour Tumbla (Mende), An Thombi, Tombei (Temne);
Slovaščina: Tamarindy;
Slovenian: Indijska Tamarinda;
Somalia: Ukwaju (Bajun), Mkwaja (Lamu Msisi), Raka (Sanya), Hamar (Somali), Mkwaja (Swahili);
Spanish: Tamarindo, Tamaríndo De La India;
Sri Lanka: Siyambala (Sinhalese);
Sudan: Tomi, N'tomi (Bambara), Toumbion (Kasombe), Toumbion (Malinke), Karale (Sominke), Dakhar;
Swahili: Mkwaju, Msisi, Ukwaju;
Swedish: Tamarind;
Taiwan: Loan- Tze;
Tanzania: Ukwaju (Bajun), Mkwaja (Lamu Msisi), Mkwedu (Makonde), Raka (Sanya),

Hamar (Somali), Mkwaja (Swahili), Mkwaja (Zaramo), Mkwaja, Mkwazu, Samburai, (Zigua);
Tanzania: Samburai, Mkwazu (Zigua), Djebé, Madiro;
Thailand: Bakham Somkham, Ma-Kharm, Makham Wan;
Tibetan: Bse Yab, Bse-Yab;
Togo: Keditia;
Tongan: Tamaline;
Tuamotuan: Pakai, Tamara, Tamarini;
Tunisia: Tamr Hindi, Havmar (Arabic), Aganat (Berber) Tamarin, Tamarinier (French);
Turkish: Demirhindi, Hind Hurma, Hind Hurmas, Hint Hurmas, Temer Hindi Ağaci, Temir Hindi Ağaci, Temirhindi;
Uganda: Mukoge (Bulamogi), Eperduru (Ngakarimojong);
Venezeula: Tamarindo;
Vietnamese: Me, Cây Me, Me Chua, Quả Me, Trái Me;
Virgin Islands: Tamon;
West Africa: Diko (Baoulé), Djévivi (Fon), Tsamia (Hausa), Djammi (Peuhl);
Zambia: Musika, Mushishi (Bemba).

Origin/Distribution

Tamarind is native to Eastern Africa, including parts of the Madagascar dry deciduous forests. The tree grows wild throughout the Sudan. The fruit was well known to the ancient Egyptians and to the Greeks in the fourth Century B.C. Now introduced into most tropical areas around the world, tamarind has become naturalized in many areas particularly in India, southeast Asia, tropical America, the Pacific Islands and the Caribbean.

Agroecology

The tree thrives in a diverse range of soil types from deep alluvial soil to sandy soil, to poor rocky land and porous, oolitic limestone. It is drought resistant and can be grown in semi-arid areas as well salt tolerant and often found growing near the sea shores. Studies reported that tamarind can be grown in soils containing 45% exchangeable Na (Dwivedi et al. 1996). It is also reported to be hurricane resistant due to its tree and foliage architecture. However, the tree is frost sensitive and very young trees should be protected from cold. It requires a dry period for good fruit set and frequent rains during flowering and fruit development are detrimental to obtaining good yield.

Edible Plant Parts and Uses

The fruit pulp, seeds, flowers and leaves are edible. The fruit pulp has multifarious food uses. Fruit pulp is eaten fresh or raw or as a condiment or as a spice in various sauces and food dishes. Tamarind is available in specialty food stores worldwide in pod form or as a paste or concentrate. In Thailand, the fruit pulp of fully ripe fruit of some sweet tamarind varieties is sold as dessert or snack fruit and the sweet pulp is much relished by children and adults and is popular locally and is also widely exported. In Southeast Asia young pods are also fresh with a sweet shrimp sauce, or chop and incorporate them into a tamarind chilli sauce called *nahm prik ma-kahm*. Young green tamarinds are also pickled and eaten as snacks much like green pickled mango, dipped in a mixture of crushed chillies, salt and sugar. The pulp of unripe fruit is very sour and acidic and is most often used as a component of savoury dishes in Asia and elsewhere. The tender, immature, very sour pods are cooked as seasoning with rice, fish and meats in India. In the Bahamas, the fully-grown, but still unripe fruits, called "swells", are roasted in coals until they burst and the skin is then peeled back and the sizzling pulp dipped in wood ashes and eaten.

Tamarind fruit pulp is used as a spice in both Asian and Latin American cuisines and is also the vital ingredient in Worcestershire sauce and HP barbecue sauce. Worcestershire sauce is a fermented condiment sauce made of anchovies layered in brine, tamarinds in molasses, garlic in vinegar, chillies, cloves, shallots, and sugar. Tamarind pulp is used in other sauces like *pulusu*

(sauce or gravy dish, cooked with vegetables or lentils with tamarind sauce, unrefined sugar and spices from Andhra Pradesh, India) and the Jamaican-produced *Pickapeppa* sauce consisting of a combination of tomatoes, onions, cane vinegar, mangoes, raisins, tamarind, and other spices. Tamarind is an important ingredient in chutneys, curries and sauces and in a special Indian seafood pickle called "tamarind fish". Tamarind is a staple in the South Indian diet, where it is used to prepare *Rasam* (spicy preparation of tomatoes, onion, garlic, chillies, tamarind, jiggery, mustard seeds, curry leaves, red chilli, coriander seeds, cumin seeds, peppercorns and oil); *Puliyogare* (South Indian rice preparation with tamarind usually eaten as a snack), *Kuzhambu* or *Sambhar* (spicy lentil soup vegetables and tamarind), a soupy preparation called *puli-kuzhambu* (sour soup of tamarind, chilli and salt) popular in Tamil Nadu, *Puliyodarai* rice, and various types of chutneys. It may be used to flavour pulse dishes, rice dishes, or as an ingredient in sauces and side dishes for pork, fowl and fish Tamarind pulp is widely used in popular Thai cuisine such as the Hot and Sour Prawn Soup called *tom yum Goong* (a sour soup dish with the following ingredients: prawns, or medium-to large-size shrimps, lemon grass, fish sauce *(nahm bplah),* galangal *(kah),* kaffir lime leaves *(bai ma-gkrood),* chillies *(prik kee noo)*, onion, roasted chilli paste *(nahm prik pow)*, tamarind water, brown mushrooms, tomato, onions, lime juice and cilantro); in Green Papaya Salad called *Som Dtam* and the common Thai-Style Stir-Fried rice Noodles called *Pad Thai*. A tamarind-based sweet-and-sour sauce served over deep-fried fish is also a common dish in Central Thailand. In Malaysia, tamarind is used together with *Garcinia atroviridis* (asam gelugor) pieces in the popular Penang Lasksa also called Asam Laksa – thin rice noodles mixed with shredded and poached fish flakes to which is added lemongrass, galangal (Lengkuas), tamarind, asam gelugor, chilli and garnish with sliced pineapple bits, onions, cucumber, petals of torch ginger 'Bunga kantan' and *hei-ko* a thick, sweet and black prawn paste. All these ingredients impart a distinctive and delicious flavour to the rice noodles. Another use of tamarind is found in Asam fish head curry, popular in Malaysia and Singapore where tamarind impart the unique and distinctive sour flavour to the fish dish. Over in East Malaysia, tamarind is used in Sarawak *laksa,* a type of rice noodle soup containing *sambal belacan*, sour tamarind, garlic, galangal, lemon grass and coconut milk, topped with omelette strips, chicken strips, prawns, fresh coriander and optionally with lime. In the Philippines, tamarind is used to add a sour taste in *Sinigang* – a spicy sour soup made with tamarind, tomato, onion, green pepper, and added meat or fish. In Indonesia, tamarind is used in the preparation of *manisan*, jellies, syrup. Half-ripe pods are used for the preparation of *angen asem* (Sundanese) or *sayur asem* (Malay, Javanese) – a dish made with leafy vegetables, pulses, shallots, red chillies, pepper, sugar and tamarind. Young pods are mixed with *rujak* or pounded together with small fish. In Java, the salted pulp is made up into balls called "*assam kawak*".

Tamarind pulp is also used for making various jams, jellies, marmalades, preserves, confection, cakes puddings, beverages and drinks. Sugared tamarind pulp is often prepared as a confection. This sweetmeat is commonly found on the market in Jamaica, Cuba and the Dominican Republic. Many popular Tamarind concoctions are hard candies and suckers. Tamarind pulp can be made into a tart jelly, and tamarind jam is canned commercially in Costa Rica. Tamarind is a popular ingredient in many Mexican candies such as *pulparindo*. In Panama, the pulp may be sold in corn husks, palm-leaf fibre baskets, or in plastic bags. Tamarind is sold in various snack forms in Southeast Asia (dried and salted, dried and candied, as a cold drink). In Thailand the pulp is dusted with sugar and eaten as a candy. Vietnamese New Year's Candy, *mut me*, is a chewy bit of preserved tamarind pulp rolled in sugar and salt. In making fruit preserves, tamarind is sometimes combined with guava, papaya or banana. In the Philippines, the pulp is boiled with mashed sweet potato, water and sugar and the resultant thickened mixture is processed into balls called *champoy*.

In some countries, the pulp is turned into syrup which is used as a base for making carbonated

water and refreshing drinks. A refreshing drink made from tamarind syrup and resembling lemonade is popular in the Middle East. In Egypt, there is an acidic chilled tamarind drink is popular in summertime. In Jordan, *sous* a refreshing drink is made from tamarind pulp, liquorice and local sweet wood, *mulahatt*i and *yastimadhu*. In Latin America, especially Mexico, and Latin American immigrant communities in the US, the fruit is widely popular and is processed into the popular *aguas frescas* (fresh fruit juice drink flavoured with tamarind) known as "*Agua de Tamarindo*". Tamarind syrup is bottled for domestic use and export in Puerto Rico. Other blends of beverages include tamarind ginger punch, tamarind punch with rum and angostura bitters, Jus de tamarin or Tamarind Juice, a refreshing drink, is made by combining the seed pods with water and sugar. It is said to lower body temperature. In Mayaguez, street vendors sell cones of shaved ice saturated with tamarind syrup. Tamarind sherbet and ice cream are popular and refreshing. Sometimes tamarind fruit pulp is made into wine. Tamarind-ade has long been a popular drink in the Tropics and it is now bottled in carbonated form in Guatemala, Mexico, Puerto Rico and elsewhere.

Various formulae for the commercial production of non-spiced and spiced tamarind beverages (with or without the addition of seasonings such as cloves, cinnamon, allspice, ginger, pepper or lime slices) have been developed by food technologists in India. In Thailand, tamarind drink *Nam Ma kham Wan* is very popular. This drink is prepared by mixing and blending tamarind pulp with water followed by boiling and the addition of salt and sugar. The resultant is then cooled, strained and served over crushed ice. Another variant is a popular Spiced Tamarind Drink which consist of dried tamarind pulp, whole coriander seeds, whole cumin seeds, whole black peppercorns, dry mustard, garlic cloves, clear, light chicken broth and green pepper. Canned tamarind drink is available in many grocery stores.

Young leaves and very young seedlings and flowers are cooked and eaten as greens and in curries in India. The edible leaves and flowers of tamarind trees are also sour and are eaten fresh in salads and with chilli dips. In Zimbabwe, the leaves are added to soup and the flowers are used as an ingredient in salads. In the state of Andhra Pradesh in India, a tangy pickle is made from Tamarind flowers. In Indonesia, the young leaves are used in the preparation of *pindang atep* (Javanese) – a kind of spicy soup, cooked with meat, asem leaves, white onions, salt and *lombok* (young green chilli). In Timor, the young shoots are mixed with other *lalab* or eaten with *lombok* and salt.

Seeds are gaining importance as an alternative source of proteins, and are besides rich in some essential minerals. Tamarind seeds have also been used as snacks or emergency food. They are roasted or soaked to remove the seedcoat, then boiled or fried, or ground to a flour or starch and made into cakes. In Indonesia, the seeds are eaten after roasting or they are steeped in brine for 24 h after removal of the seedcoat and eaten with grated coconut and salt. In East Java and Madura, the seed kernels are eaten cooked after soaking in water for a day in the dish called *klungsu godongan*. Roasted seeds are ground and used as a substitute for, or adulterant of, coffee as is done in Thailand.

The starch, obtained from the seeds, is used in the food-, paper-and jute industry. Tamarind xyloglucan, commonly referred to as tamarind gum is the major component of tamarind seed kernel powder. Tamarind gum forms a stiff gel and is used in thickening, stabilising and gelling in food. It is commercially available as a food additive for improving the texture and viscosity of processed foods. Purified and refined tamarind kernel powder is produced and permitted in Japan as a thickening, stabilizing and gelling agent in the food industry (Glicksman 1986). Indian scientists have patented a process to extract and purify a gel forming substance from decorticated kernels or kernel powder. This gel is called "Jellose", "polyose", or "pectin", and has been found superior to fruit pectin in the manufacture of jellies, jams, and marmalades. It has been recommended for use as a stabiliser in ice cream, mayonnaise and cheese. Studies showed that a 40:60, 20:80 and 0:100 blend of pectin/polyose gave a good jelly set at 2.0%, beyond which the jellies were hard and difficult to chew. From the values of gel strength, 2%

polyose from tamarind kernel powder was found to adequately substitute 1% pectin in ready –to – eat jelly formulations (Marathe et al. 2002). Polyose can be used in fruit preserving with or without acids and gelatinizes with sugar concentrates even in cold water or milk. It is recommended as a stabilizer in ice cream, mayonnaise and cheese and as an ingredient or agent in a number of pharmaceutical products. In Madura, Indonesia, tamarind twigs are sometimes used as "chew sticks" and the bark as a masticatory, alone or in place of lime with betel-nut.

Botany

A slow growing, evergreen, much-branched perennial tree that can attain a height of 25–30 m with a dome-shaped, dense canopy spread of 12 m, dark ashy bark and a trunk dbh of 30–50–90 cm. It has strong supple branches bearing graceful, feathery foliage (Plate 1) and a dark-grey, rough, fissured bark. The mass of bright-green, fine, feathery foliage is composed of pinnate leaves. The leaves are alternate, paripinnate, stipulate and petiolate, 7.5–15 cm in length, each having 10–20 pairs of oblong leaflets 1.25–2.5 cm long by 5–6 mm wide with rounded base and entire margins (Plates 2 and 4). Inflorescences are lax, lateral and terminal racemes, up to 13 cm long. Flowers are small, 3 cm long, fragrant, calyx tube 7 mm with four unequal lobes, five petals – two of which are much reduced and linear, the posterior and lateral petals are large, obovate and showy, yellow with reddish brown veins, stamens 3, free and one pistil, slightly incurved, terete, pubescent with up to 18 ovules (Plates 3 and 4). Fruits are sub-cylindrical, straight or irregularly curved and bulging pods, indehiscent with rounded ends and crustaceous and scurfy skin which is cinnamon-brown or greyish-brown externally (Plates 5–8). Fruit may be up to 15 cm long and 5 cm wide with ten flattened, shiny, rhomboid hard brown seeds, about 1.1–1.25 cm long. The seeds are enclosed by a parchment-like membrane and embedded in a juicy, thick and syrupy acidulous to sweetish pulp which turns brown or reddish brown when ripe (Plate 8).

Plate 1 Feathery foliage and prolific fruiting tree

Plate 2 Compound paripinnate leaves

Nutritive/Medicinal Properties

Analyses carried out in the United States reported raw tamarind (excluding pod and seeds) to have the following proximate composition (per 100 g edible portion): water 31.40 g, energy 239 kcal (1,000 kJ), protein 2.8 g, total lipid 0.6 g, ash

Plate 3 Close-up of tamarind flowers

Plate 6 Sweet tamarind variety

Plate 4 Young, developing tamarind pods

Plate 7 Tamarind fruit packed for export

Plate 5 Sour tamarind variety

Plate 8 Tamarind pod with shell removed to show the pulp

2.7 g, carbohydrates 62.5 g, total dietary fibre 5.1 g, total sugars 57.4 g, Ca 74 mg, Fe 2.8 mg, Mg 92 mg, P 113 mg, K 628 mg, Na 28 mg, Zn 0.10 mg, Cu 0.086 mg, Se 1.3 μg, vitamin C 3.5 mg, thiamine 0.428 mg, riboflavin 0.152 mg, niacin 1.938 mg, pantothenic acid 0.143 mg, vitamin B-6 0.066 mg, total folate 14 μg, choline 8.6 mg, vitamin A 30 IU, vitamin E (α-tocopherol) 0.10 mg, vitamin K (phylloquinone) 2.8 μg, total saturated fatty acids 0.272 g, 14:0 (myristic acid) 0.007 g, 16:0 (palmitic acid) 0.168 g, 18:0 (stearic acid) 0.060 g; total monounsaturated fatty acids 0.181 g, 18:1 undifferentiated (oleic acid) 0.181 g; total polyunsaturated fatty acids 0.059 g, 18:2 undifferentiated (linoleic acid) 0.059 g; tryptophan 0.018 g, lysine 0.139 g, methionine 0.014 g and β-carotene 18 μg (USDA 2010).

Another analysis (Parvez et al. 2003b) of ripe tamarind fruit reported moisture content of the ripened fruits to be 20%. The amounts of crude protein, crude lipids, crude fibres, ash and total crude carbohydrates expressed as 100 g dry weight were 8.5–9.1, 2.7–3.1, 2.8–3.4, 2.9–3.3 and 82.1–82.6 g, respectively. The energy values ranged from 1,539 to 1,581 kJ and the total sugar content varied between 46.5 and 58.7 g. Among the analysed mineral components, the amounts of Mg (25.6–30.2 mg) and Na (23.8–28.9 mg) were found to be highest, while the lowest amounts were recorded for Cu (0.8–1.2 mg) and Zn (0.8–0.9 mg). Tamarind kernel protein was found to be rich in lysine, glutamic acid, aspartic acid, glycine, and leucine but deficient in sulphur-containing amino acids and its in-vitro digestibility was 71·3 (Bhattacharya et al. 1994).

Eighty-one constituents were identified in the volatile component of tamarind fruit, from which 2-phenylacetaldehyde, 2-furfural and hexadecanoic acid (palmitic acid) were the major compounds (Pino et al. 2004). Thirteen components were identified, in leaf oil of tamarind, among which limonene (24.4%) and benzyl benzoate (40.6%) were most predominant (Pino et al. 2002). Other compound in descending percentage order were hexadecanol (12.4%), pentadecanol (8.2%), linalool anthranilate (4.7%0, (E)-2-hexanal (1.7%), ß-pinene (1.4%), ct-pinene (1%), linalool 1%), nerol (1%), a-terpineol (0.7%), p-cymene (0.6%) and (E)-ß-ocimene (traces). Seven hydrocarbons, β-amyrin, campesterol and β-sitosterol were identified in the unsaponifiable component of the seeds (Ibrahim et al. 1995). The major fatty acids were palmitic, oleic, linoleic and eicosanoic acids. Arabinose, xylose, galactose, glucose and uronic acid were identified from the mucilage and pectin hydrolysates. Sixty-six volatile compounds were identified in the fruit pulp of *T. indica*, furan derivatives and carboxylic acids were dominant, accounting for 44.4% and 33.3% of the total volatiles, respectively (Wong et al. 1998). The major components were furfural (38.2%), palmitic acid (14.8%), oleic acid (8.1%) and phenylacetaldehyde (7.5%). Lee et al. (1975) identified 61 major volatile constituents components in tamarind. The most abundant volatile constituent of tamarind was found to be 2-acetylfuran, coupled with traces of furfural and 5-methylfurfural, which constituted the total aroma of tamarind. Several pyrazines and thiazoles, normally formed during roasting of a variety of foods, were found in tamarind. The results of this study suggested that the overall aroma of tamarind consisted of citrus notes and warm spice-like flavours with some roasted character.

Tamarind fruit pulp contained tartaric acid (8–18%), reducing sugars (25–41%), pectin (2.0–3.5%) and proteins (2–3%), besides fibre and cellulosic material (Lewis and Neelakantan 1964a). Of-the reducing sugars present, *about 70%* was glucose and 30% fructose. About half of the tartaric acid was present as potassium bitartarate (cream of tartar) and to a smaller extent as calcium tartarate. About 2% of other acids are also present, chiefly malic acids. Other organic acids The anthocyanin pigment, chrysanthemin, was found in the red variety of tamarind fruit, and a leucocyanidin in the common variety (Lewis and Neelakantan 1964a, b). The fruits were found to have low anthoxanthin content, while the flowers contained only xanthophylls. The seed testa contained a leucoanthocyanidin. The seed comprised about 35% of the whole fruit, testa 30% of the seed and the endosperm 70% (Lewis and Neelakantan 1964a). The testa contained 40% water soluble, 80% of which comprised a mixture of tannins

and colouring matter. The seed kernel contained 17% protein, 7% fat, 5.6% crude fibre, 65% non-fibre carbohydrates, 2.8% ash and 5.4% other components. The carbohydrates of the seed consisted mainly of a polysaccharide composed of n-galactose, n-xylose and n-glucose in the ratio 1:2:3. The polysaccharide had excellent sizing, creaming and jelling properties-and can be used as a substitute for starch and pectin, although it was structurally different from them. Tamarind fruit pulp was found to be relatively poor in protein (87.9 g/k) and oil (25.3 g/kg) but the seed was a good source of both (269.3 g/k protein and 109.1 g/kg lipid) (Ishola et al. 1990). Both the pulp and seed were found to be good sources of calcium, and the seed of phosphorus, magnesium and potassium. Low levels of phytic acid and heat-labile trypsin inhibitors were present in the fruit.

In a recent study, major chemicals detected in tamarind fruit pulp were 2-furancarboxaldehyde, 2,3-butanediol, 2-furancarboxaldehyde 5-methyl in the acetinic extract; 2,3-butanediol, hydroxymethylfurfurole and –o-methyl-d-glucose in the methanol extract; and 2-furancarboxaldehyde, 2-furancarboxaldehyde 5-hydroxy methyl, –o-methyl-d-glucose and D-allose in the ethanol extract (Jadhav et al. 2010).

Chemical composition of commercial tamarind juice concentrate was reported by Nagaraja et al. 1975 as moisture 30%, tartaric acid 13%, invert sugars, 50%, proteins 2%, crude fibre 2%. Chemical composition of commercial tamarind pulp powder was reported as: moisture 3.6–8.8%, tartaric acid 8.17–11.1%, invert sugars 15.8–25%, proteins 1.7–2.4%, starch 20–41.3%, ash 2.1–3.2%, calcium 74–143 mg, potassium 23.8–27.7 mg (Manjunath et al. 1991). The total solid content ranged from 18.6% to 25% and acidity varied from 8.7% to 11.1%, with an average value of 9.9% (as tartaric acid).

Of 15 fatty acids found in tamarind seed kernel oil, the major ones were palmitic (14–20%), stearic (6–7%), oleic (15–27%), linoleic (36–49%), arachidic (2–4%), behenic (3–5%) and lignoceric (3–8%) acids (Andriamanantena et al. 1983). The protein contents were very low (trace-0.1%). Of seven sterols detected, the main sterols were β-sitosterol (66–72%), campesterol (16–19%) and stigmasterol (11–14%). Polyose was isolated from tamarind kernel powder (TKP) (Marathe et al. 2002).

Tamarind pectin was reported to contain 7.7–8.9% moisture, 2.3–3.0% ash, 70–80.4% calcium pectate, 7.9–9.9% methoxyl and 43–56.4% uronic acid (Krishna 1955).

Chemical composition of tender leaves was reported as: moisture 70.5–78.0%, energy 75 kcal, proteins 4.0–5.8%, fat/oil 1.2–2.1%, fibre 1.9–3%, carbohydrates (total) 16.0–18.0%, ash 1–1.5%, Ca 101–250 mg, Mg, 71 mg, P 140 mg, Fe 2–5.2 mg, Cu 2 mg, Na 8 mg, K 270 mg, Cl 95 mg, S 63 mg, thiamine 0.1–0.2 mg, riboflavin 0.1–0.2 mg, niacin 1.5–4.1 mg, vitamin C 3–6 mg, B-carotene 2,500 ug, oxalic acid 196 mg (Lewis and Neelakantan 1964a; CSIR 1976; Duke 1981). Tamarind leaves are a fair source of vitamin C and β-carotene; mineral content is high, particularly P, K, Ca and Mg (De Caluwé et al. 2009). The leaves of *Tamarindus indica* were found to contain two pairs of ring isomers vitexin and isovitexin (saponaretin) and orientin and iso-orientin (homo-orientin) (Bhatia et al. 1966). The leaves contained tartaric (12–27%) and malic acids as the major acids, 10–14% crude protein (N X6.25), 4–12% ash, 1.2–3.5% Ca and 60–80% moisture (Lewis and Neelakantan 1964a). The anthoxanthin pigments, luteolin and apigenin content in the amounted to 2% in the leaves.

Nutrient composition of tamarind flowers was reported as: moisture 80%, proteins 2.8%, fat/oil 1.54%, fibre 1.5%, ash 0.72%, Ca 35.5 mg, P 45.6 mg, Fe 1.5 mg, thiamine 0.072 mg, riboflavin 0.148 mg, niacin 1.141 mg, vitamin C 13.8 mg (CSIR 1976; Duke 1981).

The root bark of *Tamarindus indica* afforded n-hexacosane, eicosanoic acid, b-sitosterol, octacosanyl ferulate, 21-oxobehenic acid, (+)-pinitol, apigenin and vitexin (Jain et al. 2007). Two triterpenes (lupanone and lupeol) were isolated from the leaves (Imam et al. 2007).

Scientific studies have reported that tamarind pulp, seed, leaves and stem bark have many pharmacological and bioactive attributes such as antimicrobial, antioxidant, anti-inflammatory, molluscidal, hypoglycaemic,

antihypercholesterolemic activity, antidiabetogenic, antivenom, antiemetic, analgesic, immunomodulatory, retarding fluorosis, antiplatelet, analgesic, UVB protection and corneal healing, etc.

Antioxidant Activity

Tamarind fruit was found to contain biologically important source of mineral elements, high levles of phenolics and displayed high antioxidant capacity. Studies showed that the values for the antioxidant activity expressed by the oxygen radical absorbance capacity (ORAC) and the total phenolic content (TPC) in the tamarind fruit pulp tested ranged from 59.1 to 66.3 μmol of Trolox equivalent (TE) g DW-1 and 626.6–664.0 mg of gallic acid equivalent (GAE) 100 g/DW, respectively (Parvez et al. 2003b). Strong positive correlations between ORAC and TPC were observed, suggesting that the increased antioxidant activity was due to high phenolics in tamarind fruit. The increased antioxidant activity due to high phenolics in tamarind fruit could provide protection against certain human degenerative conditions associated with oxygen free radical damage. Tamarind fruit or food-products from tamarind fruit pulp may act as functional foods, endowing specific beneficial effects on human health.

The seed coat extract of tamarind was found to contain a polyphenolic flavonoid with antioxidant property inhibiting nitric oxide production in-vitro using a murine macrophage-like cell line (Komutarin et al. 2004). In-vitro exposure of RAW 264.7 cells or peritoneal macrophages to 0.2–200 μg/ml of *T. indica* extract significantly attenuated (as much as 68%) nitric oxide production induced by lipopolysaccharide (LPS) and interferon gamma (IFN-gamma) in a concentration-dependent manner. In-vivo administration of tamarind extract (100–500 mg/kg) to B6C3F1 mice dose dependently suppressed TPA (12-O-tetradecanoylphorbol-13-acetate), LPS and/or IFN-gamma induced production of nitric oxide in mouse peritoneal macrophages in the absence of any effect on body weight. Exposure to *T. indica* extract had no effect on cell viability. In B6C3F1 mice, preliminary safety studies demonstrated a decrease in body weight at only the highest dose tested (1,000 mg/kg) without alterations in haematology, serum chemistry or selected organ weights or effects on NK cell activity. A significant decrease in body weight was observed in BALB/c mice exposed to concentrations of extract of 250 mg/kg or higher. Oral exposure of BALB/c mice to tamarind extract did not modulate the development of T cell-mediated sensitization to DNFB (dinitrofluorobenzene) or HCA (α-hexyl cinnamic aldehyde) as measured by the local lymph node assay, or dermal irritation to nonanoic acid or DNFB. These studies suggested that in mice, *T. indica* extract at concentrations up to 500 mg/kg may modulate nitric oxide production in the absence of overt acute toxicity.

Hypoglycaemic Activity

Studies reported that aqueous extract of the seed of tamarind had potent antidiabetogenic activity that reduced blood sugar level in streptozotocin (STZ)-induced diabetic male rat (Maiti et al. 2004). Supplementation of this aqueous extract by gavage at the dose of 80 mg/0.5 ml distilled water/100 g body weight per day in STZ (streptozotocin)-induced diabetic rat resulted in a significant diminution of fasting blood sugar level after 7 days. This supplementation produced a significant elevation in liver and skeletal muscle glycogen content, activity of liver glucose-6-phosphate dehydrogenase in respect to diabetic group. Activities of liver glucose-6-phosphatase, liver and kidney glutamate oxaloacetate transaminase (GOT) and glutamate pyruvate transaminase (GPT) activities were decreased significantly in the aqueous extract supplemented group in respect to diabetic group. All these parameters were not resettled to the controlled level after 7 days of this extract supplementation but after 14 days of this supplementation, all the above mentioned parameters were restored to the control level. Another study found that administration of tamarind seed and mesocarp mucilages significantly decreased blood glucose concentrations (60.48% and 54.68%, respectively) in

alloxan-induced diabetic rats (Ibrahim et al. 1995). Administration of seed pectin also reduced blood glucose concentration by 28.49% after 24 h. However no hypocholesterolaemic activity was observed. Roy et al. (2010) found significant anti-hyperglycemic activity of the methanol extract of tamarind fruits and seeds at a dose of 200 mg extract/kg body weight in glucose-loaded Swiss albino mice. Methanol extract of seeds demonstrated greater antihyperglycemic activity when compared to the methanol extract of fruits.

Studies by Hamidereza et al. (2010) showed that the aqueous extract of *Tamarindus indica* seeds had a restorative effect on STZ-induced damages in pancreatic islands in male wistar rats. After 8 weeks, volume density and total volume of islets, volume weighted mean islets volume, volume density islets/pancreas, volume density beta cells/islet, mass of islets and pancreas of treated diabetic groups (TD1-3, 50, 100, and 200 mg/kg/day respectively) were significantly higher than untreated diabetic group, and in TD3 (200 mg/kg/day) group these values were comparable to controls. Although total volume and mass of beta cells in TD1-3 were significantly higher than diabetic group but they were significantly lower than control group. Total number of islets, pancreas wet weight and volume did not show any significant changes between control and experimental groups. Results suggested that the extract partially restored pancreatic beta cells and repaired STZ-induced damages in rats.

Antihypercholesterolemic/ Antihyperlipidemic Activity

Treatment of hypercholesterolemic hamsters with the tamarind fruit pulp extract (5%) led to a decrease in the levels of serum total cholesterol (50%), non-HDL cholesterol (73%) and triglyceride (60%), and to an increase of high-density lipoprotein (HDL) cholesterol levels (61%) (Martinello et al. 2006). In vitro, the extract exhibited radical scavenging ability, as assessed by the 2,2-diphenyl-l-picrylhydrazyl (DPPH) and superoxide radicals assays, and led to decreased lipid peroxidation in serum, as assessed by the thiobarbituric acid reactive substances (TBARS) assay. In-vivo, the extract improved the efficiency of the antioxidant defence system, as assessed by the superoxide dismutase, catalase and glutathione peroxidase activities. Together these results indicated the potential of tamarind extracts in diminishing the risk of atherosclerosis development in humans. Dietary modifications may significantly reduce cardiovascular disease (CVD) risk factors, including cholesterol and atherosclerosis. Another study found that dried and pulverized pulp of tamarind fruits at a dose of 15 mg/kg body weight reduced total cholesterol level and LDL-cholesterol level to a significant extent in humans (Maruf Iftekhar et al. 2006). Though the fruits exerted no conspicuous effect on body weight and systolic blood pressure, it significantly reduced the diastolic pressure.

More recently, treatment of obese rats with the *T. indica* pulp extract led to a decrease in the levels of plasma total cholesterol (TCHOL), low-density lipoprotein cholesterol (LDL-C) and triglyceride (TG) and increase high-density lipoprotein cholesterol (HDL-C) level with concomitant reduction of body weight (Khairunnuur et al. 2010). The extract improved the efficiency of the antioxidant defence system, as indicated by increased superoxide dismutase (SOD) and glutathione peroxidase (GPx) activities and subsequently resulted in significantly lower lipid peroxidation indices; malondialdehyde (MDA) level. Together these results indicated the potential use of *T. indica* extracts as hypolipemic and antioxidative agent apart from its ability to reduce body weight in obese-induced rats. Tamarind fruit pulp extract upregulated genes in human HepG2 cells that encoded for the metallothioneins (MT1M, MT1F, MT1X) and glutathione S-transferases (GSTA1, GSTA2, GST02) that were involved in stress response (Razali et al. 2010). APOA4, APOA5, ABCG5 and MTTP genes were also significantly regulated that could be linked to hypolipidaemic activities of tamarind fruit pulp.

Antimicrobial Activity

Leaf and stem extracts

Methanol leaf extracts of *Tamarindus indica* were shown to exhibit anti- *Burkholderia pseudomalleus* inhibitory potentials under in vitro conditions (Muthu et al. 2005). *Burkholderia pseudomalleus* (*Pseudomonas pseudomallei*) causes melioidosis, a life-threatening infection common among paddy cultivators in Southeast Asian countries. Tamarind leaf extract exhibited bacteriostatic effect against *Bacillus pyocyaneus* reported to be resistant to many known drugs (Choudhury and Sengupta 1970). It was postulated that the acidity of oxalic acid in the leaf extract that was possibly responsible for the bacteriostatic property. In another study, tamarind was reported to possess broad spectrum antibacterial activity and may provide a potential source of new classes of antibiotics that could be useful for infectious disease chemotherapy and control. Aqueous and fluid extracts of fresh and dried tamarind leaves were found to contain phenols and flavonoids and the phenols were found to be active against *Bacillus subtilis* cultures, but not against other microorganisms (*Enterococcus faecalis, Staphylococcus aureus, Escherichia coli*, *Salmonella typhimurium, Pseudomonas aeruginosa* and *Candida albicans*) (Escalona-Arranz et al. 2010). On the other hand, the essential oil exhibited a good antimicrobial spectrum when pure, but its relative low concentrations in common folk preparations did not allow for any good activity in these extracts.

Extracts of the stem bark and leaves inhibited *Salmonella paratyphi, Bacillus subtilis, Salmonella typhi* and *Staphylococcus aureus* (Doughari 2006). Phytochemical studies revealed the presence of tannins, saponins, sesquiterpenes, alkaloids and phlobatamins and the extracts were active against both gram positive and gram negative bacteria. The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of the extracts on the test organisms showed that the lowest MIC and the MBC were demonstrated against *Salmonella paratyphi, Bacillus subtilis* and *Salmonella typhi* and the highest MIC and MBC was exhibited against *Staphylococcus aureus*. The leaf extracts generally showed lower activity against the test organisms compared to the stem bark extracts. Several fractions of the crude ethanol extract tamarind stem bark exhibited antibacterial activity (Nwodo et al. 2010). TiA fraction showed activity against 100% of the test gram negative bacterial strains and 60% of the gram positive strains; TiB, TiC, and TiD each showed activity against 71.4% of the gram negative test strains and 100, 80 and 60%, respectively, of the gram positive strains. Fractions TiE and TiF, respectively, showed activity against 42.9% and 14.3% of the gram negatives and 60% and 20% against the gram positives bacteria. The phytochemistry of these fractions showed varied contents of tannins, saponins, flavonoids, alkaloids, antroquinone, glycosides and terpene.

Seed extracts

French studies found that decoctions and macerations of tamarind seeds exhibited the strongest antibacterial activity against *E. coli* and warranted further investigation on its potential use as water purifying agents (Blech et al. 1991). The methanol, ethanol and acetone extracts of tamarind seed coat were found to contain antimicrobial substances like furfural and its derivatives, levuglucosan, tetrazene, cyclohexasiloxane, dioxalene, etc. (Waghmare et al. 2010). The microorganisms used were *Staphylococcus aureus, Salmonella typhimurium* and *Pseudomonas aeruginosa*. Tamarind juice was found to reduce *Listeria monocytogenes* and *Salmonella typhimurium* populations on washed raw shrimps stored at 4°C (Norhana et al. 2009). Compared to sterile distilled water, tamarind juice significantly reduced aerobic bacteria (APC), *L. monocytogenes* and *S. typhimurium* populations immediately after washing (0 day). Regardless of washing treatments or methods, populations of *S. typhimurium* decreased slightly (5.10–6.29 log cfu/g on day 7 of storage) while populations of *L. monocytogenes* (8.74–9.20 log cfu/g) and APC (8.68–8.92 log cfu/g) increased significantly during refrigerated storage. The pH of experimental shrimps was significantly decreased by 0.15–0.22 pH units after washing

with bilimbi and tamarind juice. Acetone and methanol extracts of *T. indica* seeds were found to have antibacterial activity against both gram-positive and gram-negative organisms with MIC values ranging from 53 to 380 μg/ml (Kothari and Seshadri 2010). The methanol extract was also found to be bactericidal.

Fruit extracts

Aqueous pulp extract of *Tamarindus indica* showed antibacterial activity against all the tested bacteria in the order of sensitivity as *Staphylococcus aureus*>*Escherichia coli*>*Pseudomonas aeruginosa* with the exception *Salmonella typhi* (Abukakar et al. 2008). Phytochemical constituents present in the extract were found to include saponins (2.2%), alkaloids (4.32%) and glycosides (1.59%). The ethanol extracts of tamarind exerted strong antibacterial activity against *Escherichia coli, Klebsiella pneumoniae, Salmonella paratyphi* A and *Pseudomonas aeruginosa* while *Staphylococcus aureus* was resistant to the extracts (Daniyan and Muhammad 2008). The aqueous extracts have the least antibacterial activity compared to ethanol extract except against *P. aeruginosa*. Tamarind fruit pulp extracts exhibited antimicrobial activities in the following descending order against *Salmonella typhimurium* > *Staphylococcus aureus* > *Bacillus cereus* > *Pseudomonas aeruginosa* > *Micrococcus luteus* > *Escherichia coli* > *Proteus vulgaris* > *Aspergillus niger* (Jadhav et al. 2010). The extract was more potent than tartaric acid solution. Studies showed that aminated tamarind xyloglucan possessed biocompatibility, strong hydrogel behaviour with very useful blue fluorescence and to have has potential applications in the medical and biotronics field (Simi and Abraham 2010). The aminated xyloglucan exhibited good thermal properties and better antimicrobial activity in comparison to chitosan.

Immunomodulatory Activity

A polysaccharide isolated and purified from *Tamarindus indica* showed immunomodulatory activities such as phagocytic enhancement, leukocyte migration inhibition and inhibition of cell proliferation (Sreelekha et al. 1993). These properties suggested that this polysaccharide from tamarind may have some biological applications. Experimental and epidemiologic evidence indicated dietary factors to be one of the commonest predisposing factors in the development of several types of cancers including large intestine. Storage xyloglucans (XGT) from tamarind seeds were found to have immunomodulatory effects when evaluated on peritoneal macrophages (do Rosário et al. 2011). Phagocytic activity was observed in macrophages treated with XGT. At 25 μg/ml XGT caused a 100% increase in NO production when compared to the control group; however, it did not affect O_2^- production in the absence of PMA (phorbol-12-myristate-13-acetate). XGT greatly stimulated interleukin-6 production. Based on the results, XGT could be classified as biological response modifiers (BRM).

Enhancing Delivery/Bioavailability of Medicinal Drugs

Studies showed that water-soluble neutral polymers, i.e. hydroxypropylcellulose (HPC), xanthan gum (XG), tamarind gum (TG) and polyvinyl alcohol (PVA) could be used as bases for nasal mucoadhesive powder formulations for drug delivery (Nakamura et al. 1996). XG showed the longest residence of the dye in the cavity, followed by TG, HPC and PVA in this order. Results suggested that it was feasible to control the residence time by mixing two or more polymers differing in adhesiveness. Tamarind seed polyose was found to have potential as a polysaccharide for sustained release of verapamil hydrochloride (Kulkarni et al. 1997). Its formulation was found comparable to Isoptin SR, the commercially available sustained release tablets.

Tamarind kernel powder was found to be suitable as a carrier to improve the dissolution rate of poorly water-soluble drug, Celecoxcib (Babu et al. 2003). Among four different methods to assess the effective of the preparation, the order of dissolution efficiencies was found to be solvent deposition > cogrinding > kneading > physical

mixing > pure celecoxcib. Although, the solvent deposition technique improved the dissolution rate to maximum, co-grinding technique was found to be suitable from practical point of view and commercialization. The tamarind seed polysaccharide appeared to be a promising candidate as a vehicle for rufloxacin for the topical treatment of bacterial keratitis, a serious infectious ocular disease (Ghelardi et al. 2004). Rufloxacin delivered by tamarind polysaccharide reduced *Pseudomonas aeruginosa* and *Staphylococcus aureus* in the cornea at a higher rate than that obtained by rufloxacin alone. The polysaccharide prolonged the precorneal residence times of antibiotics and enhanced drug accumulation in the cornea, probably by reducing the washout of topically administered drugs.

An aqueous mixture of tamarind seed polysaccharide (TSP) and hyaluronic acid (HA) was found to have potential for the development of a potential excipient for eye drops synergistically improved over those of the separate polymers (Uccello-Barretta et al. 2010). The mucoadhesivity of the TSP/HA (3/2) mixture, was found to be responsible for the TSP/HA (3/2) synergistic enhancement of either extra- or intra-ocular drug bioavailability. The mucoadhesivity of the TSP/HA (3/2) mixture, was stronger than that of the component polysaccharides or the TSP/HA mixtures of different composition. TSP/HA (3/2) was little viscous and well tolerated by rabbit eyes. It stabilized the tear film, thereby prolonging the residence of ketotifen fumarate and diclofenac sodium in tear fluid, but was unable to permeabilize the cornea. Tamarind seed polysaccharide was found to be the most effective in prolonging the residence of ketotifen and diclofenac in precorneal area indicating it to be the optimal eye drop additive as it was mucoadhesive while not increasing viscosity excessively (Di Colo et al. 2009). Tamarind gum based formulation displayed best slow and extended drug release profile compared to the other formulations (Mehra et al. 2010). In-vivo miotic study also showed the most significant long lasting decrease in pupil diameter of rabbits with tamarind gum based formulation. Prolonging the drug action and higher pharmacodynamic action clearly indicated enhancement of pilocarpine bioavailability as compared to conventional eye drop solution. Ocular irritation studies indicated that the formulations were well tolerated and non-irritating. Studies showed that lactoferin tablet prepared with tamarind gum as bioadhesive showed longest residence time in oral cavity as compared with xanthan gum and carboxymethyl cellulose but an unpleasant taste gradually developed (Takahashi et al. 2007).

Study on the influence of tamarind fruit extract incorporated in a traditional meal on the bioavailability of aspirin tablets indicated that tamarind fruit extract significantly increased the bioavailability of aspirin (Mustapha et al. 1996). There was a statistically significant increase in the plasma levels of aspirin and salicylic acid, respectively, when the meal containing *Tamarindus indica* fruit extract was administered with the aspirin tablets than when taken under fasting state or with the meal without the fruit extract.

Studies showed that there was a statistically significant increase in the plasma levels of Ibuprofen and its metabolites hydroxy-ibuprofen and carboxy-ibuprofen respectively in the 6 healthy human volunteers when the meal containing tamarind fruit extract was administered with the ibuprofen tablets than when taken under fasting state or with the meal without the fruit extract (Garba et al. 2003). Another study reported that aqueous extracts of different parts of tamarind such as fruits, leaves and unroasted seeds exhibited significant hepatoregenerative in rats intoxicated by administration of paracetamol (Pimple et al. 2007).

Antivenom Activity

Tamarind seed extract was also reported to significantly reduce and neutralise the effects of envenomation such as local tissue damage, inflammation and hypotension caused by the venom of *Vipera russelli* (Ushanandini et al. 2006). The extract inhibited hydrolytic enzymes and pharmacological effects, it may be used as an alternative treatment to serum therapy and, in addition, as a rich source of potential inhibitors

of phospholipase A2 (PLA$_2$), metalloproteinases, serine proteases, hyaluronidases and 5′-nucleotidases, enzymes involved in several physiopathological human and animal diseases.

Antiplatelet Activity

Tamarind seeds also contain a serine proteinase inhibitor denoted PG50 (Fook et al. 2005). PG50 had selective activity while cysteine proteinases (papain and bromelain) and serine proteinases (porcine pancreatic elastase and bovine chymotrypsin) were not inhibited, it was strongly effective against serine proteinases such as bovine trypsin and isolated human neutrophil elastase. The IC_{50} value was determined to be 55.96 μg/ml. PG50 showed neither cytotoxic nor haemolytic activity on human blood cells. The study further showed that PG50 preferentially affected elastase release by PAF (platelet activating factor) stimuli and this may indicate selective inhibition on PAF receptors.

Antiemetic Activity

Studies in India reported that tamarind leaf extracts in absolute methanol and n-butanol displayed antiemetic activity when compared with chlorpromazine (Khan et al. 2005). However, methanol extract had more pronounced antiemetic potential using young chicks. The criterion of antiemetic potential was a decrease in number of retching in contrast with those of control.

Antinociceptive Activity

Tamarind also had analgesic activity (Dighe et al. 2009). Petroleum ether extract of the bark showed significant increase in reaction time as compared to other extracts using suitable animal screening models as hot plate test and acetic acid induced writing test at the dose of 50 mg/kg, i.p. Preliminary phytochemical test showed presence of sterols and triterpenes in the extract; hence these compounds might be responsible for the analgesic activity. The aqueous tamarind fruit extract was found to possess potential antinociceptive activity at both the peripheral and central levels, which were mediated via activation of the opioidergic mechanism (Khalid et al. 2010). The extract (60–600 mg/kg) significantly inhibited the writhing test in a dose-dependent fashion with the percentage of analgesia recorded between 51.8% and 74.1%. Further, the extract also significantly and dose-dependently raised the latency time in the hot plate test. The extract also exhibited inhibitory activity in both the early and late phases of the formalin test. Pre-treatment with 5 mg/kg naloxone, a non-selective opioid receptor antagonist, significantly modified the antinociceptive effect of the extract in all tests.

Antiinflammatory Activity

Aqueous, ethanol and chloroform extracts of tamarind were found to have antiinflammatory activity when evaluated in mice (ear oedema induced by arachidonic acid) and rats (subplantar oedema induced by carrageenan) after topical or i.p. administration, respectively (Rimbau et al. 1999). The results supported the traditional uses of the plant but indicated that the active principles in the chloroform extract were probably more active and/or are contained in larger concentrations than the principles in the polar extracts used in the traditional medicine of North-African countries. Administration of the hydroalcoholic extract of tamarind fruit pulp prevented the increase in lytic activity of the complement system caused by the cholesterol-rich diet in hamsters (Landi Librandi et al. 2007). Hamsters administered a diet rich in cholesterol showed increased lytic activity of the classical/lectin pathways and alternative pathway after 45 days. By itself, the extract had no effect on the complement system in-vivo. The complement system is a mediator of the inflammatory process.

Spasmogenic and Spasmolytic Activity

The aqueous extract of *Tamarindus indica*, at concentrations ranging from 10^{-8} mg/ml to 10^{-2} mg/ml, was found to increase the spontaneous

contractile activity of guinea pig taenia coli in a dose-dependent manner ($EC_{50} = 4 \times 10^{-6}$ mg/ml) (Souza and Aka 2007). This activity was unaffected by atropine. In high K^+, Ca^{2+}-free solution containing EDTA, the extract as well as acetylcholine, used as a control, induced tonic contraction. These results suggested that the plant extract exerted a spasmogenic effect that would not involve cholinergic mechanism of action. In separate studies, the methanolic extract of tamarind fruits was found to have spasmolytic activity (Ali and Shah 2010). Relaxant effects on KCl-induced contractions on rabbit's jejunum preparations were prominent at a concentration of 5.0–10.0 mg/ml of the extract. A right shift at a concentration of 3.0 mg/ml ($EC_{50} = 1.98$) and 10.0 mg/ml ($EC_{50} = 1.79$) versus control ($EC_{50} = 2.33$) resembled the effects of verapamil on the calcium chloride curves. The results confirmed its possible mode of relaxing effects i.e. through calcium channel blockade.

UVB-Protection and Corneal Wound Healing Activity

Studies showed that corneal-derived cells exposed to UV-B rays accumulate H_2O_2, and had higher levels of 8-hydroxy-2′-deoxyguanosine and a lower amount of 3H-methyl-thymidine incorporated in DNA than control cells (Raimondi et al. 2003). In the presence of tamarind-polysaccharide, the H_2O_2 and 8-hydroxy-2′-deoxyguanosine accumulation, and the 3H-methyl-thymidine incorporation were significantly reduced with respect to the values measured in cells exposed in the absence of the polysaccharide. The scientists proposed a protective role of the polysaccharide in reducing UV-B derived DNA damage to eye cells. This finding could be of some clinical importance when the polysaccharide is used as a delivery system for ophthalmic preparations. Another study showed that the xyloglucan, the tamarind seed polysaccharide (TSP) exhibited the ability to promote corneal wound healing (Burgalassi et al. 2000). Compared to hyaluronate, TSP slightly but significantly increased the wound healing rate. TSP 1.0% exerted a positive influence on cell adhesion to laminin, up to a certain laminin concentration. The ability of the polysaccharide to promote corneal wound healing was suggested to depend on its influence on the integrin recognition system.

Anti-aging Activity

Extracts of *Tamarindus indica*, *Camellia sinensis* and *Artocarpus lakoocha* were found to demonstrate significant antioxidant effect, and also showed a promising antiglycation effect and could be further developed for use in anti-aging cosmetics (Povichit et al. 2010). The IC_{50} (mg/ml) were 0.9–0.16 for the DPPH method; TEAC values (mg Trolox/mg sample) of 1.72–2.83 for the ABTS method; IC_{50} (mg/ml) of 0.64–1.22 for the TBARS method; and IC_{50} ranging from 0.01 to 3.20 for the antiglycation method.

Alopecia Ameliorating Activity

Tamarind extract and its mixture with turmeric were found to have a mitigating effect on radiation –induced alopecia (Vyas et al. 2010). Radiation was found to cause a generalized lymphocyte mediated hypersensitivity reaction as reflected in the high lymphocyte count of 25.16% in irradiated untreated mice while the lymphocyte count decreased to 16.66% in irradiated mice treated with *T. indica* in irradiated mice treated with the polyherbal mixture (ethanol extracts of tamarind seed and turmeric rhizome) was reduced to 17.00%. The lymphocyte counts in the control (non-radiated and untreated) mice group was 15.83%. Hair density in the irradiated, untreated mice was low 12.83 per sq mm, compared with the higher hair density for in irradiated tamarind treated mice (15.66 per sq mm) and in irradiated polyherbal treated mice (17.88 per sq mm). The result of histopathological analysis showed that in the control group maximum hair follicles (HFs) were in the anagen phase of hair cycle while that in irradiated untreated group were in the telogen phase which may be due to radiation effect on hair follicle cycling. While in the irradiated *T. indica* and polyherbal treated group,

majority of the hair follicles were in the anagen phase of hair cycle.

Fluorosis Modulating/Fluoride Toxicity Ameliorating Activities

Tamarind intake appears to have an additional beneficial effect on the mobilization of deposited fluoride from bone, by enhancing urinary excretion of fluoride (Khandare et al. 2002). Tamarind intake led to significant increase in the excretion of fluoride in 24 hours urine as compared to excretion on control diet. However, excretion of magnesium and zinc decreased significantly on tamarind diet as compared to the control diet. Excretion of calcium and phosphorous were not significantly different while creatinine excretion decreased with tamarind intake. Tamarind intake was postulated to help in delaying progression of fluorosis by enhancing urinary excretion of flouride. Another study showed that there was a significant increase in fluoride excretion and urinary pH and a significant decrease in urinary calcium and copper excretion in the experimental group as compared with the control group (Khandare et al. 2004). There was no change in urinary volume between groups.

Studies revealed that tamarind fruit pulp extract exhibited potential to mitigate fluoride toxicity (Ranjan et al. 2009). Aqueous extract of tamarind fruit pulp (100 mg/kg body weight) orally once daily for 90 days lowered plasma fluoride concentrations in rabbits receiving fluorinated drinking water (200 mg NaF/L water). Cortical indices and metaphysial width in animals receiving the extract also revealed beneficial effects. Changes in plasma biochemistry suggested less hepatic and renal damages in animals receiving the extract along with fluorinated water in comparison to that receiving fluorinated water alone. Results of animal studies suggested that concomitant use of tamarind fruit pulp extract could reduce fluoride concentration in blood and bone and enhanced urinary excretion, indicating the ameliorative potential of fruits of tamarind in fluoride toxicity (Dey et al. 2011).

Ocular Protective Activity

Results of an open-label, randomised, single-centre clinical study with 30 patients over a period of 90 days suggested that tamarind seed polysaccharide (TSP) 0.5% and 1% offer at least equivalent relief to hyaluronic acid 0.2% for dry eye syndrome (Rolando and Valente 2007). TSP 1% demonstrated benefits over hyaluronic acid 0.2% for the subjective symptoms; trouble blinking, ocular burning and foreign body sensation. The 'mucin-like' molecular structure of TSP was found to be similar to corneal and conjunctival mucin 1 (MUC1), a transmembrane glycoprotein thought to play an essential role in protecting and wetting the corneal surface and may explain its increased retention on the eye surface.

Sialagogue Activity

Tamarind was also reported to be a sialagogue, as it was reported to increase the flow of saliva (Veena and Jayaprakash 1999).

Proteinase Inhibitory Activity

Two major storage protein were found in tamarind seeds: (1) Kunitz-type trypsin inhibitor and (2) class III endochitinase (34,000 Da) (Rao and Gowda 2008). The Kunitz inhibitor was specific toward inhibiting trypsin The endochitinase accounted for >50% of the total seed protein, and was found to be an acidic glycoprotein exhibiting a very low endotype hydrolytic activity toward chitin derivatives. It was designated as "tamarinin". A Kunitz-type proteinase inhibitor was also purified from tamarind seeds (Patil et al. 2009). Tamarind possessed a complex of Kunitz-type trypsin inhibitor and porcine trypsin (Tomar et al. 2009).

Tamarind seeds were found to have proteinaceous inhibitors with high inhibitory activities against human neutrophil elastase (HNE) (Fook et al. 2005). A serine proteinase inhibitor denoted PG50 was purified and showed selective activity while cysteine proteinases (papain and bromelain)

and serine proteinases (porcine pancreatic elastase and bovine chymotrypsin) were not inhibited, it was strongly effective against serine proteinases such as bovine trypsin and isolated human neutrophil elastase. The IC_{50} value was determined to be 55.96 μg/ml. PG50 showed neither cytotoxic nor haemolytic activity on human blood cells. PG50 exhibited different inhibition on elastase release by PAF (platelet activating factor) at 44.6% and on release by fMLP (N-formyl-L-methionyl-L-leucyl-phenylalanine), at 28.4%. These results showed that PG50 preferentially affected elastase release by PAF stimuli indicating selective inhibition on PAF receptors.

Molluscicidal Activity

Water and methanol extracts of tamarind fruit pulp were found to have molluscicidal activity against *Bulinus truncatus* (Imbabi and Abu al Futuh 1992). The molluscicidal activity was greater in samples extracted with methanol than with water and was thought to be due to the presence of saponins. *Bulinus truncatus* is a vector of the parasite, *Schistosoma haematobium* that causes schistomiasis.

Toxicity Studies

A study showed that administration of tamarind extract was safe and not toxic. The extract made with *T. indica* fruit pulp was devoid of clastogenic and genotoxic activities in the cells of the rodents, when administered by gavage at these three acute doses of 1,000, 1,500 and 2,000 mg/kg body weight (Silva et al. 2009). In another study, tamarind seed polysaccharide (Glyloid) was incorporated at the level of 4, 8, 12% in a standard commercial diet and fed *ad lib*. to male and female rats for 2 years. No significant changes were noted in the behaviour, mortality, body weight, food intake, biochemical analysis of urine and blood, haematological test, organ weight and histopathological findings of rats receiving Glyloid. In all groups containing control (standard) treatment, spontaneous diseases with aging, such as myocardial change, nephropathy, mammary tumour (in female), pituitary tumour etc., were seen. These diseases played important role as the cause of death of the dead rats. (Iida et al. 1978). Further studies reported that tamarind seed polysaccharide is not carcinogenic in B6C3F1 mice of either sex (Sano et al. 1996). There were no treatment-related clinical signs or adverse effects on survival rate, food and water consumption, haematology findings or organ weights. Detailed histopathological examination also revealed no treatment-related increase in the incidence of any non-neoplastic or neoplastic lesions.

Adverse Effects

Colonic cell proliferation was reported as the prerequisite for the genesis of cancer (Pooja and Devi 2004). Significant increase in the crypt cell proliferation rate (CCPR) and radio-labelled precursor incorporation was observed in N-nitroso N′-methyl urea (MNU)-induced plus tamarind fed group of animals (group 4) in all the three segments of the large intestine when compared with control diet fed normal (group 1) as well as MNU-induced (group 3) animals. The results showed that fruit pulp of tamarind exhibited a co-stimulatory effect on N-nitroso N′-methyl urea (MNU)-induced colonic cell kinetics.

Tamarind juice was found to have the potential to erode dental enamel but studies for a total of 29 days with tamarind juice and shrimp paste showed that shrimp paste could reduce the erosive potential of tamarind juice and re-harden softened enamel in-vitro (Chuenarrom and Benjakul 2010).

Traditional Medicinal Uses

The fruit pulp, leaves, and bark have been used in traditional medicine and modern medicine in many parts of the world. The fruit pulp has been official in the British and American and most other pharmacopoeias and considerable volume of the shelled fruits have been annually imported into the United

States for the drug trade, primarily from the Lesser Antilles and Mexico. Tamarind preparations are globally recognized as refrigerants in fevers and as laxatives and carminatives. It is used in traditional medicine for the treatment of cold, fever, stomach disorder, diarrhoea and jaundice and as skin cleanser. Alone, or in combination with lime juice, honey, milk, dates, spices or camphor, the pulp is regarded effective as a digestive, and as a remedy for biliousness and bile disorders, and as an anti-scorbutic. In traditional medicine, the pulp is applied on inflammations, is employed in a gargle for sore throat and, when mixed with salt, as a liniment for rheumatism. The pulp is said to help in the restoration of sensation in cases of paralysis. In Colombia, an ointment made of tamarind pulp, butter, and other ingredients is used to purge domestic animals of vermin. Due to its medicinal attributes, tamarind is used in Ayurvedic Medicine for gastric and digestion problems. The fruit shells are burned and reduced to an alkaline ash which enters into medicinal formulas. The powdered seeds are made into a paste for treating boils and, with or without cumin seeds and palm sugar, are prescribed for chronic diarrhoea and dysentery. The seedcoat is astringent, and also prescribed for the latter disorders. An infusion of the roots is believed to have curative value in chest complaints and is used as an ingredient in prescriptions for leprosy. Seeds are also roasted, soaked and eaten whole as a folk medicine to drive out intestinal parasites.

Tamarind leaves and flowers, dried or boiled, are used as poultices for swollen joints, sprains and boils. Lotions and extracts made from them are used in treating conjunctivitis, dysentery, jaundice, erysipelas, haemorrhoids and various other ailments and also used as antiseptics and vermifuge. In the Philippines, the leaves have been traditionally used in herbal teas for reducing malaria fever. The bark of the tree is regarded as an effective astringent, tonic and febrifuge. Fried with salt and pulverized to an ash, it is given as a cure for indigestion and colic. A decoction is used in cases of gingivitis, asthma and eye inflammations; and lotions and poultices made from the bark are applied on open sores and caterpillar rashes.

In Benin, tamarind seeds are employed for menses problems (Adjanohoun et al. 1989) and in the Popular Republic of Congo (Brazzaville) the leaves are used for chicken pox (Adjanohoun et al. 1988). In Niger, ripe tamarind leaves with other plant ingredients are used for treating intestinal worms, and leaves are used with *Rottboellia exaltata* flowers in a decoction for rhino-pharyngitis (Adjanohoun et al. 1985). In Central African Republic, leaves are utilised for rhino-pharyngitis (Ake Assi et al. 1981). In Comoros, the leaf sap is used for contusion (Adjanohoun et al. 1982). In East Africa (Kenya, Somalia, Tanzania) the acid pulp is made into a drink for alleviating fevers, and a laxative for children (Weiss et al. 1979). In Uganda, the bark is used for malaria (Tabuti 2008). In Central Nigeria (Kwara state), crushed leaf extract used as a laxative, also a decoction of tamarind leaves and *Prosopis africana* leaves used for malaria (Bhat et al. 1990). Tamarind fruits are used as laxative or febrifuge throughout the Sahel and Soudan ecological zones (Havinga et al. 2010). In central West Africa, tamarind bark and leaves are often involved in the treatment of wounds The bark is also used to treat diarrhoea in West Africa, the leaves are used for similar purpose in East Africa. The bark is astringent and is used as a tonic and in lotions or poultices to treat sores, ulcers, boils and rashes in the Philippines and Eastern Sudan (Dalziel 1955). In Kenya, a bark decoction is used for cough and gargle (Kokwaro 1976). In Senegal, the pounded fruit is used as a laxative, the macerated leaves used for ulcers and powdered bark used for treating cough (Kerharo and Adam (1964). In Uganda, a bark decoction is used for treating uterine fibroids and root decoction for syphilis (Tabuti et al. 2003). In Burkina Faso, boiled leaves are used as mouth wash for oral sores, and decoction of the bark ash is used for staining teeth Tapsoba and Deschamps (2006). In Tanzania, a root decoction is used for treating epilepsy (Moshi et al. 2005). In Ethiopia dried or fresh seed are crushed and eaten to treat tapeworm (Lukekal et al. 2008).

In the northwest of Coimbatore, Tamil Nadu, India, the Irula' tribals of the Anaikkatty hills drink the ground root bark powder infusion for abortion and to prevent pregnancies (Lakshmanan

and Narayanan 1994) in the Philippines, flower poultice is used a remedy for eye diseases and conjunctivitis (de Padua et al. 1977–1983). The flowers are administered internally for jaundice and piles. Treatment for digestive tract complaints and indigestion has been reported in Kampuchea, Philippines and India (Jayaweera 1981; Rama Rao 1975).

Other Uses

Tamarind trees are used as ornamental trees, wind breaks and shade trees to provide shade on the country roads and highways and as a live support tree for black pepper. Tamarind root exerted allelopathic competence, suppressing the growth of other plant species in the soil under the tree and in greenhouse studies. This allelopathy contributed to a weed free environment around the tamarind tree (Parvez et al. 2003a).

In recent years it has become popular in bonsai culture in Asian countries like Indonesia, Taiwan and the Philippines. Its fruits and leaves are a well-known favourite of ring-tailed lemurs, providing as much as 50% of their food resources.

The sapwood of the tamarind tree is pale-yellow. The heartwood is rather small, dark purplish-brown, very hard, heavy, strong, durable and insect-resistant. Due to its density and durability, tamarind heartwood can be used in making furniture, building houses, farm tools and wood flooring. It bends well and takes a good polish and, while hard to work, it is highly prized for furniture, panelling, wheels, axles, gears for mills, ploughs, planking for sides of boats, wells, mallets, knife and tool handles, rice pounders, mortars and pestles. It has at times been sold as "Madeira mahogany". The wood is valued for fuel, especially for brick kilns, for it gives off an intense heat, and it also yields a charcoal for the manufacture of gun-powder. In Malaysia, even though the trees are seldom felled, they are frequently topped to obtain firewood. The wood ashes are employed in tanning and in de-hairing goatskins. The ash can be mixed with fruit pulp for cleansing and polishing brass and copper vessels. Young stems and also slender roots of the tamarind tree are fashioned into walking-sticks. The bark contains up to 7% tannin and is often employed in tanning hides and in dyeing, and is burned to make an ink. Bark from young trees yields a low-quality fibre used for twine and string. The tamarind tree is a host for the lac insect, *Kerria lacca that* deposits a resin on the twigs. The lac may be harvested and sold as stick-lac for the production of lacquers and varnish.

Ethanol or water extract of tamarind fruit was found efficacious in controlling the tropical cattle tick, *Boophilus microplus* (Chungsamarnyart and Jansawan 2001). Of five plant extracts, tamarind extract was found to be the most effective in control citrus canker on the leaves (Leksomboon et al. 2001).

Tamarind kernel powder is an important sizing material in textile, paper and jute industries. The powder made from tamarind kernels has been adopted by the Indian textile industry as being more efficient and more economical than cornstarch for sizing and finishing cotton, jute and spun viscose, as well as having other technical advantages. It is commonly used for dressing homemade blankets. Other industrial uses include employment in colour printing of textiles, paper sizing, leather treating, the manufacture of a structural plastic, a creaming agent for latex used as soil stabilizer, a glue for wood, a stabilizer in bricks, a binder in sawdust briquettes, and a thickener in some explosives. Tamarind kernel powder is also used in microbial production of lipids (Jambhulkar and Shankhapal 1992). A composite material of tamarind seed gum and the cellulosic rich sisal plant fibre was found to have potential industrial applications such as false roofing and room partitioning (Veluraja et al. 1997). Cationic tamarind kernel polysaccharide (Cat TKP) was found to be a novel polymeric flocculent for the treatment of textile industry waste-water (Pal et al. 2009). Studies showed that it surpassed the flocculation efficiency over commercial flocculent. Activated and MnO_2-coated tamarind fruit hull could be used to remove fluoride from water (Sivasankar et al. 2010). Studies showed that tamarind seed meal and 10% molasses could completely replace maize in the diet of growing Desi pigs (Reddy et al. 1986).

Iron oxide impregnated tamarind hull carbon (IOITHC) was developed for use as an adsorbent for the removal of Arsenic from water (Maiti et al. 2010). The removal of As(V) on IOITHC was compared with the untreated tamarind hull carbon as well as with the activated commercial carbon and IOITHC was found to be better adsorbent. Arsenic adsorption from arsenic contaminated groundwater on IOITHC in batch mode indicated that 98% removal was achieved for adsorbent loading of 3.0 g/l with initial arsenic concentration of 264 µg/l.

Tamarind seeds yield an amber lipid oil (6–8%) useful as an illuminant and as a preferred varnish for painting dolls and idols. The tannin-rich seedcoat (testa) is being trialled for utility as an adhesive for plywoods and in dyeing and tanning. Pulverized, boiled and mixed with gum, the seeds produce a strong wood cement and is utilised as a stabiliser for bricks, as a binder for sawdust briquettes and a thickener for some explosives (Rama Rao 1975; El-Siddig et al. 2006). The seed husk has also been found to be an effective fish poison (Roy et al. 1987). The seed is utilised as Jena (1991) reported that powdered tamarind seed husks added to water killed several fish species, *Labeo rohita, Calta calta, Cirrhinus mrigala, Cyprinus carpio, Oreochromis mossabicus* and *Channa marlius,* within 2 hours of its application.

An infusion of the whole pods is added to the dye when colouring goat hides in West Africa. The fruit pulp may be used as a fixative with turmeric or annatto in dyeing in Kelantan and Pattani, and as a fixative for dyes in India and in Africa. The pulp has served to coagulate rubber latex. The pulp, mixed with sea water, is excellent for cleaning metals like silver, copper and brass removing dulling and the greenish patina that forms. Tartaric acid, pectin, citric acid, lactic acid and, after fermentation, alcohol is extracted from the pulp.

Tamarind foliage is used as common mulch for tobacco plantings. Tamarind leaves are used as feed stock by cattle and goats, wild animals including elephant, and fodder for silkworms – *Anaphe sp.* in India, and *Hypsoides vuilletii* in West Africa. Tamarind leaves are added to the boiling water to bleach the leaves of the buri palm (*Corypha elata*) to process them for hat-making. A yellow dye derived from the leaves colours wool red and turns indigo-dyed silk to green. Tamarind leaves and flowers are useful as mordants in dyeing. Tamarind leaf extract was found to have fungicidal activity; it was reported to inhibit growth of many important phytopathogenic fungi: *Phytophthora palmivora, Colletotrichum gloeosporioides, Alternaria solani, Fusarium solani, Rhizoctonia bataticola, Sclerotium rolfsii, Pellicularia filamentosa* and *Macrophomina phaseolina* (John et al. 2004).

Tamarind flowers are regarded as a good source of nectar for honeybees in South India and the honey obtained is golden-yellow and slightly acid in flavour.

Comments

Tamarind is propagated by seeds and by marcotting, grafting, budding and air-layering.

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Trigonella foenum-graecum

Scientific Name

Trigonella foenum-graecum L.

Synonyms

Buceras foenum-graecum (L.) All., *Foenum-graecum officinale* Moench, *Foenum-graecum officinale* var. *cultum* Alef., *Foenum-graecum sativum* Medik., *Trigonella foenum-graecum* provar. *foenum-graecum* apud Mansf., *Foenum-graecum officinale* Moench var. *cultum* Alef., *Telis foenum-graeca* (L.) Kuntze, *Trigonella foenum-graecum* provar. *foenum-graecum*, *Trigonella foenum-graecum* subsp. *culta* (Alef.) Gams, *Trigonella jemenensis* (Serp.) Sinskaya, *Trigonella graeca* St.-Lag., *Trogonella tibetan* (Alef.) Vassilcz.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Bird's-Foot, Classical Fenugreek, Common Fenugreek, Cultivated Fenugreek, Cultivated Trigonella, Fenugreek, Greek Clover, Greek Hay, Greek Hayseed, Methi seed Plant, Sicklefruit fenugreek, Trigonella

Vernacular Names

Afghanistan: Holba;
Afrikaans: Fenegriek;
Albanian: Kopër Greqie, Trëndetina Yzerlike, Trëndetinë, Yzerlik;
Amharic: Abesh, Abish;
Arabic: Hilbeh, Hulbah;
Armenian: Chaiman, Hatzhamem Hynakan Khot, Šambala;
Azerbaijan: Shembele;
Basque: Allibre, Allorbe;
Belarusian: Pažytnik Grečaski;
Brazil: Feno-Grego;
Bulgarian: Chimen, Sminduh, Sminduh Grutski, Tilchets;
Burmese: Penantazi;
Catalan: Fenigrec;
Chinese: Hsiang-T'sao, Hu Lu Ban, Ku-Dou, K'u Tou, Xiang-Cao, Xiang-Dou;
Croatian: Grčka Djetlina, Grčko Sijeno, Pjeskavica;
Czech: Pískavice, Pískavice Oecké Seno, Pískavice Řecké Seno, Seneka;
Danish: Almindelig Bukkehorn, Ægte Bukkehorn, Bukkehorn, Bukkehornskløver, Bukkehorns-Frø;
Dhivehi: Oabaiy, Oabath;
Dutch: Fenegriek;
Eastonian: Kreeka Lambalääts, Põld-Lambalääts;
Egypt: Helbah;
Finnish: Rohtosarviapila, Pukinsarviapila, Sarviapila;

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French: Fénugrec, Foin Grec, Sénegré, Trigonelle Fenugrec;
Galician: Alforfa, Fenacho, Fenogreco;
Georgian: Chaman, Solinji;
German: Bockshornklee, Bockskornlee, Griechischer Bockshornklee, Griechisches Heu, Schabzieberklee, Siebengezeit, Ziegenklee;
Greek: Moschositaro, Telis, Trigonella;
Hebrew: Hilbeh;
Hungarian: Görögszéna;
Icelandic: Fenugreek;
India: Methi (Assamese), Methi (Bengali), Methi (Dogri), Methi (Gujarati), Methi, Meti, Muthi, Mutti (Hindu), Mente, Mentepalle, Mentesoffu, Mentesoppu, Menthe, Menthya, Mentya, Menthya Gida, Menthya Soppu (Kannada), Uluva, Ventayam, Venthiam (Malayalam), Methi, Methi-Chi Bhaji (Marathi), Methi (Oriya), Mehti (Punjabi), Bahuparni, Bahupatrika, Chandrika, Dipani, Gandhabija, Gandhaphala, Jyoti, Kairavi, Kalanusari, Kunchika, Mantha, Medhika, Methe, Methi, Methika, Methini, Misrapushpa, Munindrika, Pitabija, Vallari, Vedhani (Sanskrit), Calepaccalam, Cayarovaram, Cirepari, Cittiravaku, Civamatanu, Kairalam, Kairavi, Kaivitai, Kalintam, Kantapalai, Makarampu, Makarantappu, Mathai, Meti, Menti, Mentikai, Mentiyam, Muninturaicceti, Nariventayam, Nariventiyam, Pitapicam, Tevaputtira, Uluva, Uluvacceti, Uluvam, Uluvay, Venciyam,Vendayam, Vendhayam, Vendium, Venkuntakikam,Ventai, Ventaiyam, Vetani, Vental,Ventalayam,Ventayacceti,Ventayakkirai, Ventayam,Venthayam,Ventiyam,Vimalotayacceti, Vimalotayam, Uluva, Uluvaarisi, Yamunacitti (Tamil), Mentikura, Mentulu, Menthikoora, Menthulu (Telugu), Methi, Shanbalid, Kasuri Methi, Tukhm Methi, Tukhm Methi (Urdu);
Indonesia: Kalbat;
Italian: Fieno Greco, Fieno Greco Commun, Trigonella;
Japanese: Fenu-Guriku, Koruha;
Kashimiri: Meth;
Korean: Horopa, Penigurik;
Latvian: Sierāboliņš;
Lithuanian: Vaistinė Ožragė;
Macedonian: Grčko Seme;
Malaysia: Hakba, Kelabat;
Maltese: Fenugreek;
Moldava: Molotru Komum;
Nepal: Methi (Nepali), Mi (Newari);
Norwegian: Bukkehorn, Bukkehornskløver, Fillegrek, Fillegrækum, Foenum Græcum, Fænum Græcum, Gresk Høy, Methi;
Pahlavi: Shabaliidga;
Pakistan: Methi;
Persian: Sambalidag, Şambélilé, Shamlid, Shamlit, Shamliz, Shanbalid Shanbalileh;
Philippines: Fenugreek;
Polish: Kozieradka, Kozieradka Pospolita, Nasiona Kozieradki;
Portuguese: Alfarva, Alforba, Fenacho, Feno Grego;
Provençal: Senigré;
Romanian: Molotru, Molotru Comun, Schinduf;
Russian: Pazhitnik Grecheski, Pazhitnik Cennoj, Pažitnik Sennoj, Šambala, Shambala;
Serbian: Piskavica, Grčko Seme;
Slovakia: Pískavica, Senovka Grécka;
Slovenian: Grško Seno, Sabljasti Triplat ;
Spanish: Alhova, Fenogreco, Fenugreco, Heno Griego;
Sri Lanka: Asumodhagam, Ulu Hal (Sinhalese);
Sumerian: Sullim;
Swahili: Uwatu;
Swedish: Bockhornsklöver, Grekiskt Hö;
Tadzhistan: Khasbeda;
Thai: Luk Sat;
Tibetan: Mi Ti, Shu-Mo-Sa;
Tigrinya: Abaka;
Turkish: Boy Tohumu, Boyotu, Çemen, Çimen, Hulbe, Kokulu Yonca;
Ukraine: Guniba Svizhe Sino, Hunba Sinna;
Vietnamese: Cỏ Ca Ri, Hồ Lô Ba;
Welsh: Ffenigrig;
Yiddish: Fenigrekum, Khilbe.

Origin/Distribution

The exact origin of fenugreek is difficult to ascertain as the plant has been cultivated since antiquity, about 4,000 BC. The plant is probably indigenous to eastern Mediterranean, West Asia and India. It has been grown as a traditional minor pulse crop in the Mediterranean area, Near and

Middle East countries, India, NE Africa (Ethiopia), Arabia. It is grown in small scale in Europe, North America, Latin America and China.

Agroecology

Fenugreek is a cool climate species and grows best in sub-tropical and temperate areas with an optimum range of 8–27°C and annual rainfall of 400–1,500 mm. It is fairly drought tolerant. It thrives best on rich, well-drained loams or sandy-loam soils with pH of 5.8–8.2 but will grow on sandy and gravelly soils but not acid soils. It grows best in full sun. Growth is retarded and weak in cold temperatures and wet soils. As a leguminous plant, it needs little if any nitrogen fertilizer as it can fix nitrogen and enrich the soil.

Edible Plant Parts and Uses

Fenugreek is one of the earliest spices known to man and was used by the ancient Egyptians as a food, medicine and religious embalming rites. The seed is widely used as spice and the shoot and leaves as a vegetable and culinary spice.

The young leaves and seedling sprouts of fenugreek are eaten as greens. In Asia and Egypt the roots of sprouted seedlings, 5–8 cm long are eaten as vegetables. The fresh or dried leaves have a bitter taste and a strong unique odour and are used to flavour other dishes. Fenugreek greens are popular in curries combine with other vegetables such as potato, spinach and yam and eaten in accompaniment to rice or naan bread in the Indian subcontinent. It is usually eaten boiled in China, and central and Western Asia. Chopped young shoots are used in salad to impart a bitter taste. In north-western China, the young shoots are dried, ground and the powder used for pastries. The dried leaves – also called *kasuri methi* (or *kasoori methi* in India), after the region of Kasur in Punjab, Pakistan province, where it grows abundantly – are used to flavor sauces and gravies.

Mature fenugreek seeds are used whole, ground and sometimes roasted as spice or boiled and mixed with honey as a snack. Roasted seeds are used a substitute for coffee. In Egypt, a refreshing fenugreek tea is prepared by boiling fenugreek seeds and then sweetening. A milk substitute is also prepared from dried and ground sprouted seeds. Fenungreek seeds are used as condiment for soups, porridge, as curry powder and paste ingredient, for flavouring bread, beverages, pickles, chutneys, butter confections, and imitation maple syrup. In North America, where maple syrup is popular but expensive, fenugreek is widely used in lower-cost syrup products as a maple syrup flavoring such as Mapleine. Fenugreek is also used a substitute for vanilla, caramel, butterscotch, rum and liquorice. Fenugreek seeds are frequently used in the preparation of pickles, curry powders, and pastes, and the spice is widely used in the cuisine of the Indian subcontinent and the Middle East. In India, fenugreek is an ingredient in a type of bread, *khakhra*, a type of bread and is one of the three ingredients of *idli* and *dosa.* In Bulgaria, fenugreek seeds are used as one of the ingredients in a traditional spice mixture called *sharena sol.* In Ethiopia and Eritrea, it is used in *injera/taita*, a type of bread. It is also used as an ingredient in the production of clarified butter similar to Indian *ghee* called *tesme* (Ethiopian and Eritrean Tigrinya), or *qibé* in Amharic. Fenungreek is an essential ingredient in a hot paste used in pastirma in Egypt and Turkey. In Yemen, fenugreek is the primary condiment ingredient for *saltah* the national dish. In Iran, fenugreek is used in the delicacy called *Ghormeh Sabzi.* In Afghanistan, fenugreek is used in the preparation of a spinach-based cuisine *Qormeh Sabzi* and in the specialty *Sholeh Holba*, a sweet rice pudding. A cake dessert called *Helba* is widely consumed in the Islamic world during Islamic holidays. This is prepared using fenugreek seeds in a semolina cake covered in sugar or maple-like syrup, on top of which is sprinkled some fenugreek seeds. A cake dessert known as Helba in the Islamic world is a tasty treat during Islamic holidays. This is a semolina cake covered in sugar or maple-like syrup, and sprinkled with

Plate 1 Fenugreek seeds

fenugreek seeds on top. Jews in Yemen often prepare a foamy substance from fenugreek seeds that they add to soups. Fenugreek is a key ingredient besides salt found in their unleavened bread, used for the Jewish Festival of Passover. In Malaysia, fenugreek is sued as an ingredient in a traditional dessert called *butir nangka*, which is very popular during Ramadan.

Botany

An erect, scented, branched annual, 30–80 cm tall, sparingly pubescent. Leaves alternate, trifoliate on 2–4 cm long grooved, teret petioles. Stipules deltoid, acuminate, small adnate to the petiole. Leaflets 1–5 cm long, 0.5–1.5 cm wide, obovate to oblanceolate, apex rounded, margin denticulate. Flowers, axillary, solitary, papilionaceous, hermaphrodite, subsessile. Calyx 7–8 mm long, campanulate, teeth as long as the tube. Corolla pale yellow, sometimes tinged with lilac, standard hood-shaped, obovate, clawed pale yellow; wings obovate, clawed, pale yellow, keel ladle shaped, clawed. Stamens 10 in 2 bundles 1 and 9, ovary sessile with glabrous style andcapitate stigma. Fruit cylindrical, slender, straight to sickle shaped legume, yellow-brown, 5–19 cm long, 3–5 mm broad, glabrous or pubescent, tapering into a beak, containing 10–20 oblong-rhomboid seeds, 3–5 mm by 2–3 mm, yellowish–brown (Plate 1) and finely glandular punctate.

Nutritive/Medicinal Properties

Nutrient Value

Analyses carried out in the United States (USDA 2010) reported that fenugreek seeds had the following proximate composition (per 100 g edible portion): water 8.84 g, energy 323 kcal (1,352 kJ), protein 23.00 g, total lipid 6.413 g, ash 3.40 g, carbohydrates 58.35 g, total dietary fibre 24.6 g, Ca 176 mg, Fe 33.53 mg, Mg 191 mg, P 296 mg, K 770 mg, Na 67 mg, Zn 2.50 mg, Cu 1.11 mg, Mn 1.228, Se 6.3 mcg, vitamin C 3 mg, thiamine 0.322 mg, riboflavin 0.366 mg, niacin 1.640 mg, vitamin B-6 0.6 mg, total folate 57 mcg, vitamin A 60 IU, total saturated fatty acids 1.46 g, phytosterols 140 mg, tryptophan 0.391 g, threonine 0.898 g, isoleucine 1.241 g, leucine 1.757 g, lysine 1.684 g, methionine 0.338 g, cystine 0.369 g, phenylalanine 1.089 g, tyrosine 0.764 g, valine 1.102 g, arginine 2.465 g, histidine 0.668, alanine 1.020 g, aspartic acid 2.708 g, glutamic acid 3.988 g, glycine 1.306 g, proline 1.198 g and serine 1.215 g.

The seed is nutritious, being high in proteins, amino acids, vitamin A and minerals potassium, iron. It also has vitamin C (ascorbic acid), thiamine, riboflavin, niacin, vitamin B.

Total lipids extracted from fenugreek (*Trigonella foenum-graecum*) seeds amounted to 7.5% of the dry seeds (Hemavathy and Prabhakar 1989). The total lipids consisted of 84.1% neutral lipids, 5.4% glycolipids and 10.5% phospholipids. Neutral lipids comprised mainly of triacylglycerols (86%), diacylglycerols (6.3%) and small amounts of monoacylglycerols, free fatty acids and sterols. Five glycolipids and seven phospholipids were found. The major glycolipids were acylatedsterylglycoside and acylmonogalactosyldiacylglycerol, and the minor glycolipids were sterylglucoside, monogalactosylmonoacylglycerol and digalactosyldiacylglycerol. The major phospholipids comprised phosphatidylcholine, and phosphatidylethanolamine while the minor phospholipids were phosphatidylserine, lysophosphatidylcholine, phosphatidylglycerol, phosphatidylinositol and phosphatidic acid.

Other Phytochemicals

Diosgenin and its 25β-epimer, yamogenin were found to be the major sapogenins of *Trigonella foenum-graecum* seeds from West Pakistan and Moroco (Fazli and Hardman 1971). Trigonellagenin, found by other workers, was shown to be a mixture of these two epimers. Gitogenin was found only in the seeds and not in the leaf, stem and root. Traces of tigogenin was detected in the Moroccan seed only. Petrol extraction of the powdered seeds yielded fixed oil (7%) in which squalane-like hydrocarbons were tentatively identified. The sterols included β-sitosterol and cholesterol. A new C27-steroidal sapogenin-peptide ester, fenugreekine, was isolated from seeds of *Trigonella foenum-graecum*. On acid hydrolysis, it yielded diosgenin, yamogenin, (25R)-spirosta-3,5-diene, a mixture of three isomeric (2S,3R,4R-, 2S,3R,4S-, 2S,3S,4R-)-4-hydroxyisoleucine lactones, 4′-hydroxyisoleucyl-4-hydroxyisoleucine lactone, and a C14-dipeptide which was partially characterized (Ghosal et al. 1974). Fenugreekine, exhibited a number of interesting pharmacological and virological activities.

Using gas chromatography-olfactometry, 3-Hydroxy-4,5-dimethyl-2(5H)-furanone (sotolone) was established as the character impact flavor compound of fenugreek (Blank et al. 1997). Fenugreek was found to have trigonelline (Zhuo et al. 2010), galactomannan (Reid and Meier 1970) and steroidal saponins (Taylor et al. 1997). The steroidal saponin, diosgenin levels from mature fenungreek seeds ranged from 0.28% to 0.92% (28–92 μg/10 mg) (Taylor et al. 2002). Diosgenin [(25R)-spirost-5-en-3β-ol] was identified as the major component in seed and foliage extracts hydrolyzed with hydrochloric acid (Taylor et al. 1997). Yamogenin, tigogenin, neotigogenin, smilagenin, and sarsasapogenin were identified in the extracts. Dihydroxy steroidal sapogenins, tentatively identified as yuccagenin, gitogenin, and neogitogenin, were detected as minor components in hydrolyzed extracts from seed.

A total of 67 compounds including several pyrazines, 2,5-dimethyl-4-hydroxy-3(2H)-furanone or 1-epi-cubenol were identified, from Tunisian fenugreek seeds (Mebazaa et al. 2009).

The flavone C-glycosides, apigenin 6-C-β-chinovopyranosyl-8-C-β-galactopyranoside (6) and apigenin 6-C-β-xylopyranosyl-8-C-(6‴-O-(3-hydroxy-3-methylglutaroyl)-β-glucopyranoside) (7), in addition to the known flavone C-glycosides, apigenin 6,8-C-di-β-galactopyranoside (1), apigenin 6-C-β-xylopyranosyl-8-C-β-galactopyranoside (2), apigenin 6-C-β-arabinopyranosyl-8-C-β-galactopyranoside (3), luteolin 8-C-β-glucopyranoside (4), luteolin 6-C-β-glucopyranoside (5), apigenin 8-C-β-glucopyranoside (8), apigenin 6-C-β-glucopyranoside (9), luteolin 8-C-(2″-O-(E)-p-coumaroyl-β-glucopyranoside) (10), and apigenin 8-C-(2″-O-(E)-p-coumaroyl-β-glucopyranoside) (11) were isolated from fenugreek seeds (Rayyan et al. 2010). Ten flavonoids were isolated from the ethyl acetate-soluble fraction of the ethanolic extract of fenugreek seeds and elucidated as 5,7,3′-trihydroxy-5′-methoxylisoflavone (1), biochanin A (2), formononetin (3), irilone (4), tricin (5), daidzein (6), calycosin (7), orientin-2″-O-p-trans-coumarate (8), vitexin-2″-O-p-trans-coumarate (9), and tricin-7-O-β-D:-glucopyranoside (10) (Wang et al. 2010). Compounds 1 and 8 are new flavonoids, and 8 and 9 strongly promoted 2BS fibroblast cell proliferation induced by hydrogen peroxide.

Galactomannan reserves in the endosperm of intact fenugreek seeds were found to be mobilized in part by endo-β-D-mannanase (mannan endo-1,4-β mannosidase, EβM,) activity (Dirk et al. 1999). Increases in glucose, fructose, and sucrose in the embryo reflected the mobilization of the galactosyl-sucrose sugars and the uptake of the hydrolytic products of galactomannan breakdown from the endosperm. Concurrent with the accumulation of both axial and cotyledonary starch, there were increases in the steady state amounts of transcripts of both the large and small subunits of adenosine diphosphate glucose pyrophosphorylase (glucose-1-phosphate adenylyl-transferase,), the key regulatory enzyme of starch synthesis. The corresponding sugar, adenosine diphosphoglucose, accumulated only within the cotyledons after starch began to

decrease. The activity of the starch degradative enzyme β-amylase increased in the cotyledon as starch commenced to decline, although low amounts of α-amylase were constitutively present.

The main components of the fenugreek oil from the aerial plant parts were found to be δ-cadinene (27.6%), α-cadinol (12.1%), γ-eudesmol (11.2%) and α-bisabolol (10.5%) (Ahmadiani et al. 2004). Steroid saponins namely furostanol glycosides isolated from *Trigonella foenum-graecum* seeds as their methyl ethers included trigofoenosides A and D (Gupta et al. 1985), trigofoenosides F and G (Gupta et al. 1984), and trigofoenosides B and C (Gupta et al. 1986). The principal free amino acid present in *Trigonella foenum-graecum* seed was isolated and identified as (2S, 3R, 4R)-4-hydroxyisoleucine (Fowden et al. 1973).

A trimethylcoumarin 3, 4, 7-trimethylcoumarin was isolated from the stem of *Trigonelia foenum-graecum* (Khurana et al. 1982). Two kaempferol glycosides [kaempferol 3-O-β-D-glucosyl(1→2)-β-D-galactoside 7-O-β-D -glucoside and kaempferol 3-O-β-D-glucosyl (1→2)-(6″-O-acetyl)-β-D-galactoside 7-O-β-D-glucoside] as well as the quercetin glycoside [quercetin 3-O-β-D-glucosyl(1→2)-β-D-galactoside 7-O-β-D-glucoside] were isolated from *Trigonella foenum-graecum* stems together with a known kaempferol glycoside, lilyn [kaempferol 3-O-β-D-glucosyl(1→2)-β-D-galactoside]. Among the phenolics identified, kaempferol-3-O-α-L-rhamnoside, kaempferol 3,7-O-α-L-dirhamnoside, quercetin 3,7-O-α-L-dirhamnoside, and 3-O-α-L-rhamnosyl quercetin were reported in fenugreek seeds for the first time (Chatterjee et al. 2009).

Pharmacological properties of fenugreek reported are elaborated below.

Anticancer Activity

Raju et al. (2004) found that, by comparison with control, continuous feeding of 1% fenugreek seed powder (FSP) and 0.05% and 0.1% diosgenin suppressed total colonic aberrant crypt foci (ACF) and reduced the number of multicrypt foci. Dietary diosgenin at 0.1% and 0.05% inhibited total colonic ACF and multicrypt foci formation in a dose-dependent manner. Diosgenin dose-dependently inhibited cell growth and induced apoptosis in the HT-29 human colon cancer cell line, in part by inhibition of bcl-2 and by induction of caspase-3 protein expression. The findings suggested the fenugreek constituent diosgenin to have potential as a colon cancer preventive agent. Treatment with fenugreek seed extract (10-15 ug/ml) inhibited growth of breast, pancreatic and prostate cancer cell lines (PCa) (Shabbeer et al. 2009). At higher doses(15–20 ug/ml), was still inhibitory to growth of PCa cell lines but not to either primary prostate or hTert-immortalized prostate cells. Growth inhibition was partially to the apotopsis of cancer cells. Molecular changes induced in PCa cells included: downregulation of mutant p53 in DU-145 human prostate cancer cells, and upregulation of p21 and inhibition of TGFβ induced phosphorylation of Akt in PC-3 human prostate cancer cells.

Antioxidant Activity

Results of studies by Bukhari et al. (2008) revealed that methanol, ethanol, acetone, hexane, dichloromethane, and ethyl acetate extracts of the fenugreek seeds exhibited antioxidant activity as assayed by 1,1-diphenyl-2-picryl-hydrazyl (DPPH). total phenolic content (TPC) by Folin-Ciocalteu method as well as flavonoid content, chelating activity, reducing power were also determined. The findings suggested that the fenugreek extracts could act as potent source of antioxidants. Supplementation with fenugreek seed powder to diabetic rats normalised the elevated lipid peroxidation and enhanced susceptibility to oxidative stress associated with depletion of antioxidants in liver, kidney and pancreas (Anuradha and Ravikumar 2001). In normal rats treatment resulted in enhanced antioxidant status with reduction in peroxidation. Ca2+ ATPase activity in liver was protected by the aqueous extract to nearly 80% of the initial activity. The findings suggested that the soluble portion of the seeds could be responsible

for the antioxidant property. Gamma-irradiation did not bring about any significant changes in the fatty acid profile of fenugreek and turmeric despite a high content of unsaturation (Chatterjee et al. 2009). Oleic and linoleic acid were the dominant fatty acids with an appreciable amount of linolenic acid in both spices. The ability of aqueous methanolic extract of both spices with high phenolic content to prevent lipid peroxidation suggested a possible role of phenolic constituents in preventing lipid radiolysis.

Treatment of germinated fenugreek seed extract to rats with cypermethrin induced hepatic and renal toxicity, restored antioxidant status and enzymatic activities to near normal levels (Sushma and Devasena 2010). The extract elevated the decreased activities of superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx) and glutathione-S-transferase (GST) and the low levels of glutathione and total phospholipids in liver and kidneys. The extract reduced the enhanced activities of phospholipases A (PLA) and C (PLC) in liver and kidneys and serum marker enzymes, aspartate transaminase (AST), alanine tansaminase (ALT), alkaline phosphatase (ALP), lactate dehydrogenase (LDH) and gamma glutamyl transferase (GGT).

Studies showed that fenugreek protected against selenite-induced oxidative stress in experimental cataractogenesis in-vitro and in-vivo (Gupta et al. 2010). Fenugreek significantly restored glutathione and decreased malondialdehyde levels in rats lenses in culture medium supplemented with selenite and fenugreek aqueous extract. A significant restoration in the activities of antioxidant enzymes such as superoxide dismutase, catalase, glutathione peroxidase, and glutathione-S-transferase was observed in the fenugreek supplemented group as compared to control. In-vivo, none of the rats eyes was found with nuclear cataract in fenugreek treated group as opposed to 72.5% in the control group.

Antidiabetic Activity

A profusion of scientific studies have been reported on the antidiabetic property of Fenugreek seed and leaf extracts. Fenugreek was found to improve peripheral glucose utilization and glucose tolerance in diabetic patients in a cross-over design study (Raghuram et al. 1994). An intravenous glucose tolerance test at the end of each study period indicated that fenugreek in the diet significantly decreased the area under the plasma glucose curve, half-life, and enhanced the metabolic clearance rate. In addition, it increased erythrocyte insulin receptors. Khosla et al. (1995) found that *Trigonella foenum graecum*, administered orally produced a significant decrease in blood glucose both in the normal as well as alloxan-induced diabetic rats in a dose-dependent manner.

The aqueous extract of the methanol extractive-free residue of fenugreek seed powder exhibited significant hypoglycemic activity at different prandial states (Ali et al. 1995). The soluble dietary fibre (SDF) fraction of fenugreek seed displayed no effect on the fasting blood glucose levels of nondiabetic or NIDDM model rats, but when fed simultaneously with glucose, it exhibited a significant hypoglycemic effect in NIDDM (noninsulin-dependent diabetes mellitus) model rats. Chemical analysis showed that the major constituent of the SDF was a galactomannan. Aqueous extract of *Trigonella foenum-graecum* leaves administered both orally and intraperitoneally exerted a hypoglycaemic effect in normoglycaemic and alloxan induced hyperglycaemic rats (Abdel-Barry et al. 1997). The LD_{50} of i.p. and oral administration were 1.9 and 10 g/kg respectively. The glycosidic extract of *T. foenum-graecum* leaves was considered to be safe at its medium lethal dose and had minimal adverse effect in treated mice (Abdel-Barry and Al-Hakiem 2000). Zia et al. (2001) found that the methanolic extract of *Trigonella foenum-graecum* seeds administered orally to normal mice produced hypoglycaemic effect only at the dose of 1 g/kg body weight. Fenugreek seed powder treatment to alloxan diabetic rats for 21 days lowered the elevated fasting blood glucose levels and restored altered glycolytic, gluconeogenic enzyme activities in the liver and kidney to control levels (Raju et al. 2001). The antidiabetic effect was attributed to improved glucose

homeostasis in the liver and kidney. In another study, oral administration of fenugreek seed extract to subdiabetic and mild diabetic rabbits for 15 days caused significant attenuation of the glucose tolerance curve and amelioration in the glucose induced insulin response, suggesting that the hypoglycemic effect may be mediated through promoting insulin synthesis and/or secretion from the β pancreatic cells of Langerhans (Puri et al. 2002). Prolonged administration of the same dose for 30 days to the overtly diabetic rabbits reduced fasting blood glucose significantly, but could elevate the fasting serum insulin level to a much lower extent, which suggested an extra-pancreatic mode of action for the active principle. The effect may also be attributed to increased sensitivity of tissues to available insulin. The hypoglycemic effect was observed to be slow but sustained, without any risk of developing severe hypoglycemia.

Studies showed that blood glucose and serum and tissue lipids were elevated in STZ-induced diabetic rats. Supplementation of fenugreek leaves for 45 days lowered the elevated serum and tissue lipid profile and blood glucose levels in streptozotocin -induced diabetic rats (Balakrishnan and Prince 2004). Studies by Xue et al. (2007) found that *Trigonella foenum-graecum* seed extract lowered kidney/body weight ratio, blood glucose, glycated haemoglobin, triglycerides, total cholesterol and higher higher-density-lipoprotein-cholesterol in streptozotocin-induced diabetic rats following repeated treatment for 6 weeks. The extract also improved hemorheological properties (plasma viscosity, blood viscosity, erythrocyte sedimentation and platelet conglutination). Hannan et al. (2007) found that *Trigonella foenum graecum* soluble dietary fibre (SDF) exerted antidiabetic effects through inhibition of carbohydrate digestion and absorption, and enhancement of peripheral insulin action. The SDF fraction suppressed the elevation of blood glucose after oral sucrose ingestion in both non-diabetic and type 2 diabetic rats. The SDF fraction decreased intestinal disaccharidase activity and glucose absorption, but elevated gastrointestinal motility. Daily oral administration of SDF to type 2 diabetic rats for 28 days lowered serum glucose, elevated d liver glycogen content and increased total antioxidant status. Glucose transport in 3T3-L1 adipocytes and insulin action were enhanced. The ethanolic fenugreek seed extract significantly reduced the blood glucose levels in alloxan-induced diabetic rats (Mowla et al. 2009). The most effective dose obtained was 1 g/kg. No acute toxicity was observed for when the extract was administered orally at high dose level (3 g/kg body weight).

Supplementation of fenugreek leaves mixed with diet at doses of 0.5 g and 1.0 g/kg of body weight twice daily to streptozotocin-induced diabetic rats for 45 days produced change in bodyweight, increased weight of pancreas, and the insulin levels and significantly decreased fasting blood glucose contents (Balakrishnan and Menon 2010). Fenugreek leaves ameliorated the functional state of the pancreatic β-cells and partially retained the damage caused by streptozotocin to the pancreatic islets. The effect observed with the fenugreek leaves was better than that of glibenclamide (600 μg/kg bodyweight). Tripathi and Chandra (2009, 2010) reported that treatment of alloxan-induced diabetic rats for 30 days with *Momordica charantia* and *Trigonella foenum graecum* significantly ameliorated fasting blood glucose levels to near normal glucose levels and TBARS levels. On administration of *M. charantia* and *T. foenum graecum*, lipid peroxidation was reduced, and antioxidant enzymes activities (superoxide dismutase, catalase, reduced glutathione content and glutathione-s-transferase) enhanced. The results demonstrated that *M. charantia* and *T. foenum graecum* were not only useful in controlling the blood glucose levels, but also had antioxidant potential to protect vital organs such as heart and kidney against damage caused due to diabetes induced oxidative stress.

Separate administrations of sodium orthovanadate and fenugreek seed powder (TSP) to diabetic rats were able to restore the elevated activities of mitochondrial and cytosolic aminotransferases and arginase to control values (Thakran et al. 2003). The lower dose of sodium orthovanadate (0.2%) administered in combination with TSP to diabetic rats lowered the enzyme activities more significantly than when given in a

higher dose (0.6%) separately during experimental type-1 diabetes. The combined oral administration of sodium orthovanadate and TSP to diabetic rats provided a possible method to minimize potential vanadate toxicity without compromising its positive effects in the therapy of experimental type-1 diabetes. Lower doses of vanadate could be used in combination with TSP to effectively counter diabetic alterations in glucose levels and enzymatic activities (pyruvate kinase, phosphoenolpyruvate carboxykinase, glutathione peroxidase, glutathione reductase, superoxide dismutase and catalase) without any toxic side effects (Mohamad et al. 2004; Siddiqui et al. 2005). Treatment with SOV and TSP significantly decreased elevated blood glucose, glycosylated haemoglobin levels and polyol pathway enzymes (aldose reductase and sorbitol dehydrogenase) that caused accumulation of sorbitol and fructose in the diabetic lens down to control levels (Preet et al. 2006). Similarly, SOV and TSP treatments modulated the activities of hexokinase, glucose-6-phosphate dehydrogenase, glutathione peroxidase and glutathione reductase in the rat lens to control values. Ultrastructure of the diabetic retina revealed disintegration of the inner nuclear layer cells with reduction in rough endoplasmic reticulum and swelling of mitochondria in the bipolar cells; and these histopathological events were effectively restored to control state by sodium orthovanadate and TSP treatments. The results indicated the potential of sodium orthovanadate and TSP alone or in low dose combination as promising approaches for the prevention of diabetic retinopathy and other ocular disorders. TSP treatment to the diabetic rats effectively prevented the alteration in the activities of the two enzymes, glutamate dehydrogenase and D-β-hydroxybutyrate dehydrogenase (Thakran et al. 2004). The treatment also partially prevented the structural abnormalities in the liver and kidney thus suggesting a protective effect of TSP on the liver and kidney of the diabetic rats.

Fenugreek oil was found to significantly improve blood glucose levels, glucose intolerance, and insulin sensitivity compared to the diabetic group (Hamden et al. 2010a). The pancreatic islet and less β-cells damage were observed after the administration of fenugreek oil to diabetic rats. Fenugreek oil restored to near normal levels the low activities of superoxide dismutase, catalase, glutathione peroxidase, and reduced glutathione content in kidney of diabetic rats. The elevated levels of lipid peroxidation, creatinine, albumin, and urea in diabetic rats decreased significantly in diabetic rats treated with fenugreek oil. Diabetic rats treated with fenugreek oil restored almost a normal architecture of pancreas and kidney. The study indicated the efficacy of fenugreek oil in the amelioration of diabetes, hematological status, and renal toxicity which may be attributed to its immunomodulatory activity and insulin stimulation action along with its antioxidant potential.

GII an anti-hyperglycemic compound purified form the aqueous fenugreek seed extract at 50 mg/kg body weight, po, decreased blood glucose in glucose tolerance test (GTT) in the sub-diabetic and moderately diabetic rabbits and significantly lowered the area under the curve (AUC) of GTT (Moorthy et al. 2010a). Treatment of moderately diabetic rabbits with GII (100 mg/kg body weight for 3 weeks) reduced fasting blood glucose (FBG) to nearly normal value and ameliorated GTT. GII was more effective than the standard drug tolbutamide. Intermittent therapy given on days 1–5, 11–15, 26–30 and 56–60 to moderately diabetic rabbits leaving in between days without treatment lowered FBG to normal and AUC during GTT was unaltered. After 15 days treatment with GII (100 mg/kg body weight for 3 weeks) glycosylated haemoglobin declined and insulin increased to normal values in the sub-diabetic, moderately diabetic and severely diabetic rabbits. GII treatment (100 mg/kg body weight for 15 days) decreased all the altered serum lipids (TC, HDLC, TAG, PLs and FFAs) to normal levels. The results suggested that intermittent therapy, instead of daily therapy was possible and GII had good potential as an oral anti-diabetic drug with intermittent therapy. GII appeared to decrease lipid content of liver and stimulated the glycolytic enzymes (phosphofructokinase and pyruvate kinase except glucokinase) (Moorthy et al. 2010b). GII also inhibited

enzymes of gluconeogenesis (glucose-6-phosphatase and fructose-1,6-diphosphatase) in the liver of the diabetic especially moderately diabetic rabbits.

Daily oral treatment of fenugreek steroids, designated F(steroids), to diabetic rats during 30 days demonstrated a decrease of blood glucose level and a considerable increase of the area of insulin-immunoreactive β-cells in diabetic rats (Hamden et al. 2010b). The study showed that F(steroids) enhanced testosterone and estradiol levels in the plasma of surviving diabetic rats by unregulating key steroidogenesis enzymes such as 3-hydroxy-3-methyl-glutaryl-CoA reductase (HMG-CoA reductase), malic enzyme, 3β-hydroxysteroid dehydrogenase (3β-HSD) and glucose-6-phosphate dehydrogenase (G6P-DH) activities in the rat testis. In addition, F(steroids) prevented the alteration of the key carbohydrate enzymes such as hexokinase and pyruvate kinase activities as well as testicular glycogen and seminal fructose contents in surviving diabetic rats. Further, F(steroids) administration to surviving diabetic rats significantly decreased the sperm shape abnormality and improved the sperm count. The potential protective action of reproductive systems was confirmed by the histological study of testis and epididymis.

Vats et al. (2004) found that administration of the plant extracts *Pterocarpus marsupium* bark, *Trigonella foenum-graecum* seeds and *Ocimum sanctum* leaves, exerted a favourable effect on body weight and blood glucose in descending order of effectiveness in animal studies. *Pterocarpus marsupium* and *Trigonella* exhibited anti-cataract effect as indicated from decreased opacity index. However, *Ocimum sanctum* failed to produce any anti-cataract effect in spite of significant antihyperglycemic activity.

A double-blind, randomized balanced study showed that acceptable baked products could be prepared with added fenugreek, which would reduce insulin resistance and treat type 2 diabetes (Losso et al. 2009). The area under the curve for glucose and insulin was lower in the diabetic subjects fed fenugreek bread, but only reached significance with insulin. There was no statistically significant difference in proximate composition, colour, firmness, texture, and flavour intensity between the fenugreek and wheat bread. The fenugreek-containing bread was indistinguishable from the whole wheat bread control.

Anti dyslipidemic/Anti hypertriglyceridemic/Anti obesity Activities

In a placebo controlled study fenugreek (2.5 g) administered twice daily for 3 months to coronary artery disease (CAD) and non-insulin-dependent diabetes mellitus (NIDDM) patients significantly decreased blood lipids (total cholesterol and triglycerides) without affecting the HDL-cholesterol (Bordia et al. 1997). However, fenugreek given in the same daily dose for the same duration to healthy individuals did not affect the blood lipids and blood sugar (fasting and post-prandial). When administered in the same daily dose to NIDDM (non-CAD) patients (mild cases), fenugreek lowered significantly the blood sugar (fasting and post-prandial). In severe NIDDM cases, blood sugar (both fasting and post-prandial) was only slightly reduced. The changes were not significant. Fenugreek administration did not affect platelet aggregation, fibrinolytic activity and fibrinogen.

Gupta et al. (2001) using a double blind placebo controlled study found that adjunct use of fenugreek seeds improved glycemic control and decreased insulin resistance in mild type-2 diabetic patients. In patients administered hydroalcoholic extract of fenugreek seeds, insulin and area under curve of glucose were lower. Also there was a decrease in percent β-cell secretion and increase in percent insulin sensitivity compared with the placebo group. There was also a favourable effect on hypertriglyceridemia as they exhibited lower serum triglycerides and an increase in HDL cholesterol.

Studies by Hannan et al. (2003) found that *Trigonella foenum graecum* soluble dietary fibre (SDF) from the seeds exerted a effect on dyslipidemia and a tendency to inhibit platelet aggregation in Type 2 model diabetic rats. The SDF

fraction lowered serum fructosamine level and atherogenic lipids, i.e. triglycerides, cholesterol and LDL-cholesterol. Conversely the extract elevated HDL-cholesterol. No significant effect on platelet aggregation was found although there was a tendency to lower the aggregation. The unusual amino acid, 4-hydroxyisoleucine 5, isolated from fenugreek seeds, was found to significantly lower the plasma triglyceride levels by 33%, total cholesterol (TC) by 22% and free fatty acids by 14% (Narender at al. 2006). This was accompanied by an elevation in HDL-C/TC ratio by 39% in the dyslipidemic hamster model. In a separate study, 4-Hydroxyisoleucine (50 mg/kg), isolated from fenugreek seeds when given orally to type II diabetic mice, lowered their elevated blood glucose, plasma insulin, triglycerides, total cholesterol, low-density lipoprotein-cholesterol levels and elevated their lowered plasma high-density lipoprotein-cholesterol level (Singh et al. 2010). This effect was attributed to enhancement of insulin sensitivity and glucose uptake in peripheral tissue.

Repeated administration of a fenugreek seed extract to over-weight male individuals, slightly but significantly decreased dietary fat consumption in healthy overweight subjects, in a 6-week double-blind randomized placebo-controlled parallel study (Chevassus et al. 2010). There was a significant decrease in the insulin/glucose ratio in subjects treated with fenugreek seed extract relative to the placebo group. No significant effect was observed on weight, appetite/satiety scores or oxidative parameters. In a single blind, randomized, crossover study, fenugreek fibre (8 g) given to healthy obese subjects at breakfast significantly increased satiety and reduced energy intake at lunch, suggesting it may have short-term beneficial effects in obese subjects (Mathern et al. 2009). Satiety results were not related to postprandial blood glucose.

A novel thermostable extract of fenugreek seeds (TEFS) exhibited hypolipidemic effect, attributable to inhibition of fat accumulation and enhancement of low-density lipoprotein receptor (LDLR) expression (Vijayakumar et al. 2010). At molecular level, TEFS suppressed fat accumulation in differentiating and differentiated 3T3-L1 cells via decreased expression of adipogenic factors such as peroxisome proliferators activated-receptor-gamma (PPAR-gamma), sterol regulatory element-binding protein-1 (SREBP-1), and CAAT element-binding proteins-alpha (c/EBP-alpha). Following TEFS treatment, cellular triglycerides (TGs), and cholesterol concentrations decreased significantly in HepG2 cells via reduced expression of SREBP-1, at mRNA as well as protein level. Under sterol enriched condition, TEFS enhanced LDLR expression resulting in increased LDL uptake. Treating fat supplement fed C57BL6/J mice with TEFS for 15 days resulted in decrease of serum TG, LDL-cholesterol (), and body weight in a dose- and time-dependent fashion. The study suggested that fenugreek seed extract may have potential application in the management of dyslipidemia and its associated metabolic disorders.

Administration of fenugreek ethyl acetate extract significantly lowered the plasma levels of total cholesterol (TC), triglycerides (TG), and low-density lipoprotein cholesterol (LDL-C), while increasing the plasma level of high-density lipoprotein cholesterol (HDL-C) (Belguith-Hadriche et al. 2010). Further, the content of TBARS and catalase (CAT) and superoxide dismutase (SOD) activities in liver, heart and kidney decreased significantly after oral administration of the extract compared with those of rats fed a cholesterol-rich diet. These lipid effects and in-vivo antioxidative effects were correlated with the in-vitro phenolic content scavenging ability. Additionally, three flavonoids (kaempferol 3-O-glycoside, apigenin-7-O-rutinoside, and naringenin) were identified with naringenin (7.23 mg/g) being the most abundant flavonoid compound in the ethyl acetate extract. The results revealed significant hypocholesterolemic effects and antioxidant activity in an ethyl acetate extract of fenugreek seed, which may be partly due to the presence of flavonoids, especially naringenin.

Treatment of KK-Ay mice with a high fat diet supplemented with 2% fenugreek ameliorated diabetes (Uemura et al. 2010). Further, fenugreek attenuated the adipocytes and elevated the mRNA expression levels of differentiation-related genes in adipose tissues. Fenugreek also inhibited macrophage infiltration into adipose tissues and lowered the mRNA expression levels of

inflammatory genes. Additionally, diosgenin, a major aglycone of saponins in fenugreek, was found to promote adipocyte differentiation and to suppress expressions of several molecular candidates associated with inflammation in 3T3-L1 cells. These results suggested that fenugreek ameliorated diabetes by promoting adipocyte differentiation and inhibiting inflammation in adipose tissues, and its effects were mediated by diosgenin. Fenugreek containing diosgenin may be useful for ameliorating the glucose metabolic disorder associated with obesity.

Antinociceptive/Analgesic Activities

Trigonella foenum-graecum leaf extract exerted antinociceptive effects through central and peripheral mechanisms as evaluated using tail-flick and formalin tests (Javan et al. 1997). The antinociceptive effects of 2,000 mg/kg of the extract was more potent than 300 mg/kg of sodium salicylate.

All the extracts (petroleum ether, chloroform, ethyl acetate and methanolic) of *Trigonella foenum-graecum* seeds and leaves exhibited significant central and peripheral analgesic activity at the dose of 50 mg/kg intraperitoneally in mice (Bhalke et al. 2009). Amongst all the extracts, the methanolic extract of leaves displayed highest increase in reaction time in hot plate method and more inhibitory effect on writhing induced by acetic acid. *Trigonella foenum-graecum* leaf extract showed analgesic effects in intraperitoneal (i.p.) (1 g/kg) and intrathecal (i.t.) (0.5, 1, and 2 mg/rat) but not in intra-cerbroventricular (i.c.v) (1 and 3 mg/rat) administrations in rat using both formalin and tail flick tests (Parvizpur et al. 2004). The results confirmed the central action of fenugreek extract and that spinal serotonergic system, but not endogenous opioid system, was involved in *Trigonella* induced analgesia (in the second phase of formalin test). Subsequent studies suggested that the blocking of spinal purinoceptors may contribute to the analgesic effect *T. foenum graecum* leaf extract (Parvizpur et al. 2006). The leaf extract inhibited ADP induced platelet aggregation, α, β-Me-ATP induced isometric contraction in vas deferens, and α, β-Me-ATP induced hyperalgesia in tail flick test.

Antiinflammatory and Antipyretic Activities

Trigonella foenum-graecum leaf extract was found to have antiinflammatory as well as antipyretic properties in both i.p. and p.o. (oral gavage) administration (Ahmadiani et al. 2001). Both the leaf extract (1,000 and 2,000 mg/kg) and sodium salicylate (300 mg/kg) significantly reduced formalin-induced edema in single dose and chronic administration. Both also significantly reduced hyperthermia induced by brewer's yeast in 1 and 2 h after their administration. Phytochemical studies indicated that alkaloids, cardiac glycosides, and phenols to be the major compounds in the extract. The ethanol extract of fenugreek seeds at dose 200 mg/kg showed significant antiinflammatory as evaluated using carrageenan induced rat paw edema (Malviya et al. 2010). The hydro alcoholic fenugreek extract exhibited significant antiinflammation and analgesic effect (Sofi et al. 2011). The hydro alcoholic extract reduced inflammation significantly in carrageenin induced rat paw edema. The extract reduced the number of writhing in acetic acid induced writhing test compared to control. However, in hot plate test all groups showed no significant difference in reaction time.

Application of *Trigonella foenum graecum* restored the inflammatory and oxidative damage caused to chronic restraint stressed mice skin induced by trichloroethylene and subsequently exposed to UVB (Ali and Sultana 2010). As compared to the non stressed toxicant groups, all the antioxidant enzymes: glutathione reductase (GR), glutathione-s-transferase (GST), glutathione peroxidase GPx, glucose 6-phosphate dehydrogenase (G6PD), and quinone reductase (QR), superoxide dismutase (SODs) and xanthine oxidase (XO) exhibited a significant decline following restraint stress. Lipid peroxidation and ornithine decarboxylase (ODC) increased significantly in the restraint stress group treated with trichloroethylene and UVB as compared with the non-stressed mice. Myeloperoxidase exhibited a significant decline in the stressed mice as compared to the non stressed toxicant groups where it increased significantly, suggesting suppressed non-specific immune response. *Trigonella* was

successful in ameliorating this oxidative stress, inflammation and ODC, suggesting a central role of oxidants in the pathology of stressed mice.

Antimelanogenic Activity

Studies indicated that fenugreek extract and its active constituents could protect against skin damage (Kawabata et al. 2010)The methanol fenugreek seed extract suppressed the production of phorbol-12-myristate-13-acetate-induced inflammatory cytokines such as tumour necrosis factor (TNF)- α in cultured THP-1 cells, and also hindered the intracellular synthesis of melanin in murine melanoma B16F1 cells. Three active constituents from fenugreek seed extracts were isolated and identified as the steroidal saponins 26-O-β-D-glucopyranosyl-(25R)-furost-5(6)-en-3 β,22 β,26-triol-3-O-α-L-rhamno-pyranosyl-(1″→2′)- O-[β- D-glucopyranosyl-(1‴→6')- O]-β- D-glucopyranoside 1, minutoside B 2, and pseudoprotodioscin 3. Compounds 1 and 2 strongly hindered the production of inflammatory cytokines, whereas 3 exhibited a weaker inhibitory effect. Melanogenesis in B16F1 cells was significantly suppressed by 1 and 3, and weakly suppressed by 2. All three compounds displayed moderate cytotoxicities. A water/oil emulsion formulation containing fenugreek seeds extract using liquid paraffin oil, caused a significant decrease on skin melanin and erythma when applied to the cheeks of human volunteers for 6 weeks (Waqas et al. 2010). An insignificant decrease in transepidermal water loss was observed for the formulation.

Antilithogenic Activity

Daily oral treatment with *Trigonella foenum-graecum* seed extract significantly decreased the quantity of calcium oxalate deposited in the kidneys of male rats with oxalate urolithiasis induced by 3% glycolic acid in their diet (Ahsan et al. 1989). The results supported its use in Saudi folk medicine. The effects obtained by *Amni majus* were not significant. Dietray fenugreek was found to have antilithogenic activity in the gallbladder (Reddy and Srinivasan 2009a, b). Studies in animals with pre-established cholesterol gallstones (CGS) induced by 10 weeks of high-cholesterol diet, when fed for another 10 weeks with high and low doses of fenugreek powder, incidence of CGS were significantly reduced dietary fenugreek significantly reduced concentrations of serum cholesterol, hepatic cholesterol and biliary chlosterol in the cholesterol fed animals. There was also reductions cholesterol:phospholipid ratio and biliary cholesterol:bile acid ratio. The cholesterol saturation index in the bile was also beneficially decreased by fenugreek treatment during the post-CGS induction period. The study provided distinct evidence of the potency of hypolipidemic fenugreek seeds in regressing pre-established CGS, and this beneficial antilithogenic effect was attributable to its primary influence on cholesterol levels and metabolism.

Immunomodulatory Activity

Trigonella foenum graecum plant extract was found to exert a stimulatory effect on immune functions in mice (Bin-Hafeez et al. 2003). The plant extract produced a significant elevation in the delayed type of hypersensitivity response at doses of 50 and 100 mg/kg. Humoral immunity as measured by plaque-forming cell assay exhibited an increased response only at a dose of 100 mg/kg. In the haemagglutination titre test, the extract demonstrated modulatory effect at all the doses. Additionally, the plant extract evoked a significant increase in phagocytic index and phagocytic capacity of macrophages. The immunostimulatory results supported its use in several Ayurvedic and Unani drugs.

Acetylcholinesterase Inhibitory Activity

The ethyl acetate fraction of the alcohol extract of fenugreek seeds and its total alkaloid fraction exhibited acetylcholinesterase inhibitory activity with IC_{50} values of 53 μg/ml and 9.23 μg/ml

respectively (Satheeshkumar et al. 2010). Trigonelline which was detected (13 mg/g) in the hydro alcoholic extract had an IC_{50} of 233 μM. Acetylcholinesterase inhibitors had been reported to give a symptomatic relief to some of the clinical manifestations of memory disorders.

Hepatoprotective Activity

Fenugreek (*Trigonella foenum graecum*) seed extract exhibited cytoprotective effects against ethanol-induced toxicity and apoptosis in chang liver cells (Kaviarasan et al. 2006). Incubation of the polyphenolic extract of fenugreek seeds significantly increased cell viability in a dose-dependent manner, caused a reduction in lactate dehydrogenase leakage and normalized reduced glutathione/oxidized glutathione ratio. The extract reduced apoptosis by decreasing the accumulation of sub-G1 phase cells in EtOH-treated cells. The extract dose-dependently reduced thiobarbituric acid reactive substances formation. The cytoprotective effects of the extract were comparable with those of a positive control silymarin, a known hepatoprotective agent. The findings suggested that the polyphenolic compounds of fenugreek seeds could be deemed cytoprotective during EtOH-induced liver damage.

Cardio-vascular Protective Activity

A novel cardenolide from fenugreek seeds identified as digoxigenin-3-O-rutin, ameliorated isoproterenol-induced myocardial infarction in rat (Pandar and Kar 2010). digoxigenin-3-O-rutin at 10 mg/kg markedly reduced the isoproterenol-induced increase in cardiac lipid peroxidation and in the levels of serum creatinine phosphokinase-MB, glutamate oxaloacetate transaminase, glutamate pyruvate transaminase, lactate dehydrogenase, and creatinine. It also reversed the isoproterenol -induced changes in the cardiac histomorphology. digoxigenin-3-O-rutin appeared to be more potent and safer than digoxin, the commonly used cardiac glycoside.

Anabolic Activity

The furostanol glycosides fraction of *Trigonella foenum-graecum* (Fenu-FG) displayed anabolic activity without androgenic activity (Aswar et al. 2010). Fenu-FG (35 mg/kg p.o.) and testosterone (10 mg/kg, s.c. biweekly) increased the weight of the levator ani muscle as well as body weight of immature castrated male Wistar rats. Fenu-FG (10 or 35 mg/kg p.o.) did not change the testosterone level in castrated rats. The testis of non-castrated rats treated with Fenu-FG (10, 35 mg/kg p.o.) exhibited normal architecture of the testis.

Estrogenic Activity

Fenungreek seeds have estrogenic activities and could be a suitable alternative to HRT (hormone replacement therapy) (Sreeja et al. 2010). The chloroform extract of fenugreek seeds stimulated the proliferation of MCF-7 breast cancer cells. It showed binding to estrogen receptor (IC_{50} = 185.6 μg/ml) and acted as an agonist for estrogen receptor mediated transcription via ERE (estrogen receptor element). It also induced the expression of estrogen responsive gene pS2 in MCF-7 cells.

Antibacterial Activity

Ethanolic fenugreek seed extract exhibited antibacterial activity against selected Gram positive and negative bacteria that included : *Escherichia coli, Salmonella typhi, Vibrio cholera, Staphylococcus aureus, Bacillus subtilis* and *Mycobaterium luteum*.(Khanra et al. 2010).

Antiplasmodial Activity

Ethanol extract (50%) of fenugreek plant exhibited potent anti-plasmodial activity with IC_{50} value of 8.75 μg/ml and 10.25 μg/ml against chloroquine sensitive and resistant *Plasmodium falciparum* isolates, respectively (Palaniswamy

et al. 2010). Among the investigated six fractions of the plant extracts, ethanol and butanol extracts were found to have significant anti-plasmodial activity with IC_{50} values <10 μg/ml. Two extracts chloroform and ethyl acetate sexhibited moderate activity with IC_{50} values ranging from 10 to 20 μg/ml, and the other two extracts, hexane and water appeared to be inactive with IC_{50} values >85 μg/ml. Further, preliminary phytochemical screening of the various extracts indicated the presence of alkaloids, saponin, tannin like phenolic compounds, flavonoids and steroids.

Teratogenic Effect

Results of studies concluded that fenugreek seeds extract may have deleterious toxic effects on reproductive performance and potential teratogenic effects in foetuses (Khalki et al. 2010). Administration of lyophilized aqueous extract from fenugreek seeds to mated female mice during the entire period of pregnancy, at doses of 500 and 1,000 mg/kg/day caused developmental toxicity in offspring. There was an increase in the foetal death rate, a decrease in the litter size, and a reduction in the foetal body weight. In addition there was an increase in the incidence of morphological abnormalities.

Traditional Medicinal Uses

Fenugreek seed is regarded in traditional medicine as a carminative, aperient, diuretic, supporative, demulcent, expectorant, laxative, and stomachic. Traditionally, fenugreek seeds are used to stimulate metabolism and to help control blood sugar levels in diabetes, to relieve stomach and digestive disorders, to lower blood pressure, and to treat anaemia. It has also been employed against bronchitis, fevers, sore throats, wounds swollen glands, skin irritations, diabetes, ulcers, and in the treatment of cancer. Fenugreek seed is widely used as a galactagogue (milk producing agent) by nursing mothers to increase inadequate breast milk supply. Fenugreek has also been used as an aphrodisiac and as an oral insulin substitute.

In Ethiopia it is used as a natural herbal medicine in the treatment of diabetes. It has been employed for dropsy, heart disease, chronic cough and enlargement of the spleen and liver and as poultices applied to burns in Malaysia and in Java. It has been used in complex oil mixtures for small pox. In India, fenugreek seeds are mixed with yogurt and used as a conditioner for hair. It has been used during the middle ages for baldness and in Indonesia as hair tonic.

Fenugreek is currently available commercially in encapsulated forms and is being prescribed as dietary supplements for the control of hypercholesterolemia and diabetes by practitioners of complementary and alternative medicine.

Other Uses

The plant contains the alkaloid trigonelline and an essential oil which is used as an insect repellent. *Trigonella foenum-graecum* has been used as an anthelmintic against most common nematodes. The extracted oleoresin from Fenugreek seeds is extensively used in perfumery, cosmetics and hair oils and tonics. Fenugreek seeds are used as a source of dye and industrial galactomannan mucilage. In Europe the seeds are used in veterinary preparations, and in Java for glanders (bacterial respiratory disease of horses). The plant is also grown for animal fodder, forage and green manure for soil improvement. In Canada, fenugreek is developed as a high quality hay crop. Fenugreek herbage is incorporated with hay to promote animal health and to enhance the acceptability of spoiled hay In India, fenugreek is often used as a cover crop in citrus fruit orchards to take advantage of its nitrogen-fixing qualities.

Comments

Fenugreek (*Trigonella foenum-graecum*) is one of the oldest cultivated spice and medicinal plants. It was used by the ancient Egyptians as a food, medicine and embalming agent. Today it is widely grown in the Mediterranean countries, France, India, North Africa, Argentina, and the

United States as a food, condiment, medicinal, dye, and forage plant. The plant is not grown in southeast Asia, but is widely used as a spice, introduced centuries ago by Arab and Indian travellers. India is the major world producer of fenugreek. The spice is exported as whole seed and in powdered forms, as well as in the form of extracted oil.

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Vicia faba

Scientific Name

***Vicia faba* L.**

Synonyms

Faba bona Medik., *Faba equina* Medik., *Faba faba* (L.) H.D. House, *Faba major* Desf., *Faba minor* Roxb., *Faba sativa* (L.) Bernh., *Faba vulgaris* Moench, *Faba vulgaris* var. *major* Harz, *Faba vulgaris* var. *minor, Faba vulgaris* var. *minuta* hort. ex Alef., *Potamogeton bifolius* Lapeyr., *Vicia esculenta* Salisb., *Vicia faba* var. *major* (Harz) Beck, *Vicia faba* var. *minor* (Harz) Beck, *Vicia faba* L. forma *anacarpa* Makino, *Vicia faba* L. subsp. *faba* L.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Bell Bean, Broad Bean, English Bean, Fava Bean, Faba Bean, Field Bean, Haba, Horse Bean, Field Bean, Tic Bean, Tick Bean, Windsor Bean

Vernacular Names

Arabic: Fûl, Bâqilâ;
Burmese: Sandusi;
Canada: Gourgane;
Chinese: Can Dou, Hu Dou, Tsaam Dou, Ts'an Tou, Zan Dou;
Czech: Bob Obecný;
Danish: Agerbønne, Hestebønne, Vælskbønne, Valsk Bønne;
Dutch: Duiveboon, Groote Boon, Molboon, Paardeboon, Roomsche Boon, Veldboon Tuinboon, Tuinbonen;
Eastonian: Põlduba;
Ethiopia: Bakela;
Finnish: Härkäpapu;
French: Fève, Fève De Marais, Féverole, Grosse Fève, Grosse Fève Commune, Gorgane;
German: Acker-Bohne, Dicke Bohne, Pferde-Bohne, Puffbohne,Sau-Bohne, Saubohnen;
Greek: Κουκιά, Koukiá;
Hungarian: Disznóbab, Laposbab, Lóbab, Lóbükköny;
India: Anhuri, Bakla, Kala Matar (Hindu), Bakla, Chastang, Kabli Bakla (Punjabi);
Indonesia: Kacang Babi, Ontjet (Javanese), Kacang Diéng, Kacang Babi;
Italian: Fava, Fava Grossa Comune, Fagioli;
Japanese: Gora-Mame, Sora Mame, Otafuku-Mame;

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Norwegian: Baunevikke;
Pakistan: Bakla;
Persian: Bagli, Bakila;
Polish: Wyka Bob, Bób;
Portuguese: Fava, Faveira;
Russian: Konskij Bob;
Slovašcina: Grašica-Bob;
Spanish: Haba, Haba Común, Haba Mayor, Haba De Huerta, Habas, Habichuela, Haboncillo, Faba;
Sudan: Ful Masri;
Swedish: Åkerböna, Bondböna;
Thai: Thua Yang;
Turkish: Bakla, Yeshil Bakla;
Welsh: Ysgewyll Brysel.

Origin/Distribution

Faba bean is known only in cultivation. However some authorities believed that it originated in south-west Asia and in North Africa. Faba beans have a long tradition of cultivation in old world agriculture. Today, it is widely cultivated in Europe and other cool climatic regions.

Agroecology

Faba bean is a cool climate crop. It is grown from near sea level to an altitude of 3,700 m. It is grown as a winter annual in warm temperate and subtropical areas. Optimum temperature for production is from 18 to 27°C. Depending on the hardiness of the cultivars, temperatures in the Mediterranean area as low as 15 or 10°C can be tolerated without detriment. In tropical areas it can be grown in the higher elevation but it does not produce pods in humid or high rainfall areas. Annual rainfall of 650–1,000 mm uniformly distributed throughout the year is most suitable for faba beans; it is deemed as the least drought tolerant of all the legume crops.

Faba bean is tolerant of a wide range of soil; types but thrive best in fertile, moist, well-drained loams. It is more tolerant to acid soil conditions than most legumes and can be grown without liming.

Edible Plant Parts and Uses

Faba beans are used as pulses or as vegetables and the young leaves eaten as vegetables. Faba beans are eaten while still young and tender; the beans are also dried and canned. The beans can be fried, causing the skin to split open, and then salted to produce a crunchy snack. These are popular in China, Peru (*habas saladas*), Mexico (*habas con chile*) and also in Thailand where their name means "open-mouth nut". Roasted seeds are eaten like peanuts in India. In the Szichuan cuisine of China, broad beans are combined with soybeans and chilli peppers to produce a spicy fermented bean paste called *doubanjiang*.

In most Arab countries the faba bean (usually crushed) is used for a breakfast meal called *Ful Medames*. Other popular dishes of faba bean are *Medamis* (stewed beans), *Falafel* (deep fried cotyledon paste with some vegetables and spices), *Bissara* (cotyledon paste poured onto plates) and *Nabet* soup (boiled germinated beans). In Egyptian diet, faba beans are the most common fast food. The most popular way of preparing faba beans in Egypt is by taking the cooked beans and adding oil, garlic, lemon, salt and cumin to it. It is then eaten with bread. Faba bean has also been considered as a meat extender or substitute and as a skim-milk substitute. In Greece, young faba beans in pods are combined with artichokes in a stew and eaten; the dried beans are eaten boiled, sometimes mixed with garlic sauce. In Crete, fresh broad beans are shelled and eaten as accompaniment to the alcoholic drink *tsikoudia.*

Botany

Annual erect robust herb, 60–120 cm tall (Plate 1). Stem is tetragonous, thick and glabrous. Leaves are distichous, paripinnate with one to three pairs of leaflets and hastate or triangular-ovate, 10–17 mm long stipules. Leaflets oblong, elliptic or obovate, 4.0–10.0 cm long, 1.0–4.0 cm wide, oval to elliptic, obtuse, glabrous with mucronate apex. Flowers 1–6, in axillary racemes. Calyx

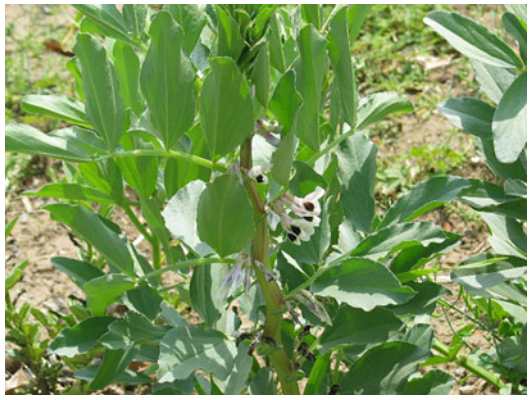

Plate 1 Leaves and flowers

Plate 2 Broad bean pods

Plate 3 Fresh broad beans

Plate 4 Brown broad beans

12–15 mm long, campanulate and unequally toothed; Corolla white with dark violet spots (Plate 1), standard petal constricted in the middle longer than the wings and wings longer than the keel; ovary sessile and linear, one-celled with 2–4(−6) ovules. Legume pod turgid, coriaceous, 8–25 cm long by 2.0–3.0 cm broad, pubescent green (Plates 2 and 3) maturing to blackish-brown. Each pod contains 2–4(−6) seeds. Seeds 2.0–3.0 cm, 5–10 mm thick, ovoid-oblong, laterally compressed.

Nutritive/Medicinal Properties

Raw fava bean in pod was reported to have the flowing nutrient composition per 100 g edible portion (3% ends excluded) (USDA 2010): water 72.60 g, energy 88 kcal (370 kJ), protein 7.92 g, total lipid 0.73 g, ash 1.12 g, carbohydrates 17.63 g, Ca 37 mg, Fe 1.55 mg, Mg 33 mg, P 129 mg, K 332 mg, Na 25 mg, Zn 1.00 mg, Cu 0.402 mg, Mn 0.661 mg, Se 0.8 μg, vitamin C 3.7 mg, thiamine 0.133 mg, riboflavin 0.290 mg, niacin 2.249 mg, pantothenic acid 0.225 mg, vitamin B-6 0.104 mg, total folate 148 μg, vitamin A 333 IU, vitamin A, RAE 17 μg, β-carotene 196 μg, β-cryptoxanthin 9 μg, phytosterols 22 mg, stigmasterol 1 mg, campesterol 3 mg, β-sitosterol 18 mg, total saturated fatty acids 0.118 g, 12:0 (lauric acid) 0.001 g, 14:0 (myristic acid) 0.002 g, 15:0 (pentadecanoic acid) 0.002 g, 16:0 (palmitic acid) 0.065 g, 18:0 (stearic acid)

0.028 g, 20:0 (arachidic acid) 0.010 g, 22:0 (behenic acid) 0.005 g, 24:0 (lignoceric acid) 0.003 g; total monounsaturated fatty acids 0.104 g, 16:1 undifferentiated (palmitoleic acid) 0.004 g, 18:1 undifferentiated (oleic acid) 0.097 g, 20:1 (gadoleic acid) 0.003 g; total polyunsaturated fatty acids 0.342 g, 18:2 undifferentiated (linoleic acid) 0.312 g and 18:3 undifferentiated (linolenic acid) 0.03 g (Plate 4).

Analyses carried out in the United States reported that raw, mature broad bean seeds had the following proximate composition (per 100 g edible portion): water 10.98 g, energy 341 kcal (1,425 kJ), protein 26.12 g, total lipid 1.53 g, ash 3.08 g, carbohydrates 58.29 g, total dietary fibre 25.0 g, total sugars 5.70 g, Ca 103 mg, Fe 6.70 mg, Mg 192 mg, P 421 mg, K 1,062 mg, Na 13 mg, Zn 3.14 mg, Cu 0.824 mg, Mn 1.626 mg, Se 8.2 μg, vitamin C 1.4 mg, thiamine 0.555 mg, riboflavin 0.333 mg, niacin 2.832 mg, pantothenic acid 0.976 mg, vitamin B-6 0.366 mg, total folate 423 μg, choline 95.8 mg, vitamin A 53 IU, vitamin E (α-tocopherol) 0.05 mg, vitamin K (phylloquinone) 9 μg, total saturated fatty acids 0.254 g, total monounsaturated fatty acids 0.303 g, total polyunsaturated fatty acids 0.627 g, phytosterols 124 mg, tryptophan 0.247 g, threonine 0.928 g, isoleucine 1.053 g, leucine 1.964 g, lysine 1.671 g, methionine 0.213 g, cystine 0.334 g, phenylalanine 1.103 g, tyrosine 0.827 g, valine 1.161 g, arginine 2.411 g, histidine 0.664 g, alanine 1.070 g, aspartic acid 2.916 g, glutamic acid 4.437 g, glycine 1.095 g, proline 1.099 g, serine 1.195 g and β-carotene 32 μg (USDA 2010).

Broad bean is exceedingly nutritious and very rich in proteins, amino acids, fibre, carbohydrates, folate, niacin, pantothenic acid, and minerals like Ca, Fe, K, Mg, P, Zn, and Se. Its amino acid composition is well balanced. Its concentration of unsaturated fatty acids is high, accounting 88% of its total fatty acid composition.

Other Phytochemicals

The seed globulins from *Vicia faba* predominantly were found to consist of two components, vicilin and legumin, exclusively located within the protein bodies of the storage cotyledons (Scholz and Manteuffel 1975). Vicilin being characterized by micro-heterogeneity appeared to indicate molecular polymorphism. Studies also revealed the heterogeneity of broad bean legumin (Utsumi and Mori 1980). The nature of the heterogeneity was common to all cultivars examined in terms of the molecular sizes of the subunits. Four groups of molecular species with molecular weights of 320,000, 350,000, 380,000 and 400,000 were detected. The smallest molecular species was composed of only three kinds of subunit, with molecular weights of 20,500, 23,000 and 36,000, and the largest one was composed of five kinds of subunit with molecular weights of 19,000, 23,000, 36,000, 49,000 and 51,000. All molecular species were composed of intermediary subunits which consisted of acidic and basic subunits.

Free and esterified sterols were found in seeds of five cultivars of *Vicia faba* (Cerri et al. 1985). Sitosterol was the most abundant free sterol, followed by stigmasterol and campesterol. Cholesterol could not be detected. Esters were generally present in greater amounts than the free form of sterols.

Immature fruit of *Vicia faba* was found to contain plant growth regulators (−)-jasmonic acid and (+)-7-iso-jasmonic acid and three structurally related cyclopentanoidal C12-acids, identified as (−)-9,10-dihydrojasmonic acid, 3,7-didehydrojasmonic acid and (+)-6-epi-7-iso-cucurbic acid (Miersch et al. 1989).

From the leaves of *Vicia faba*, one known and five new flavonol glycosides were identified: kaempferol 3-O-(2″-α-l-rhamnopyranosyl-6″-acetyl-β-d-galactopyranoside)-7-O-α-l-rhamnopyranoside, kaempferol 3-O-(6″-acetyl-β-d-galactopyranoside)-7-O-α-l-rhamnopyranoside, quercetin 3-O-(6″-acetyl-β-d-galactopyranoside)-7-O-α-l-rhamnopyranoside and their deacylated derivatives (Tomás-Lorente et al. 1989). The aerial parts of *Vicia faba* – leaves and stems were found to contain a considerable amount of flavonol glycosides (Tomás-Lorente et al. 1990). The extraction yield (about 1 g of flavonoid/kg fresh plant material) was slightly higher when

extracting with alkaline water. However, this extraction hydrolysed the acetyl derivatives, leaving almost exclusively the deacetylated compounds.

Antioxidant Activity

Faba bean was found to possess antioxidant activity. Ten polyphenolic fractions, mainly mixtures of two compounds and five pure flavonoids, were isolated from the methanolic extracts of aerial plant parts of *Vicia faba and Lotus edulis* respectively (Spanou et al. 2008). All of these fractions exhibited significant DPPH (2,2-diphenyl-2-picrylhydrazyl hydrate) radical scavenging capacity. In addition, they exhibited significant protective activity against free radical-induced DNA damage. They significantly inhibited the activity of the topoisomerase I enzyme. Another paper reported that flavonoids in broad beans and not phenolic acids, were the main phenolic compounds that acted as natural antioxidants (Amarowicz et al. 1996).

Vacuoles isolated from mesophyll protoplasts of *Vicia faba* were found to contain ascorbate in addition to 3,4-dihydroxyphenylalanine (DOPA) and peroxidise (Takahama 1992). When a low quantity of H_2O_2 (0.25 mM) was added to the vacuole fractions, a slow decrease in the level of ascorbate was noted. When 2.5 mM H_2O_2 was added to the vacuole fractions, a rapid reduction in the content of ascorbate and formation of dopachrome were observed. The oxidation of ascorbate and the formation of dopachrome were suppressed by NaN_3 (10 mM), KCN (1 mM) and stimulated by tropolone (5 mM), suggesting the participation of peroxidase but not phenol oxidase in the reactions. Vacuolar peroxidase isolated from leaves of *V. faba* oxidized DOPA and ascorbate in the presence of H_2O_2. The oxidation of DOPA was almost completely suppressed by ascorbate but the oxidation of ascorbate was stimulated by DOPA, suggesting the reduction of an oxidized intermediate of DOPA to DOPA by ascorbate. In fact, ascorbate was found to reduce dopaquinone, a two electron oxidized DOPA.

Hypocholesterolemic Activity

Vicia faba protein was reported to be the most powerful cholesterol-lowering agents (hypocholesterolemic activity) among vegetable proteins (Weck et al. 1983). Studies in humans showed that after 30 days supplementation with *Vicia faba* flour, serum glucose, insulin, triacylglycerol, total lower-density lipoproteins (LDL)-cholesterol, and very-low-density-lipoprotein (VLDL)-cholesterol values were significantly lower than initial values in all subjects who consumed diets containing field bean flour (Frühbeck et al. 1997). Legume consumption also resulted in a significant elevation in glucagon and high-density-lipoprotein cholesterol. The cortisol and thyroid hormone values were not changed significantly. The results suggested that the hypocholesterolemic effect of field bean consumption depended at partially on a concomitant increase in glucagon and decrease in insulin levels. The more marked reduction in triacylglycerol and VLDL-cholesterol concentrations in subjects who consumed raw field beans indicated a co-participation of their thermolabile components. Studies showed that incorporation of faba bean protein concentrate or its ethanol extract in the animal diet resulted in a marked decrease in the level of circulating cholesterol associated with the lower-density lipoproteins (very-low-, intermediate- and low-density lipoproteins) compared with the levels found on the diets containing casein or the faba bean protein concentrate deprived of ethanol-soluble factors indicating its potent hypocholesterolemic activity (Mengheri et al. 1985). Alterations in apoprotein pattern were detected after the different dietary treatments. In particular, apoA-I appeared in an unusual form with electrophoretic mobility faster than normal in all lipoprotein fractions after feeding the diets that did not lower plasma cholesterol. When the diets contained the faba bean protein concentrate or its ethanol extract, the apoA-I disappeared from the lower-density lipoproteins but its normal form and the unusual one were apparent in the high-density lipoproteins. A moderate increase in faecal excretion of acidic steroids was found after feeding the diets containing the ethanol-soluble factors, irrespective of the protein source. This

antihyperchlosterolaemic effect was elucidated in relation to the presence of saponin and polyunsaturated lecithin in the ethanol extract of the faba bean protein concentrate.

Another study using animal models reported that the hypocholesterolaemic effects of *Vicia faba* were not the result of a reduction in cholesterol synthesis as assessed from HMG-CoA reductase activity, but the result of an elevation in steroid faecal excretion (Macarulla et al. 2001). The faba bean-protein isolate was useful in improving the metabolic changes induced by feeding with a hypercholesterolaemic diet compared with casein. The effectiveness of the whole seeds was higher than that of the protein isolate. The rats fed on *Vicia faba* diets displayed significantly lower body weights and energy intakes than rats fed on casein diets. The whole-seed diet induced a significant reduction in plasma triacylglycerol. Feeding rats on diets containing faba bean seeds, or the protein isolate, induced a significant decrease in plasma (LDL + VLDL)-cholesterol but not in HDL-cholesterol. Hepatic cholesterol and triacylglycerol were also lowered.

Parkinson's Disease and Faba Beans

Faba bean and faba bean sprouts were found to be rich in levo-dihydroxy phenylalanine (L-DOPA), the precursor of dopamine (DA) which plays an important role in the treatment of Parkinson's disease (Randhir and Shetty 2004). L-dopa was also a natriuretic agent, which may help in controlling hypertension and was known to increase diuresis and natriuresis through its action on renal dopaminergic receptors (Vered et al. 1997). Following ingestion of *Vicia faba* containing L-DOPA, plasma L-DOPA and urinary sodium and DA excretion increased significantly. Findings also indicated that *Vicia faba* may be of value in treating conditions such as hypertension, heart failure, renal failure, and liver cirrhosis in which natriuresis and diuresis are medically beneficial (Vered et al. 1997).

In other studies, a substantial clinical improvement was noted in five healthy volunteers and six patients with Parkinson's disease (PD) after consuming cooked broad beans after 12 h off medication (Rabey et al. 1992). Three patients showed severe dyskinesias, and plasma levodopa concentrations rose. Further, their clinical performance and plasma L-DOPA levels were compared to those found after g 125 mg L-DOPA + 12.5 mg carbidopa ingested on another day (Rabey et al. 1993). *Vicia faba* ingestion was found to produce a substantial increase in L-DOPA plasma levels, which correlated with an appreciable improvement in motor performance. These findings may have implications for the treatment of Parkinson's Disease, especially in patients with mild symptoms.

Randhir and Shetty (2003) reported that the phytopharmaceutical value of *Vicia faba* was improved during germination by a microwave treatment of the seeds. The phenolic content of the germinated sprouts increased 700% and L-DOPA content by 59% compared to control. A higher antioxidant activity was observed that correlated with total phenolics and L-DOPA contents. The elevated superoxide dismutase activity was proportional to the stimulation of antioxidant activity. The results implied that microwave treatment could significantly stimulate the phenolic antioxidant activity and Parkinson's relevant L-DOPA content of faba beans sprouts.

Anticancer Activity

Vicia faba agglutinin (VFA), the lectin present in broad beans, was found to stimulate undifferentiated colon cancer cell line, LS174T to differentiate into gland like structures (Jordinson et al. 1999). The epithelial cell adhesion molecule (epCAM) was involved in this. VFA significantly aggregated LS174T cells as well as other human colon cancer lines SW1222 and HT29 cells. VFA also inhibited proliferation of all the cell lines. The results indicated that dietary or therapeutic VFA may slow progression of colon cancer.

Antibacterial Activity

Two new antimicrobial peptides related to the γ-thionine family were isolated from broad bean

(Zhang and Lewis 1997). The peptides were named fabatins. They were found to be 47 amino acids long, with an overall positive charge and contained eight cysteines that formed four disulfide bridges characteristic of the γ-thionins. Fabatins were found to be active against both Gram-negative and Gram-positive bacteria, but were inactive against the yeasts *Saccharomyces cerevisiae* and *Candida albicans*.

Antinutritional Factors

Broad beans were found to contain several antinutritional factors which included glucosides like vicine and convicine and their hydrolytic derivatives divicine and isouramil; raffinose oligosaacharides, tyramine, favogens, phytic acid, tannins and trypsin inhibitors and protease inhibitors.

The vicine and convicine content was highest in fresh green cotyledons (moisture content about 80%) and gradually declined until a constant level was reached when seed dry matter percentage was around 40% (Burbano et al. 1995). A similar pattern of variation in glucoside concentration was observed for the seed coat. The pods contained neither vicine nor convicine but they were particularly rich in L-DOPA. These compounds were not homogeneously distributed in the seeds. Chevion and Navok (1983) found that the level of these two glucosides, vivicine and convicine in various faba bean cultivars were approximately 0.5% of the wet weight of the seeds. The aglycone moieties, isouramil and divicine were also detected.

Varieties (22) of mature faba beans were shown to contain 6.68 ± 1.12 mg vicine, 2.33 ± 0.59 mg convicine and 9.02 ± 1.32 mg (vicine + convicine)/g air-dry bean and condensed tannins varying from 7.1 to 149.7 mg, on average 87.1 mg catechin equivalent/g shell (Wang and Ueberschär 1990). The shell: bean ratio was on average 13.7%. When the content of condensed tannins in shell was converted to that in whole bean, using the shell:bean ratio, 0.82–24.0 mg (average 12.3 mg) catechin equivalent/g bean were found.

Vicine and convicine and their hydrolytic derivatives divicine and isouramil were found to induce haemolytic anaemia in people with the hereditary condition, glucose-6-phosphate dehydrogenase (G6PD) deficiency (Diggle 1953; Davies 1961). These anti-nutritional factors rendered the red blood cells of glucose-6-phosphate dehydrogenase deficient patients vulnerable to oxidation and destruction (Mahmoud et al. 1986; Ninfali et al. 2000; Koriem et al. 2008). This potentially fatal disorder is called favism after the fava bean. Favism is characterized by acute haemolysis occurring in sensitive subjects after inhalation of the pollen or ingestion of the seed of the broad bean plant (Diggle 1953; Davies 1961). Studies demonstrated that vicine and convicine when injected intraperitoneally into the rat were converted to their aglycones which caused symptoms similar in many respects to those observed in the human metabolic disease, favism (Mahmoud et al. 1986). There was enhanced respiration rates, generalised cyanosis, abdominal convolutions and, after several hours, death which appeared to be caused by asphyxiation. The tissues of the dead animals were engorged with dark brown blood and the large intestine and caecum contained entrapped gases and watery digesta and faecal matter. A second study demonstrated that injected vicine and convicine were cleared from the intraperitoneal cavity over several hours via the kidney and large intestine and that they were cleaved in the digesta of the large intestine and colon to divicine and isouramil. In a third study, rats injected daily for 10 days with vicine or convicine exhibited increases in spleen weight and blood monocytes and neutrophil counts and decreases in liver weight, blood glutathione and glucose concentrations, and lymphocyte counts. Blood from rats pre-treated in-vivo with convicine was shown to have an altered ultraviolet absorbance pattern. Studies in cultured human myoblasts showed that divicine, an aglycone derived from vicine may induce signs of oxidant stress in these cells (Ninfali et al. 2000). Divicine was found to autooxidise both at the extracellular level and into myoblasts thus stimulating the release of free iron, which initiated oxidation of cellular proteins and lipids. Animal studies showed that convicine produced significant

decreases in red blood cell counts and haemoglobin content (Koriem et al. 2008). The serum albumin/globulin ratio was significantly lowered. There were significant increases in serum and liver total protein, serum bilirubin, globulin, and iron concentrations. Data indicated that convicine produced similar alterations in blood as observed in human metabolic disease (favism).

Favism is common in Mediterranean, Africa and Southern Asia. In 1971, Bottini et al. described an association between haemolytic clinical favism and the phenotype of erythrocyte acid phosphatise in G-6-PD-deficient males in Rome and Sardinia (Bottini et al. 1971). The global distribution of this Glucose-6-phosphate dehydrogenase (G6PD) deficiency is the most common human enzyme defect and is remarkably similar to that of malaria, lending support to the so-called malaria protection hypothesis (Cappellini and Fiorelli 2008). The most frequent clinical manifestations of G6PD deficiency are neonatal jaundice, and acute haemolytic anaemia, which is usually triggered by an exogenous agent. After decades of research it was proven that fava beans themselves also fought malaria in the same way as G6PD deficiency (reducing the amount of oxygen in the blood). Luzzatto et al. (1969) found that in blood from female children with acute *Plasmodium falciparum* malaria, the parasite rate was 2–80 times higher in normal than in deficient erythrocytes. This was attributed to be the mechanism whereby the gene for glucose-6-phosphate dehydrogenase deficiency conferred selective advantage against malaria to heterozygous females. It was generally believed that the anaemia resulting from favism acted as protection from malaria, because certain species of malarial protozoa could not prosper in blood lacking in iron.

French broad bean extracts were found to reduce the blood glutathione (GSH) levels 48–70%, in favism sensitive subjects in Sakiz, Milas-Region, a favism endemic area in Turkey (Vural and Sardas 1984). The decrease in GSH percent was taken as an index of haemolytic activity. Active principles which were responsible for the haemolysis (vicine and convicine) were isolated from broad beans and their effects on GSH levels of blood were 99% and 81%, respectively, in favism sensitive subjects and 33.3% and 19% in normal subjects.

Broad beans were found to be rich in tyramine (Shulman et al. 1989), and thus should be avoided by those taking monoamine oxidase inhibitors (MAOI). MAOIs remained an important class of drugs for a variety of psychiatric conditions, including depressive illnesses, anxiety, and eating disorders (Walker et al. 1996).

In a chemical investigation, epicatechin, epigallocatechin, the procyanidins B-1, B-3 and B-4, and the prodelphinidins gallocatechin-(4α,8)-catechin, gallocatechin-(4α,8)-epicatechin and gallocatechin-(4α,8)-epigallocatechin were isolated from the testa of faba beans (Helsper et al. 1993). Trypsin inhibitory activity comparison of the proanthocyanidin samples suggested that the degree of polymerization, the number of phenolic hydroxyl groups and the 2,3-stereochemistry of the constituent units affected remarkably the magnitude of the inhibition.

Faba beans ware also found to contain high concentration of haemagglutinins (lectins) that could be troublesome. However, these substances were destroyed during the normal food preparation process (heat). Favin, a purified lectin from the fava bean with a mass of 53,000 Da, was found to bind glucose- and mannose-like saccharides, and was mitogenic for lymphocytes (Wang et al. 1974). Favin was found to compose of two non-identical polypeptide chains held together by non-covalent interactions (Hemperly et al. 1979). The complete amino acid sequence of the smaller alpha chain (Mr = 5,571) was shown to be homologous to the alpha chain of the lectins from lentil and pea and to residues 72–120 of concanavalin A (Con A). The larger beta chain (Mr = 20,000) was found to contain carbohydrate and was homologous to the beta chain of lentil, pea, soybean, peanut, and red kidney bean lectins and was homologous to a portion of the Con A molecule beginning at residue 122. Favin also contained a minor component, beta' (Mr = 18,700).

Faba beans were found to contain mono and raffinose family oligosaccharides (Lattanzio et al. 1986). The raffinose content of the whole dry seed ranged from 0.12% to 0.29%, the stachyose content between 0.46% and 1.02%, the verbascose

content, the principal α-galactoside, from 0.82% to 1.61% on a dry matter basis. These components occurred in seeds with more than 30% of dry matter, while fructose, glucose and sucrose gradually decreased during seed development.

The raffinose family oligosaccharides accounted for 67.3%, 63.2%, 53.0% and 51.0% of the total soluble sugars in cowpea, faba bean, lentil and common bean, respectively (Abdel-Gawad 1993). The major oligosaccharide was verbascose in faba bean and stachyose in the other three legumes. Raffinose family oligosaccharides (raffinose, stachyose and verbascose) present in legume seeds had been reported to cause flatulence. These molecules contained glucose and galactose residues which could persist in sugar metabolism pathway in digestive tracts and ferment and produce methane and other gases causing discomfort and abdominal pains.

Removal of Antinutrient Factors

Gamma irradiation was found to reduce the level of vicine and convicine (Jaddou 1988). Test of gamma radiation at a dose 10.0 kGy on solutions of a mixture of vicine and convicine was found to cause a reduction of 92% in vicine and convicine; the reduction was very much lower when powdered dry beans was irradiated. Removal of favism-inducing factors vicine and convicine by extraction and hydrolysis followed by oxidation of their pyrimidine moieties (divicine and isouramil) was investigated by Jamalian (1999). Treatments of whole cotyledons resulted in recovery of 59–93% vicine and 50–70% convicine originally present in the seeds. Treatments of faba bean powders, however, were capable of lowering the vicine content by 94–100% and convicine content by 100%. Germinated seeds showed a drop in vicine content of 86% and their hydrogen peroxide treatment 91–93%. Convicine was totally absent in germinated and oxidised seeds. Protein content of original faba bean powders was well recovered (up to 94.00%) and its digestibility was almost complete (99.34%).

Gamma irradiation was also found to have an effect on the anti-nutritional factors in broad beans. Trypsin inhibitor activity was reduced by 4.5%, 6.7%, 8.5% and 9.2% at 2.5, 5, 7.5 and 10 kGy, respectively (Al-Kaisey et al. 2003). Meanwhile, irradiation at 10.2, 12.3, 15.4 and 18.2 kGy reduced the phytic acid content. The flatulence causing oligosaccharides were decreased as the radiation dose increased. The chemical composition (protein, oil, ash and total carbohydrates) of the tested seeds was also determined. Gamma radiation appeared to be a good procedure to improve the quality of broad bean from the nutritional point of view.

The soaking of legume seeds in tap water or sodium bicarbonate solution resulted in a decreased concentration of sucrose and the raffinose family of sugars (Abdel-Gawad 1993). The magnitude of losses was enhanced as the time of soaking was increased. The removal of oligosaccharides from legume seeds was higher in alkaline medium than in water. Cooking of unsoaked seeds led to a large decrease in oligosaccharide content of all studied legumes compared with soaking for 12 hours. The loss in the raffinose family oligosaccharides after cooking of soaked seeds was highest in common bean and lowest in faba bean. Autoclaving had a greater effect on removal of oligosaccharides than did cooking. In all cases, autoclaving of soaked seeds resulted in complete removal of raffinose.

Studies by Abusin et al. (2009) showed that cooking of the faba bean cultivars seeds caused significant change in the proximate composition, with increase in some parameters and decrease in others. Cooking of faba bean significantly reduced the anti-nutritional factors (tannin, phytate, and polyphenols). The in-vitro protein digestibility of faba bean and white bean cultivars was greatly improved after cooking with a maximum value of 89.66% obtained for faba bean cultivar BB7 and a minimum value of 48.10% obtained for white bean cultivar RO21. Cooking of faba and white bean cultivars was found to improve the metabolism of albumin and glutelin. The protein content was 29.57% for BB7 and 31.83% for H93 (faba bean cultivars) and 21.49% for Giza3 and 19.83% for RO21 (white bean cultivars). After cooking the protein content was found to be 27.7% and 28.15% for

BB7 and H93 (faba bean cultivars) and 21.32% for Giza3 and 18.99% for RO21 (white bean cultivars). In general, cooking significantly decreased the protein content of both faba and white bean. The ash content of faba bean cultivars was 3.47% for BB7 and 3.37% for H.93 while that of white bean cultivars was found to be 4.90% and 4.60% for Giza3 and RO21. Cooking caused a significant reduction in ash content for both faba bean and white bean cultivars. Untreated seeds were fractionated into albumin, globulin, prolamin and glutelin. The results obtained indicated that about 96.4% of BB7 and 95.3% H93 proteins and 97.99% of Giza 3 and 97.05% of RO21 proteins could be extracted by solvents and the remaining percentage accounted for the non-protein nitrogen and insoluble protein. Cooking of the seeds significantly decrease albumin, globulin and prolamin content, it caused a significant increment in glutelin content for both faba bean and white bean cultivars.

Soaking and dehulling of broad bean seeds caused marked reductions in phytic acid (4%) and saponin (26–29%) contents whereas lectins could not be removed, though they were found in the soaking water (Sharma and Sehgal 1992). Loss of antinutrients was at a maximum when soaked and dehulled seeds were autoclaved for 25 min Antinutrient concentrations declined during germination; the longer the period of germination the greater was the reduction. Lectin was present even after 48 h of sprouting.

Traditional Medicinal Uses

As a folk medicine, faba bean has been used as a diuretic, lithontripic, expectorant, or tonic.

Other Uses

Faba bean is also cultivated as a fodder and as stock feed for pigs, horses, poultry and pigeons in industrialized countries. It is sometimes grown as a green manure crop. Straw from faba bean harvest fetches a premium in Egypt and Sudan and is considered as a cash crop. The straw can also be used for brick making and as a fuel in parts of Sudan and Ethiopia. A fibre is obtained from the stems. The burnt stems are rich in potassium and can be used in making soap. Studies showed that faba bean could be used as source of organic and biological manure for the Algerian arid regions (Chafi and Bensoltane 2009).

Comments

Cultivars of faba bean are categorised according to the following types: White-seeded, Green-seeded, Red-seeded; Short-podded, Long-podded; White-flowered, Red-flowered; Pendant pod and Erect pod.

Small seeded types (*Vicia faba* var. *minor*) are also called tick bean or faba bean and are commonly used for human consumption and animal feed. Large seeded type (*Vicia faba* var. *major*) are called broad bean and are used commonly as dry broad bean or as green bean.

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Vigna angularis

Scientific Name

***Vigna angularis* (Willdenow) Ohwi & H. Ohashi**

Synonyms

Azukia angularis (Willdenow) Ohwi, *Dolichos angularis* Willdenow, *Phaseolus angularis* (Willdenow) W. Wight, *Phaseolus chrysanthos* Savi, *Phaseolus nipponensis* Ohwi, *Vigna angularis* var. *nipponensis* (Ohwi) Ohwi & H. Ohashi.

Family

Fabaceae also placed in Leguminosae, Papilionaceae

Common/English Names

Adzuki Bean, Adanka Bean, Azuki Bean, Cultivated Azuki, Chinese Red Bean, Greater Red Bean, Red Gram

Vernacular Names

Argentina: Judía Adzuki, Poroto Arroz;
Brazil: Feijão-Adzuki;
Chinese: Ao Ye Chi Dou, Chi Dou, Du Chi Dou, Hong Chi Dou, Hong Dou, Hung Tou, Hong Xiao Dou, Jin Hong Dou, Jin Hong Xiao Dou, Mi Chi Dou, Mi Dou, Shi Mu Dou, Síu Hùhng Dáu, Xiao Hong Dou, Xiao Dou, Xiao Hong Lu Dou, Zhu Dou;
Chile: Frijol Adzuki, Frijol Diablito;
Cuba: Frijol Adzuki, Frijol Diablito;
Danish: Adzukibønne, Adsukibønne;
Dutch: Azuki-Boon, Azuki-Boon;
French: Haricot Anguleux, Haricot À Feuilles Angulaires, Haricot Adzuki, Haricot Du Japon;
German: Adzukibohne, Adsuki-Bohne;
India: Chori (Gujarat), Guruns, Rains (Hindu), Lal Chavali (Marathi), Ravaa'n (Punjabi);
Indonesia: Kacang Merah Kecil;
Italian: Fagiolo Adzuki;
Japanese: Azuki, Akamame, Ankomame, Shoumame, Omame, Gururimame, Konaremame, Anmame, Antoki, Irakuri, Narazu, Kannome;
Korean: Pat;
Latin America: Frijol Adzuki;
Malaysia: Kacang Merah Kecil;
Mexico: Judía Adzuki;
Portuguese: Feijão-Adzuki;
Russian: Adzuki, Fasol' Uglovataia;
Seychelles: Amberique Gros;
Samoan: Pipi;
Spanish: Frijol Adzuki;
Vietnamese: Đậu Đỏ.

Origin/Distribution

Azuki is regarded to have been domesticated in China, Manchuria, Korea or Japan from its wild ancestral form, *Vigna angularis* var. *nipponensis*

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(Ohwi) Ohwi & Ohashi. Recently, the natural distribution of *Vigna angularis* var. *nipponensis* was reported to be wider than recognized before, ranging from Japan, Korea, China to Himalaya (Tibet, Bhutan, Nepal). Almost all global production of azuki occurs in four countries: Japan, China, Taiwan, and South Korea.

Agroecology

Adzuki bean is a short day plant and a cool temperature species growing in areas with an annual mean temperature range of 8–28°C and annual rainfall from 530 to 1,750 mm. It grows well in soils with pH range of 5–7.5. It is grown in the subtropics and high altitude tropics.

Edible Plant Parts and Uses

In Japan and China azuki plants are grown mainly for the edible seeds. Seeds are used as pulse, cooked whole or made into a meal used in soups, cakes or confections. In Japan, azuki bean has been used for making "sekihan" (steamed glutinous rice coloured red by boiled azuki or sausage bean, *V. unguiculata*) and/or "azuki-gayu" (rice porridge with azuki bean) for the traditional ceremony and celebration. It is also cooked as "ann" (azuki bean jam) and/or "shiruko" (sweet azuki soup with glutinous rice cake). Azuki bean sprouts (*moyashi*) are eaten raw or cooked as vegetables. Young pods are also an excellent vegetable, eaten like snow peas. Beans are roasted and used as coffee substitute or eaten candied. Azuki beans are also processed into flour.

In Japan, the azuki bean is the second-most important legume after soybeans, and it is commonly used as an essential ingredient for many dishes. Azuki beans are used for making the popular festive dish, *sekihan* (steamed glutinous rice coloured red by boiled azuki or long bean, *Vigna unguiculata*) and *azuki-gayu* (rice porridge with azuki bean) for the traditional ceremony and celebration. It is also cooked as *ann* (azuki bean jam, paste) and *shiruko* (sweet azuki soup with glutinous rice cake). Azuki beans are cooked with a sweetener and made into sweet soups (*zenzai* and *sarashi ame*), candied whole beans (*amanatto*), and various confectionary products. When cooked with varying proportions of sugar, water, starch, plant gums, and other ingredients, the resulting *ann* products are fillings for bread (*annpan*), steamed breads or dumplings and sweet cakes. Popular desserts include cakes, *manju* (steamed *an*-filled buns), *yokan* (cold gelatinized *an* slices), *taiyaki* (*an*-filled waffle), ice cream, snow cone toppings, and as a base for a beverage served hot from vending machines. *Ann* can also be flavoured with soy sauce or with sweet syrups. A white seeded azuki is also used to make high quality white *ann* for specialty Japanese bakery products Other beans are used to make these pastes, but the adzuki bean is the most prized.

In China, azuki beans are cooked with rice to make a richer food staple and the bean paste is used for pastries such as the "Eight Precious Pudding". In Malaysia and Singapore, the beans are cooked with rice and sweetened with palm sugar to make a sweet broth served as dessert. Also, the beans are the main ingredient in the ice dessert called 'Ice Kacang' in Malaysia and Singapore.

Botany

An annual herb usually erect, twining or bushy, 30–90 cm tall, with green or purplish tinged pilose, angular stem and branches (Plate 1). Roots comprise a tap root and lateral roots with many nodules. Stipules are peltate, lanceolate, acuminate and with basal appendages. Leaves trifoliolate, leaflets usually ovate or rhomboid-ovate (Plate 1), 5–10×5–8 cm, sparsely pilose on both surfaces, apex broadly triangular or subrounded, lateral leaflets oblique, entire or shallowly 3-lobed. The central leaflet has a long petiolule. Inflorescence axillary and racemose, short with 6–20 pedunculate flowers. Flowers with a campanulate calyx, 3–4 mm, five pale yellow petals, 15 mm, the standard petal oblate or reinform with emarginated apex, the wings broader than keel, shortly clawed and auriculate; keel asymmetrical with incurved apex and clawed base; ovary is

Plate 1 Red gram pods and leaves

Plate 2 Red gram seeds

Plate 3 Close-up of red gram seeds

linear with curved, hairy style and a flattened stigma. Pods smooth, cylindrical, 6–13 cm by 0.5 cm wide, thin-walled, and green (Plate 1) turning straw-coloured to grey-brown as they mature with 6–14 seeds. Seeds are sub-cylindric with sub-truncate ends with a length of 5–9 mm, width of 4–6 mm, smooth, dull red, wine-red (Plates 2 and 3), sometimes buff, creamy black or mottled; the hilum is 2.4–3.3 mm long and 0.6–0.8 mm wide, white and not impressed.

Nutritive/Medicinal Properties

Nutrient Value

Fresh, raw adzuki (*Vigna angularis*) seeds was reported to have the following nutrient composition per 100 g value (USDA 2010): water 13.44 g, energy 329 kcal (1,377 kJ), protein 19.87 g, total lipid 0.53 g, ash 3.26 g, carbohydrates 62.90 g, total dietary fibre 12.7 g, Ca 66 mg, Fe 4.98 mg, Mg 127 mg, P 381 mg, K 1,254 mg, Na 5 mg, Zn 5.04 mg, Cu 1.094 mg, Mn 1.730 mg, Se 3.1 µg, vitamin C 0 mg, thiamine 0.455 mg, riboflavin 0.220 mg, niacin 2.630 mg, pantothenic acid 1.471 mg, vitamin B-6 0.351 mg, total folate 622 µg, vitamin A 17 IU, vitamin B-6 0.351 g, total saturated fatty acids 0.191 g, 18:1 undifferentiated (oleic acid) 0.050 g, 18:2 undifferentiated (linoleic acid) 0.113 g, phytosterols 76 mg, tryptophan 0.191 g, threonine 0.674 g, isoleucine 0.791 g, leucine 1.668 g, lysine 1.497 g, methionine 0.210 g, cystine 0.184 g, phenylalanine 1.443 g, tyrosine 0.591 g, valine 1.023 g, arginine 1.284 g, histidine 0.524 g, alanine 1.160 g, aspartic acid 2.355 g, glutamic acid 3.099 g, glycine 0.756 g, proline 0.874 g and serine 0.976 g.

Adzuki beans is exceedingly nutritious and very rich in proteins, amino acids, fibre, carbohydrates, folate, niacin, pantothenic acid, vitamin B6 and minerals like Ca, Fe, K, Mg, P, Zn, Cu and moderately rich in riboflavin and thiamine. Lipids in adzuki beans comprised primarily of phospholipids (72.2–73.4 wt-%) and triacylglycerols(20.6–21.9 wt-%) and 0.1–3.4 wt-% of other components (Yoshida et al. 2010).

Three cDNA isoforms of 7S globulin (vicilin), the major seed storage protein in adzuki bean were obtained (Fukuda et al. 2007). The three isoforms of cDNAs had highest homology with

the mung bean 8Sα globulin (7S globulin), and then soybean β-conglycinin (7S globulin) β subunit among legume plants. Adzuki bean 7S globulin isoforms contain more methionine and tryptophan than mung bean 8Sα globulin and soybean β-conglycinin β subunit. In addition, high mannose types of glycans were attached to two or one N-glycosylation sites of adzuki bean 7S globulins.

Other Phytochemicals

The flavonoid with pharmaceutical property, vitexin was identified from *Vigna angularis* seeds (Prati et al. 2007). A digalactosyl ononitol was isolated from seeds of adzuki bean (*Vigna angularis*) (Peterbauer et al. 2003). Its structure was established as O-α-D-galactopyranosyl-(1→6)-O-α-D-galactopyranosyl-(1→3)-4-O-methyl-D-myo-inositol.

Numerous scientific studies had shown that adzuki bean extracts have beneficial and interesting pharmacological properties that include antioxidant, renal-protective, hepatoprotective, antitumourigenic, antimetastatic, anticancerous, antimicrobial, and hypoglycaemic and hypotensive activities. These studies had highlighted the potential of adzuki beans in treating inflammation, hypertension, and diabetic nephropathy (Sato et al. 2009).

Antioxidant Activity

Azuki beans (*Vigna angularis*) were found to contain polyphenols such as proanthocyanidins a group of polyphenolic bioflavonoids that had been reported to exhibit remarkable radical scavenging activities (Mukai and Sato 2009; Sato et al. 2009). The aroma extracts isolated from all beans including adzuki beans inhibited the oxidation of hexanal for nearly 1 month at a concentration of 250 μl/ml (Lee et al. 2000). Azuki and kidney bean extracts at the 250 μl/ml level inhibited malonaldehyde (MA) formation from cod-liver oil by 76% and 53%, respectively.

Antihypertensive Activity

Sato et al. (2008) found that polyphenol-containing azuki bean extract (ABE) attenuated the elevation of systolic blood pressure (SBP) and macrophage infiltration in the heart, as well as in the glomeruli and tubulointerstitium of the kidney, using a spontaneously hypertensive rats (SHR) model. Also, the nicotinamide adenine dinucleotide phosphate (NADPH)-stimulated superoxide (O^{2-}) levels in the kidney in untreated SHR rats was significantly higher than that in untreated normotensive Wistar-Kyoto (WKY) rats. The O^{2-} levels in ABE-treated SHR were significantly reduced compared with the untreated SHR group. In further studies, Mukai and Sato (2009) found that ABE lowered the elevated blood pressure and increased nitric oxide production in long-term treatment. The systolic blood pressure of the ABE-treated SHR was significantly lower than that of the untreated SHR. The level of 24-h urinary NOx excretion was significantly higher in the ABE-treated SHR than in the untreated SHR. The eNOS and iNOS expressions in the aorta and kidney were remarkably upmodulated in the untreated SHR but suppressed in the ABE-treated SHR. The vascular and renal caveolin-1 expressions were upregulated in the ABE-treated SHR. In more recent studies, Mukai and Sato (2010) found that that the polyphenol-containing ABSC could attenuate vascular oxidative stress and inflammation during the progression of hypertension, and this may lead to an improvement in hypertension. Polyphenol-containing ABSC suppressed the elevation of SBP throughout the treatment period. The NADPH-stimulated O^{2-} level decreased significantly in the aorta of ABSC-treated SHR compared with the level of untreated SHR. The content of p47phox mRNA was significantly lower in ABSC-treated SHR than in untreated SHR. The protein abundance of both iNOS and COX-2 was significantly decreased in the aorta of the ABSC-treated SHR compared with this abundance in untreated SHR. The macrophage chemoattractant protein-1 (MCP-1) and its receptor C-C chemokine receptor 2 (CCR2) mRNA expressions in the aorta

increased in untreated SHR, and these levels were significantly lower in ABSC-treated SHR.

Anticancer Activity

Treatment of human stomach cancer KATO III cells with hot-water extracts from adzuki beans led to their growth inhibition as well as apoptosis induction (Itoh et al. 2004a). There were morphological changes in the cultured cells treated with the extracts, by which DNA fragmentation characteristic of apoptosis was actualized both concentration- and time-dependently. In contrast, N-acetyl-L-cysteine suppressed such DNA fragmentation, implying that the extracts from adzuki beans might exert antitumourigenicity via active oxygen-induced apoptosis. This was verified in an animal experiment, where the 40% ethanol fraction of hot-water of adzuki exhibited its preventive effect against benzo(a)pyrene-induced tumorigenesis in the forestomach of A/J mice. Consequently, forestomach cancer was reduced by 36–62% in tumour weight relative to the control. These results suggested that the fraction of hot-water adzuki extracts may serve as a nutrapharmaceutical or functional food available for cancer prevention. The 40% ethanol fraction of the hot-water extract from adzuki beans was found to significantly lower the number of tumour colonies (Itoh et al. 2005). It also inhibited the adhesion and migration of B16-BL6 melanoma cells into extracellular matrix components and their invasion into reconstituted basement membrane (matrigel) without affecting cell proliferation in-vitro. The in-vivo data suggested that the ethanol extract possessed a strong antimetastatic ability, with potential as a lead compound in functional food development.

Antihyperglycemic Activity

A hot water extract obtained by boiling adzuki beans (*Vigna angularis*) showed inhibitory activity against α-glucosidase, α-amylase, maltase, sucrase, and isomaltase (Itoh et al. 2004b). The IC_{50} values for each hydrolylase were 0.78 mg/ml (α-amylase), 2.45 mg/ml (maltase), 5.37 mg/ml (sucrase), and 1.75 mg/ml (isomaltase). The active fraction exhibited potential hypoglycemic activity in both normal mice and streptozotocin (STZ)-induced diabetic rats after an oral administration of sucrose, but did not display any effect on the blood glucose concentration after glucose administration, suggesting that the active fraction suppressed the postprandial blood glucose level by inhibiting α-glucosidase and α-amylase, irrespective of the endogenous blood insulin level. Itoh et al. (2009) further found that compared with the control group, EtEx.40 (40% ethanol fraction of hot-water extracts of adzuki) supplementation had a significant effect in decreasing blood glucose levels, water intake, serum insulin levels, urinary glucose, urinary microalbumin/creatinine ratio, liver triacylglycerol, and total cholesterol levels. Similar results were observed in 7-week-old diabetic KK-A(y) mice fed EtEx.40 for 4 weeks. These effects were also found after short-term administration of EtEx40. Overall, EtEx.40 improved several diabetic symptoms in KK-A(y) mice. They concluded that the preventive and ameliorative effects by EtEx.40 were due to the modulation of blood glucose levels and the protective effect against oxidative damage in diabetes mellitus. Sato et al. (2005b) found that administration of a diet containing azuki bean (*Vigna angularis*) seed coats which contain polyphenols (ABSC) to streptozotocin (STZ)-induced diabetic rats suppressed the increased number of infiltrating macrophages and MCP-1 mRNA expression, and attenuated the glomerular expansion in STZ-induced rat diabetic nephropathy. There was no difference in plasma glucose levels between diabetic rats treated with and without ABSC. The plasma levels of malondialdehyde (MDA) in the ABSC-treated diabetic rats were significantly lower than those in the untreated diabetic rats.

Antihypertriglyceridemia/ Antihyperchlolesteromic Activity

In a random parallel-group design study involving healthy Japanese women, azuki bean juice

consumption, a traditional Kampo prescription, of 150 g daily for one menstrual cycle, was found to be beneficial for preventing hypertriglyceridemia (Maruyama et al. 2008). Triglyceride levels in the azuki and CA (concentrated adzuki) juice groups decreased by 0.170 mmol/l (15.4%) and 0.159 mmol/l (17.9%), respectively compared to control. The azuki and CA juice inhibited pancreatic lipase activity in-vitro 29.2% and 56.9%, respectively. Lipid peroxide changes did not differ among the three groups. Serum low density lipoprotein-cholesterol and high density lipoprotein-cholesterol (HDL) cholesterol concentrations did not change. Itoh and Furuichi (2009) found that ingestion of 40% ethanol fraction of the hot aqueous extract of adzuki beans was found to suppressed serum cholesterol level in rats fed the high-fat cholesterol and serum triacylglycerol level in rats fed the high-fat cholesterol-free diet.

Hepatoprotective Activity

Han et al. (2004) found that the water-extract from adzuki bean hulls exhibited prophylactic effect against oxidative damage to the liver induced by acetaminophen.

Serum aspartate aminotransferase activity and levels of hepatic phosphatidylcholine hydroperoxide and phosphatidylethanolamine were higher in acetaminophen treated animal group than in the control and acetaminophen+adzuki extract-treated groups. Hepatic glutathione content and hepatic glutathione reductase and catalase activities were also lower in the acetaminophen group. Hepatic glutathione peroxidase activity was higher in the acetaminophen-treated group than in the control group, although there was no significant difference between both acetaminophen-treated and acetaminophen+Adzuki extract-treated groups. In separate studies using acute hepatic injury tests, an adzuki bean extract decreased D-galactosamine (GalN)-induced alterations in the serum alanine aminotransferase and aspartate aminotranferase activities to about 37% and 25%, respectively (Ohba et al. 2005). However, there were no significant differences in these activities between the GalN-treated group with the adzuki bean extract and the GalN-treated group without the adzuki bean extract. Additionally, the hepatic glutathione peroxidase, glutathione reductase, and Mn- and Cu, Zn-superoxide dismutase mRNA levels in the GalN-treated group with the adzuki bean extract were higher than those in the control group and GalN-treated group without the adzuki bean extract.

Antimicrobial Activity

Exudate fluids from soaked small red adzuki beans were found to display strong antiviral activity against the rabies virus infections in culture (Kawai and Fujita 2007). In contrast, no antiviral activity was detected in the exudate fluids from non-coloured azuki beans (white azuki), implicating that a certain anthocyanin-related substance was involved in the antiviral activity of red beans. Antiviral and cytotoxic activities were affected differently depending on the bean-soaking conditions. In addition, the antiviral activity resisted to 10 minute-heating in boiling water, while the cytotoxicity was greatly weakened by the heating, suggesting that different compounds were involved in the antiviral and cytotoxic activities. Further studies on the antiviral activity of the exudate fluids demonstrated that anti-rabies activity of the bean exudates affected not only the very early phase of infection cycle, but the viral infectivity was also affected similarly, implicating a possible application of azuki bean exudate fluids to post-exposure treatment of rabid dog-bite injuries in combination with vaccination.

The water extracts of green, black and red coloured azuki beans showed antibacterial effects against *Staphylococcus aureus, Aeromonas hydrophila* and *Vibrio parahaemolyticus* (Hori et al. 2006). In contrast, the extract of white azuki beans exerted no inhibition towards any of the bacteria examined. Findings suggested that polyphenols including proanthocyanidins in coloured azuki beans might be responsible for the antibacterial activity.

Renal Protective Activity

The content of polyphenols in the red adzuki bean seed coats (RABSC) (76.3 g/kg of plant material)

was higher than that in the white adzuki bean seed coats WABSC (18.1 g/kg) (Sato et al. 2005a). Proanthocyanidins were detected in the RABSC (20.4 g/kg) but not in the WABSC. Histologically, the fibrotic areas consisting of fibroblastic cells and mononuclear cells developed around the dilated or atrophic tubules in the corticomedullary junction in cisplatin (CDDP)-treated rat kidney, whereas the extent and magnitude of damage were less in the WABSC- and RABSC-treated rats. Additionally, the number of macrophages in CDDP plus WABSC or RABSC groups was significantly smaller than that in CDDP-treated rats. Further, the number of macrophages in the RABSC group was significantly smaller than in the WABSC group, indicating that RABSC prevented macrophages from infiltrating into areas of interstitial fibrosis. These results suggested that adzuki bean seed coat, especially RABSC, suppressed the increase of infiltrating macrophages in the damaged kidney and may lead to amelioration of interstitial fibrosis. Based on the composition of adzuki bean seed coat, compounds such as proanthocyanidins and/or dietary fibres may be associated with the amelioration of renal damage.

Photoprotective Activity

A water fraction of adzuki beans was found to stimulate tyrosinase activity in cultured mouse B16 melanoma cells and hair colour pigmentation in C3H mice (Itoh and Furuichi 2005). At concentrations of 1–3 mg/ml, the adzuki extract stimulated melanogenesis without inhibiting cell growth. The addition of the extract activated the adenylcyclase and protein kinase pathways and, as a result, stimulated melanogenesis. The extract was found to have pigmentation activity on hair colour in C3H mice suggesting that it may be useful in anti-greying and protecting human skin from irradiation.

Appetite Suppressing Activity

Studies by Sufian et al. (2010) found that peptides in azuki beans potently stimulated cholecystokinin secretion in the enteroendocrine cell line STC-1 indicating that these peptides could potently suppress food intake. The cholecystokinin-releasing peptides were derived from protein similar to dolicholin in country beans.

Protease Inhibition Activity

Double-headed protease inhibitors I, IIa, and IIc (AB I, AB IIa, and AB IIc) were purified from azuki beans "Takara" (*Vigna angularis*) (Ishikawa et al. 1985). AB I stoichiometrically inhibited both trypsin and chymotrypsin at a molar ratio of 1:1. In contrast, AB IIa and AB IIc both inhibited trypsin at a molar ratio of about 1:2 and also inhibited weakly chymotrypsin. A major molecular form of subtilisin inhibitor and a minor form of subtilisin inhibitor which lacked the amino-terminal 19 residues of the major one, were found in adzuki beans (Nozawa et al. 1989). Comparison of amino acid sequences revealed that the adzuki bean subtilisin inhibitors were 29–68% homologous in sequence to the inhibitors of so-called "potato inhibitor I family." Adzuki beans also contained a trypsin inhibitor with a molecular weight of 13 kDa (Wati et al. 2010). The precipitate IV fraction was found to effectively prevent the degradation of the tilapia muscle in a concentration dependent manner. The results indicated that precipitate IV from adzuki beans had potential for use as a protease inhibitor in fishery related products. In another study, a trypsin inhibitor from adzuki bean seed was isolated and characterised (Klomklao et al. 2010). The purified inhibitor was stable over a broad pH range and retained high inhibitory activity toward trypsin after incubation at 90°C for 60 min.

Traditional Medicinal Use

In China the beans are used in traditional medicine to treat kidney ailments, constipation, abscesses, threatened miscarriage, retained placenta and non-secretion of milk. The leaves are used to alleviate fever and the sprouts are used to avert threatened abortion.

Other Uses

Adzuki bean flour has been used for facial cream and shampoos.

Comments

Adzuki bean is the second most important dry bean crop in Japan.

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Vigna mungo

Scientific Name

***Vigna mungo* (L.) Hepper**

Synonyms

Azukia mungo (L.) Masam., *Phaseolus mungo* L. non Gagn., *Phaseolus mungo* L. non Roxb. and auct. mult., *Phaseolus mungo* L. var. *radiatus* sensu Baker, *Phaseolus radiatus* Roxb., non L., *Phaseolus roxburghii* Wight and Arn., *Vigna mungo* (L.) Hepper var *mungo.*

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Black Gram, Black Lentil, Black Matpe, Black Mung Bean, Mash Bean, Mung Bean, Urd Bean, Urad bean, White Lentil

Vernacular Names

Burmese: Mat Pe;
Canada: Ambérique;
Chinese: Hei Lü Dou;
Czech: Fazol, Mungo;
Danish: Urdbønne, Urdbřnne;
Dutch: Mungoboon;
French: Dolique, Haricot Mung;
German: Urdbohne, Mungbohne, Mungobohne;
Hawaiian: Urd;
India: Mash Kalai (Bengali), Urad, Urd (Hindu), Uddina Bele, Uddu (Kannada), Kattulunnu, Katu-Ulunu, Ulunnu, Uzhunnu (Malayalam), Shagol-Hawai (Manipuri), Moong (Marathi), Payaru, Ulundu, Ulunthi, Ulunthu, Uluntu (Tamil), Minumulu, Nallaminumulu, Pesalu, Pesalu Pessara Uddulu (Telugu);
Italian: Fagiolo Mungo, Mungo Nero;
Japanese: Ke Tsuru Azuki;
Pakistan: Maanh, Sabit Maash;
Portuguese: Feijão-Da-China, Feijão-Urida;
Russian: Fasól' Mungo, Fasol' Vidov;
Spanish: Fríjol Mungo, Judía Mung, Poroto Mung;
Sri Lanka: Mun (Sinhalese);
Swahili: Mchooko Mweusi,
Swedish: Mungböna;
Thai: Thuaa Dahm;
Vietnamese: Đậu Đen, Dau Muong An.

Origin/Distribution

Black gram originated in India where it has been in cultivation from ancient times and is one of the most highly prized pulses of India. It has been domesticated in India from its wild ancestor, *Vigna mungo* var. *silvestris* Lukoki, Marechal and Otoul. Its centre of genetic diversity is found in

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India (Zeven and de Wet 1982) and its natural distribution of *V. mungo* var. *silvestris* extends from India to Myanmar (Tateishi 1996). It has also been introduced to other tropical areas mainly by Indian immigrants. The crop is traditionally cultivated in South Asia and adjacent regions (India, Pakistan, Afghanistan, Bangladesh and Myanmar).

Agroecology

Black gram grows mainly in the coastal lowlands but will grow up to 1,800 m elevation. It is drought tolerant and can withstand dry areas but is frost intolerant. The optimum temperature range for growth is 27–30°C. It grows on many soil types but thrives in loamy soils with pH of 5.5–7.5 and tolerates heavier soil such as the cotton soils than green gram.

Edible Plant Parts and Uses

Black gram is grown mainly as a pulse crop for dhal production make from whole or split dehusked seeds (white lentils) and its flour or paste is used for making pappadams, *dosa, idli* and *vadai* in India and Pakistan. Pappadams are thin Indian wafer or thin round, flat-bread served with an Indian curry meal or eaten after a meal. When used this way, the white lentils are usually used and are called '*ulundu*' in Tamil. Regular *dosa* batter is made from rice and split, dehusked black gram blended with water and left to ferment overnight. A *masala dosa* is made by stuffing a *dosa* with a lightly cooked filling of potatoes, fried onions and spices. *Adai* is prepared from a combination of dals namely black gram, *Channa* and *Moong dal*. *Idli* is made by steaming a batter consisting of fermented black gram, rice and fungreek and is very popular in south India. It is usually eaten at breakfast or as snack with chutney and *sambar* (dhal based vegetable stew such as pea, vegetable, tamarind stew and pigeon pea dhal). *Vadai* is popular savory dessert in Tamil Nadu, shaped like a doughnut and is made from dehusked black gram or potato.

In Japan, black gram is used to produce bean sprouts '*moyashi*' because the sprouts have a good white colour.

Plate 1 Black gram seeds

Botany

An erect to sub-erect hairy annual with long twining branches 30–100 cm high. Leaves trifoliolate with 3 ovate or rhombic ovate leaflets, 4–10 cm by 2.5–5 cm, acuminate tip and entire borne on 6–20 cm long petioles. Flowers small, axillary, bright yellow on elongating peduncles, bracteoles linear longer than calyx, corolla bright yellow with spirally coiled keel with a long terminal horn-like appendage. Fruits cylindrical, upright legume pods, 4–6 cm long, hairy with a short, hooked beak; seeds 4–10 per pod, ellipsoid, generally black (Plate 1) or grey black or mottled with a white hilum protruding from the seeds.

It may be distinguished from *Vigna radiata* (Linn.) Wilczek by its brighter yellow flowers, the more upright and shorter pods, the longer hairs on the shorter pods and the distinctly raised rim-aril around the hilum of the seeds and the colour of the seeds.

Nutritive/Medicinal Properties

Nutrient Value

Analyses carried out in the United States reported raw, mature, black gram seeds to have the following proximate composition (per 100 g value): water 10.8 g, energy 341 kcal(1,427 kJ); protein 25.21 g, total lipid 1.64 g, ash 3.36 g, carbohydrates 58.99 g, total dietary fibre 18.3 g, Ca 138 mg, Fe 7.57 mg, Mg 267 mg, P 379 mg, K 983 mg, Na 38 mg, Zn 3.35 mg, Cu 0.0.981 mg, Mn 1.527 mg, Se 8.2 mcg,

vitamin C 0 mg, thiamine 0.273 mg, riboflavin 0.254 mg, niacin 1.447 mg, pantothenic acid 0.906 mg, vitamin B-6 0.281 mg, total folate 216 mcg, vitamin A 23 IU, total saturated fatty acids 0.114 g, total monounsaturated fatty acids 0.144 g, total polyunsaturated fatty acids 1.071 g, tryptophan 0.263 g, threonine 0.875 g, isoleucine 1.287 g, leucine 2.089 g, lysine 1.674 g, methionine 0.367 g, cystine 0.234 g, phenylalanine 1.473 g, tyrosine 0.783 g, valine 1.416 g, arginine 1.642 g, histidine 0.706 g, alanine 1.077 g, aspartic acid 2.984 g, glutamic acid 4.126 g, glycine 1.053 g, proline 1.166 g and serine 1.327 g (USDA 2010).

Black gram is exceedingly nutritious and very rich in proteins, amino acids, fibre, carbohydrates, folate, niacin and minerals like Ca, Fe, K, Mg, P, Zn, and moderately rich in pantothenic acid, riboflavin, thiamine, vitamin A and vitamin 6. It is also rich in flavonoids which are important natural plant antioxidants imparting positive health benefits.

Dehulled and defatted flour of urdbean (*Vigna mungo*), var T-9, contained 25% protein with maximum contribution by globulins (63%) (Mahajan et al. 1988). Albumins and glutelins contributed 12% and 21% respectively, whereas prolamins were present only in traces (1%). Globulins were further fractionated into legumin and vicilin type proteins which were present in the ratio of 4:1. Albumins, globulins, prolamins and glutelins resolved into 4, 8, 6 and 13 different sized components of molecular weights ranging from 10.23 to 25.53, 10.84 to 112.72, 10.33 to 51.52 and 8.91 to 112.72 kd, respectively. Amino acid analysis of all fractions revealed that glutamic acid was present in maximum concentration followed by aspartic acid and lysine. Just like other pulse proteins, the urdbean proteins were also deficient in sulphur containing amino acids.

Other Phytochemicals

Studies in Japan reported that the hypocotyls, seed-coats and mature leaves of *Vigna mungo, V. radiata* var. *radiata* and *V. radiata* var. *sublobata* were found to contain 12 kinds of flavonoid including 3 anthocyanins, 2 leucoanthocyanins, 2 glycoflavones and 5 flavonol glycosides (Ishikura et al. 1981). The leaves of *V. radiata* var. *radiata* and *V. radiata* var. *sublobata* contained the glycosides (mainly rutin) of both quercetin and kaempferol, while those of *V. mungo* contained only kaempferol glycosides, with robinin as the major pigment, and the purple-red hypocotyls of the former group contained delphinidin 3-p-coumaroylglucoside, while those of the latter contained cyanidin 3-glucoside, although delphinidin 3-glucoside was commonly found in all of the plants. all of the seed-coats contained in common four compounds of vitexin, isovitexin, leucocyanidin and leucodelphinidin, and additionally the black seed coats of *V. mungo* and one line of *V. radiata* var. *sublobata* TC 1965 contained delphindin 3-glucoside.

Saponins were extracted with methanol extract from defatted black beans, *V. mungo* (Lee et al. 1999) Structures of saponins of black bean cotyledon were determined to be soyasaponin I, soyasaponin II, soyasaponin V, 3-O-[α-L-rhamnopyranosyl-(1→2)-β-D-galactopyranosyl-(1→2)-β-D-glucuronopyranosyl]complogenin (saponin A) and 3-O-[α-L-rhamnopyranosyl-(1→2)-β-D-glucopyranosyl-(1→2)-β-D-glucopyranosyl] oleanolic acid (saponin B). For the black bean shell and the root of black bean sprout, analysis confirmed the saponins of soyasaponin I, soyasaponin II, soyasaponin V, saponin A, saponin B, acetylsoyasaponin A(4) and soyasaponin β(g). Moreover, all the studied saponins were found in the stem and leaves of the black bean sprouts, except soyasaponin β(g) and acetylsoyasaponin A(4), respectively.

Immunomodulatory Activity

V. mungo seed extract was found to have profound immunostimulatory activities (Solanki and Jain 2010b). Studies showed that primary and secondary antibody titers in the rats were significantly increased by treatment with the *V. mungo* extract as compared with those noted among rats in a control group. Increases in delayed-type hypersensitivity (DTH) response, the percentage (%) neutrophil adhesion, and in situ phagocytosis were also observed after treatment with the extract. The apparent immunostimulatory effect

of the *V. mungo* seed extract may be attributed to an augmentation of humoral and cell-mediated responses, phagocytosis, and hematopoiesis in the treated rats.

Antihyperlipidemic Activity

Oral administration of the hydroalcoholic extract of the seeds of *V. mungo* to poloxamer 407-induced and diet- induced hyperlipidemic rats resulted in a significant reduction of serum total cholesterol, triglycerides, very low-density lipoprotein cholesterol, and low-density lipoprotein cholesterol levels (Solanki and Jain 2010a). The atherogenic index and the HDL/LDL ratio were also normalized after treatment in diet-induced hyperlipidemic rats. The cholesterol-lowering effects of *V. mungo* seeds were postulated to be attributed to decreased HMG-CoA reductase activity, elevated biliary excretion, and decreased absorption of dietary cholesterol. Additionally, they improved natural antioxidant defence mechanisms.

Antinutritional Factors

Three trypsin-chymotrypsin inhibitors were isolated from seeds of the black gram (*Vigna mungo*) (Cheung et al. 2009). The trypsin inhibitory activity of the inhibitors was attenuated in the presence of the reducing agent dithiothreitol. The protease inhibitors did not exert any inhibitory effect on hepatoma (Hep G2) and breast cancer (MCF 7) cells or antifungal action toward *Botrytis cinerea, Fusarium oxysporum* and *Mycosphaerella arachidicola*. Two of the inhibitors slightly inhibited the activity of HIV-1 reverse transcriptase, with an IC_{50} in the millimolar range. In separate studies, a proteinase inhibitor (BgPI) was purified from black gram seeds and it showed 100% similarity with Bowman-Birk inhibitor (BBI) family (Prasad et al. 2010). BgPI exhibited non-competitive-type inhibitory activity against both bovine pancreatic trypsin (K(i) of 309.8 nM) and chymotrypsin (K(i) of 10.7 μM), however, with a molar ratio of 1:2 with trypsin.

Black gram (*Vigna mungo*) seeds were found to contain two D-galactose-specific lectin species, BGL-I and BGL-II (Suseelan et al. 2004). BGL-I consisted of two monomeric lectins, BGL-I-1 and BGL-1–2, of relative molecular weights 94 and 89 kDa, respectively. BGL-II is another monomeric lectin with a molecular weight of 83 kDa. The maximum amount of lectin per seed was found at 28 days after flowering. In another study, Black gram (*Vigna mungo*) seeds were shown to contain a monomeric lectin with certain unusual features (Singh and Rao 1991). The lectin agglutinated only trypsinized red cells, and its sugar specificity was complex as none of the common sugars, oligosaccharides or complex polysaccharides exhibited any affinity for the lectin. The purified lectin had a molecular weight of 58 kDa. Unlike other plant lectins, antibodies to the *P. mungo* lectin did not exhibit any immunological cross reactivity. The clot forming ability of the lectin was unusual in that the clot once formed was rapidly disaggregated indicated that it induced, as yet undefined, certain membrane alterations.

Tannin contents in black gram beans could be reduced by soaking and cooking (Zia-Ur-Rehman and Shah 2001). Soaking black grams in water at 100°C reduced tannins by 22.14% in 45 min whereas about 2.5 times more tannin was reduced after soaking in sodium bicarbonate solution with or without sodium chloride. Maximum improvement in protein digestibility was also noted after soaking black grams in sodium bicarbonate solution. Tannin contents were further reduced along with improvement in protein digestibility as a result of cooking.

Traditional Medicinal Uses

In traditional medicine, black gram is recommended for diabetes, as are other pulses however excessive consumption causes flatulence. The roots are narcotic and are used for ostalgia, abscess and inflammations. The seeds are sweet, emollient, thermogenic, diuretic, aphrodisiac, tonic, nutritious, galactagogue, appetising, laxative and nervine tonic. They are useful in dyspepsia, anorexia, strangury, and constipation, vitiated

conditions of vita, haemorrhoids, hepatopathy, neuropathy and agalactia. They are used in the form of decoction, powder, or paste.

Other Uses

Black gram is also grown for forage, silage, hay and chicken pasture.

Comments

The product sold as "black lentil" comprises the whole urad bean or urad dal. The product sold as "white lentil" is the same lentil with the black skin dehusked (removed).

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Vigna radiata

Scientific Name

***Vigna radiata* (L.) Wilczek**

Synonyms

Azukia radiata (L.) Ohwi, *Cadelium radiatum* (L.) S.Y.Hu, *Phaseolus abysissinicus* Savi, *Phaseolus aureus* Roxburgh, *Phaseolus aureus* Wall., *Phaseolus aureus* Zuccagni, *Phaseolus hirtus* Retz., *Phaseolus hirtus* Wall., *Phaseolus mungo* auct., *Phaseolus radiatus* L., *Phaseolus radiatus* L. var. *aurea* Roxb., *Phaseolus radiatus* L. var. *typica* Matsum., *Phaseolus radiatus* L. var. *typicus* Prain, *Rudua aurea* (Roxb.) Maekawa, *Vigna aureus* (Roxb.) Hepper., *Vigna aureus* Piper.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Golden Gram, Green Gram, Mung Bean, Chinese Mung Bean, Golden-Seeded Mung Bean, Indian Mung Bean, Jerusalem Pea, Burmese Mung Bean, Mung Dahl, Cultivated Mung Bean

Vernacular Names

Burmese: Pe-Di, Pe-Di-Sein, Pè Di Sien, Pe-Nauk, To-Pi-Si;
Brazil: Feijão-Mungo-Verde (Portuguese);
Canada: Ambérique, Ambérique Jaune;
Chinese: Lü Dou, Luhk Dáu ,Qing Xiao Dou, Xiao Dou, Xi Dou;
Czech: Fazol zlatý, Mungo fazole, Vigna Zlatá;
Danish: Mung-Bønne;
Dutch: Jerusalembønne, Mungboon;
Eastonian: Munguba;
Finnish: Mungopapu;
French: Haricot Doré, Haricot Mungo, Haricot Mung À Grain Doré, Haricot Velu De La Basse Nubier;
German: Jerusalembohne, Lunjabohne, Mungbohne, Mungobohne;
India: Mug, Mung (Bengali), Moong, Mugani, Mugvan, Mumg, Mung, Pessara (Hindu), Hesaru, Hesaru Bele, Hesaru Gida, Hesaru Kaalu, Hesaru Kaalu Gida, Pacche Hasiru (Kannada), Cheru Payaru, Cherupayar, Putsja-Paeru (Malayalam), Mung-Hawai (Manipuri), Mung, Udid (Marathi), Muga (Oriya), Moongi (Punjabi), Chiruppataru, Chiruppayaru, Karumpayir, Paccappayaru, Pacchai Payaru, Pani Payar, Pasipayar, Pasippayaru, Payiru (Tamil), Kaaruminumulu, Paccapesalu, Pacha-Pesalu, Pachha Pesalu, Pesalu (Telugu);
Indonesia: Arta Ijo, Kacang Djong;

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Italian: Fagiolino Verde, Fagiolo Aureo, Fagiolo Mungo, Fagiolo Semi-Verdi;
Japanese: Bundou, Fundou, Yaenari, Ryokutou;
Khmer: Sândaèk Ba:Y;
Laotian: Thwàx Khiêw, Thwàx Ngo:K, Thwàx Sadê:K;
Latin America: Frijo Mungo;
Malaysia: Kacang Hijau;
Nepal: Mas;
Peru: Frijolito Chino, Loctao;
Philippines: Balatong (Bisaya), Balataong (Ibanag), Balatong (Ifugao), Balatong (Iloko), Balatong, Munggo, Mongo (Tagalog);
Polish: Fasolka mung, Fasola Złota, Ola Mung;
Portuguese: Feijão-da-china;
Russian: Mash, Maš, Fasol' Vidov, Fasol' Zolotistaya, Vigna Luchistaia;
Sri Lanka: Bu Me, Mun, Mun Eta (Sinhalese);
Spanish: Frijol, Fríjol chino, Frijol De Oro, Frijol Mungo, Fríjol verde;
Swahili: Mchooko, Mchoroko;
Swedish: Mungböna;
Thai: Thuaa Khiaao, Thua Khieo, Thua Thong;
Vietnamese: Dâu Xanh, Dâu Che.

Origin/Distribution

India is regarded to be the centre of domestication of mungbean and supported by archaeological remains (Jain and Mehra 1980). However wild forms of mungbean, *Vigna radiata* var. *sublobata* show a wide area of distribution, extending from Central and East Africa, Madagascar, through Asia, New Guinea, to North and East Australia (Tateishi 1996). Studies of mungbean landraces in Asia led Tomooka et al. (1992) to conclude that the region of protein type diversity is found in West Asia (Afghanistan-Iran-Iraq area) rather than in India. They proposed on the basis of geographical distribution of protein types that mungbean may have spread mainly to the east by two routes. One route is from India to Southeast Asia; strains consisting of a few protein types with prominent protein type 1 were disseminated by this route. Another dissemination pathway may have occurred for protein type 7 and 8 strains from West Asia or India to China and Taiwan via the Silk Road and not via Southeast Asia. Mungbean is now widely grown in tropical and subtropical areas throughout the world. Mung beans are mainly cultivated in China, Thailand, Philippines, Vietnam, Indonesia, Burma, Bangladesh and India, but also in hot and dry regions of southern Europe and the southern USA.

Agroecology

Mungbean is a warm climate crop with an optimum temperature range of 30–35°C. It is cultivated from near sea level to 1850 m altitude. It can be grown in sub-temperate areas and requires 90–120 days of frost free conditions from planting to maturity. Mungbean is photoperiodic and responsive to length of daylight, so short days hasten flowering and long days delay it. Adequate rainfall is required from flowering to late pod fill in order to ensure good yield. High humidity and excess rainfall late in the season can result in disease problems and harvesting losses due to delayed maturity. They thrive best on fertile, well-drained sandy, loam soils at a pH range of 6.2–7.2. They perform poorly on heavy clay soils with poor drainage.

Edible Plant Parts and Uses

Mungbean is an important and widely consumed pulse crop. Young tender mungbean leaves are also edible (Plate 1). Mungbean seeds (Plate 4) are commonly used in many Asian cuisine. They are generally eaten whole (with or without skins), dehulled and split (Plates 5 and 6), as bean sprouts (Plates 2 and 3) or as flour (starch). The seeds are eaten cooked and the bean sprouts eaten fresh or cooked as stir-fries or in soups, and glass-noodles, vermicelli (Plate 7). Mungbean flour or starch is extracted from ground mung beans. It is widely used to make transparent noodles called cellophane noodles, bean thread noodles, bean threads, glass noodles, or vernacularly known as *fen si, mees sua, tung hoon*, *miến*, *bún tàu*, or *bún tà.* The cellophane noodles are also available in

Plate 1 Mungbean plant with pods

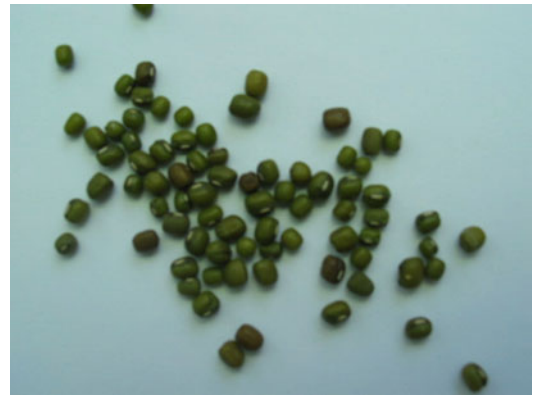

Plate 4 Mungbean seeds

Plates 2 Mungbean bean sprouts

Plate 5 Split mungbean seeds with adherent testa

Plate 3 Mungbean bean sprouts with radicles removed

Plate 6 Split mungbean seeds without testa

Plate 7 Mungbean vermicelli

sheets. In Chinese the mungbean sheets or skin is called *Fen-pi* or *Fen-p'i*. In Korea, *Nokdamuk* or *cheongpomuk* a jelly is made from mungbean starch and a similar yellow coloured jelly is called *hwangpomk* made by incorporating gardenia colouring. A popular Chinese dish *mayishangshu* is stewed cellophane noodles with a spicy ground pork meat sauce. In Filipino cuisine, meat is sauteed with garlic, onions, and bay leaves, then mung beans noodles are added and cooked. In Vietnam, the transparent wrapping of Vietnamese spring rolls is made from mung bean flour. Mung bean starch is also used to fortify protein in cereal flours. Mungbean batter is used to make crepes called *Pesarattu* in Andhra Pradesh, India.

Whole mung bean seeds are eaten boiled or cooked in the form of porridge, soups or made into desserts. In Chinese cuisine, whole mung beans are used to make a *tong sui*, or sweetened soup, called *lǜdòu tāng*, which is served either warm or chilled. In southeast Asia the beans are cooked with brown sugar, coconut or soy milk with or without a little ginger to make a porridge like dessert. In Indonesia, they are made into a popular cold dessert snack called *es kacang hijau*. In Kerala, India, whole *moong dal (cheru payaru)* is commonly boiled to make a dry preparation that is often consumed with rice gruel (*Kanji*). In the Philippines, it is the main ingredient of the dessert *hopiang munggo*. In India, mung beans are also consumed as a snack. The dried mung beans are soaked in water, then partly dried to a dry matter content of about 42% before deep-frying in hot oil.

Mung beans with their skins removed, are light yellow in color. They are made into mung bean paste or mungbean jam by de-hulling, cooking, and pulverizing the beans to the consistency of a dry paste. The paste is sweetened and is made into ice creams or frozen ice pops and as fillings in buns, glutinous and non-glutinous dumplings and moon cakes, a popular item during the moon cake festival

Mung bean sprouts (Plates 2–3) called are dòu yá (literally "bean sprout/germ"), yá cài (literally "sprout vegetable"), or yín yá (literally "silver sprouts") in Chinese, and Hokkien (Min Nan), *moyashi* in Japanese, *tauge* in Indonesian, *taugeh* in Bahasa Melayu, *togue* in Pagbasa Filipino, *thua-ngok* in Thai, and *giá đậu* or *giá đỗ* in Vietnamese are widely and commonly consumed in Northern Asian and southeast Asia. Mung bean sprouts are used raw and fresh in mixed salads, in fillings of Vietnamese spring rolls, as garnish for the rice noodle dish *pho*. They are use in simple stir-fry with ingredients like chopped spring onion, garlic, ginger and pieces of salted dried fish to add flavour or in stir fries with shrimps, and other sautéed meat. They are also an important ingredient in a variety of Malaysian and Peranakan Nyonya cuisine including *char kway teow*, *Hokkien mee*, *mee rebus*, and *pasembor*. In Korea, slightly cooked mung bean sprouts, called *sukjunamul* are often served as a side dish. In the Philippines, mung bean sprouts are made into "*lumpia* roll" called *lumpiang tugi*.

Botany

An erect or sub-erect, twining or creeping annual herb, growing to 30–90 cm high with branches at the base, and more or less covered with brownish hairs. Leaves are alternate and trifoliolate, pale green, the terminal leaflet is broad-ovate, lateral ones oblique-ovate (Plate 1), 5–12 cm long, 3–9 cm wide, acuminate, entire with peltate, foliaceous stipules attached almost at the middle. Flowers are dull greenish-yellow to pale yellow, papilionaceous, calyx tube glabrous, 3–4 mm with narrowly deltoid lobes, the upper two connate into a bifid lip; the apical portion of the keel flushed purple,

subsessile, standard petal, twisted. The fruit (legume pod) is pendant, linear-cylindric, 4–12 cm long and 4–6 mm broad, pubescent or glabrous, green (Plate 1) ripening to gray, brown or black, with 10–15 subglobose or ellipsoid, bright green (Plate 4) yellowish green, brown or green-black mottled seeds (4–6 mm) with a flat, white hilum covered by convex spongy cushion.

Nutritive/Medicinal Properties

Analyses carried out in the United States reported raw green gram seeds to have the following proximate composition (per 100 g value): water 9.05 g, energy 347 kcal(1,452 kJ); protein 23.86 g, total lipid 1.15 g, ash 3.32 g, carbohydrates 62.62 g, total dietary fibre 16.3 g, total sugars 6.60 g, Ca 132 mg, Fe 6.74 mg, Mg 189 mg, P 367 mg, K 1246 mg, Na 15 mg, Zn 2.68 mg, Cu 0.941 mg, Mn 1.035 mg, Se 8.2 μg, vitamin C 4.8 mg, thiamine.0.621 mg, riboflavin 0.233 mg, niacin 2.251 mg, pantothenic acid 1.910 mg, vitamin B-6 0.382 mg, total folate 625 μg, choline 97.9 mg, vitamin A 114 IU, vitamin E (α-tocopherol) 0.51 mg, vitamin K (phylloquinone) 9 μg, total saturated fatty acids 0.348 g, 16:0 (palmitic) 0.250 g, 18:0 (stearic) 0.071 g; total monounsaturated fatty acids 0.161 g, 18:1 undifferentiated (oleic) 0.161 g; total polyunsaturated fatty acids 0.384 g, 18:2 undifferentiated (linoleic) 0.357 g, 18:3 undifferentiated (linolenic) 0.027 g; phytosterols 23 mg, tryptophan 0.260 g, threonine 0.782 g, isoleucine 1.008 g, leucine 1.847 g, lysine 1.664 g, methionine 0.286 g, cystine 0.210 g, phenylalanine 1.443 g, tyrosine 0.714 g, valine 1.237 g, arginine 1.672 g, histidine 0.695 g, alanine 1.050 g, aspartic acid 2.756 g, glutamic acid 4.264 g, glycine 0.954 g, proline 1.095 g, serine 1.176 g and β-carotene 68 μg (USDA 2010).

Analyses carried out in the United States reported raw green gram sprouts to have the following proximate composition (per 100 g value): water 90.40 g, energy 30 kcal (126 kJ); protein 3.04 g, total lipid 0.18 g, ash 0.44 g, carbohydrates 5.94 g, total dietary fibre 1.8 g, total sugars 4.13 g, Ca 13 mg, Fe 0.91 mg, Mg 21 mg, P 54 mg, K 149 mg, Na 6 mg, Zn 0.41 mg, Cu 0.164 mg, Mn 0.188 mg, Se 0.6 μg, vitamin C 13.2 mg, thiamine.0.084 mg, riboflavin 0.124 mg, niacin 0.749 mg, pantothenic acid 0.380 mg, vitamin B-6 0.088 mg, total folate 61 μg, choline 14.4 mg, vitamin A 21 IU, vitamin E (α-tocopherol) 0.10 mg, vitamin K (phylloquinone) 33 μg, total saturated fatty acids 0.046 g, 16: (palmitic) 0.032 g, 18:0 (stearic) 0.008 g; total monounsaturated fatty acids 0.022 g, 18:1 undifferentiated (oleic) 0.022 g; total polyunsaturated fatty acids 0.058 g, 18:2 undifferentiated (linoleic) 0.042 g, 18:3 undifferentiated (linolenic) 0.016 g; phytosterols 15 mg, tryptophan 0.037 g, threonine 0.078 g, isoleucine 0.132 g, leucine 0.0175 g, lysine 0.166 g, methionine 0.034 g, cystine 0.017 g, phenylalanine 0.117 g, tyrosine 0.052 g, valine 0.130 g, arginine 0.197 g, histidine 0.070 g, alanine 0.099 g, aspartic acid 0.479 g, glutamic acid 0.161 g, glycine 0.063 g, serine 0.033 g, β-carotene 6 μg, α-carotene 6 μg and β-cryptoxanthin 6 μg (USDA 2010).

As shown above, green gram seed is exceedingly nutritious and very rich in proteins, amino acids, fibre, carbohydrates, folate, niacin, pantothenic acid and minerals like Ca, Fe, K, Mg, P, Zn, and moderately rich in riboflavin, thiamine, vitamin A and vitamin 6. The sprouts are also rich in proteins, minerals and also have Vitamins A, B and C, vitamin B-6, pantothenic acid, vitamin E (α-tocopherol) and vitamin K (phylloquinone). Sprouts also have β-carotene, α-carotene and β-cryptoxanthin. Both seeds and sprouts are also rich in flavonoids which are important natural plant antioxidants imparting good health benefits. Studies in Japan reported that the hypocotyls, seed-coats and mature leaves of *Vigna mungo, V. radiata* var. *radiata* and *V. radiata* var. *sublobata* were found to contain 12 kinds of flavonoid including three anthocyanins, two leucoanthocyanins, two glycoflavones and five flavonol glycosides (Ishikura et al. 1981). The leaves of *V. radiata* var. *radiata* and *V. radiata* var. *sublobata* contained the glycosides (mainly rutin) of both quercetin and kaempferol, while those of *V. mungo* contained only kaempferol glycosides, with robinin as the predominant pigment. The purple-red hypocotyls of the former group

contained delphinidin 3-p-coumaroylglucoside, while those of the latter contained cyanidin 3-glucoside, although delphinidin 3-glucoside was commonly found in all of the plants. The seedcoats contained in common four compounds of vitexin, isovitexin, leucocyanidin and leucodelphinidin, and additionally the black seed coats of *V. mungo* and one line of *V. radiata* var. *sublobata* TC 1965 contained delphindin 3-glucoside.

Mung bean seeds were found to contain storage proteins globulins such as vicilin type (8S) and basic 7S globulins and legumin type (11S) globulins (Mendoza et al. 2001). The percent composition of total globulins was estimated to be as follow: vicilin 8S, 89%; basic 7S globulin, 3.4%; and legumin 11S, 7.6%. The N-terminal sequences of the different subunits/fragments of the globulins were found to have strong homology with storage proteins of other legumes and crops. The 8S vicilin-type seed storage globulins of mung bean consisted of three isoforms: 8Sα, 8Sα′ and 8Sβ (Itoh et al. 2006). The three isoforms possessed high sequence identities with each other (around 90%). Suseelan (1997) found *Vigna radiata* seeds to contain two major lectins, MBL-I and MBL-II . MBL-I was found to be a tetramer with native molecular weight of 132 kDa and subunit molecular weight of 33 kDa having α-galactosidase activity. MBL-II consisted of two monomeric lectins with molecular weight of 94 kDa and 89 kDa which were associated mainly with β-galactosidase activity. Both MBL-I and MBL-II are D-galactose-specific lectins.

Antioxidant Activity

Comparatively little studies have been published on the medicinal attributes of mung bean. A few paper published relate to the flavonoids, antioxidant and hypotensive property. In one study, both mung bean and adzuki bean aqueous extracts demonstrated the strongest anti-lipid peroxidation activity and the highest superoxide anion scavenging activity (Lin et al. 2001). All extracts of the legumes showed anti-superoxide formation activity indicating the important and beneficial role played by such legumes in our diet.

Hexane-extracted seed oil contents of 4 cultivars of mung beans (*V. radiata*) were found to vary from 1.20% to 1.56% (Anwar et al. 2007). Mung bean seeds were found to be a rich source of protein (20.97–31.32%). The contents of Fe, Cu, Mg, Na, K, Ca, and Zn were found to be 105.8–190.9, 4.8–6.3, 48.6–51.7, 382.6–562.7, 11.6–18.8, 359.2–482.9, and 24.9–47.2 mg/kg, respectively. The mung bean seeds contained linoleic acid in the highest amount, 340.5–465.7 mg/100 g of dry seed, followed by palmitic, oleic, linolenic, stearic, and arachidic acids: 278.1–401.2, 212.6–293.5, 188.7–236.8, 135.5–168.4, and 22.8–24.5 mg/100 g of dry seed, respectively. The seeds were found to be a rich source of tocopherols (α, γ, δ) which ranged from 1.1 to 10.1, 60.7 to 80.9, and 4.6 to 11.2 mg/kg, respectively. Methanolic extracts of the seeds of the mung bean cultivars exhibited a good antioxidant activity as determined in terms of measurement of total phenolic contents (TPC) (0.62–1.08 g/100 g of dry matter), percent inhibition of peroxidation (49.8–89.2%), reducing power (1.19–1.45%), and bleaching β-carotene. The results of the study revealed these four mung bean cultivars to be a potential source of essential fatty acids, antioxidants, minerals and protein, all linked with positive health benefits.

Hepatoprotective Activity

Studies showed that the serum glutamate-oxalate-transaminase (sGOT) and serum glutamate-pyruvate-transaminase (sGPT) activities in rats, increased by acetaminophen (APAP), were decreased significantly through treatment with increasing concentrations up to 1,000 mg/kg body wt. of the extracts of mung bean, adzuki bean, black bean and rice bean (Wu et al. 2001). In particular, the mung bean aqueous extract showed the best hepatoprotective effect on APAP-induced hepatotoxicity. The pathological changes of liver injury caused by APAP were ameliorated by the treatment with all of the legume extracts, which were compared to silymarin as a standardized drug. The extract of mung bean acted as a potential hepatoprotective agent in dietary supply.

Hypotensive Activity

In studies with normotensive rats, aqueous extracts of green gram (*Phaseolus aureus*), common rue (*Ruta graveolens*) and kelp (*Laminaria japonica*) were hypotensive, and found to contain bioactive proteinaceous substances that stimulated urine flow (Chiu and Fung 1997a, b). A combination of two or three plant extracts showed subtractive or additive effects, suggesting important bearing on their therapeutic use. Combinations of rue and green beans and of rue and kelp showed responses that were either positive or negative chronotropically, were less than the sum total of their individual responses (i.e., subtractive) and were not concentration dependent. A combination of all three showed subtractive effects on the decrease in atrial rate that were concentration related. No change in atrial tension was observed upon treatment with a combination of the three plant extracts.

Estrogenic Activity

Seven legume extracts: soybean (*Glycine max* L.), green bean (*Phaseolus vulgaris* L.), alfalfa sprout (*Medicago sativa* L.), mung bean sprout (*Vigna radiata* L.), kudzu root (*Pueraria lobata* L.), and red clover blossom and red clover sprout (*Trifolium pratense* L.) containing phytoestrogens exhibited estrogenic activity (Boué et al. 2003). Estrogenic activity was determined using an estrogen-dependent MCF-7 breast cancer cell proliferation assay. Kudzu root, red clover blossom and sprout, mung bean sprout, and alfalfa sprout extracts displayed increased cell proliferation above levels observed with estradiol. The pure estrogen antagonist, ICI 182,780, suppressed cell proliferation induced by the extracts, suggesting an ER-related signalling pathway was involved. All seven of the extracts exhibited preferential agonist activity toward ERbeta.

Antimicrobial Activity

Antifungal proteins from the field bean and mung bean had an intermediate potency in inhibitory HIV-1 protease and integrase (Ng et al. 2002). However, mung bean antifungal protein was not capable of inhibiting HIV-1 reverse transcriptase.

Antinutrient – Trypsin Inhibitor Activity

Mung bean seeds were found to contain a trypsin inhibitor (Chrispeels and Baumgartner 1978). The protease inhibitor exhibited inhibitory activity toward trypsin, but not toward chymotrypsin. It exhibited immunological cross-reactivity against extracts of black gram and black-eyed pea, but not against soybean. It had no inhibitory activity against vicilin peptidohydrolase, the principal endopeptidase in the cotyledons of mung bean seedlings. Lorensen et al (1981) found that ungerminated seeds of mung bean contained a single major species (F) of trypsin inhibitor with five minor species (A–E) separable on diethylaminoethyl-cellulose. During germination the level of trypsin inhibitory activity decreased from 1.8 units/g dry weight in ungerminated cotyledons to 1.2 units/g in cotyledons from 5 day old germinated seeds. This decrease was accompanied by major changes in the distribution of inhibitory activity among the inhibitor species. By 48 hours of germination, inhibitor F was dissipated with an accompanying rapid elevation in inhibitor C. Similarly, , inhibitor E fell while inhibitor A increased. A similar sequence of changes was found in-vitro on incubating purified inhibitor F with extracts from seeds germinated 96 h. The combined in-vivo and in-vitro data suggested a conversion sequence of: F →E→C → A. Five green gram varieties, viz. Mg 161, M3, Co_2, Pusa 8793 and Pusa baisakhi, were found to have phytic acid, tannic acid and trypsin activity (Philip and Prema 1999). Significant varietal variation in tannin (310–400 mg percent), phytic acid (201.33–265.33 mg percent) and trypsin inhibitor activity (55.74–97.70 TIU/mg) were observed.

Traditional Medicinal Uses

Medicinally, in the Philippines, a decoction of the seeds is employed either raw or cooked in maturative

poultices. Mungbean extract has also been reported to have protective and curative properties in polyneuritis galinarum.

In India, the roots are said to be narcotic and are prescribed as a remedy for aching bones. The seeds are much used as medicine in India, both internally and externally, especially in paralysis, rheumatism, and affection s of the nervous system. They are also used in fevers, are considered hot and tonic, are useful in piles and affections of the liver, and are helpful in coughs. A poultice is useful for checking secretion of milk and reducing distension of the mammary glands. The seeds are considered antiscorbutic in Indo-China and are used as a diuretic.

In traditional Chinese medicine mung bean sprouts, Lu Dou bean flour and flower have enjoyed a long history of food and medicinal uses, with a written record dating back to the tenth century A.D. The sprouts are considered to be a yin or cooling food and deem to have anticancer qualities. It is also used by Oriental herbalists for all hot, inflammatory conditions, ranging from systematic infections to heat stroke to hypertension. Mung bean has also been used in remedies as antipyretic, antihypertensive, antidote to toxic poisonings and a nutritive tonic. Mung bean flour has found its way into some skin care cosmetics.

Other Uses

Mungbean is also grown as fodder, hay, green manure or cover crops.

Comments

The cultivated types of mung bean are grouped as *Vigna radiata* var. *radiata*.

The wild types of mung bean, which are usually smaller in all parts than cultivated types, are grouped into two botanical varieties:

– var. *sublobata* (Roxb.) Verdc., occurring in India, Sri Lanka, South-East Asia, northern Australia (Queensland), in tropical Africa from Ghana to East Africa, southern Africa and Madagascar; stems twining or creeping, leaflets 2- oe -3 lobed, acute at apex;
– var. *setulosa* (Dalzell) Ohwi & Ohashi, with large, almost orbicular stipules and dense long hairs on the stem, and occurring in India, China, Japan and Indonesia.

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Vigna subterranea

Scientific Name

***Vigna subterranea* (L.) Verdc.**

Synonyms

Arachis africana Burm. f., *Cryptolobus africanus* (Burm. f.) Spreng., *Cryptolobus subterraneus* (L.) Spreng., *Geolobus flavus* Raf., *Glycine subterranea* L. (basionym), *Tetrodea subterranea* (L.) Raf., *Voandzeia subterranea* (L.) Thouars ex DC.

Family

Fabaceae also placed in Leguminosae, Papilionaceae

Common/English Names

African Groundnut, Baffin Pea, Bambara Bean, Bambara Groundnut, Congo Goober, Congo Groundnut, Earth Bean, Earth Nut, Earth Pea, Ground-Bean, Hog-Peanut, Jugo Bean, Kaffir Pea, Madagascar Groundnut, Njugo Bean, Stone Groundnut, Underground Bean

Vernacular Names

Afrikaans: Dopboontjie, Jugoboon;
Arabic: Gertere, Guerte;
Brazil: Mandubi d'Angola, Mancara De Bijagó, Jinguba-De-Cabambe (Portuguese); ***Central Africa***: Njogo Bean;
Danish: Jordaert, Angolaaert;
Dutch: Afrikaanse Aardnoot;
Finnish: Maapapu;
French: Voandzou, Pois d'Angole, Pistache De Terre, Haricot Pistache, Pois Arachide, Pois Bambarra, Pois De Terra, Pois Souterrain, Vanzon, Voandzou;
German: Angola-Erbse, Erderbse, Mandubi-Erbse, Bambara-Erdnuß;
Ghana: Aboboi, Akyii;
Hausa: Juijiya;
Ibo: Okpa Otuanya;
Indonesia: Kacang Pendem, Kacang Banten (Javanese), Kacang Tanah, Kacang Manila (Malay), Kacang Bogor, Kacang Bandung, Kacang Banten, Kacang Gengge, Kacang Gondolo, Kacang Maneela, Kacang Tanah (Sundanese);
Italian: Pisello Di Terra;
Japanese: Banbara Mame;
Kenya: Njugu Mawe;
Madagascar: Pistache Malagache, Voandzu, Voanjobory;
Malawi: Nzama, Njama;
Malaysia: Kacang Poi, Nela-Dakalai;
Ndebele: Indlubu, Ditloo;
Nigeria: Epi Roro, Guijiya, Gujuya, Okboli Ede;
Portuguese: Mancara De Bijagó;
Shona: Nyimo;
Senegal: Mampua (Badyara), Psukia, Su (Balanta), O-Yèl (Basari), E-Br, Ge-Mbr, Ma-Wr (Bedik),

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Mãnkara Di Biago (Crioulo), Bamoyu, Bamoyon (Diola), Guba-Gobgob, Gub-Gub;
Sierra Leone: Agbaroro (In Creole);
Sotho: Ditloo-Marapo;
South Africa: Njugo Bean;
Spanish: Guisante De Tierra, Maní Africano, Maní De Bambarra, Bambarra, Vuandzú, Cacahuete De Bambarra, Guandsú;
Sudan: Ful Abungawi;
Surinam: Gobbe;
Swahili: Njugu, Njugu Mawe;
Swaziland: Tindlubu (Siswati);
Swedish: Bambara Jordnöt;
Thailand: Thua Rang;
Tsonga: Kochane, Nyume, Ndlowu;
Venda: Nduhu, Nwa, Tzidzimba;
Xhosa: Jugo;
Yoruba: Epi Roui;
Zambia: Juga Bean, Ntoyo;
Zimbabwe: Nlubu, Nyimo, Jugo Bean;
Zulu: Indlubu, Izidlubu.

Origin/Distribution

Bambara groundnut is indigenous to Africa – endemic to Chad, Mali, Niger, North Nigeria, North Cameroon and the North Central African Republic, but has been dispersed to Egypt, the Republic of Sudan, East Africa and Madagascar. Although wild types are still to be found in tropical eastern Africa, the crop is believed to have originated in the region encompassing north-eastern Nigeria and northern Cameroon from its presumed wild ancestor, *Vigna subterranean* var. *spontanea* (Herms) Hepper (Smartt 1990). It is also cultivated elsewhere in the tropics like Indonesia, Malaysia and Thailand.

Agroecology

Bambara groundnut thrives well in climatic areas growing groundnut maize, millet, or sorghum in areas with 500 mm minimum rainfall. Best yields are obtained in areas with 900–1,200 mm/year and in soils with a pH range of 5.0–6.5. Fertilized flowers are geotropic, as in groundnuts and buried beneath the soil surface for fruit development as such a well-drained, friable light to deep sandy soils are best. The crop needs abundant sunshine, high temperatures, at least four frost-free months, and adequate rains during the period between sowing and flowering. For optimal growth the temperature requirement is reported as 20–28°C but it can tolerate high temperatures to 40°C. It is also drought tolerant. Thus, the legume is suitable for hot dry regions that is unsuitable for growing other pulses. Satisfactory yields can be obtained at elevations up to at least 1,600 m. Most cultivars are adapted to short days of the tropical and subtropical latitudes.

Edible Plant Parts and Uses

Bambara groundnut is one of the main staple foods in parts of the Sahel and Sudanian savannas, with cowpea, millet and groundnut. The pulse is grown for its edible seed. Bambara groundnut is eaten in several ways and at different stages of maturation. The young fresh seeds may be boiled and eaten as a snack in a manner similar to boiled peanuts and could be made into pudding locally called *Moi Moi* or *Okpa* (bean porridge) in the some parts of Nigeria (Okpuzor et al. 2010). It has been reported that in Zambia, bambara groundnut is used for bread making (Brough et al. 1993) while Poulter and Caygill (2006) also reported that it could be used for milk making. The mature seeds are boiled and eaten as part of a main meal but they can also be ground into flour and be used in making porridge. When roasted or boiled with salt, even the mature seeds are sweet and pleasant tasting. Mature bambara groundnuts are boiled in their shells and are offered for sale, ready cooked (Plates 3 and 4), on roadsides and in markets in various parts of Africa. They are boiled with maize meal and used in a relish or roasted or fried. The seeds are often roasted and ground into nutritious flour which is especially appetizing and is blended into many traditional dishes. Mashed bambara groundnut is steamed to prepare a local dish called *okpa*.

Plate 1 Bambara groundnut pod

Plate 4 Cooked Bambara groundnut pod and seed

Plate 2 Bambara groundnut pod, seed and hull

Plate 3 Cooked Bambara groundnut pods

In West Africa, bambara groundnut flour can be used make a batter from which fritters are made. These fritters (known as *accra*, *akara*, *akla*, *binch akara*, *bean balls*, *kosai*, *koose*, *kose*, *koosé*, and *kwasi*) are commonly prepared at home for breakfast, for snacks, or as an appetizer or side dish. They are also fast-food, sold by vendors on the street, in marketplaces, and at bus stations. Blends of bambara groundnut flour and wheat flour in different ratios are used in making bread. Bambara groudnut can also be processed into fermented food products such as *dawadawa* and *tempe*. To produce a *dawadawa*-type product Bambara groundnut is fermented using a starter culture of *Bacillus licheniformis* (Amadi et al. 1999a). To prepare *tempe*, two fungal species are used, *Rhizopus oligosporus and R. stolonifer* (Amadi et al. 1999b). Sensory evaluation showed that bambara groundnut *tempe* rated similar in taste and texture and higher in colour and flavour than soybean *tempe*. Bambara groundnut would be an acceptable food product in the diet as a good protein supplement. Seeds are also canned commercially in Zimbabwe.

In west Java and southern Thailand, bambara groundnut is eaten as snack, dessert ingredient or as a soup vegetable. In Java, the pod is cooked with salt and the seeds are eaten as a delicacy or roasted and eaten as snacks called *kacang beledeg* (Sundanese); the young pods are mixed whole through the *sayor*. In the northern states (Perlis, Kedah and Kelantan) of Peninsular Malaysia, bambara groundnut is commonly marketed as raw nuts at farmers markets and night markets. It is mostly consumed as boiled nut (similar to peanut).

Botany

A low short-lived, erect- bushy or prostrate annual herb, 10–15 cm high with branched, hairy stems having short internodes. It has a well-developed taproot with profuse geotropic lateral roots bearing nitrogen-fixing nodules. Leaves on 8–30 cm long petiole, pinnately trifoliate, leaflets oblong to lanceolate, 3–7.5 cm by 0.8–3 cm wide, green, glabrous, with cuneate or obtuse base, entire margin and rounded emarginate apex. Peduncles are axillary, 0.6–1.2 cm long with 1–3 flowers at the apex. Flowers are short-pedicel, small, yellow. Standard petal is obovate and emarginate, limb pale yellow and wings with brown spots, stamens free and vexillary. After fertilisation, the corolla is shed, the peduncle elongates and pushes the developing pod into the ground (geotropic). Pods are ellipsoid-globular, 1.5–2.5 cm long usually with one seed (Plate 1). Seeds may be cream, brown, red (Plate 2), mottled, or black-eyed.

Nutritive/Medicinal Properties

The proximate nutrient composition of bambara groundnut seed was found to be 9.7% moisture, 16.6% protein, 5.9% fat, 2.9% ash, 4.9% crude fibre and 64.9% carbohydrate (Enwere et Hung 1996). The ranges (mg/100 g dry matter) obtained for the macro minerals in the raw seeds were: Ca 37–128, K 1,545–2,200, Mg 159–335, Na 16–25, P 313–563, and for the microminerals (ppm): Cu 3.0–13.2, Fe 23.0–150 and Zn 13.9–77.0 (Amarteifio et al. 2006). The Mg and P contents were found to be similar to those of groundnut (*Arachis hypogaea*, P 376 and Mg 168). The data indicated great potential of bambara groundnut for incorporation into various human foods where it could provide useful plant proteins.

Minka and Bruneteau (2000) found that linoleic, palmitic and linolenic acids were the most predominant fatty acids with average values of 44%, 30% and 21%, respectively. Stearic acid was present in small quantities. Sugar analysis showed that 30% of the neutral sugars were present and identified essentially as glucose and galactose. The total essential amino acids amounted to an average of 32.7%. Lysine was the most predominant essential amino acid with average value of 10.3%. The protein was reported to be higher in the essential amino acid methionine than other grain legumes Another research found that the seed crude protein varied from 17.5% to 21.1%; crude fat 7.3–8.5%; total ash 4–5%; crude fibre 1.8–2.0%; carbohydrate and moisture content for the different cultivars were 53.0–60.8%and 7.5–12.3%, respectively (Onimawo et al. 1998). The bulk density ranged from 0.65 to 0.75 g/ml; water binding capacity 2.1–2.9 g/2 g sample; oil binding capacity 0.9–1.6 g/2 g sample; emulsifying activity 55.1–60.0% and emulsifying stability 10–12%. Ojimelukwe (1999), reported that bambara groundnut seeds contained 18–21% protein 6–8% fat, 8–10% moisture and 1.2–2.6% ash. The cooking time for softening was shorter for the cream and brown coloured cultivars than for the red black coloured cultivars. There were no varietal differences in starch viscosity and swelling properties among cultivars. Estimation of tannin content of bambara groundnut seeds showed that tannin contents of the red and black seed cultivars (0.96% and 1.1%, respectively) were significantly higher than the tannin contents of cream and brown seed cultivars (0.68% and 0.72%, respectively).

Bambarra groundnut seeds contained only low levels of essentially non-toxic lectin, moderate amounts of trypsin inhibitors and negligible quantities of α-amylase inhibitors and they have great potential as dietary protein sources for man and animals (Grant et al. 1995). Three anthocyanins were identified in bambarra groundnut: delphinidin 3-O-β-glucoside, petunidin 3-O-β-glucoside, and malvidin 3-O-β-glucoside (Pale et al. 1997).

Oboh et al. (2009) reported that fermentation caused a significant increase in the free soluble phenol content of the pigeon pea, bambarra groundnut and African yam bean, while there was a significant decrease in the bound phenol content of the legumes. Free soluble phenol from both the fermented and unfermented legumes had a significantly higher reducing power (except *C.*

cajan), free radical scavenging ability (except *C. cajan*) and inhibition of lipid peroxidation than bound phenolic extract. However, free soluble phenolic compounds from the fermented beans had a significantly higher reducing power, free radical scavenging ability, and inhibition of lipid peroxidation than free soluble phenols from unfermented beans. Hence, it was concluded that, fermentation could increase the free soluble phenolic content of the underutilized legumes tested and consequently enhance the antioxidant activities of the legumes; fermented *V. subterranea* was found to be the most promising condiment with antioxidant activity.

Significant differences were observed in some of the chemical components of the different varieties of bambara in northern Ghana (Nti 2009). The cultivars had distinct colour differences ranging from cream through brown, maroon to black, with variations in the seed sizes and seed coat thickness. Protein and fat contents ranged from 19.3% to 27.1% and 4.8% to 7.0%, respectively, while ash content was not significantly different among the cultivars. Tannin content varied between 4.5 mg CE/g sample for the cream-coloured and 14.9 mg CE/g sample for the black variety. Dehulling increased the protein content, decreased tannin content by up to 92% and improved the colour of bambara products, while heat treatment enhanced their taste, aroma and overall acceptability.

The incorporation of modified bambara isolate flour (MBI) into fermented maize flour, '*ogi*' (FMF) resulted in a appreciable increase in the crude protein content and significant improvement in the water absorption capacity (WAC), oil absorption capacity (OAC), foaming capacity (FC), and the least gelation concentration (LGC) (Fasasi et al. 2009). The significant increase and improvement in both the proximate and functional properties of the new product may find its relevant application in food systems.

Ten proteins were identified in the malted seeds of bambara and 12 proteins in the dry seeds from the 214 peptides isolated after searching 586 proteins of the genus *Vigna* (Okpuzor et al. 2010). Proteins identified in the malted bambara included: seed storage protein B; 8S globulin α subunit, 8S globulin β isoform precursor; chain A, crystal structure of adzuki bean 7s globulin-1; 10 kDa protein precursor Clone PSAS 10), vicilin protein; BV 1 protein, heat shock protein 90; 8s globulin α isoform precursor; chain 1 crystal structure of the Bowman-Birk inhibitor from *V. unguiculata*. Seed storage protein B and vicilin were observed to be the major proteins common to both malted and dry seeds and are similar to *Vigna luteola*. Some of the other proteins observed showed amino acid sequence homology with *Vigna radiata* and *Vigna unguiculata* species. The following proteins BV1, Heat shock and Bowman-Birk Inhibitor (a protease), were observed only in the malted state. In the dry seeds, seven proteins namely, 8S globulin alpha subunit; Mung bean seed albumin; Em protein; ARG10; PDF1; 10 kDa protein precursor (Clone PSAS10) and Actin had sequence homology to *Vigna radiata* species. Two proteins, Chain A, Crystal Structure of Adzuki Bean 7s Globulin-3 and 7S globulin-2 had amino acid sequence similar to *Vigna angularis* while another two, Dehydrin and vicilin was similar to *Vigna unguiculata*. Only one protein type (seed storage protein B) was similar to *Vigna luteola.* This protein information may enhance the appreciation of the nutritional and health benefits of bambarra seed.

Studies reported that methanol extracts of cancer bush (CB, *Sutherlandia frutescens*), devil's claw (DEV, *Harpagophytum procumbens*), rooibos tea (RT, *Aspalathus linearis*), and bambara groundnut (BB, *Vigna subterranea*) inhibited, to a different extent, 12-O-tetradecanoylphorbol-13-acetate (TPA)-induced COX-2 expression in human breast epithelial (MCF10A) cells and in mouse skin in-vivo (Na et al. 2004). An abnormally elevated expression of cyclooxygenase-2 (COX-2) was implicated in pathogenesis and progression of carcinogenesis. Methanol extracts of both CB and BB inhibited the DNA binding of nuclear factor (NF)-κB activated by TPA in MCF10A cells in a dose-dependent fashion. Based on above findings, CB and BB were likely to inhibit TPA-induced COX-2 expression through suppression of DNA binding of NF-κB, which may contribute to the chemopreventive or chemoprotective activity of these African plants.

Studies in Nigeria demonstrated that the semi-purified diets incorporating the five different legume species produced very different cholesterolaemic effects (Dabai et al. 1996). Diets containing baked beans (*Phaseolus vulgaris*) and butter beans (*Phaseolus lunatus*) were more potent at lowering raised plasma cholesterol levels than diets containing marrowfat peas (*Pisum sativum*) and lentils (*Lens culinaris*). Inclusion of the bambara groundnut into the semi-purified diet resulted in an exaggeration of hypercholesterolaemia. Differences in cholesterol-lowering capacity of the various legume diets could not be attributed to concentrations of faecal bile acids or neutral sterols. However, evidence indicated that the inclusion of legumes in the diets reduced the faecal excretion of secondary bile acids.

The plant has also a number of traditional medicinal uses. It has been employed for venereal diseases and as an aphrodisiac. *Vigna subterranea* been used to treat some malignancies and inflammatory disorders in Africa. Its protein extracts, can be used directly in cosmetic products or compositions for the skin and/or the hair, nails and eyelashes.

Other Uses

Bambara groundnuts are not used for oil extraction, as they contain only 6–12% oil which is less than half the amount found in peanuts, making them not useful as an oilseed crop. They are successfully fed to pigs and poultry; the haulms are a valuable and excellent cattle fodder.

Mahala and Mohammed (2010) reported the following chemical composition and fermentation characteristics of bambara seeds, pods and hulls for animal feed. Seeds contained crude protein 24.98%, crude fibre 12.94%, fat 1.6%, ash 3.6%, and organic matter digestibility 62.17%. Hulls contained crude protein 5.56%, crude fibre 43.43%, fat 4.3%, ash 5.3%, and organic matter digestibility 38.79%. Pod contained crude protein 15.30%, crude fibre 25.19%, fat 3.5%, ash 3.8%, and organic matter digestibility 55.92%. The metabolizable energy was significantly higher (10.78 MJ/kg DM) in seed than in pods. Gas produced from the quickly degradable fraction (a) was lower in seeds (−5.76 ml), and pods (−4.61 ml) but higher in hull (−1.63 ml). The slowly degradable fraction (b) was lowest in hull (23.41 ml) but highest in seeds (60.32 ml). Potential gas production was significantly higher in seeds (54.56 ml), than in hulls (21.78 ml) while gas production rate fraction (c) was significantly highest in pods (9.20mlh), and lowest in seeds (6.23mlh). Crude protein was positively and significant, correlated with soluble fraction (a), degradable fraction (b) and potential gas production (a+b). This result revealed that pods contained more or less medium crude fibre content, (25.19%) and high crude protein content, (15.30%) which was quite adequate for animal feed whereas hulls exhibited the lowest fermentation activities and resulted in low in-vitro organic matter digestibility (38.79%).

Comments

The plant can enhance soil fertility as it harbours nitrogen fixing *Rhizobium* bacteria in its root nodules.

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Vigna unguiculata cv-gr. Biflora

ScientificNa me

***Vigna unguiculata* (L.) Walpers cv-gr. *Biflora* E. Westphal** or ***Vigna unguiculata* (L.) Walp. subsp. *cylindrica* (L.) Verdc.,** (See comments)

Synonyms

Dolichos biflorus L., *Dolichos catjang* L., *Dolichos catjang* Burm. f., *Phaseolus cylindricus* L., *Vigna catjang* (Burm. f.) Walp., *Vigna catjang* Endl., *Vigna cylindrica* (L.) Skeels, *Vigna sinensis* var. *cylindricus*, *Vigna sinensis* var. *catjang* (Burm. f.) Chiovenda, *Vigna sinensis* subsp. *cylindrica* (L.) Van Eseltine, *Vigna unguiculata* (L.) Walpers subsp. *cylindrica* (L.) van Eseltine, *Vigna unguiculata* subsp. *unguiculata* (cultigroup Biflora) Marechal, *Vigna unguiculata* subsp. *cylindrica* (L.) Eselt. ex Verdc., *Vigna unguiculata* var. *cylindrica* (L.) H. Ohashi., *Vigna unguiculata* subsp. *cylindrica* (L.) Skeels.

Family

Fabaceae also placed in Leguminosae, Papilionaceae

Common/English Names

Bombay Cowpea, Catjang Bean, Catjang Cowpea, Catjang Pea, Indian Cowpea, Catjung Bean, Catjung Pea, Cylindric-Seeded Cowpea, Cylindric-Shape-Seeded Cowpea, Hindu Cowpea

Vernacular Names

Arabic: Lûbyâ' Baladî;
Chinese: Duan Jia Jiang Dou, Fan Dou (Medicinal Name), Fan Jiang Dou, Mei Dou, Yang Dou Jiao, Bai Dou, Hung Ch'iang Tou;
Danish: Vignabønne;
Dutch: Katjang Pandjang;
French: Dolique De Chine, Dolique Des Vaches, Dolique Cajun, Dolique Mongette, Dolique Catjan;
German: Catjangbohne;
Italian: Fagiolo Del Occhio;
Indonesia: Kacang Merah, Kacang Peudjit, Kacang Tunggak;
Japanese: Hata Sasage, Yakko Sasage;
Khmer: Sândaêk Khmau, Sândaêk Krâhâm, Sândaêk Sâ;
Laotian: Thwàx Siênx;
Malaysia: Kacang Merah;
Portuguese: Feijão-Fradinho;
Russian: Korovii Gorokh, Korovii Goroshek, Vigna Kitaiskaia;

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Spanish: Judía Catjang, Caupi Catjang;
Thai: Thua Khaao, Thua Rai, Po Thoh Saa;
Vietnamese: Dâu Ca, Dâu Do, Dâu Trang.

Origin/Distribution

Catjang bean is considered to have developed in India from cowpea (cultigroup *Unguiculata*) which originated in West Africa (Ng and Marechal 1985). Catjang is widely cultivated in India, China, Kampuchea, Japan, Korea, Laos, Vietnam, Africa and America.

Agroecology

As described for the common cowpea, *V. unguiculata* spp. *uguiculata*.

Edible Plant Parts and Uses

In Japan, catjang bean is used to make "*sekihan*" (steamed glutinous rice coloured red by boiled cowpea or azuki) for traditional ceremony and celebration. It is also cooked as "*ann*" (bean jam) and/or "*zenzai*" (sweet bean soup with glutinous rice cake). It is also eaten mixed with rice. In India, it is commonly prepared as "dhal soup" (dehusked split bean soup).

Botany

The plant is an annual or perennial erect, trailing or twining herb, 0.5–3 m long or high with striate, glabrous, scabrous or pubescent stem. Leaf is trifoliolate with ovate or rhombic, simple, entire glossy green leaflets, 1.5–16.5 × 1–12.5 cm, apex acute, base rodunded or subacute (Plates 1 and 2); lateral leaflets are oblique. Stipules submedifixed, constricted at the point of attachment and multi-nerved. Flower pink to purple or white. Calyx glabrous or pubescent; tube 2–5.5 mm long; lobes subequal, standard petal with two parallel widely spaced appendages. Flower and seed smaller than cowpea. Fruit linear-cylindrical, glabrous, scabrous legume 7–10–(13) mm (much shorter than cowpea), 2.5–5 mm wide, straight or curved, pale or variously mottled, erect, sub-erect to horizontal (Plates 1 and 3). Seed 4–6.5 × 2–4.5 mm with hilum one third to half the longest dimension, black red or brown.

Plate 1 Immature Catjang pod

Plate 2 Trifoliolate leaf

Plate 3 Catjang pods

Nutritive/Medicinal Properties

Proximate composition of raw, mature catjang (*V. unguiculata* spp. *cylindrica*) seeds per100 g edible portion reported by USDA (2010) was reported as follows: water 11.05 g, energy 343 kcal (1.435 kJ), protein 23.85 g, total lipid 2.07 g, ash 3.39 g, carbohydrate 59.64 g, total dietary fibre 10.7 g, Ca 85 mg, Fe 9.95 mg, Mg 333 mg, P 438 mg, K 1.375 mg, Na 58 mg. Zn 6.11 mg, Cu 1.059 mg, Mn 1.544 mg, Se 9.1 µg, vitamin C 1.5 mg, thiamine 0.68 g, riboflavin 0.170 mg, niacin 2.795 mg, pantothenic acid 1.511 mg, vitamin B-6 0.361 mg, total folate 639 µg, vitamin A, 2 µg RAE, vitamin A 33 IU, total saturated fatty acids 0.542 g, 12:0 (lauric acid) 0.001 g, 14:0 (myristic acid) 0.004 g, 16:0 (palmitic acid) 0.417 g, 18:0 (stearic acid) 0.087 g; total monounsaturated fatty acids 0.173 g, 16:1 undifferentiated (palmitoleic acid) 0.006 g, 18:1 undifferentiated (oleic acid) 0.144 g, 20:1 (gadoleic acid) 0.002 g, 22:1 undifferentiated (erucic acid) 0.019 g; total polyunsaturated fatty acids 0.889 g, 18:2 undifferentiated (linoleic acid) 0.563 g, 18:3 undifferentiated (linolenic acid) 0.326 g; tryptophan 0.294 g, threonine 0.908 g, isoleucine 0.969 g, leucine 1.828 g, lysine 1.614 g, methionine 0.340 g, cystine 0.263 g, phenylalanine 1.394 g, tyrosine 0.771 g, valine 1.137 g, arginine 1.652 g, histidine 0.740 g, alanine 1.088 g, aspartic acid 2.881 g, glutamic acid 4.518 g, glycine 0.985 g, proline 1.072 g, and serine 1.194 g.

Thangadurai (2005) reported the following proximate composition for *V. unguiculata* ssp. *cylindrica* seeds: crude protein 29%, crude fat 10%, ash 4%, nitrogen free extract 53% and energy 1.737 kJ (per 100 g dry matter). The essential amino acids, isoleucine, lysine and tyrosine + phenylalanine were found to be present in high concentrations of 124.3, 79.5 and 79.1 mg/100 g crude protein, respectively. The unsaturated fatty acids constituted more than 60% of total fatty acids. The seeds were found to be a good source of minerals such as potassium, calcium, phosphorus, zinc and iron. Recently Arinathan et al. (2009) reported the following proximate composition for *V. unguiculata* subsp *cylindrica* seeds (g/100 g seed flour): moisture 3.2 g, crude protein 14.0 g, crude lipid 3.4 g, dietary fibre 3.4 g, ash 3.6 g , nitrogen free extract 75.6 g, gross energy 1,625.3 kJ/100 g DM), Na 20 mg, K 1,734.5 mg, Ca 240.5 mg, Mg 84.1 mg, P 1.163 mg, Zn 3.9 mg, Mn 1.5 mg, Fe 15.1 mg, Cu 0.3 mg, niacin 14.62 mg, and ascorbic acid 127.67 mg.

Antinutritional Compounds

The anti-nutritional compounds such as total free phenols, tannins, L-DOPA, hydrogen cyanide and phytic acid contents were detected in catjang seeds (Thangadurai 2005). Cooking was found to reduce contents of potassium, calcium and phosphorus by 0.02%, 0.59% and 0.36% respectively. More than 70% of the antinutritional factors were eliminated and there was an increase of crude fibre content. In a later study, anti-nutritional factors (g/100 g) in *V. unguiculata* subsp *cylindrica* seeds were reported by Arinathan et al. (2009) as follows: total free phenolic 2.77 g, tannin 0.27 g, L-DOPA 1.96 g, hydrogen cyanide 0.29 mg.

Four isoinhibitors of plant thiol proteinases were purified from seeds of *Vigna unguiculata* subsp. *cyclindrica* and occurred in very low amounts compared to the trypsin inhibitor (Rele et al. 1980). The isoinhibitors were specific for papain, chymopapain, and ficin but exhibited different inhibition of the proteinase, esterase, and amidase activities. They did not inhibit pepsin, bromelain, and the serine proteinases, trypsin, chymotrypsin, and subtilisin. Two subtilisin inhibitors and two trypsin-chymotrypsin inhibitors were purified from seeds of *Vigna unguiculata* subsp. *cylindrica* (Vartak et al. 1980a). A third subtilisin inhibitor was partially purified. The subtilisin isoinhibitors occurred in very small levels in the seeds. The subtilisin inhibitors were inactive on papain, ficin, chymopapain, bromelain, trypsin, chymotrypsin, or papain and the trypsin-chymotrypsin inhibitors were also inactive with other enzymes. Vartak et al. (1980b) further compared the properties of four thiol proteinase inhibitors, and of four serine proteinase inhibitors (two subtilisin and two

trypsin inhibitors). They were similar in their molecular weights (5,000–15,000) and dissociation constants (10−8 to 10−9 M). Papain inhibitor A1 and subtilisin inhibitor 2a were low in cystine. At low pH, all the inhibitors were stable upon heating to 80°C for 5 minutes. The subtilisin inhibitor did not bind to catalytically inactive subtilisin derivatives, whereas the papain inhibitor was stoichiometrically bound to the Hg or thioacetamide derivatives of papain. Separate sites were present on the trypsin-chymotrypsin inhibitors for trypsin and chymotrypsin. The papain inhibitors shared the same binding sites for papain and ficin.

Other Uses

Catjang bean is also used as a forage crop for livestock.

Comments

Classification of cultivated cowpea is now based on five so-called cultivar-groups (cv.-gr., also "cultigroups"): *Unguiculata*, *Biflora*, *Sesquipedalis* (equivalent to the former subspecies *unguiculata*, *catjang* and *sesquipedalis* respectively), *Textilis* and *Melanophtalmus.*

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Vigna unguiculata cv-gr. Sesquipedalis

Scientific Name

***Vigna unguiculata* (L.) Walpers cv-gr. Sesquipedalis E. Westphal**

Synonyms

Dolichos sesquipedalis L., *Vigna sesquipedalis* (L.) Fruhwirth, *Vigna sinensis* (L.) Hassk. ssp. *sesquipedalis* (L.) van Eseltine, *Vigna sinensis* var. *sesquipedalis* (L.) Körnicke ex Ascherson & Schweinfurth, *Vigna unguiculata* (L.) Walp. cv. group *Sesquipedalis* (L.) Verdc., *Vigna unguiculata* (L.) Walp. subsp. *sesquipedalis* (L.) Fruw., *Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt, *Vigna unguiculata* subsp. *unguiculata* (cultigroup Sesquipedalis) Marechal, *Vigna unguiculata* (L.) Walp. var. *sesquipedalis* (L.) Ohashi.

Family

Fabaceae, also placed in Leguminosae, Papilionaceae

Common/English Names

Asparagus Bean, Bodi Bean, Chinese Long Bean, Garter Bean, Green Asparagus Bean, Green Podded Cow Pea, Long Bean, Long Horn Bean, Long Podded Cowpea, Long Podded Kidney Bean, Snake Bean, String Bean, Yard Long Bean, Yard-Long Cowpea

Vernacular Names

Arabic: Lûbyâ' Baladî;
Chinese: Cai Dou, Chang Dou, Chang Jiang Dou, Chang Qing Dou Jiao, Chèung Chèng Dauh Gok, Chèung Kong Tau, Cheung Kong Tau, Chèung Ts'ing Tau Kok, Dou Jiao, Dau Kok, Jiang Dou;
Czech: Dlouhatec Kubánský;
Danish: Aspargesbønne, Kaempeaspargesbønne, Meterbønne;
Ethiopia: Adenguare;
French: Dolique Asperge, Dolique Géante, Haricot Asperge, Haricot Kilomètre;
German: Langbohne, Spargelbohne;
Hmong: Taao-Hla-Chao;
India: Borboti, Vali (Bengali), Eeril (Goa), Karamani, Payathangai (Tamil);
Italian: Fagiolo Asparago, Fagiolo Gigante;
Indonesia: Kacang Belut, Kacang Panjang, Kacang Tolo;
Japanese: Furou Mame, Juuroku Sasage, Naga Sasage;
Khmer: Sândaèk Troeung;
Malaysia: Kacang Panjang;
Philippines: Utong (Iloko), Sitao, Sitaw (Tagalog), Banor, Hamtak (Visaya);
Portugal: Dólico Gigante, Feijão-Chicote, Feijão-Espargo;
Russian: Boby Sparzhevye, Metrovye Boby, Sparzhevaia Fasol', Vigna V'jushchaiasia;

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Spanish: Dólico Gigante, Dolico Esparrago, Judía Espárrago, Poroto Esparrago;
Thai: Tua Fak Yaow, Tua Phnom;
Vietnamese Dâu Dûa, Dâu Giai Áo;
West Indies: Bora;

Origin/Distribution

Yardlong bean is considered to have been selected and developed in Southeast Asia from cowpea (*Vigna unguiculata*), which is considered to have originated in Africa. The centre of genetic diversity of yard long bean is in Southeast Asia. The bean is widely cultivated in Africa, East Asia – China, Korea, Japan and Southeast Asia. It is also cultivated in northern Australia – Northern Territory and northern Queensland.

Agroecology

Yard long bean is a tropical species that tolerates high temperature. It prefers day temperatures of 20–35°C and night temperatures above 15°C. It grows on a wide range of soils but thrives best on well-drained, fertile soil from pH 5.5–7.5. It can be grown in sandy soils if supplemented with adequate irrigation. It is usually grown supported on poles or trellis in full sun.

Edible Plant Parts and Uses

Young pods, young tender shoots, leaves and seeds are edible. The yard-long bean pod is considered to be one of the most important vegetable crops in southeast Asia: Malaysia, Indonesia, Thailand, Vietnam, Philippines; and also in Taiwan and China.

The pods are best if picked for vegetable use before they reach full maturity at 15–20 days after flower opening. The crisp, tender , young pods are eaten both fresh and cooked. They are cut into short sections and used in stir fries with meat in Chinese cuisine; or finely cut into very fine sections and fried in omelettes. In Malay cuisines they are popularly stir-fried with dried shrimp, chillies and shrimp paste; cooked in vegetable curries; in stews or use in salads (*Kerabu*). In many parts of the tropics, the young shoot tips and young tender leaves are steamed or boiled and eaten as vegetables in soups or stir-fries. In some areas, the leaves are boiled about 15 min, drained, dried in the sun, and stored for use as a relish.

Botany

A glabrous annual climber, 2–4 m high, with ribbed, green and a strong tap root system and with root nodules. Leaves are trifoliolate, stipules prominent appendaged, leaflets ovate-rhombic, lateral ones oblique, 12–15 cm long by 4–7 cm wide, acute, bade rounded or cuneate (Plates 1 and 2). Flowers white, yellow or light purple, papilionaceous, hermaphrodite, paired at apex of slender axillary peduncle (Plate 2). Pods 30–100 cm long, colour light green, white, purple, or white with purple mottle, smooth or rugose or crinkled, (Plates 1–5) becoming inflated and flabby before ripening and

Plate 1 Long, green pod and trifoliolate leaves

Plate 2 Long pods, leaves and yellow flowers

Plate 3 Red asparagus beans

with elongated reniform seeds, 8–12 mm long. Seed colour ranged from black, tan, brown, red and various types of mottled colour.

Nutritive/Medicinal Properties

Nutrient composition of raw yard-long beans per 100 g edible portion (USDA 2010) was reported as: water 87.85 g, energy kcal 47 (197 kJ), protein

Plate 4 Curved and crinkled skinned asparagus beans

Plate 5 Green, red and mottled asparagus beans

2.80 g, total fat 0.40 g, ash 0.60 g, carbohydrate 8.35 g, Ca 50 mg, Fe 0.47 mg, Mg 44 mg, P 59 mg, K 240 mg, Na 4 mg, Zn 0.37 mg, Cu 0.048 mg, Mn 0.205 mg, Se 1.5 µg, vitamin C 18.8 mg, thiamine 0.107 mg, riboflavin 0.110 mg, niacin 0.410 mg, pantothenic acid 0.055 mg, vitamin B-6 0.024 mg, total folate 62 µg, vitamin A 43 µg RAE, vitamin A 865 IU, total saturated fatty acids 0.105 g, 14:0 (myristic) 0.001 g, 16:0 (palmitic) 0.084 g, 18:0 (stearic) 0.013 g; total monounsaturated fatty acids 0.036 g, 16:1 undifferentiated (palmitoleic) 0.001 g, 18:1 undifferentiated (oleic acid) 0.021 g, 22:1 (erucic) 0.013 g, total polyunsaturated fatty acids 0.169 g, 18:2 undifferentiated (linoleic) 0.096 g, 18:3 undifferentiated (linolenic) 0.070 g, tryptophan 0.032 g, threonine 0.104 g, isoleucine 0.150 g, leucine 0.200 g, lysine 0.184 g, methionine 0.040 g, cystine 0.042 g, phenylalanine 0.154 g, tyrosine

0.115 g, valine 0.162 g, arginine 0.196 g and histidine 0.090 g.

Nutrient composition of raw yard-long bean seeds per 100 g edible portion (USDA 2010) was reported as: water 8.43 g, energy kcal 347 (1,452 kJ), protein 24.33 g, total fat 1.31 g, ash 4.03 g, carbohydrate 61.91 g, total dietary fibre 11.0 g, Ca 138 mg, Fe 8.61 mg, Mg 338 mg, P 559 mg, K 1,157 mg, Na 17 mg, Zn 3.50 mg, Cu 0.879 mg, Mn 1.590 mg, Se 8.2 μg, vitamin C 1.6 mg, thiamine 0.887 mg, riboflavin 0.235 mg, niacin 2.158 g, pantothenic acid 1.556 mg, vitamin B6 0.371 mg, total folate 658 μg, vitamin A 3 μg RAE, vitamin A 52 IU, total saturated fatty acids 0.339 g, 14:0 (myristic) 0.001 g, 16:0 (palmitic) 0.318 g, 18:0 (stearic) 0.020 g, total monounsaturated fatty acids 0.114 g, 18:1 undifferentiated (oleic acid) 0.0114 g, total polyunsaturated fatty acids 0.565 g, 18:2 undifferentiated (linoleic) 0.308 g, 18:3 undifferentiated (linolenic) 0.258 g; tryptophan 0.300 g, threonine 0.926 g, isoleucine 0.989 g, leucine 1.864 g, lysine 1.646 g, methionine 0.346 g, cystine 0.269 g, phenylalanine 1.421 g, tyrosine 0.786 g, valine 1.160 g, arginine 1.685 g, histidine 0.755 g, alanine 1.109 g, aspartic acid 2.938 g, glutamic acid 4.608 g, glycine 1.004 g, proline 1.094 g and serine 1.218 g.

Anthocyanins play an important role in physiological functions related to human health. In the purple pods of yard-long bean, five individual anthocyanins were identified: delphinidin-3-O-glucoside (2), cyanidin-3-O-sambubioside (4), cyanidin-3-O-glucoside (5), pelargonidin-3-O-glucoside (7), and peonidin-3-O-glucoside (8) (Ha et al. 2010). From the black seed coat of the yard-long beans, seven anthocyanins were identified, including delphinidin-3-O-galactoside (1), cyanidin-3-O-galactoside (3), petunidin-3-O-glucoside (6), and malvidin-3-O-glucoside (9), together with compounds 2, 5, and 8.

The nutritive and functional properties of raw asparagus beans were found to be slightly improved by malting (Nwosu et al. 2010). Each portion of whole asparagus beans soaked in 12 and 24 hours was malted for 48, 60 and 72 hours and then dehulled, dried and milled into flour. Results showed that protein content was highest in samples soaked for 24 hours and malted sample for 72 hours (23.90%). The sample soaked for 12 hours and malted for 72 hours had 22.95% protein content while the unmalted samples had 22.26%. Ash, fibre and moisture contents of the samples soaked for 12 hours and malted for 72 hours ranged from 2.42%, 1.97% and 16.00%, respectively and that for sample soaked for 24 hours and malted for 72 hours ranged from 2.20%, 1.82% and 17.70%, respectively while the unmalted sample gave 2.98%, 2.24% and 8.26%, respectively. Malting enhanced foam capacity from 16.00% to 18.05%, water absorption capacity from 1.35% to 1.98% emulsion capacities from 29.20% to 29.98% and bulk densities were (0.75–0.98%). As a result of this improvement in both the proximate and functional properties of the flour, it could be incorporated in various foods to augment their nutritional value.

Yard-long bean seeds were found to contain lectin and peptides with antimicrobial, anti-HIV, anti cancerous and mitogenic activities. A lectin, with a molecular mass of approximately 60 kDa and two different subunits exhibiting an N-terminal sequence manifesting considerable homology to phytohemagglutinin from *Phaseolus* species, was isolated from the ground bean (*Vigna sesquipedalis*) (Wong and Ng 2003). The lectin was unique in hemagglutinating activity and was inhibited by polygalacturonic acid and not by galacturonic acid and other simple monosaccharides. Ground bean lectin exhibited mitogenic activity on murine splenocytes with the maximal response achieved at a dose of 156 nM, similar to the concentration required for Con A. The viability of hepatoma (HepG2), leukemia (L1210), and leukemia (M1) cells was reduced in the presence of ground bean lectin, which also exerted an inhibitory activity toward HIV-1 reverse transcriptase IC_{50} of 73 μM. Wong and Ng (2005) also isolated an antifungal peptide with a molecular mass around 7 kDa and an N-terminal sequence highly homologous to defensin from ground beans (*Vigna sesquipedalis* cv. 'Ground Bean'). It exerted an antifungal action on *Botrytis cinerea, Fusarium oxysporum* and *Mycosphaerella arachidicola*; and an antibacterial action on *Escherichia coli* B, *Proteus vulgaris, Mycobacterium phlei* and *Bacillus megaterium*.

The peptide exerted antiproliferative activity toward breast cancer (MCF-7) cells and leukemia M1 cells. It also exhibited some inhibitory activity toward human immunodeficiency virus-type 1 reverse transcriptase.

Other Uses

Long beans can also be used as fodder.

Comments

Classification of cultivated cowpea is now based on five so-called cultivar-groups (cv.-gr., also "cultigroups"): *Unguiculata*, *Biflora*, *Sesquipedalis* (= the former subspecies *unguiculata*, *catjang* and *sesquipedalis* respectively), *Textilis* and *Melanophtalmus*.

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Vigna unguiculata cv-gr. Unguiculata

Scientific Name

***Vigna unguiculata* (L.) Walpers cv-gr. Unguiculata E. Westphal**

Synonyms

Dolichos sinensis L., *Dolichos unguiculatus* L., *Phaseolus unguiculatus* (L.) Piper, *Phaseolus sphaerospermus* L., *Vigna sinensis* Endl., *Vigna sinensis* (L.) Savi ex Hassk., *Vigna sinensis* (L.) Savi ex Hassk. subsp. *unguiculata*, *Vigna sinensis* var. *sinensis, Vigna unguiculata* (L.) Walp., *Vigna unguiculata* (L.) Walp. subsp. *unguiculata* (L.) Walp., *Vigna unguiculata* (L.) Walp. subsp. *unguiculata* (Unguiculata Group) apud Westphal, *Vigna unguiculata* subsp. *unguiculata* (cultigroup Unguiculata) Marechal.

Family

Fabaceae also placed in Leguminosae, Papilionaceae

Common/English Names

Bachapin Bean, Black Eyed Cowpea, Black Eyed Dolichos, Black-Eyed Pea, Black-Eyed Bean, China Bean, Common Cowpea, Cowgram, Cowpea, Crowder Bean, Crowder Pea, Cultivated African Cowpea, Field Pea, Kafir Bean, Macassar Bean, Marble Pea, Red Pea, Rope Bean, Poona Pea, Southern Pea

Vernacular Names

Afrikaans: Akkerboon, Boontjie, Koertjie, Dopboontjie, Swartbekboon;
Arabic: Lûbyâ' Baladî, Mash;
Argentina: Poroto Caupi;
Bolivia: Cumandá, Frijol Camba;
Brazil: Feijão Caupe, Feijão De Corda;
Central America: Frijol De Costa;
Chinese: Da Jiao Dou, Dou Jiao, Jiang Dou, Mei Dou;
Columbia: Frijol Caupi;
Cuba: Frijol Carita;
Danish: Koaert, Vignabønne;
Domincan Republic: Anconi, Caupi;
East Africa: Kunde;
Ecuador: Tumbe;
Finnish: Lehmänpapu;
French: Dolique À Oeil Noir, Dolique De Chine, Niébé (Africa), Pois À Oeil Noir, Pois À Vache;
German: Augenbohne, Kuherbse, Langbohne;
Honduras: Frijol Alacin;
India: Ghangra (Bengali), Chauli, Chola, Kulath, Kulathi, Lobiya, Soonth (Hindu), Alasabde, Alasandi, Alasande, Alasandige, Alasundi, Chelaavare, Halasande, Kaaraamani, Kaalu, Kadagani, Kursana Pairu, Kursandi (Kannada), Perumpayar (Malayalam), Alasunda, Chavali (Marathi), Mahamasah, Rajamasah (Sanskrit),

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Kaattu Ulundu, Karamani, Thattapayir (Tamil), Alasandalu, Kaaraamanulu (Telugu);
Indonesia: Kacang Tunggak;
Italian: Fagiolo Dall'occhio Nero, Fagiolino Piccolo;
Japanese: Sasage;
Kenya: Likhubi;
Khmer: Sândaêk Kâng, Sândaèk Ângkuy;
Korean: Tongpu;
Laotian: Thwàx Do;
Latin America: Caupi;
Malaysia: Kacang Bol, Kacang Merah, Kacang Toonggak;
Mexico: Chicharo De Vaca, Frijol Pelón, Frijol Yorimón;
Nicaragua: Frijol Alacin Frijol De Vara;
Panama: Frijol Ojo Negro;
Peru: Chiclayo, Frijol Castilla;
Philippines: Batong, Otong, Kibal (Bisayan) Paayap, Sitaw-Turo (Tagalog);
Portuguese: Feijão-Frade, Feijão-Pequeno, Feijão-Miúdo;
Russian: Vigna Kitaiskaia;
Senegal: Niao, Seub;
Spanish: Caupi, Chicharo De Vaca, Chicharo Tropical, Costeño, Frijol Da Costa, Frijol De Vaca, Judia Carilla, Judia De Vaca, Rabiza;
Swahili: Kunde;
Swedish: Vignaböna;
Thai: Tua Dam;
Turkish: Börülce;
Uganda: Boo, Ngor (Acholi), Amuli, Obo (Alur & Jonam), Likote (Bugisu), Laputu, Namuri "Wild", Nyele (Kakwa), Maruet "Wild" (Karamajong), Eggobe, Ekiyindiru, Mpindi (*Langi*), Bojo (*Luganda*), Enkoole Omugobe (Runyankore), Omugobe (Runyoro), Omugobe (Rutooro), Eboo, Lmere (Teso);
Venezuela: Frijol;
Vietnamese: Dôu Den, Dôu Trắng, Dôu Tua;
West Africa: Ewa, Niebe, Wake;
Zulu: Imbumba, Indumba, Isihlumaya.

Origin/Distribution

The cultivated cowpea, *Vigna unguiculata* spp. *unguiculata* is considered to have originated in Africa from its wild ancestral form, *V. unguiculata* subsp. *dekindtiana* (Harms) Verdc. (Ng and Marechal 1985) and a large genetic diversity of wild types occurs throughout the African continent, with southern Africa being the richest. The greatest genetic diversity of cultivated cowpea is found in West Africa, in the savannah region of Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria and Cameroon. Cowpea was probably brought to India around 200 BC and to Europe 300 BC. Today, cowpea is cultivated throughout the tropics and subtropics between 35 N and 30 S, across Asia and the Pacific, the Middle East, southern Europe, Africa, southern United States, and Central and South America.

Agroecology

Cultivated cowpea is a warm-season crop, well-adapted to many areas of the humid tropics and warm temperate zones where the mean annual temperatures varies from 25°C to 35°C. It tolerates heat and dry conditions, but is frost sensitive. It grows from sea level up to 1,500 m elevation. Cowpea generally is day neutral. Cowpeas are cultivated under both irrigated and non-irrigated regimes. The crop responds well to irrigation but will also produce well under dry land conditions. Cowpea is more drought resistant than the common bean. It is adaptable to drier conditions where other legumes perform poorly. It performs well on a wide variety of soils and soil conditions, but thrives best on well-drained, sandy loams or sandy soils where soil pH is in the range of 5.5–6.5. It tolerates acidic soils or strongly alkaline soils better than other legumes. Cowpeas do not tolerate extended flooding or salinity. Excessive soil moisture adversely impedes growth and promotes infection by soil-borne fungal diseases. Cowpeas are often grown as green manure crops in poor soil as they enrich the soil with nitrogen.

Edible Plant Parts and Uses

Cowpea is widely used as pulses and is a major food staple in many African countries where every part of the plant is eaten. Leaves, roots, flowers, young pods and immature and mature

seeds are eaten. The roots are sometimes eaten roasted, e.g. in Ethiopia and Sudan. The green leaves are boiled and eaten like spinach or fried and are usually eaten with a porridge Leaves may be preserved by sun-drying or boiling followed by sun-drying to be used during the dry season. In Botswana and Zimbabwe boiled cowpea leaves are kneaded to a pulp and squeezed into small balls, which are dried and stored. Immature pods are steamed or boiled and eaten whole. In Asia this is the most important use of cowpea. In Benue State, Nigeria, the stringless coiled pods with little parchment of a landrace called '*Eje-O'Ha'* are parboiled for a few minutes, opened and split in half. The seeds are eaten directly while the pod walls are dried and preserved for later use. Pods are also consumed locally in Benin.

Green seeds are roasted and used like peanuts. Immature, green and still soft seeds are cooked to a thick soup and used as relish. In Malawi the seeds are boiled with their seed coat, or the latter is removed. The mature seeds are cooked and eaten alone or together with vegetables, spices and often palm oil, to produce a thick bean soup, used as an accompaniment to the staple food (cassava, yam, plantain). Scorched, dried seeds are sometimes used as a coffee substitute. Dried seeds may be boiled and used in soups or stews, or ground into flour and made into cakes.

In West Africa the seeds are decorticated and ground into a flour and mixed with chopped onions and spices and made into cakes which are either deep fried ('akara balls'), or steamed ('moin moin'). In Nigeria, cowpea flour from large brown eye Kano white cowpea (*Vigna unguiculata*) seeds was used to make *akara* balls (fried paste) (Enwere et al. 1998). Small quantities of cowpea flour are processed into crackers, composite flour and baby foods in Senegal, Ghana and Benin.

Cowpea is called "Sasage" in Japan. It is believed to have been introduced into Japan before ninth century (Hoshikawa 1981). Red or black seeded variety is common and is used in the same manner as azuki bean. It is used in "*sekihan*" (steamed glutinous rice colored red by boiled cowpea or azuki) for the traditional ceremony and celebration. It is also cooked as "*ann*" (bean jam) and/or "*zenzai*" (sweet bean soup with glutinous rice cake). In India, cowpea seed is prepared as "*dhal* soup" (dehusked split bean soup).

Extrusion and lipoxygenase inactivation are promising options for developing corn/cowpea extruded snack products with good physical properties and nutritional quality (Sosa-Moguel et al. 2009). Extrudate chemical composition indicated high crude protein levels compared with standard corn-based products. With the exception of lysine, essential amino acids content in the three treatments met FAO requirements. Studies showed that the major storage globulin, vicilins of cowpea (*Vigna unguiculata*) or protein isolates (CPI) could be purified and used in the food processing industry (Rangel et al. 2003). Koki is a nutritious cowpea-based food product usually processed by steam cooking whipped cowpea (*Vigna unguiculata*) paste mixed with spices and palm oil (Mbofung et al. 1999). Soft wheat flour can blended with dehulled cowpea meal to make pasta (Bergman et al. 1996). Refined wheat flour can be partially substituted with 30% whole *Vigna sinensis* flour for the preparation of cookies and foodstuffs traditionally consumed by school age children in Venezuela (Granito et al. 2010). The protein content for the cookies was 10%, in-vitro protein digestibility 93% and calorie value 237 kcal.

Bean pastes from the black eyed bean (*Vigna unguiculata*), pigeon pea (*Cajanus cajan*) and Ife brown (*V. unguiculata*) were processed into a popular West African snack moi-moi, cooked in open aluminium cups and in sealed, thin, transparent cellophane bags (Okolie and Omoigberale 1999). Cooking of moi-moi in cellophane bags was found to reduce the risks of cyanide exposure from legumes.

Botany

A herbaceous, leguminous annual with a strong tap root and adventitious roots with nodules. The plant habit is variable – erect, semi-erect, prostrate (trailing), or climbing. Stems up to 3 m long, angular or sub-terete and, slightly ribbed. Leaves are alternate and trifoliolate and borne on 2–13 cm long petioles that are grooved apically

Plate 1 Leaves, flower and young pods

Plate 2 Maturing pendant pods and leaves

Plate 3 Mature cowpea pods

Plate 4 Blackeye cowpea seeds

Plate 5 Black cowpea seeds

and swollen at the base (Plates 1 and 2). Leaflets are 5–16 cm long, 1–12.5 cm wide, ovate-lanceolate to rhomboid, lateral leaflets are oblique, apex acuminate to obtuse or mucronulate, glabrous or sparsely pubescent on both surfaces, three veined; petiolule 2–5 mm long; stipule 8–25 mm long, ovate and spurred at the base. Inflorescences are axillary or terminal, 2–12 flowered, peduncle 2–36 cm long; bracts 3–5 mm long, bracteoles spatulate and 3–5 mm long. Flowers are hermaphroditic, papilionanceous on 1–4 mm long pedicel. Calyx glabrous, tube 3–5.5 mm long with five narrowly deltoid teeth 2.5–14 mm long. Corolla white, greenish yellow or purple; standard hood-shaped and broadly obovate; wings obovate; keel boat-shaped; stamens, nine fused and one free, ovary superior, laterally compressed with > 16 ovules, style upturned with obliquely globular stigma. Pods 12–30 cm long, pendant, cylindrical and generally slightly curved, glabrous or minutely pilose (Plates 1–3). Seed 6–12 mm long, rhomboid, oblong laterally compressed. The seed coat can

be either smooth or wrinkled and of variously coloured white, cream, green, buff, red, brown, purplish and black (Plates 4 and 5). Seed may also be speckled, mottled, or blotchy.

Nutritive/Medicinal Properties

Proximate composition of raw, mature common cowpea (*V. unguiculata* spp. *unguiculata)* seeds per 100 g edible portion reported by USDA (2010) was reported as follows: water 11.95 g, energy 336 kcal (1,406 kJ), protein 23.52 g, total lipid 1.26 g, ash 3.24 g, carbohydrate 60.03 g, total dietary fibre 10.6 g, total sugars 6.90 g, Ca 110 mg, Fe 8.27 mg, Mg 184 mg, P 424 mg, K 1,112 mg, Na 16 mg. Zn 3.37 mg, Cu 0.845 mg, Mn 1.528 mg, Se 9.0 μg, vitamin C 1.5 mg, thiamin 0.853 g, riboflavin 0.226 mg, niacin 2.075 mg, pantothenic acid 1.496 mg, vitamin B-6 0.352 mg, total folate 633 μg, vitamin A 3 μg RAE, vitamin A 50 IU, β-carotene 30 μg, vitamin E (α-tocopherol) 0.39 mg, vitamin K (phylloquinone) 5.0 μg, total saturated fatty acids 0.331 g, 12:0 (lauric acid) 0.001 g, 14:0 (myristic acid) 0.003 g, 16:0 (palmitic acid) 0.254 g, 18:0 (stearic acid) 0.053 g; total monounsaturated fatty acids 0.106 g, 16:1 undifferentiated (palmitoleic acid) 0.004 g, 18:1 undifferentiated (oleic acid) 0.088 g, 20:1 (gadoleic acid) 0.001 g, 22:1 undifferentiated (erucic acid) 0.012 g; total polyunsaturated fatty acids 0.542 g, 18:2 undifferentiated (linoleic acid) 0.343 g, 18:3 undifferentiated (linolenic acid) 0.199 g; tryptophan 0.290 g, threonine 0.895 g, isoleucine 0.956 g, leucine 1.802 g, lysine 1.591 g, methionine 0.335 g, cystine 0.260 g, phenylalanine 1.373 g, tyrosine 0.760 g, valine 1.121 g, arginine 1.629 g, histidine 0.730 g, alanine 1.072 g, aspartic acid 2.840 g, glutamic acid 4.454 g, glycine 0.971 g, proline 1.067 g and serine 1.178 g.

Proximate composition of raw, young cowpea (*V. unguiculata* spp. *unguiculata)* pods excluding refuse of 9% ends and strings, per 100 g edible portion was reported by USDA (2010) as follows: water 86.00 g, energy 44 kcal (184 kJ), protein 3.30 g, total lipid 0.30 g, ash 0.90 g, carbohydrate 9.50 g, Ca 65 mg, Fe 1.00 mg, Mg 58 mg, P 65 mg, K 215 mg, Na 4 mg. Zn 0.34 mg, Cu 0.100 mg, Mn 0.308 mg, Se 0.9 μg, vitamin C 33 mg, thiamine 0.150 g, riboflavin 0.140 mg, niacin 1.200 mg, pantothenic acid 0.945 mg, vitamin B-6 0.173 mg, total folate 53 μg, vitamin A 80 μg RAE, vitamin A 1,600 IU, total saturated fatty acids 0.079 g, 14:0 (myristic acid) 0.001 g, 16:0 (palmitic acid) 0.063 g, 18:0 (stearic acid) 0.010 g; total monounsaturated fatty acids 0.027 g, 16:1 undifferentiated (palmitoleic acid) 0.001 g, 18:1 undifferentiated (oleic acid) 0.016 g, 22:1 undifferentiated (erucic acid) 0.010 g; total polyunsaturated fatty acids 0.127 g, 18:2 undifferentiated (linoleic acid) 0.072 g, 18:3 undifferentiated (linolenic acid) 0.052 g.

Proximate composition of raw, young leafy cowpea (*V. unguiculata* spp. *unguiculata)* tips excluding refuse of 48% tough stems and leaves, per 100 g edible portion was reported by USDA (2010) as follows: water 89.78 g, energy 29 kcal (121 kJ), protein 4.10 g, total lipid 0.25 g, ash 1.05 g, carbohydrate 4.82 g, Ca 63 mg, Fe 1.92 mg, Mg 43 mg, P 9 mg, K 445 mg, Na 7 mg. Zn 0.29 mg, Cu 0.191 mg, Mn 0.509 mg, Se 0.9 μg, vitamin C 36 mg, thiamine 0.3540 g, riboflavin 0.175 mg, niacin 1.120 mg, pantothenic acid 0.060 mg, vitamin B-6 0.177 mg, total folate 101 μg, vitamin A 36 μg RAE, vitamin A 712 IU, total saturated fatty acids 0.066 g, 14:0 (myristic acid) 0.001 g, 16:0 (palmitic acid) 0.053 g, 18:0 (stearic acid) 0.008 g; total monounsaturated fatty acids 0.022 g, 16:1 undifferentiated (palmitoleic acid) 0.001 g, 18:1 undifferentiated (oleic acid) 0.013 g, 22:1 undifferentiated (erucic acid) 0.008 g; total polyunsaturated fatty acids 0.106 g, 18:2 undifferentiated (linoleic acid) 0.060 g and 18:3 undifferentiated (linolenic acid) 0.044 g. The nutrient composition values of cowpea leaves, on a dry weight basis, was found to range from 9.4% to 13.0% for moisture, 303.8–468.9 mg/100 g for phosphorus, 33.5–148.0 mg/100 g for ascorbic acid, and 27.1–34.7% for protein (Ahenkora et al. 1998).

Hussain and Basahy (1998) reported the proximate composition of *Vigna unguiculata* seeds as: crude protein 23%, fat 3.40% ash 3.60% and 17% amino acids including most of the essential ones. The essential amino acids valine, leucine,

phenylalanine and lysine were slightly higher, but sulphur-containing amino acids were lower than recommended in the WHO/FAO requirement profile. Qualitative phytochemical screening of seeds showed fructose, α-glucose, β-glucose, glycerol, manitol, inositol and some oligosaccharides, e.g. raffinose, stachyose, and verbascose. Proximate nutrient composition value for *V. unguiculata* seeds was found as follows: moisture 6.20–8.92%; protein 20.5–31%. 7%; fat 1.14–3.03%, fibre 1.70–4.5%, and carbohydrate 56.0–65.7% (Onwuliri and Obu 2002). Overall, potassium was the most abundant element in the seeds. Sixteen amino acids were identified. Antinutritional factors such as total cyanide, tannin, total oxalate and phytate were found in varying concentrations.

Kalogeropoulos et al. (2010) evaluated the bioactive micronutrients of cooked broad beans, chickpeas, two split peas varieties, two lentils varieties, pinto beans, black-eyed beans, five white beans varieties and white lupines. Crude protein was found to range from 6.1% to 11.5%, crude fibre 3.6–11.7%, and energy content 103–155 kcal/100 g. Phytosterols contents varied from 13.5 to 53.6 mg/100 g. Tocopherols and squalene ranged from 0.26 to 1.78 and 0.12 to 1.74 mg/100 g, respectively. Legumes' lipids were rich in α-linolenic acid which comprised 2.5–41.7% of fatty acids. Total phenolic content of the cooked legumes ranged from 11.8 to 25.9 mg gallic acid equivalents/100 g, simple polyphenols ranged between 0.32 and 2.4 mg/100 g and triterpenic acids between 0.34 and 8.5 mg/100 g with lentils exhibiting the higher values in all cases. Among the simple polyphenols determined, flavonoids – mainly catechins-predominated in lentils and chickpeas, and phenolic acids in the rest of legumes.

The protein in cowpea seed is rich in the amino acids, lysine and tryptophan, compared to cereal grains; however, it is deficient in methionine and cystine when compared to animal proteins. Cowpea seed is valued as a nutritional supplement to cereals and an extender of animal proteins.

Germination of cowpea seeds had little effect on amino acid profile of cowpeas (Nnanna and Phillips 1989). In-vitro protein digestibility was not improved significantly by germination nor by decortication but was improved by cooking. Calculated protein efficiency ratio (C-PER) and computed protein efficiency ratio (DC-PER) ranged from 1.95 to 2.21 and from 1.63 to 1.82, respectively. DC-PER compared well with reported the PER of cowpea products and appeared more sensitive than C-PER. Decortication resulted in up to 30% loss in niacin while thiamin content was reduced 41% by cooking.

High protein (18–35%) and carbohydrate (50–65%) contents, together with an amino acid profile complementary to that of cereal grains, make cowpeas potentially important to the human diet from a nutritional aspect (Prinyawiwatkul et al. 1996b). Cow pea flour can be used in various food products. Germinated cowpea flour (GCF) prepared from cowpeas germinated at 25°C for either 24 h was found to be most suitable as weaning food for household consumption (Jirapa et al. 2001). In-vitro protein quality and starch digestibility were ameliorated in germinated cowpea flour. The amino acid pattern, protein digestibility, corrected amino acid scores (PDCAAS) of control cowpea flour (CCF)-weaning food (46.74%) was lower than 24 h germinated cowpea flour (GCF) weaning food (55.49%). Vitamin A activity in CCF-weaning food was lower than in 24 h GCF weaning food. In-vitro starch digestibility of 24 h GCF and 48 h GCF-weaning foods were higher than that of CCF weaning food. The 24 h GCF-weaning food had a higher overall acceptability score by sensory panelist than 48 h GCF and CCF-weaning food. In another study, supplementation of the traditional weaning food with cowpea was found to augment the lysine, tryptophan and threonine levels while the sulphur-amino acids decreased with increasing contents of cowpea (Nti and Plahar 1995). Further supplementation of 70:30 maize/cowpea blends with lysine, threonine or methionine did not significantly improve protein quality in terms of the biological value (BV) and net protein utilization (NPU), although significant increases in the protein scores were noted. However, considerable improvements in the BV and NPU were recorded in blends fortified with either tryptophan alone or a combination of lysine, tryptophan,

methionine and threonine. Cooking whole cowpea seeds for 45 min before incorporating in the blend formulation also significantly ameliorated the protein quality of maize/cowpea blends. The BV and NPU of blends containing 30% precooked cowpea increased from 52% to 76% and 50% to 71% respectively compared to pure maize porridge. The protein content increased from 10% to 14% and the utilizable proteins more than doubled. The weight increase of experimental rats fed with these blends was comparable to that of rats on casein diet. A 30% supplementation of the maize-based weaning food with cowpea therefore greatly enhanced the nutritive value especially when the cowpea was pre-cooked for 45 min.

Studies by Rangel et al. (2003) showed that cowpea protein isolate (CPI) manifested good functional properties, including solubility, emulsifying and foaming activities. Further feeding studies in rats showed that the nutritional parameters measured for the diet containing CPI exhibited a positive nitrogen balance, a net protein retention (NPR) of 0.7 and protein digestibility of 87% (Rangel et al. 2004). Further, CPI did not present detectable hemagglutinating activity and very low trypsin inhibitory activity (18 TIU/mg protein) after heat treatment. In terms of its essential amino acid content, CPI presented a better profile than purified cowpea vicilin. No significant histological differences were found in several internal organs of the rats that were fed a diet containing CPI when compared to the group fed with a casein-containing diet. Thus, these results suggested that CPI may provide a new, inexpensive source of protein for use as a potential functional and nutritional agent in the food industry.

Globulins were found to constitute over 51% of the total cowpea seed protein, with albumins comprising approximately 45% (Freitas et al. 2004). The globulins may be fractionated into three main components, which were termed (in decreasing order of anodic mobility) α-vignin, β-vignin, and γ-vignin. α-vignin, was found to be a major, nonglycosylated globulin, composed of a major 80 kDa subunit, which upon reduction, yielded two polypeptides (20 and 60 kDa). β-vignin, also a major glycosylated globulin, was composed of two main polypeptides (55 and 60 kDa) with no disulfide bonds. Finally, γ-vignin, a minor globulin, was composed of one main type of subunit (22 kDa), which upon reduction, was converted into a single, apparently heavier polypeptide chain (30 kDa) due to the presence of an internal disulfide bond. Haemagglutination activity toward trypsinized rabbit erythrocytes was found exclusively in the albumin fraction and was strongly inhibited by N-acetylglucosamine or chitin.

A new triterpenoid saponin, 3-Oα-L-rhamnopyranosyl-(1→4)-β-D-galactopyranosyl-(1→4)-β-D-glucuronopyranosyl]-soyaspogeno 1 B was isolated along with cycloartenol, stigmasterol, 3-O-acetyloleanolic acid, and sitosterol 3-β-D-glucoside from a methanolic extract of the seeds of *Vigna unguiculata* subsp. *unguiculata* (Noorwala et al. 1995).

Seed oil contents of four cowpea cultivars commonly grown in Pakistan, was found to vary from 2.71% to 2.96% with triacylglycerols being present in highest amount (Zia-Ul-Haq et al. 2010). Despite variations, unsaturated fatty acids were observed as being present in higher concentration in all cultivars. Among sterols, stigmasterol occurred in highest amount followed by β-sitosterol and campesterol. Among tocopherols, α-, and β-tocopherols were observed as being present in highest and lowest concentrations, respectively. Results from most of the parameters revealed no significant differences among the cultivars.

Amino acid analysis showed a very low sulfur amino acid content and relatively high content of aspartic and glutamic acids. Total neutral sugar analysis indicated less than 1% of saccharides. A soluble lipolytic acylhydrolase was isolated from cowpea leaves (Sahsah et al. 1994). The hydrolytic activity of the enzyme on different substrates was determined: the relative rates were digalactosyl-diacylglycerol > monogalactosyl-diacylglycerol > phosphatidylcholine > phosphatidylglycerol. For all substrates, the products of hydrolysis were free fatty acids. Triacylglycerols were not hydrolysed. The enzyme was activated by calcium but was not calcium-dependent.

Anticancer Activity

The treatment of MCF-7 breast cancer cells with 200 μM BTCI (Black-Eyed Pea Trypsin/Chymotrypsin Inhibitor), purified from *Vigna unguiculata* seeds was found to induce significant reduction of the cell viability and proliferation (arrest in S and G2/M phase) (Joanitti et al. 2010). These cytostatic effects were accompanied by acute morphological modifications including changes of the nuclear morphology, plasma membrane fragmentation, cytoplasm disorganization, presence of double-membrane vesicles, mitochondrial swelling, and an increase in the size of lysosomes. Significant DNA fragmentation, annexin-V(+) cell number increase, mitochondrial membrane potential reduction, and cytoplasm acidification were also observed. Taken together, these cytostatic and cytotoxic effects led to BTCI-induced apoptosis cell mortality associated with severe cell morphological alterations and lysosome membrane permeabilization. The study confirmed the anticarcinogenic potential of Bowman-Birk protease inhibitors and identified BTCI as a promising tool for drug developments aimed at the treatment of breast cancer.

Antiviral, Antibacterial and Antifungal Activities

Multiple proteins with antifungal and antiviral potency were found in cowpea seeds (Ye et al. 2000). The two proteins, designated α- and β-antifungal proteins, were capable of inhibiting human immunodeficiency virus (HIV) reverse transcriptase and one of the glycohydrolases associated with HIV infection, α-glucosidase, but β-glucuronidase was not suppressed. The ability of the proteins in retarding mycelial growth of a variety of fungi was also demonstrated, with α-antifungal protein being more potent in most of the cases. β-antifungal protein was more active in only one instance. Both antifungal proteins had low cell-free translation-inhibitory activity. α-antifungal protein was characterized by an N-terminal sequence showing close resemblance to sequences of chitinases. β-antifungal protein exhibited an N-terminal sequence hitherto unknown in the literature. Ng et al. (2002) found that the cowpea β-antifungal protein had a high potency in inhibiting HIV-1 protease and HIV-1 integrase. Cowpea α-antifungal protein was potent in inhibiting HIV-1 reverse transcriptase and HIV-1 integrase. A protein designated unguilin isolated from seeds of the black-eyed pea (*Vigna unguiculata*) was found capable of inhibiting human immunodeficiency virus-1 reverse transcriptase and the glycohydrolases α- and β-glucosidases involved in HIV infection (Ye and Ng 2001). Unguilin was devoid of lectin and ribonuclease activities. It inhibited methyl-3H-thymidine uptake by mouse splenocytes and it weakly suppressed translation in a rabbit reticulocyte lysate system. Unguilin also exerted an antifungal effect toward fungi including *Coprinus comatus, Mycosphaerella arachidicola*, and *Botrytis cinerea*. Unguilin was found to resemble mungin, a cyclophilin-like antifungal protein from mung beans in some aspects, but differed from it in others.

Cowpea leaf extracts exhibited inhibitory effect on bacterial and fungal pathogens (Kritzinger et al. 2004). Acetone and ethanol leaf extracts of two cultivars, Bechwana White (BW) and Kpodjiguégué (Kpod) significantly inhibited the growth of *Altenaria alternata* and *Fusarium proliferatum*. BW acetone extracts inhibited growth of *Staphylococcus aureus* and *Enterococcus faecalis*, at 2.5 mg/ml and *Bacillus cereus, B. subtilis* and *Enterobacter cloacae* at 5.0 mg/ml. Ethanol extract of the same cultivar only showed antibacterial activity against *Enterococcus faecalis* and *Enterobacter cloacae* at 5.0 mg/ml. The Kpod extracts exerted no inhibitory effect on the bacteria.

Antioxidant Activity

The unprocessed light brown seeds (LB) of cowpea were found to have significantly higher content of total phenolics and tannins than the dark brown seeds (DB) (Siddhuraju and Becker 2007). At 800 μg of the seed extract, the superoxide anion radical scavenging activity was found to be

significantly higher in the raw and dry heated seed extracts than the hydrothermally processed seed samples of the Lb and DB varieties. The DPPH radical and ABTS cation radical scavenging activities were confirmed and correlated with the ferric reducing antioxidant capacity of the extracts. Of the various extracts, dry heated samples of LB and DB showed the highest hydroxyl radical scavenging activity of 83.6% and 68.2%, respectively. All extracts exhibited good antioxidant activity (74.3–84.6%) against the linoleic acid emulsion system. Using the β-carotene-linoleic acid assay, the values were significantly lower than BHT, BHA and Trolox.

Studies showed that bioactive peptides from *V. unguiculata* proteins could be obtained by means of a controlled protein hydrolysis using Alcalase®, Flavourzyme® and pepsin-pancreatin (Segura Campos et al. 2010). Fractionation enhanced in-vitro biological activities in the peptide fractions, with IC_{50} (hydrolysate concentration in μg protein/ml required to produce 50% angiotensin-I converting enzyme inhibition) value ranges of 24.3–123 μg/ml for Alcalase hydrolysate, 0.04–170.6 μg/ml for Flavourzyme hydrolysate and 44.7–112 μg/ml for pepsin-pancreatin hydrolysate. The antioxidant activity in terms of TEAC (Trolox equivalent antioxidant coefficient) value was 303.2–1,457 mmol/l/mg protein for Alcalase hydrolysate, 357.4–10 211 mmol/l/ mg protein for Flavourzyme hydrolysate and 267.1–2,830.4 mmol/l/ mg protein for pepsin-pancreatin hydrolysate. The protein hydrolysates and their corresponding ultrafiltered peptide fractions could be utilized for physiologically functional foods with antihypertensive and antioxidant activities.

Antinutritional Factors

Soaking cowpeas (25°C, 24 hours) was found to decrease folacin content but did not affect thiamin, niacin, and riboflavin (Prinyawiwatkul et al. 1996a). Boiling soaked seeds for 45 minutes sharply decreased thiamin, folacin, niacin, and riboflavin. Losses of folacin, niacin, and riboflavin were recovered during fermentation with *Rhizopus microsporus*. Soaking reduced trypsin inhibitor activity (TIA) by about 20%, whereas boiling of soaked seeds decreased TIA by about 85%. A slight increase in TIA occurred in soaked, cooked cowpeas after 18 hours fermentation. In a subsequent study, they found that soaking of cowpea seeds and fungal fermentation with *Rhizopus microsporus* subsp. *oligosporus* before milling had less influence on functionality of flour compared to soaking/boiling, which markedly lessened solubility and weakened emulsifying properties (Prinyawiwatkul et al. 1997). Solubility of heat-denatured proteins was slightly improved by fermentation. The combined effects of heat treatment and fungal fermentation on equilibrium moisture content were apparent at 75–97% equilibrium relative humidity. Cowpea flours were consistently more hydrophilic than lipophilic, regardless of processing treatment. The least gelation capacity of flours increased as a result of heat treatment.

A new thionin from cowpea (*Vigna unguiculata*) with proteinase inhibitory activity was purified and characterised (Melo et al. 2002). Cowpea thionin was found to inhibit trypsin, but not chymotrypsin. A lectin without blood group specificity and with a molecular weight of approximately 55,000 was isolated from cowpeas (*Vigna unguiculata*) (Roberson and Strength 1983).

Cooking was found to be ineffective in reducing amylase inhibitor activity in cowpea seeds (Piergiovanni and Gatta 1994). Soaking in alkaline solutions under different conditions produced 10–47% reductions of these anti-nutrients. The most pronounced decrease of amylase inhibitor (55%) was observed when soaked seeds were boiled. A marked enhancement of anti-amylasic activity was observed when seeds were subjected to extensive cooking. No such increase was shown in samples cooked in a microwave oven. Soaking cowpea seeds for 12 hours and cooking for 30 minutes removed most of the sucrose, raffinose and stachyose (Nwinuka et al. 1997). The resultant amounts were sucrose 0.03–0.81%, raffinose 0.04–0.20% and stachyose 0.12–0.72%. The sugar contents in whole raw cowpea were sucrose 0.73–4.58%, raffinose 0.71–6.86% and stachyose 2.38–3.87%.

Roasting lessened paste viscosity properties of all the cowpea cultivars studied (Plahar et al. 1997). Tannin concentrations found were 0.3–6.9

and 7.2–116 mg CE/g flour from whole cowpea seeds and seed coats respectively, increasing with intensity of seed color. Although dehulling removed 98% of the tannin content of raw cowpeas, improvement in protein quality as a result of dehulling was observed for only the highly-pigmented Maroon-red variety. Roasting significantly improved digestibility and more than doubled the Tetrahymena protein efficiency ratio (t-PER) of all cowpea cultivars studied. Roasted cowpeas was found to possess adequate nutritional and functional qualities as protein supplements in cereal-based weaning foods. The results indicated that dehulling was essential to enhance the nutritional quality of the highly pigmented cultivars of cowpea.

Many respondents complained of mild abdominal discomfort with undehulled cowpeas (72.5%) and dehulled cowpeas (42.5%) that had been cooked at atmospheric pressure (Ndubuaku et al. 1989). The problems reported were indigestion, vomiting, diarrhoea, increased belching, bad breath, offensive stool, flatulence, constipation, mild abdominal discomfort and sleepiness. Only 12.5% of the respondents complained of discomfort with dehulled cowpeas cooked under extra pressure. Thus, dehulling resulted in substantial reduction in the frequency and incidence of reported discomforts but pressure cooking also had beneficial effects, probably because of the higher cooking temperature attained.

Traditional Medicinal Uses

Various medicinal uses of cowpea have been reported. Leaves and seeds are employed as a poultice to treat skin infections and swellings. Leaves are applied on burns and are used as a snuff to treat headaches. Leaves are chewed to treat tooth disorders. Seed powder is applied on insect stings. The root is employed as an antidote for snakebites and is prescribed for chest pain, constipation, dysmenorrhoea and epilepsy, and unspecified plant parts are employed as a sedative in tachycardia and to relieve various pains (Brink and Belay 2006). The cooked liquor of cowpea seeds with spices is used a therapy for the common cold (Siddhuraju and Becker 2007). Boiled cowpea eaten as food is also deemed to destroy worms in the stomach (Chopra et al. 1986). A seed infusion is taken for amenorrhea whilst pulverized roots eaten with porridge to remedy painful menstruation, chest pain and epilepsy (Van Wyk and Gericke 2000). Emetics made from the plant are administered for fever (Hutchings et al. 1996). The plant is used by traditional healers as a remedy for urinary schistosomiasis (bilharzias) caused by *Schistosoma haematobium* (Ndamba et al. 1994). The seeds are cooked with the roots of other plants to treat blood in urine and bilharzias (Nyazema 1987; Kritzinger et al. 2004).

Other Uses

Cowpea is also used as fresh cut and carry forage, fodder, hay, silage, green manure, mulch and cover crop. Cowpea is used as fodder in West Africa, Asia (especially India) and Australia; it is used for grazing or cut and mixed with dry cereals for animal feed. In the United States and elsewhere cowpea is grown as a green manure and cover crop. Cowpea has the potential to make excellent hay. In Australia, cowpea is grown as a green manure crop in coastal sugarcane areas, as a forage or dual-purpose grain and forage crop in coastal and subcoastal southern Queensland, and as a sole grain crop from central Queensland to central NSW. In Africa, cowpea is often grown in rotation with maize and sorghum where it enriches the soil with nitrogen through its nitrogen-fixing nodules which harbour the bacterium, *Rhizobium.*

Comments

The cultivated cowpeas were earlier divided into four subspecies (Verdcourt 1970). A widely used classification subdivided all domesticated forms of cowpea into four cultivar groups based primarily on pod and seed characteristics (Westphal 1974; Ng and Marechal 1985). These included *Unguiculata* (common cowpea) grown as pulse, *Biflora* (catjang) mainly used as a forage, *Sesquipedalis* (yardlong bean, asparagus bean)

grown as a vegetable and *Textilis* grown for the fibres of its long floral peduncles. In 1998, Pasquet proposed the addition of another cultivar group called *Melanophthalmus* (black-eyed pea). Thus, classification of cultivated cowpea, *Vigna unguiculata* is now based on five so-called cultivar-groups (cv.-gr., also "cultigroups"): *Unguiculata*, *Biflora*, *Sesquipedalis*, *Textilis* and *Melanophtalmus.*

A brief, salient features of the five cultivar groups or cultigroups under subspecies *unguiculata* is presented below:

1. Cultigroup Unguiculata: pendant pods 12–30 cm long; rhomboid seeds 6–12 mm long; ovule number higher than 16; originally from Africa and now popular world over.
2. Cultigroup Biflora or cylindrica: erect pods <12 cm long; rhomboid seeds 5–6 mm, seed testa thick, shiny; flower and seed most often coloured; ovule number <17; from India mostly grown for fodder and seeds in Asia and used as pulse.
3. Cultigroup Sesquipedalis: vey long fleshy, succulent pods >30 cm (30–60 cm) wrinkled when ripe; seeds kidney-shaped, usually 8–12 mm long; ovule number >17; of India, south-east Asia and China, mostly grown in Asia as vegetable; also called yard-long bean, asparagus bean.
4. Cultigroup Textiles: long fibrous peduncles (50–80 cm long); mostly grown in northern Nigeria for fibre.
5. Cultigroup Melanophthalmus: unfleshy pod, <30 cm long; seed not spaced within pod, seed testa thin often wrinkled; flower and seed partly white; ovule number <17; separated from unguiculata (cowpea) group; include black-eye pea.

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Medical Glossary

AAD allergic airway disease – inflammatory disorder of the airways caused by allergens.

AAPH 2,2′-azobis(2-amidinopropane) dihydrochloride, a water-soluble azo compound used extensively as a free radical generator, often in the study of lipid peroxidation and the characterization of antioxidants.

Abeta aggregation amyloid beta protein (Abeta) aggregation is associated with Alzheimer's disease (AD); it is a major component of the extracellular plaque found in AD brains.

Abdominal distension referring to generalised distension of most or all of the abdomen. Also referred to as stomach bloating often caused by a sudden increase in fiber from consumption of vegetables, fruits and beans.

Ablation therapy the destruction of small areas of myocardial tissue, usually by application of electrical or chemical energy, in the treatment of some tachyarrhythmias.

Abortifacient a substance that causes or induces abortion; causing abortion.

Abortivum a substance inducing abortion.

Abscess a swollen infected, inflamed area filled with pus in body tissues.

ABTS 2.2 azinobis-3-ethylhenthiazoline-6-sulfonic acid, a type of mediator in chemical reaction kinetics of specific enzymes.

ACAT acyl CoA: cholesterol acyltransferase.

ACE see angiotensin-converting enzyme.

Acetogenins natural products from the plants of the family Annonaceae, are very potent inhibitors of the NADH-ubiquinone reductase (Complex I) activity of mammalian mitochondria.

Acetylcholinesterase (AChE) is an enzyme that degrades (through its hydrolytic activity) the neurotransmitter acetylcholine, producing choline.

Acne vulga´ris also known as chronic acne, usually occurring in adolescence, with comedones (blackheads), papules (red pimples), nodules (inflamed acne spots), and pustules (small inflamed pus-filled lesions) on the face, neck, and upper part of the trunk.

Acidosis increased acidity.

Acquired Immunodeficiency Syndrome (AIDS) an epidemic disease caused by an infection by human immunodeficiency virus (HIV-1, HIV-2), retrovirus that causes immune system failure and debilitation and is often accompanied by infections such as tuberculosis.

Acridone an organic compound based on the acridine skeleton, with a carbonyl group at the 9 position.

ACTH adrenocorticotropic hormone (or corticotropin), a polypeptide tropic hormone produced and secreted by the anterior pituitary gland. It plays a role in the synthesis and secretion of gluco- and mineralo-corticosteroids and androgenic steroids.

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Activating transcription factor (ATF) a protein (gene) that binds to specific DNA sequences regulating the transfer or transcription of information from DNA to mRNA.

Activator Protein-1 (AP-1) a heterodimeric protein transcription factor that regulates gene expression in response to a variety of stimuli, including cytokines, growth factors, stress, and bacterial and viral infections. AP-1 in turn regulates a number of cellular processes including differentiation, proliferation, and apoptosis.

Acyl-CoA dehydrogenases A group of enzymes that catalyzes the initial step in each cycle of fatty acid β-oxidation in the mitochondria of cells.

Adaptogen a term used by herbalists to refer to a natural herb product that increases the body's resistance to stresses such as trauma, stress and fatigue.

Adaptogenic increasing the resistance of the body to stress.

Addison's disease is a rare endocrine disorder. It occurs when the adrenal glands cannot produce sufficient hormones (corticosteroids). It is also known as chronic adrenal insufficiency, hypocortisolism or hypocorticism.

Adenocarcinoma a cancer originating in glandular tissue.

Adenoma a benign tumour from a glandular origin.

Adenopathy abnormal enlargement or swelling of the lymph node.

Adenosine receptors a class of purinergic, G-protein coupled receptors with adenosine as endogenous ligand. In humans, there are four adenosine receptors. A_1 receptors and A_{2A} play roles in the heart, regulating myocardial oxygen consumption and coronary blood flow, while the A_{2A} receptor also has broader antiinflammatory effects throughout the body. These two receptors also have important roles in the brain, regulating the release of other neurotransmitters such as dopamine and glutamate, while the A_{2B} and A_3 receptors are located mainly peripherally and are involved in inflammation and immune responses.

ADH see alcohol dehydrogenase.

Adipocyte a fat cell involved in the synthesis and storage of fats.

Adiponectin a protein in humans that modulates several physiological processes, such as metabolism of glucose and fatty acids, and immune responses.

Adipose tissues body fat, loose connective tissue composed of adipocytes (fat cells).

Adrenal glands star-shaped endocrine glands that sit on top of the kidneys.

Adrenalectomized having had the adrenal glands surgically removed.

Adrenergic having to do with adrenaline (epinephrine) and/or noradrenaline (norepinephrine).

Adrenergic receptors a class of G protein-coupled receptors that are targets of the noradrenaline (norepinephrine) and adrenaline (epinephrine).

Adulterant an impure ingredient added into a preparation.

Advanced Glycation End products (AGEs) resultant products of a chain of chemical reactions after an initial glycation reaction. AGEs may play an important adverse role in process of atherosclerosis, diabetes, aging and chronic renal failure.

Aegilops an ulcer or fistula in the inner corner of the eye.

Afferent something that so conducts or carries towards, such as a blood vessel, fiber, or nerve.

Agammaglobulinaemia an inherited disorder in which there are very low levels of protective immune proteins called immunoglobulins. Cf. x-linked agammaglobulinaemia.

Agalactia lack of milk after parturition (birth).

Agglutinin a protein substance, such as an antibody, that is capable of causing agglutination (clumping) of a particular antigen.

Agglutination clumping of particles.

Agonist a drug that binds to a receptor of a cell and triggers a response by the cell.

Ague a fever (such as from malaria) that is marked by paroxysms of chills, fever, and sweating that recurs with regular intervals.

AHR AhR, aryl hydrocarbon receptor, a cytosolic protein transcription factor.

AIDS see Acquired Immunodeficiency Syndrome.

Akathisia a movement disorder in which there is an urge or need to move the legs to stop unpleasant sensations. Also called restless leg syndrome, the disorder is often caused by long-term use of antipsychotic medications.

Akt signaling pathway Akt are protein kinases involved in mammalian cellular signaling, inhibits apoptotic processes.

Akt/FoxO pathway Cellular processes involving Akt and FoxO transcription factors that play a role in angiogenesis and vasculogenesis.

Alanine transaminase (ALT) also called Serum Glutamic Pyruvate Transaminase (SGPT) or Alanine aminotransferase (ALAT), an enzyme present in hepatocytes (liver cells). When a cell is damaged, it leaks this enzyme into the blood.

ALAT (Alanine aminotransferase) see Alanine transaminase.

Albumin water soluble proteins found in egg white, blood serum, milk, various animal tissues and plant juices and tissues.

Albuminaria excessive amount of albumin in the urine, a symptom of severe kidney disease.

Aldose reductase, aldehyde reductase an enzyme in carbohydrate metabolism that converts glucose to sorbitol.

Alexipharmic an antidote, remedy for poison.

Alexiteric a preservative against contagious and infectious diseases, and the effects of poisons.

Alcohol dehydrogenase (ADH) an enzyme involved in the break-down of alcohol.

Algesic endogenous substances involved in the production of pain that is associated with inflammation, e.g. serotonin, bradykinin and prostaglandins.

Alkaline phosphatase (ALP) an enzyme in the cells lining the biliary ducts of the liver. ALP levels in plasma will rise with large bile duct obstruction, intrahepatic cholestasis or infiltrative diseases of the liver. ALP is also present in bone and placental tissues.

Allergenic having the properties of an antigen (allergen), immunogenic.

Allergic pertaining to, caused, affected with, or the nature of the allergy.

Allergic conjunctivitis inflammation of the tissue lining the eyelids (conjunctiva) due to allergy.

Allergy a hypersensitivity state induced by exposure to a particular antigen (allergen) resulting in harmful immunologic reactions on subsequent exposures. The term is usually used to refer to hypersensitivity to an environmental antigen (atopic allergy or contact dermatitis) or to drug allergy.

Allogeneic cells or tissues which are genetically different because they are derived from separate individuals of the same species. Also refers to a type of immunological reaction that occurs when cells are transplanted into a genetically different recipient.

Allografts or homografts, a graft between individuals of the same species, but of different genotypes.

Alloknesis itch produced by innocuous mechanical stimulation.

Allostasis the process of achieving stability, or homeostasis, through physiological or behavioral change.

Alopecia is the loss of hair on the body.

Alopecia areata is a particular disorder affecting hair growth (loss of hair) in the scalp and elsewhere.

ALP see Alkaline phosphatase.

Alpha-adrenoceptor receptors postulated to exist on nerve cell membranes of the sympathetic nervous system in order to explain the specificity of certain agents that affect only some sympathetic activities (such as vasoconstriction and relaxation of intestinal muscles and contraction of smooth muscles).

Alpha amylase α-amylase a major form of amylase found in humans and other mammals that cleaves alpha-bonds of large sugar molecules.

ALT see Alanine transaminase.

Alterative a medication or treatment which gradually induces a change, and restores healthy functions without sensible evacuations.

Alveolar macrophage a vigorously phagocytic macrophage on the epithelial surface of lung alveoli that ingests carbon and other inhaled particulate matter. Also called coniophage or dust cell.

Alzheimer's disease a degenerative, organic, mental disease characterized by progressive brain deterioration and dementia, usually occurring after the age of 50.

Amastigote refers to a cell that does not have any flagella, used mainly to describe a certain phase in the life-cycle of trypanosome protozoans.

Amenorrhea the condition when a woman fails to have menstrual periods.

Amidolytic cleavage of the amide structure.

Amoebiasis state of being infected by amoeba such as *Entamoeba histolytica*.

Amoebicidal lethal to amoeba.

Amyloid beta (Aβ or Abeta) a peptide of 39–43 amino acids that appear to be the main constituent of amyloid plaques in the brains of Alzheimer's disease patients.

Amyotrophic lateral sclerosis or ALS, is a disease of the motor neurons in the brain and spinal cord that control voluntary muscle movement.

Amyotrophy progressive wasting of muscle tissues. *adj.* amyotrophic.

Anaemia a blood disorder in which the blood is deficient in red blood cells and in haemoglobin.

Anaesthesia condition of having sensation temporarily suppressed.

Anaesthetic a substance that decreases partially or totally nerve the sense of pain.

Analeptic a central nervous system (CNS) stimulant medication.

Analgesia term describing relief, reduction or suppression of pain. *adj.* analgetic.

Analgesic a substance that relieves or reduces pain.

Anaphoretic an antiperspirant.

Anaphylaxis a severe, life-threatening allergic response that may be characterized by symptoms such as reduced blood pressure, wheezing, vomiting or diarrhea.

Anaphylactic *adj.* see anaphylaxis.

Anaphylotoxins are fragments (C3a, C4a or C5a) that are produced during the pathways of the complement system. They can trigger release of substances of endothelial cells, mast cells or phagocytes, which produce a local inflammatory response.

Anaplasia a reversion of differentiation in cells and is characteristic of malignant neoplasms (tumours).

Anaplastic *adj.* see anaplasia.

Anasarca accumulation of great quantity of fluid in body tissues.

Androgen male sex hormone in vertebrates. Androgens may be used in patients with breast cancer to treat recurrence of the disease.

Android adiposity centric fat distribution patterns with increased disposition towards the abdominal area, visceral fat – apple shaped cf gynoid adiposity.

Angina pectoris, Angina chest pain or chest discomfort that occurs when the heart muscle does not get enough blood.

Angiogenesis a physiological process involving the growth of new blood vessels from pre-existing vessels.

Angiogenic *adj.* see angiogenesis.

Angiotensin an oligopeptide hormone in the blood that causes blood vessels to constrict, and drives blood pressure up. It is part of the renin-angiotensin system.

Angiotensin-converting enzyme (ACE) an exopeptidase, a circulating enzyme that participates in the body's renin-angiotensin system (RAS) which mediates extracellular volume (i.e. that of the blood plasma, lymph and interstitial fluid), and arterial vasoconstriction.

Anglioplasty medical procedure used to open obstructed or narrowed blood vessel resulting usually from atherosclerosis.

Anisonucleosis a morphological manifestation of nuclear injury characterized by variation in the size of the cell nuclei.

Ankylosing spondylitis (AS) is a type of inflammatory arthritis that targets the joints of the spine.

Annexitis also called adnexitis, a pelvic inflammatory disease involving the inflammation of the ovaries or fallopian tubes.

Anodyne a substance that relieves or soothes pain by lessening the sensitivity of the brain or nervous system. Also called an analgesic.

Anoikis apoptosis that is induced by inadequate or inappropriate cell-matrix interactions.

Anorectal relating to the rectum and anus.

Anorectics appetite suppressants, substances which reduce the desire to eat. Used on a short term basis clinically to treat obesity. Also called anorexigenics.

Anorexia lack or loss of desire to eat.

Anorexic having no appetite to eat.

Anorexigenics see anorectics.

Antagonist a substance that acts against and blocks an action.

Antalgic a substance used to relive a painful condition.

Antecubital vein This vein is located in the antecubital fossa – the area of the arm in front of the elbow.

Anterior uveitis is the most common form of ocular inflammation that often causes a painful red eye.

Anthelmintic an agent or substance that is destructive to worms and used for expulsion of internal parasitic worms in animals and humans.

Anthocyanins a subgroup of antioxidant flavonoids, are glucosides of anthocyanidins. Which are beneficial to health. They occur as water-soluble vacuolar pigments that may appear red, purple, or blue according to pH in plants.

Anthrax a bacterial disease of cattle and ship that can be transmitted to man though unprocessed wool.

Anthropometric pertaining to the study of human body measurements.

Antiamoebic a substance that destroys or suppresses parasitic amoebae.

Antiamyloidogenic compounds that inhibit the formation of Alzheimer's β-amyloid fibrils (fAβ) from amyloid β-peptide (Aβ) and destabilize fAβ.

Antianaphylactic agent that can prevent the occurrence of anaphylaxis (life threatening allergic response).

Antiangiogenic a drug or substance used to stop the growth of tumours and progression of cancers by limiting the pathologic formation of new blood vessels (angiogenesis).

Antiarrhythmic a substance to correct irregular heartbeats and restore the normal rhythm.

Antiasthmatic drug that treats or ameliorates asthma.

Antiatherogenic that protects against atherogenesis, the formation of atheromas (plaques) in arteries.

Antibacterial substance that kills or inhibits bacteria.

Antibilious an agent or substance which helps remove excess bile from the body.

Antibiotic a chemical substance produced by a microorganism which has the capacity to inhibit the growth of or to kill other microorganisms.

Antiblennorrhagic a substance that treats blenorrhagia a conjunctival inflammation resulting in mucus discharge.

Antibody a gamma globulin protein produced by a kind of white blood cell called the plasma cell in the blood used by the immune system to identify and neutralize foreign objects (antigen).

Anticarcinomic a substance that kills or inhibits carcinomas (any cancer that arises in epithelium/tissue cells).

Anticephalalgic headache-relieving or preventing.

Anticestodal a chemical destructive to tapeworms.

Anticholesterolemic a substance that can prevent the build up of cholesterol.

Anticlastogenic having a suppressing effect of chromosomal aberrations.

Anticoagulant a substance that thins the blood and acts to inhibit blood platelets from sticking together.

Antidepressant a substance that suppresses depression or sadness.

Antidiabetic a substance that prevents or alleviates diabetes. Also called antidiabetogenic.

Antidiarrhoeal having the property of stopping or correcting diarrhoea, an agent having such action.

Antidote a remedy for counteracting a poison.

Antidopaminergic a term for a chemical that prevents or counteracts the effects of dopamine.

Antidrepanocytary anti-sickle cell anaemia.

Antidysenteric an agent used to reduce or treat dysentery and diarrhea.

Antidyslipidemic agent that will reduce the abnormal amount of lipids and lipoproteins in the blood.

Anti-edematous reduces or suppresses edema.

Anti-emetic an agent that stops vomiting.

Anti-epileptic a drug used to treat or prevent convulsions, anticonvulsant.

Antifebrile a substance that reduces fever, also called antipyretic.

Antifeedant preventing something from being eaten.

Antifertility agent that inhibits formation of ova and sperm and disrupts the process of fertilization (antizygotic).

Antifilarial effective against human filarial worms.

Antifungal an agent that kills or inhibits the growth of fungi.

Antigen a substance that prompts the production of antibodies and can cause an immune response. *adj.* antigenic.

Antigenotoxic an agent that inhibits DNA adduct formation, stimulates DNA repair mechanisms, and possesses antioxidant functions.

Antiganacratia anti-menstruation.

Antigastralgic preventing or alleviating gastric colic.

Antihematic agent that stops vomiting.

Antihemorrhagic an agent which stops or prevents bleeding.

Antihepatotoxic counteracting injuries to the liver.

Antiherpetic having activity against Herpes Simplex Virus (HSV).

Antihistamine an agent used to counteract the effects of histamine production in allergic reactions.

Antihyperalgesia the ability to block enhanced sensitivity to pain, usually produced by nerve injury or inflammation, to nociceptive stimuli. *adj.* antihyperalgesic.

Antihypercholesterolemia term to describe lowering of cholesterol level in the blood or blood serum.

Antihypercholesterolemic agent that lowers cholesterol level in the blood or blood serum.

Antihyperlipidemic promoting a reduction of lipid levels in the blood, or an agent that has this action.

Antihypersensitive a substance used to treat excessive reactivity to any stimuli.

Antihypertensive a drug used in medicine and pharmacology to treat hypertension (high blood pressure).

Antiinflammatory a substance used to reduce or prevent inflammation.

Antileishmanial inhibiting the growth and proliferation of *Leishmania* a genus of flagellate protozoans that are parasitic in the tissues of vertebrates.

Antileprotic therapeutically effective against leprosy.

Antilithiatic an agent that reduces or suppresses urinary calculi (stones) and acts to dissolve those already present.

Antileukaemic anticancer drugs that are used to treat leukemia.

Antilithogenic inhibiting the formation of calculi (stones).

Antimalarial an agent used to treat malaria and/or kill the malaria-causing organism, *Plasmodium* spp.

Antimelanogenesis obstruct production of melanin.

Antimicrobial a substance that destroys or inhibits growth of disease-causing bacteria, viruses, fungi and other microorganisms.

Antimitotic inhibiting or preventing mitosis.

Antimutagenic an agent that inhibits mutations.

Antimycotic antifungal.

Antineoplastic said of a drug intended to inhibit or prevent the maturation and proliferation of neoplasms that may become malignant, by targeting the DNA.

Antineuralgic a substance that stops intense intermittent pain, usually of the head or face, caused by neuralgia.

Antinociception reduction in pain: a reduction in pain sensitivity produced within neurons when an endorphin or similar opium-containing substance opioid combines with a receptor.

Antinociceptive having an analgesic effect.

Antinutrient are natural or synthetic compounds that interfere with the absorption of nutrients and are commonly found in food sources and beverages.

Antioestrogen a substance that inhibits the biological effects of female sex hormones.

Antiophidian anti venoms of snake.

Antiosteoporotic substance that can prevent osteoporosis.

Antiovulatory substance suppressing ovulation.

Antioxidant a chemical compound or substance that inhibits oxidation and protects against free radical activity and lipid oxidation such as vitamin E, vitamin C, or beta-carotene (converted to vitamin B), carotenoids and flavonoids which are thought to protect body cells from the damaging effects of oxidation. Many foods including fruit and vegetables contain compounds with antioxidant properties. Antioxidants may also reduce the risks of cancer and age-related macular degeneration(AMD).

Antipaludic antimalarial.

Antiperiodic substance that prevents the recurrence of symptoms of a disease e.g. malaria.

Antiperspirant a substance that inhibits sweating. Also called antisudorific, anaphoretic.

Antiphlogistic a traditional term for a substance used against inflammation, an anti-inflammatory.

Antiplatelet agent drug that decreases platelet aggregation and inhibits thrombus formation.

Antiplasmodial suppressing or destroying plasmodia.

Antiproliferative preventing or inhibiting the reproduction of similar cells.

Antiprostatic drug to treat the prostate.

Antiprotozoal suppressing the growth or reproduction of protozoa.

Antipruritic alleviating or preventing itching.

Antipyretic a substance that reduces fever or quells it. Also known as antithermic.

Antirheumatic relieving or preventing rheumatism.

Antiscorbutic a substance or plant rich in vitamin C that is used to counteract scurvy.

Antisecretory inhibiting or diminishing secretion.

Antisense refers to antisense RNA strand because its sequence of nucleotides is the complement of message sense. When mRNA forms a duplex with a complementary antisense RNA sequence, translation of the mRNA into the protein is blocked. This may slow or halt the growth of cancer cells.

Antiseptic preventing decay or putrefaction, a substance inhibiting the growth and development of microorganisms.

Anti-sickling agent an agent used to prevent or reverse the pathological events leading to sickling of erythrocytes in sickle cell conditions.

Antispasmodic a substance that relieves spasms or inhibits the contraction of smooth muscles; smooth muscle relaxant, muscle-relaxer.

Antispermatogenic preventing or suppressing the production of semen or spermatozoa.

Antisudorific see antiperspirant.

Antisyphilitic a drug (or other chemical agent) that is effective against syphilis.

Antithermic a substance that reduces fever and temperature. Also known as antipyretic.

Antithrombotic preventing or interfering with the formation of thrombi.

Antitoxin an antibody with the ability to neutralize a specific toxin.

Antitumoral substance that acts against the growth, development or spread of a tumour.

Antitussive a substance that depresses coughing.

Antiulcerogenic an agent used to protect against the formation of ulcers, or is used for the treatment of ulcers.

Antivenin an agent used against the venom of a snake, spider, or other venomous animal or insect.

Antivinous an agent or substance that treats addiction to alcohol.

Antiviral substance that destroys or inhibits the growth and viability of infectious viruses.

Antivomitive a substance that reduces or suppresses vomiting.

Antizygotic see antifertility.

Anuria absence of urine production and excretion. *adj.* anuric.

Anxiolytic a drug prescribed for the treatment of symptoms of anxiety.

APAF-1 apoptotic protease activating factor 1.

Apelin also known as APLN, a peptide which in humans is encoded by the APLN gene.

Aperient a substance that acts as a mild laxative by increasing fluids in the bowel.

Aperitif an appetite stimulant.

Aphonia loss of the voice resulting from disease, injury to the vocal cords, or various psychological causes, such as hysteria.

Aphrodisiac an agent that increases sexual activity and libido and/or improves sexual performance.

Aphthous ulcer also known as a canker sore, is a type of oral ulcer, which presents as a painful open sore inside the mouth or upper throat.

Apnoea suspension of external breathing.

Apolipoprotein B (APOB) primary apolipoprotein of low-density lipoproteins which is responsible for carrying cholesterol to tissues.

Apoplexy a condition in which the brain's function stops with loss of voluntary motion and sense.

Apoprotein the protein moiety of a molecule or complex, as of a lipoprotein.

Appendicitis is a condition characterized by inflammation of the appendix. Also called epityphlitis.

Appetite stimulant a substance to increase or stimulate the appetite. Also called aperitif.

Aphthae white, painful oral ulcer of unknown cause.

Apthous ulcer canker sore in the lining of the mouth.

Aphthous stomatitis a canker sore, a type of painful oral ulcer or sore inside the mouth or upper throat, caused by a break in the mucous membrane. Also called aphthous ulcer.

Apolipoprotein A-I (APOA1) a major protein component of high density lipoprotein (HDL) in plasma. The protein promotes cholesterol efflux from tissues to the liver for excretion.

Apolipoprotein B (APOB) is the primary apolipoprotein of low-density lipoproteins (LDL or "bad cholesterol"), which is responsible for carrying cholesterol to tissues.

Apolipoprotein E (APOE) the apolipoprotein found on intermediate density lipoprotein and chylomicron that binds to a specific receptor on liver and peripheral cells.

Apoptogenic ability to cause death of cells.

Apoptosis death of cells.

Apurinic lyase a DNA enzyme that catalyses a chemical reaction.

Arachidonate cascade includes the cyclooxygenase (COX) pathway to form prostanoids and the lipoxygenase (LOX) pathway to generate several oxygenated fatty acids, collectively called eicosanoids.

Ariboflavinosis a condition caused by the dietary deficiency of riboflavin that is characterized by mouth lesions, seborrhea, and vascularization.

Aromatase an enzyme involved in the production of estrogen that acts by catalyzing the conversion of testosterone (an androgen) to estradiol (an estrogen). Aromatase is located in estrogen-producing cells in the adrenal glands, ovaries, placenta, testicles, adipose (fat) tissue, and brain.

Aromatic having a pleasant, fragrant odour.

Aromatherapy a form of alternative medicine that uses volatile liquid plant materials, such as essential oils and other scented compounds from plants for the purpose of affecting a person's mood or health.

Arrhythmias abnormal heart rhythms that can cause the heart to pump less effectively. Also called dysrhythmias.

Arsenicosis see arsenism.

Arsenism an incommunicable disease resulting from the ingestion of ground water containing unsafe levels of arsenic, also known as arsenicosis.

Arteriosclerosis imprecise term for various disorders of arteries, particularly hardening due

to fibrosis or calcium deposition, often used as a synonym for atherosclerosis.

Arthralgia is pain in the joints from many possible causes.

Arthritis inflammation of the joints of the body.

Aryl hydrocarbon receptor (AhR) a ligand-activated transcription factor best known for mediating the toxicity of dioxin and other exogenous contaminants and is responsible for their toxic effects, including immunosuppression.

ASAT or AST aspartate aminotransferase, see aspartate transaminase,

Ascaris a genus of parasitic intestinal round worms.

Ascites abnormal accumulation of fluid within the abdominal or peritoneal cavity.

Ascorbic acid See vitamin C.

Aspartate transaminase (AST) also called Serum Glutamic Oxaloacetic Transaminase (SGOT) or aspartate aminotransferase (ASAT) is similar to ALT in that it is another enzyme associated with liver parenchymal cells. It is increased in acute liver damage, but is also present in red blood cells, and cardiac and skeletal muscle and is therefore not specific to the liver.

Asphyxia failure or suppression of the respiratory process due to obstruction of air flow to the lungs or to the lack of oxygen in inspired air.

Asphyxiation the process of undergoing asphyxia.

Asthenia a nonspecific symptom characterized by loss of energy, strength and feeling of weakness.

Asthenopia weakness or fatigue of the eyes, usually accompanied by headache and dimming of vision. *adj*. asthenopic.

Asthma a chronic illness involving the respiratory system in which the airway occasionally constricts, becomes inflamed, and is lined with excessive amounts of mucus, often in response to one or more triggers.

Astringent a substance that contracts blood vessels and certain body tissues (such as mucous membranes) with the effect of reducing secretion and excretion of fluids and/or has a drying effect.

Astrocytes collectively called astroglia, are characteristic star-shaped glial cells in the brain and spinal cord.

Ataxia (loss of co-ordination) results from the degeneration of nerve tissue in the spinal cord and of nerves that control muscle movement in the arms and legs.

Ataxia telangiectasia and Rad3-related protein (ATR) also known as Serine/threonine-protein kinase ATR, FRAP-related protein 1 (FRP1), is an enzyme encoded by the ATR gene. It is involved in sensing DNA damage and activating the DNA damage checkpoint, leading to cell cycle arrest

ATF-2 activating transcription factor 2.

Athlete's foot a contagious skin disease caused by parasitic fungi affecting the foot, hands, causing itching, blisters and cracking. Also called dermatophytosis.

Atherogenic having the capacity to start or accelerate the process of atherogenesis.

Atherogenesis the formation of lipid deposits in the arteries.

Atheroma a deposit or degenerative accumulation of lipid-containing plaques on the innermost layer of the wall of an artery.

Atherosclerosis the condition in which an artery wall thickens as the result of a build-up of fatty materials such as cholesterol.

Atherothrombosis medical condition characterized by an unpredictable, sudden disruption (rupture or erosion/fissure) of an atherosclerotic plaque, which leads to platelet activation and thrombus formation.

Athymic mice laboratory mice lacking a thymus gland.

Atonic lacking normal tone or strength.

Atony insufficient muscular tone.

Atopic dermatitis an inflammatory, non-contagious, pruritic skin disorder of unknown etiology; often called eczema.

Atresia a congenital medical condition in which a body orifice or passage in the body is abnormally closed or absent.

Atretic ovarian follicles an involuted or closed ovarian follicle.

Atrial fibrillation is the most common cardiac arrhythmia (abnormal heart rhythm) and

involves the two upper chambers (atria) of the heart.

Attention-deficit hyperactivity disorder (ADHD, ADD or AD/HD) is a neurobehavioral developmental disorder, primarily characterized by the co-existence of attentional problems and hyperactivity.

Auditory brainstem response (ABR) also called brainstem evoked response (BSER) is an electrical signal evoked from the brainstem of a human by the presentation of a sound such as a click.

Augmerosen a drug that may kill cancer cells by blocking the production of a protein that makes cancer cells live longer. Also called bcl-2 antisense oligonucleotide.

Auricular of or relating to the auricle or the ear in general.

Aurones [2-benzylidenebenzofuran-3(2 H)-ones] are the secondary plant metabolites and is a subgroup of flavonoids. See flavonoids.

Autoantibodies antibodies manufactured by the immune system that mistakenly target and damage specific tissues and organs of the body.

Autolysin an enzyme that hydrolyzes and destroys the components of a biological cell or a tissue in which it is produced.

Autophagy digestion of the cell contents by enzymes in the same cell.

Autopsy examination of a cadaver to determine or confirm the cause of death**.**

Avidity Index describes the collective interactions between antibodies and a multivalent antigen.

Avulsed teeth is tooth that has been knocked out.

Ayurvedic traditional Hindu system of medicine based largely on homeopathy and naturopathy.

Azoospermia is the medical condition of a male not having any measurable level of sperm in his semen.

Azotaemia a higher than normal blood level of urea or other nitrogen containing compounds in the blood.

Babesia a protozoan parasite (malaria–like) of the blood that causes a hemolytic disease known as Babesiosis.

Babesiosis malaria-like parasitic disease caused by Babesia, a genus of protozoal piroplasms.

Bactericidal lethal to bacteria.

Balanitis is an inflammation of the glans (head) of the penis.

BALB/c mice Balb/c mouse was developed in 1923 by McDowell. It is a popular strain and is used in many different research disciplines, but most often in the production of monoclonal antibodies.

Balm aromatic oily resin from certain trees and shrubs used in medicine.

Baroreceptor a type of interoceptor that is stimulated by pressure changes, as those in blood vessel wall.

Barrett's esophagus (Barrett esophagitis) a disorder in which the lining of the esophagus is damaged by stomach acid**.**

Basophil a type of white blood cell with coarse granules within the cytoplasm and a bilobate (two-lobed) nucleus.

BCL-2 a family of apoptosis regulator proteins in humans encoded by the B-cell lymphoma 2 (BCL-2) gene.

BCL-2 antisense oligonucleotide see augmereson.

BCR/ABL a chimeric oncogene, from fusion of BCR and ABL cancer genes associated with chronic myelogenous leukemia.

Bechic a remedy or treatment of cough.

Bed nucleus of the stria terminalis (BNST) act as a relay site within the hypothalamic-pituitary-adrenal axis and regulate its activity in response to acute stress.

Belching, or burping refers to the noisy release of air or gas from the stomach through the mouth.

Beri-beri is a disease caused by a deficiency of thiamine (vitamin B_1) that affects many systems of the body, including the muscles, heart, nerves, and digestive system.

Beta-carotene naturally-occurring retinol (vitamin A) precursor obtained from certain fruits and vegetables with potential antineoplastic and chemopreventive activities. As an anti-oxidant, beta carotene inhibits free-radical damage to DNA. This agent also induces cell differentiation and apoptosis

of some tumour cell types, particularly in early stages of tumourigenesis, and enhances immune system activity by stimulating the release of natural killer cells, lymphocytes, and monocytes.

Beta-catenin is a multifunctional oncogenic protein that contributes fundamentally to cell development and biology, it has been implicated as an integral component in the Wnt signaling pathway.

Beta cells a type of cell in the pancreas in areas called the islets of Langerhans.

Beta-thalassemia an inherited blood disorder that reduces the production of hemoglobin.

Beta-lactamase enzymes produced by some bacteria that are responsible for their resistance to beta-lactam antibiotics like penicillins.

BHT butylated hydroxytoluene (phenolic compound), an antioxidant used in foods, cosmetics, pharmaceuticals, and petroleum products.

Bifidobacterium is a genus of Gram-positive, non-motile, often branched anaerobic bacteria. Bifidobacteria are one of the major genera of bacteria that make up the gut flora. Bifidobacteria aid in digestion, are associated with a lower incidence of allergies and also prevent some forms of tumour growth. Some bifidobacteria are being used as probiotics.

Bifidogenic promoting the growth of (beneficial) bifidobacteria in the intestinal tract.

Bile fluid secreted by the liver and discharged into the duodenum where it is integral in the digestion and absorption of fats.

Bilharzia, bilharziosis see Schistosomiasis.

Biliary relating to the bile or the organs in which the bile is contained or transported.

Biliary infections infection of organ(s) associated with bile, comprise: (a) acute cholecystitis: an acute inflammation of the gallbladder wall; (b) cholangitis: inflammation of the bile ducts.

Biliousness old term used in the eighteenth and nineteenth centuries pertaining to bad digestion, stomach pains, constipation, and excessive flatulence.

Bilirubin a breakdown product of heme (a part of haemoglobin in red blood cells) produced by the liver that is excreted in bile which causes a yellow discoloration of the skin and eyes when it accumulates in those organs.

Biotin also known as vitamin B7. See vitamin B7.

Bitter a medicinal agent with a bitter taste and used as a tonic, alterative or appetizer.

Blackhead see comedone.

Blackwater fever dangerous complication of malarial whereby the red blood cells burst in the blood stream (haemolysis) releasing haemoglobin directly into the blood.

Blain see chilblain.

Blastocyst blastocyst is an embryonic structure formed in the early embryogenesis of mammals, after the formation of the morula, but before implantation.

Blastocystotoxic agent that suppresses further development of the blastocyst through to the ovum stage.

Blebbing Bulging e.g. membrane blebbing also called membrane bulging or ballooning.

Bleeding diathesis is an unusual susceptibility to bleeding (hemorrhage) due to a defect in the system of coagulation.

Blennorrhagia gonorrhea.

Blennorrhea inordinate discharge of mucus, especially a gonorrheal discharge from the urethra or vagina.

Blepharitis inflammation of the eyelids.

Blister thin vesicle on the skin containing serum and caused by rubbing, friction or burn.

Blood brain barrier (BBB) is a separation of circulating blood and cerebrospinal fluid (CSF) in the central nervous system (CNS). It allows essential metabolites, such as oxygen and glucose, to pass from the blood to the brain and central nervous system (CNS) but blocks most molecules that are more massive than about 500 Da.

Boil localized pyrogenic, painful infection, originating in a hair follicle.

Borborygmus rumbling noise caused by the muscular contractions of peristalsis, the process that moves the contents of the stomach and intestines downward.

Bowman Birk inhibitors type of serine proteinase inhibitor.

Bouillon a broth in French cuisine.

Bradicardia as applied to adult medicine, is defined as a resting heart rate of under 60 beats per minute.

Bradyphrenia referring to the slowness of thought common to many disorders of the brain.

Brain Derived Neutrophic Factor (BDNF) a protein member of the neutrophin family that plays an important role in the growth, maintenance, function and survival of neurons. The protein molecule is involved in the modulation of cognitive and emotional functions and in the treatment of a variety of mental disorders.

Bright's disease chronic nephritis.

Bronchial inflammation see bronchitis.

Bronchiectasis a condition in which the airways within the lungs (bronchial tubes) become damaged and widened.

Bronchitis is an inflammation of the main air passages (bronchi) to your lungs.

Bronchoalveolar lavage (BAL) a medical procedure in which a bronchoscope is passed through the mouth or nose into the lungs and fluid is squirted into a small part of the lung and then recollected for examination.

Bronchopneumonia or bronchial pneumonia; inflammation of the lungs beginning in the terminal bronchioles.

Broncho-pulmonary relating to the bronchi and lungs.

Bronchospasm is a difficulty in breathing caused by a sudden constriction of the muscles in the walls of the bronchioles as occurs in asthma.

Brown Fat brown adipose tissue (BAT) in mammals, its primary function is to generate body heat in animals or newborns that do not shiver.

Bubo inflamed, swollen lymph node in the neck or groin.

Buccal of or relating to the cheeks or the mouth cavity.

Bullae blisters; circumscribed, fluid-containing, elevated lesions of the skin, usually more than 5 mm in diameter.

Bursitis condition characterized by inflammation of one or more bursae (small sacs) of synovial fluid in the body.

C-jun NH(2)-terminal kinase enzymes that belong to the family of the MAPK superfamily of protein kinases. These kinases mediate a plethora of cellular responses to such stressful stimuli, including apoptosis and production of inflammatory and immunoregulatory cytokines in diverse cell systems. *cf:* MAPK.

c-FOS a cellular proto-oncogene belonging to the immediate early gene family of transcription factors.

c-Src a cellular non-receptor tyrosine kinase.

CAAT element-binding proteins-alpha (c/EBP-akpha) regulates gene expression in adipocytes in the liver.

Cachexia physical wasting with loss of weight, muscle atrophy, fatigue, weakness caused by disease.

Caco-2 cell line a continuous line of heterogeneous human epithelial colorectal adenocarcinoma cells.

Cadaver a dead body, corpse.

Ca^{2+} ATPase (PMCA) is a transport protein in the plasma membrane of cells that serves to remove calcium (Ca^{2+}) from the cell.

Calcium (Ca) is the most abundant mineral in the body found mainly in bones and teeth. It is required for muscle contraction, blood vessel expansion and contraction, secretion of hormones and enzymes, and transmitting impulses throughout the nervous system. Dietary sources include milk, yoghurt, cheese, Chinese cabbage, kale, broccoli, some green leafy vegetables, fortified cereals, beverages and soybean products.

Calcium ATPase is a form of P-ATPase which transfers calcium after a muscle has contracted.

Calcium channel blockers (CCBs) a class of drugs and natural substances that disrupt the calcium (Ca^{2+}) conduction of calcium channels.

Calculus (calculi) hardened, mineral deposits that can form a blockage in the urinary system.

Calculi infection most calculi arise in the kidney when urine becomes supersaturated with a salt that is capable of forming solid crystals. Symptoms arise as these calculi become impacted within the ureter as they pass toward the urinary bladder.

Caligo dimness or obscurity of sight, dependent upon a speck on the cornea.

Calmodulin is a Calcium Modulated protein that can bind to and regulate a multitude of different protein targets, thereby affecting many different cellular functions.

cAMP dependent pathway cyclic adenosine monophosphate is a G protein-coupled receptor triggered signaling cascade used in cell communication in living organisms.

Cancer a malignant neoplasm or tumour in nay part of the body.

Candidiasis infections caused by members of the fungus genus *Candida* that range from superficial, such as oral thrush and vaginitis, to systemic and potentially life-threatening diseases.

Canker see chancre.

Carboxypeptidase an enzyme that hydrolyzes the carboxy-terminal (C-terminal) end of a peptide bond. It is synthesized in the pancreas and secreted into the small intestine.

Carbuncle is an abscess larger than a boil, usually with one or more openings draining pus onto the skin.

Carcinogenesis production of carcinomas. *adj.* carcinogenic.

Carcinoma any malignant cancer that arises from epithelial cells.

Carcinosarcoma a rare tumour containing carcinomatous and sarcomatous components.

Cardiac relating to, situated near or affecting the heart.

Cardiac asthma acute attack of dyspnoea with wheezing resulting from a cardiac disorder.

Cardialgia heartburn.

Cardinolides cardiac glycosides with a 5-membered lactone ring in the side chain of the steroid aglycone.

Cardinolide glycoside cardenolides that contain structural groups derived from sugars.

Cardioactive having an effect on the heart.

Cardiogenic shock is characterized by a decreased pumping ability of the heart that causes a shock like state associated with an inadequate circulation of blood due to primary failure of the ventricles of the heart to function effectively.

Cardiomyocytes cardiac muscle cells.

Cardiomyopathy heart muscle disease.

Cardiopathy disease or disorder of the heart.

Cardioplegia stopping the heart so that surgical procedures can proceed in a still and bloodless field.

Cardiotonic something which strengthens, tones, or regulates heart functions without overt stimulation or depression.

Cardiovascular pertaining to the heart and blood vessels.

Caries tooth decay, commonly called cavities.

Cariogenic leading to the production of caries.

Carminative substance that stops the formation of intestinal gas and helps expel gas that has already formed, relieving flatulence: relieving flatulence or colic by expelling gas.

Carnitine palmitoyltransferase I (CPT1) also known as carnitine acyltransferase I or CAT1 is a mitochondrial enzyme, involved in converting long chain fatty acid into energy.

Carotenes are a large group of intense red and yellow pigments found in all plants; these are hydrocarbon carotenoids (subclass of tetraterpenes) and the principal carotene is beta-carotene which is a precursor of vitamin A.

Carotenoids a class of natural fat-soluble pigments found principally in plants, belonging to a subgroup of terpenoids containing eight isoprene units forming a C40 polyene chain. Carotenoids play an important potential role in human health by acting as biological antioxidants. See also carotenes.

Carotenodermia yellow skin discoloration caused by excess blood carotene.

Carpopedal spasm spasm of the hand or foot, or of the thumbs and great toes.

Capases cysteine-aspartic acid proteases, are a family of cysteine proteases, which play essential roles in apoptosis (programmed cell death).

Catalase (CAT) enzyme in living organism that catalyses the decomposition of hydrogen peroxide to water and oxygen.

Catalepsy indefinitely prolonged maintenance of a fixed body posture; seen in severe cases of catatonic schizophrenia.

Catamenia menstruation.

Cataplasia Degenerative reversion of cells or tissue to a less differentiated form.

Cataplasm a medicated poultice or plaster. A soft moist mass, often warm and medicated, that is spread over the skin to treat an inflamed, aching or painful area, to improve the circulation.

Cataractogenesis formation of cataracts.

Catarrh, Catarrhal inflammation of the mucous membranes especially of the nose and throat.

Catechins are polyphenolic antioxidant plant metabolites. They belong to the family of flavonoids; tea is a rich source of catechins. See flavonoids.

Catecholamines hormones that are released by the adrenal glands in response to stress.

Cathartic is a substance which accelerates defecation.

Caustic having a corrosive or burning effect.

Cauterization a medical term describing the burning of the body to remove or close a part of it.

cdc2 Kinase a member of the cyclin-dependent protein kinases (CDKs).

CDKs cyclin-dependent protein kinases, a family of serine/threonine kinases that mediate many stages in mitosis.

CD 28 is one of the molecules expressed on T cells that provide co-stimulatory signals, which are required for T cell (lymphocytes) activation.

CD31 also known as PECAM-1 (Platelet Endothelial Cell Adhesion Molecule-1), a member of the immunoglobulin superfamily, that mediates cell-to-cell adhesion.

CD68 a glycoprotein expressed on monocytes/macrophages which binds to low density lipoprotein.

Cecal ligation tying up the cecam.

Cell adhesion molecules (CAM) glycoproteins located on the surface of cell membranes involved with binding of other cells or with the extra-cellular matrix.

Cellular respiration is the set of the metabolic reactions and processes that take place in organisms' cells to convert biochemical energy from nutrients into adenosine triphosphate (ATP), and then release waste products. The reactions involved in respiration are catabolic reactions that involve the oxidation of one molecule and the reduction of another.

Cellulitis a bacterial infection of the skin that tends to occur in areas that have been damaged or inflamed.

Central nervous system part of the vertebrate nervous system comprising the brain and spinal cord.

Central Venous Catheter a catheter placed into the large vein in the neck, chest or groin.

Cephalagia pain in the head, a headache.

Cephalic relating to the head.

Ceramide oligosides oligosides with an N-acetyl-sphingosine moiety.

Cerebral embolism a blockage of blood flow through a vessel in the brain by a blood clot that formed elsewhere in the body and traveled to the brain.

Cerebral ischemia is the localized reduction of blood flow to the brain or parts of the brain due to arterial obstruction or systematic hyperfusion.

Cerebral infarction is the ischemic kind of stroke due to a disturbance in the blood vessels supplying blood to the brain.

Cerebral tonic substance that can alleviate poor concentration and memory, restlessness, uneasiness, and insomnia.

Cerebrosides are glycosphingolipids which are important components in animal muscle and nerve cell membranes.

Cerebrovascular disease is a group of brain dysfunctions related to disease of the blood vessels supplying the brain.

Cerumen ear wax, a yellowish waxy substance secreted in the ear canal of humans and other mammals.

cGMP cyclic guanosine monophosphate is a cyclic nucleotide derived from guanosine triphosphate (GTP). cGMP acts as a second messenger much like cAMP, activating intracellular protein kinases in response to the binding of membrane-impermeable peptide hormones to the external cell surface. cGMP is a common regulator of ion channel conductance,

glycogenolysis, and cellular apoptosis. It also relaxes smooth muscle tissues.

Chalcones a subgroup of flavonoids.

Chancre a painless lesion formed during the primary stage of syphilis.

Chemoembolization a procedure in which the blood supply to the tumour is blocked surgically or mechanically and anticancer drugs are administered directly into the tumour.

Chemokines are chemotactic cytokines, which stimulate migration of inflammatory cells towards tissue sites of inflammation.

Chemosensitizer a drug that makes tumour cells more sensitive to the effects of chemotherapy**.**

Chemosis edema of the conjunctiva of the eye.

Chickenpox is also known as varicella, is a highly contagious illness caused by primary infection with varicella zoster virus (VZV). The virus causes red, itchy bumps on the body.

Chilblains small, itchy, painful lumps that develop on the skin. They develop as an abnormal response to cold. Also called perniosis or blain.

Chlorosis iron deficiency anemia characterized by greenish yellow colour.

Cholagogue is a medicinal agent which promotes the discharge of bile from the system.

Cholecalcifereol a form of vitamin D, also called vitamin D3. See vitamin D.

Cholecyst gall bladder.

Cholecystitis inflammation of the gall bladder.

Cholecystokinin a peptide hormone that plays a key role in facilitating digestion in the small intestine.

Cholera an infectious gastroenteritis caused by enterotoxin-producing strains of the bacterium *Vibrio cholera* and characterized by severe, watery diarrhea.

Choleretic stimulation of the production of bile by the liver.

Cholestasis a condition caused by rapidly developing (acute) or long-term (chronic) interruption in the excretion of bile.

Cholesterol a soft, waxy, steroid substance found among the lipids (fats) in the bloodstream and in all our body's cells.

Cholethiasis presence of gall stones (calculi) in the gall bladder.

Choline a water soluble, organic compound, usually grouped within the Vitamin B complex. It is an essential nutrient and is needed for physiological functions such as structural integrity and signaling roles for cell membranes, cholinergic neuro-transmission (acetylcholine synthesis).

Cholinergic activated by or capable of liberating acetylcholine, especially in the parasympathetic nervous system.

Cholinergic system a system of nerve cells that uses acetylcholine in transmitting nerve impulses.

Cholinomimetic having an action similar to that of acetylcholine; called also parasympathomimetic.

Chonotropic affecting the time or rate, as the rate of contraction of the heart.

Choriocarcinoma a quick-growing malignant, trophoblastic, aggressive cancer that occurs in a woman's uterus (womb).

Chromium (Cr) is required in trace amounts in humans for sugar and lipid metabolism. Its deficiency may cause a disease called chromium deficiency. It is found in cereals, legumes, nuts and animal sources.

Chromosome long pieces of DNA found in the center (nucleus) of cells.

Chronic persisting over extended periods.

Chyle a milky bodily fluid consisting of lymph and emulsified fats, or free fatty acids.

Chylomicrons are large lipoprotein particles that transport dietary lipids from the intestines to other locations in the body. Chylomicrons are one of the five major groups of lipoproteins (chylomicrons, VLDL, IDL, LDL, HDL) that enable fats and cholesterol to move within the water-based solution of the bloodstream.

Chylorus milky (having fat emulsion).

Chyluria also called chylous urine, is a medical condition involving the presence of chyle (emulsified fat) in the urine stream, which results in urine appearing milky.

Chymase member of the family of serine proteases found primarily in mast cell.

Chymopapain an enzyme derived from papaya, used in medicine and to tenderize meat.

Cicatrizant the term used to describe a product that promotes healing through the formation of scar tissue.

Cirrhosis chronic liver disease characterized by replacement of liver tissue by fibrous scar tissue and regenerative nodules/lumps leading progressively to loss of liver function.

C-Kit Receptor a protein-tyrosine kinase receptor that is specific for stem cell factor. this interaction is crucial for the development of hematopoietic, gonadal, and pigment stem cells. Genetic mutations that disrupt the expression of proto-oncogene protein c-kit are associated with piebaldism, while over expression or constitutive activation of the c-kit protein-tyrosine kinase is associated with tumourigenesis.

Clastogen is an agent that can cause one of two types of structural changes, breaks in chromosomes that result in the gain, loss, or rearrangements of chromosomal segments. *adj.* clastogenic.

Claudication limping, impairment in walking.

Climacterium refers to menopause and the bodily and mental changes associated with it.

Clonic seizures consist of rhythmic jerking movements of the arms and legs, sometimes on both sides of the body.

Clyster enema.

C-myc codes for a protein that binds to the DNA of other genes and is therefore a transcription factor.

CNS Depressant anything that depresses, or slows, the sympathetic impulses of the central nervous system (i.e., respiratory rate, heart rate).

Coagulopathy a defect in the body's mechanism for blood clotting, causing susceptibility to bleeding**.**

Cobalamin vitamin B12. See vitamin B12.

Co-carcinogen a chemical that promotes the effects of a carcinogen in the production of cancer.

Cold an acute inflammation of the mucous membrane of the respiratory tract especially of the nose and throat caused by a virus and accompanied by sneezing and coughing.

Collagen protein that is the major constituent of cartilage and other connective tissue; comprises the amino acids hydroxyproline, proline, glycine, and hydroxylysine.

Collagenases enzymes that break the peptide bonds in collagen.

Colic a broad term which refers to episodes of uncontrollable, extended crying in a baby who is otherwise healthy and well fed.

Colitis inflammatory bowel disease affecting the tissue that lines the gastrointestinal system.

Collyrium a lotion or liquid wash used as a cleanser for the eyes, particularly in diseases of the eye.

Colorectal relating to the colon or rectum.

Coma a state of unconsciousness from which a patient cannot be aroused.

Comedone a blocked, open sebaceous gland where the secretions oxidize, turning black**.** Also called blackhead.

Comitogen agent that is considered not to induce cell growth alone but to promote the effect of the mitogen.

Concoction a combination of crude ingredients that is prepared or cooked together.

Condyloma, Condylomata acuminata genital warts, venereal warts, anal wart or anogenital wart, a highly contagious sexually transmitted infection caused by epidermotropic human papillomavirus (HPV).

Conglutination becoming stuck together.

Conjunctival hyperemia enlarged blood vessels in the eyes.

Conjunctivitis sore, red and sticky eyes caused by eye infection.

Constipation a very common gastrointestinal disorder characterised by the passing of hard, dry bowel motions (stools) and difficulty of bowel motion.

Constitutive androstane receptor (CAR, NR113) is a nuclear receptor transcription factor that regulates drug metabolism and homoeostasis.

Consumption term used to describe wasting of tissues including but not limited to tuberculosis.

Consumptive afflicted with or associated with pulmonary tuberculosis.

Contraceptive an agent that reduces the likelihood of or prevents conception.

Contraindication a condition which makes a particular treatment or procedure inadvisable.

Contralateral muscle muscle of opposite limb (leg or arm).

Contralateral rotation rotation occurring or originating in a corresponding part on an opposite side.

Contusion another term for a bruise. A bruise, or contusion, is caused when blood vessels are damaged or broken as the result of a blow to the skin.

Convulsant a drug or physical disturbance that induces convulsion.

Convulsion rapid and uncontrollable shaking of the body.

Coolant that which reduces body temperature.

Copper (Cu) is essential in all plants and animals. It is found in a variety of enzymes, including the copper centers of cytochrome C oxidase and the enzyme superoxide dismutase (containing copper and zinc). In addition to its enzymatic roles, copper is used for biological electron transport. Because of its role in facilitating iron uptake, copper deficiency can often produce anemia-like symptoms. Dietary sources include curry powder, mushroom, nuts, seeds, wheat germ, whole grains and animal meat.

Copulation to engage in coitus or sexual intercourse. *adj.* copulatory.

Cordial a preparation that is stimulating to the heart.

Corn or callus is a patch of hard, thickened skin on the foot that is formed in response to pressure or friction.

Corticosteroids a class of steroid hormones that are produced in the adrenal cortex, used clinically for hormone replacement therapy, for suppressing ACTH secretion, for suppression of immune response and as antineoplastic, anti-allergic and anti-inflammatory agents.

Corticosterone a 21-carbon steroid hormone of the corticosteroid type produced in the cortex of the adrenal glands.

Cortisol is a corticosteroid hormone made by the adrenal glands.

Cornification is the process of forming an epidermal barrier in stratified squamous epithelial tissue.

Coryza a word describing the symptoms of a head cold. It describes the inflammation of the mucus membranes lining the nasal cavity which usually gives rise to the symptoms of nasal congestion and loss of smell, among other symptoms.

COX-1 see cyclooxygenase −1.

COX-2 see cyclooxygenase-2.

CpG islands genomic regions that contain a high frequency of CpG sites.

CpG sites the cytosine-phosphate-guanine nucleotide that links two nucleosides together in DNA.

cPLA(2) cytosolic phospholipases A2, these phospholipases are involved in cell signaling processes, such as inflammatory response.

CPY1B1, CPY1A1 a member of the cytochrome P450 superfamily of heme-thiolate monooxygenase enzymes.

Corticosterone a 21-carbon corticosteroid hormone produced in the cortex of the adrenal glands that functions in the metabolism of carbohydrates and proteins.

Creatin a nitrogenous organic acid that occurs naturally in vertebrates and helps to supply energy to muscle.

Creatine phosphokinase (CPK, CK) enzyme that catalyses the conversion of creatine and consumes adenosine triphosphate (ATP) to create phosphocreatine and adenosine diphosphate (ADP).

CREB cAMP response element-binding, a protein that is a transcription factor that binds to certain DNA sequences called cAMP response elements.

Crohn Disease an inflammatory disease of the intestines that affect any part of the gastrointestinal tract.

Crossover study a longitudinal, balance study in which participants receive a sequence of different treatments or exposures.

Croup is an infection of the throat (larynx) and windpipe (trachea) that is caused by a virus (Also called laryngotracheobronchitis).

Curettage surgical procedure in which a body cavity or tissue is scraped with a sharp instrument or aspirated with a cannula.

Cutaneous pertaining to the skin.

CXC8 also known as interleukin 8, IL-8.

Cyanogenesis generation of cyanide. *adj.* cyanogenetic.

Cyclooxygenase (COX) an enzyme that is responsible for the formation of prostanoids – prostaglandins, prostacyclins, and thromboxanes that are each involved in the inflammatory response. Two different COX enzymes existed, now known as COX-1 and COX-2.

Cyclooxygenase-1 (COX-1) is known to be present in most tissues. In the gastrointestinal tract, COX-1 maintains the normal lining of the stomach. The enzyme is also involved in kidney and platelet function.

Cyclooxygenase-2 (COX-2) is primarily present at sites of inflammation.

Cysteine proteases are enzymes that degrade polypeptides possessing a common catalytic mechanism that involves a nucleophilic cysteine thiol in a catalytic triad. They are found in fruits like papaya, pineapple, and kiwifruit.

Cystitis a common urinary tract infection that occurs when bacteria travel up the urethra, infect the urine and inflame the bladder lining.

Cystorrhea discharge of mucus from the bladder.

Cytochrome bc-1 complex ubihydroquinone: cytochrome c oxidoreductase.

Cytochrome P450 3A CYP3A a very large and diverse superfamily of heme-thiolate proteins found in all domains of life. This group of enzymes catalyzes many reactions involved in drug metabolism and synthesis of cholesterol, steroids and other lipids.

Cytokine non-antibody proteins secreted by certain cells of the immune system which carry signals locally between cells. They are a category of signaling molecules that are used extensively in cellular communication.

Cytopathic any detectable, degenerative changes in the host cell due to infection.

Cytoprotective protecting cells from noxious chemicals or other stimuli.

Cytosolic relates to the fluid of the cytoplasm in cells.

Cytostatic preventing the growth and proliferation of cells.

Cytotoxic of or relating to substances that are toxic to cells; cell-killing.

D-galactosamine an amino sugar with unique hepatotoxic properties in animals.

Dandruff scurf, dead, scaly skin among the hair.

Dartre condition of dry, scaly skin

Debility weakness, relaxation of muscular fiber.

Debridement is the process of removing nonliving tissue from pressure ulcers, burns, and other wounds.

Debriding agent substance that cleans and treats certain types of wounds, burns, ulcers.

Deciduogenic relating to the uterus lining that is shed off at childbirth.

Decidual stromal cells like endometrial glands and endothelium, express integrins that bind basement components.

Decoction a medical preparation made by boiling the ingredients.

Decongestant a substance that relieves or reduces nasal or bronchial congestion.

Defibrinated plasma blood whose plasma component has had fibrinogen and fibrin removed.

Degranulation cellular process that releases antimicrobial cytotoxic molecules from secretory vesicles called granules found inside some cells.

Delayed afterdepolarizations (DADs) abnormal depolrization that begins during phase 4 – after repolarization is completed, but before another action potential would normally occur.

Delirium is common, sudden severe confusion and rapid changes in brain function that occur with physical or mental illness; it is reversible and temporary.

Demulcent an agent that soothes internal membranes. Also called emollient.

Dendritic cells are immune cells and form part of the mammalian immune system, functioning as antigen presenting cells.

Dentition a term that describes all of the upper and lower teeth collectively.

Deobstruent a medicine which removes obstructions; also called an aperient.

Deoxypyridinoline (Dpd) a crosslink product of collagen molecules found in bone and excreted in urine during bone degradation.

Depilatory an agent for removing or destroying hair.

Depressant a substance that diminish functional activity, usually by depressing the nervous system.

Depurative an agent used to cleanse or purify the blood, it eliminates toxins and purifies the system.

Dermatitis inflammation of the skin causing discomfort such as eczema.

Dermatophyte a fungus parasitic on the skin.

Dermatosis is a broad term that refers to any disease of the skin, especially one that is not accompanied by inflammation.

Dermonecrotic pertaining to or causing necrosis of the skin.

Desquamation the shedding of the outer layers of the skin.

Detoxifier a substance that promotes the removal of toxins from a system or organ.

Diabetes a metabolic disorder associated with inadequate secretion or utilization of insulin and characterized by frequent urination and persistent thirst. See diabetes mellitus.

Diabetes mellitus (DM) (sometimes called "sugar diabetes") is a set of chronic, metabolic disease conditions characterized by high blood sugar (glucose) levels that result from defects in insulin secretion, or action, or both. Diabetes mellitus appears in two forms.

Diabetes mellitus type I (formerly known as juvenile onset diabetes), caused by deficiency of the pancreatic hormone insulin as a result of destruction of insulin-producing beta cells of the pancreas. Lack of insulin causes an increase of fasting blood glucose that begins to appear in the urine above the renal threshold.

Diabetes mellitus type II (formerly called non-insulin-dependent diabetes mellitus or adult-onset diabetes), the disorder is characterized by high blood glucose in the context of insulin resistance and relative insulin deficiency in which insulin is available but cannot be properly utilized.

Diads two adjacent structural units in a polymer molecule.

Dialysis is a method of removing toxic substances (impurities or wastes) from the blood when the kidneys are unable to do so.

Diaphoresis is profuse sweating commonly associated with shock and other medical emergency conditions.

Diaphoretic a substance that induces perspiration. Also called sudorific.

Diaphyseal pertaining to or affecting the shaft of a long bone (diaphysis).

Diaphysis the main or mid section (shaft) of a long bone.

Diarrhoea a profuse, frequent and loose discharge from the bowels.

Diastolic referring to the time when the heart is in a period of relaxation and dilatation (expansion). *cf.* systolic.

Dieresis surgical separation of parts.

Dietary fibre is a term that refers to a group of food components that pass through the stomach and small intestine undigested and reach the large intestine virtually unchanged. Scientific evidence suggest that a diet high in dietary fibre can be of value for treating or preventing such disorders as constipation, irritable bowel syndrome, diverticular disease, hiatus hernia and haemorrhoids. Some components of dietary fibre may also be of value in reducing the level of cholesterol in blood and thereby decreasing a risk factor for coronary heart disease and the development of gallstones. Dietary fibre is beneficial in the treatment of some diabetics.

Digalactosyl diglycerides are the major lipid components of chloroplasts.

Diosgenin a steroid-like substance that is involved in the production of the hormone progesterone, extracted from roots of *Dioscorea* yam.

Dipsomania pathological use of alcohol.

Discutient an agent (as a medicinal application) which serves to disperse morbid matter.

Disinfectant an agent that prevents the spread of infection, bacteria or communicable disease.

Diuresis increased urination**.**

Diuretic a substance that increases urination (diuresis).

Diverticular disease is a condition affecting the large bowel or colon and is thought to be caused by eating too little fibre.

DMBA 7,12-Dimethylbenzanthracene. A polycyclic aromatic hydrocarbon found in tobacco smoke that is a potent carcinogen.

DNA deoxyribonucleic acid, a nucleic acid that contains the genetic instructions used in the development and functioning of all known living organisms.

DOCA desoxycorticosterone acetate **–** a steroid chemical used as replacement therapy in Addison's disease.

Dopamine a catecholamine neurotransmitter that occurs in a wide variety of animals, including both vertebrates and invertebrates.

Dopaminergic relating to, or activated by the neurotransmitter, dopamine.

Double blind refer to a clinical trial or experiment in which neither the subject nor the researcher knows which treatment any particular subject is receiving.

Douche a localised spray of liquid directed into a body cavity or onto a part.

DPPH 2,2 diphenyl-1-picryl-hydrazyl **–** a crystalline, stable free radical used as an inhibitor of free radical reactions.

Dracunculiasis also called guinea worm disease (GWD), is a parasitic infection caused by the nematode, *Dracunculus medinensis*.

Dropsy an old term for the swelling of soft tissues due to the accumulation of excess water. *adj*. dropsical.

Dysentery (formerly known as flux or the bloody flux) is a disorder of the digestive system that results in severe diarrhea containing mucus and blood in the feces. It is caused usually by a bacterium called *Shigella*.

Dysesthesia an unpleasant abnormal sensation produced by normal stimuli.

Dyskinesia the impairment of the power of voluntary movement, resulting in fragmentary or incomplete movements. *adj*. dyskinetic.

Dyslipidemia abnormality in or abnormal amount of lipids and lipoproteins in the blood.

Dysmenorrhea is a menstrual condition characterized by severe and frequent menstrual cramps and pain associated with menstruation.

Dysmotility syndrome a vague, descriptive term used to describe diseases of the muscles of the gastrointestinal tract (esophagus, stomach, small and large intestines).

Dyspedia indigestion followed by nausea.

Dyspepsia refers to a symptom complex of epigastric pain or discomfort. It is often defined as chronic or recurrent discomfort centered in the upper abdomen and can be caused by a variety of conditions.

Dysphagia swallowing disorder.

Dysphonia a voice disorder, an impairment in the ability to produce voice sounds using the vocal organs.

Dysplasia refers to abnormality in development.

Dyspnoea shortness of breath, difficulty in breathing.

Dysrhythmias see arrhythmias.

Dystocia abnormal or difficult child birth or labour.

Dystonia a neurological movement disorder characterized by prolonged, repetitive muscle contractions that may cause twisting or jerking movements of muscles.

Dysuria refers to difficult and painful urination.

E-Selectin also known as endothelial leukocyte adhesion molecule-1 (ELAM-1), CD62E, a member of the selectin family. It is transiently expressed on vascular endothelial cells in response to IL-1 beta and TNF-alpha.

EC 50 median effective concentration that produces desired effects in 50% of the test population.

Ecbolic a drug (as an ergot alkaloid) that tends to increase uterine contractions and that is used especially to facilitate delivery.

Ecchymosis skin discoloration caused by the escape of blood into the tissues from ruptured blood vessels.

ECG see electrocardiography.

EC–SOD extracellular superoxide dismutase, a tissue enzyme mainly found in the extracellular matrix of tissues. It participates in the detoxification of reactive oxygen species

by catalyzing the dismutation of superoxide radicals.

Eczema is broadly applied to a range of persistent skin conditions. These include dryness and recurring skin rashes which are characterized by one or more of these symptoms: redness, skin edema, itching and dryness, crusting, flaking, blistering, cracking, oozing, or bleeding.

Eczematous rash dry, scaly, itchy rash.

ED 50 is defined as the dose producing a response that is 50% of the maximum obtainable.

Edema formerly known as dropsy or hydropsy, is characterized swelling caused by abnormal accumulation of fluid beneath the skin, or in one or more cavities of the body. It usually occurs in the feet, ankles and legs, but it can involve the entire body.

Edematogenic producing or causing edema.

EGFR proteins epidermal growth factor receptor (EGFR) proteins – Protein kinases are enzymes that transfer a phosphate group from a phosphate donor onto an acceptor amino acid in a substrate protein.

EGR-1 early growth response 1, a human gene.

Eicosanoids are signaling molecules made by oxygenation of arachidonic acid, a 20-carbon essential fatty acid, includes prostaglandins and related compounds.

Elastase a serine protease that also hydrolyses amides and esters.

Electrocardiography or ECG, is a transthoracic interpretation of the electrical activity of the heart over time captured and externally recorded by skin electrodes.

Electromyogram (EMG) a test used to record the electrical activity of muscles. An electromyogram (EMG) is also called a myogram.

Electuary a medicinal paste composed of powders, or other medical ingredients, incorporated with sweeteners to hide the taste, suitable for oral administration.

Elephantiasis a disorder characterized by chronic thickened and edematous tissue on the genitals and legs due to various causes.

Embrocation lotion or liniment that relieves muscle or joint pains.

Embryotoxic term that describes any chemical which is harmful to an embryo.

Emesis vomiting, throwing up.

Emetic an agent that induces vomiting, *cf*: antiemetic.

Emetocathartic causing vomiting and purging.

Emmenagogue a substance that stimulates, initiates, and/or promotes menstrual flow. Emmenagogues are used in herbal medicine to balance and restore the normal function of the female reproductive system.

Emollient an agent that has a protective and soothing action on the surfaces of the skin and membranes.

Emulsion a preparation formed by the suspension of very finely divided oily or resinous liquid in another liquid.

Encephalitis inflammation of the brain.

Encephalopathy a disorder or disease of the brain.

Endocrine *adj.* of or relating to endocrine glands or the hormones secreted by them.

Endocytosis is the process by which cells absorb material (molecules such as proteins) from outside the cell by engulfing it with their cell membrane.

Endometriosis is a common and often painful disorder of the female reproductive system. The two most common symptoms of endometriosis are pain and infertility.

Endometritis refers to inflammation of the endometrium, the inner lining of the uterus.

Endometrium the inner lining of the uterus.

Endoplasmic reticulum is a network of tubules, vesicles and sacs around the nucleus that are interconnected.

Endostatin a naturally-occurring 20-kDa C-terminal protein fragment derived from type XVIII collagen. It is reported to serve as an anti-angiogenic agent that inhibits the formation of the blood vessels that feed cancer tumours.

Endosteum the thin layer of cells lining the medullary cavity of a bone.

Endosteul pertaining to the endosteum.

Endothelial progenitor cells population of rare cells that circulate in the blood with the ability to differentiate into endothelial cells, the cells that make up the lining of blood vessels.

Endothelin any of a group of vasoconstrictive peptides produced by endothelial cells.

Endotoxemia the presence of endotoxins in the blood, which may result in shock. *adj*. endotoxemic.

Endotoxin toxins associated with certain bacteria, unlike an 'exotoxin' that is not secreted in soluble form by live bacteria, but is a structural component in the bacteria which is released mainly when bacteria are lysed.

Enema liquid injected into the rectum either as a purgative or medicine, Also called clyster.

Enteral term used to describe the intestines or other parts of the digestive tract.

Enteral administration involves the esophagus, stomach, and small and large intestines (i.e., the gastrointestinal tract).

Enteritis refers to inflammation of the small intestine.

Enterocolic disorder inflamed bowel disease.

Enterocytes tall columnar cells in the small intestinal mucosa that are responsible for the final digestion and absorption of nutrients.

Enterohemorrhagic causing bloody diarrhea and colitis, said of pathogenic microorganisms.

Enterolactone a lignin formed by the action of intestinal bacteria on lignan precursors found in plants; acts as a phytoestrogen.

Enteropooling increased fluids and electrolytes within the lumen of the intestines due to increased levels of prostaglandins.

Enterotoxin is a protein toxin released by a microorganism in the intestine.

Enterotoxigenic of or being an organism containing or producing an enterotoxin.

Entheogen a substance taken to induce a spiritual experience.

Enuresis bed-wetting, a disorder of elimination that involves the voluntary or involuntary release of urine into bedding, clothing, or other inappropriate places.

Enophthalmos a condition in which the eye falls back into the socket and inhibits proper eyelid function.

Envenomation is the entry of venom into a person's body, and it may cause localised or systemic poisoning.

Eosinophilia the state of having a high concentration of eosinophils (eosinophil granulocytes) in the blood.

Eosinophils (or, less commonly, acidophils), are white blood cells that are one of the immune system components.

Epididymis a structure within the scrotum attached to the backside of the testis and whose coiled duct provides storage, transit and maturation of spermatozoa.

Epididymitis a medical condition in which there is inflammation of the epididymis.

Epigastralgia pain in the epigastric region.

Epigastric discomfort bloated abdomen, swelling of abdomen, abdominal ditension.

Epilepsy a common chronic neurological disorder that is characterized by recurrent unprovoked seizures.

Episiotomy a surgical incision through the perineum made to enlarge the vagina and assist childbirth.

Epileptiform resembling epilepsy or its manifestations. *adj*. epileptiformic.

Epileptogenesis a process by which a normal brain develops epilepsy, a chronic condition in which seizures occur. *adj*. epileptogenic.

Episiotomy a surgical incision through the perineum made to enlarge the vagina and assist childbirth.

Epithelioma a usually benign skin disease most commonly occurring on the face, around the eyelids and on the scalp.

Ergocalciferol a form of vitamin D, also called vitamin D2. See vitamin D.

Epistaxis acute hemorrhage from the nostril, nasal cavity, or nasopharynx (nose-bleed).

Epstein Barr Virus herpes virus that is the causative agent of infectious mononucleosis. It is also associated with various types of human cancers.

ERbeta estrogen receptor beta, a nuclear receptor which is activated by the sex hormone, estrogen.

Ergonic increasing capacity for bodily or mental labor especially by eliminating fatigue symptoms.

ERK (extracellular signal regulated kinases) widely expressed protein kinase intracellular signaling molecules which are involved in functions including the regulation of meiosis, mitosis, and post mitotic functions in differentiated cells.

Eructation the act of belching or of casting up wind from the stomach through the mouth.

Eruption a visible rash or cutaneous disruption.

Erysipelas is an intensely red *Streptococcus* bacterial infection that occurs on the face and lower extremities.

Erythema abnormal redness and inflammation of the skin, due to vasodilation.

Erythematous characterized by erythema.

Erythroleukoplakia an abnormal patch of red and white tissue that forms on mucous membranes in the mouth and may become cancer. Tobacco (smoking and chewing) and alcohol may increase the risk of erythroleukoplakia.

Erythropoietin (EPO) a hormone produced by the kidney that promotes the formation of red blood cells (erythrocytes) in the bone marrow.

Eschar a slough or piece of dead tissue that is cast off from the surface of the skin.

Escharotic capable of producing an eschar; a caustic or corrosive agent.

Estradiol is the predominant sex hormone present in females, also called oestradiol.

Estrogen female hormone produced by the ovaries that play an important role in the estrous cycle in women.

Estrogen Receptor (ER) is a protein found in high concentrations in the cytoplasm of breast, uterus, hypothalamus, and anterior hypophysis cells; ER levels are measured to determine a breast CA's potential for response to hormonal manipulation.

Estrogen Receptor Positive (ER+) means that estrogen is causing the tumour to grow, and that the breast cancer should respond well to hormone suppression treatments.

Estrogen Receptor Negative (ER-) tumour is not driven by estrogen and need another test to determine the most effective treatment.

Estrogenic relating to estrogen or producing estrus.

Estrus sexual excitement or heat of female; or period of this characterized by changes in the sex organs.

Euglycaemia normal blood glucose concentration.

Exanthematous characterized by or of the nature of an eruption or rash.

Excitotoxicity is the pathological process by which neurons are damaged and killed by glutamate and similar substances.

Excipient a pharmacologically inert substance used as a diluent or vehicle for the active ingredients of a medication.

Exocytosis the cellular process by which cells excrete waste products or chemical transmitters.

Expectorant an agent that increases bronchial mucous secretion by promoting liquefaction of the sticky mucous and expelling it from the body.

Exophthalmos or exophthalmia or proptosis is a bulging of the eye anteriorly out of the orbit. *adj*. exophthalmic.

Extrapyramidal side effects are a group of symptoms (tremor, slurred speech, akathisia, dystonia, anxiety, paranoia and bradyphrenia) that can occur in persons taking antipsychotic medications.

Extravasation discharge or escape, as of blood from the vein into the surrounding tissues.

Familial amyloid polyneuropathy (FAP) also called Corino de Andrade's disease, a neurodegenerative autosomal dominant genetically transmitted, fatal, incurable disease.

Familial adenomatous polyposis (FAP) is an inherited condition in which numerous polyps form mainly in the epithelium of the large intestine.

Familial dysautonomia a genetic disorder that affects the development and survival of autonomic and sensory nerve cells.

FasL or CD95L Fas ligand is a type-II transmembrane protein that belongs to the tumour necrosis factor (TNF) family.

FAS: fatty acid synthase (FAS) a multi-enzyme that plays a key role in fatty acid synthesis.

Fauces the passage leading from the back of the mouth into the pharynx.

Favus a chronic skin infection, usually of the scalp, caused by the fungus, *Trichophyton schoenleinii* and characterized by the development of thick, yellow crusts over the hair follicles. Also termed tinea favosa.

Febrifuge an agent that reduces fever. Also called an antipyretic.

Febrile pertaining to or characterized by fever.

Fetotoxic toxic to the fetus.

Fibrates hypolipidemic agents primarily used for decreasing serum triglycerides, while increasing High density lipoprotein (HDL).

Fibril a small slender fiber or filament.

Fibrin insoluble protein that forms the essential portion of the blood clot.

Fibrinolysis a normal ongoing process that dissolves fibrin and results in the removal of small blood clots.

Fribinolytic causing the dissolution of fibrin by enzymatic action.

Fibroblast type of cell that synthesizes the extracellular matrix and collagen, the structural framework (stroma) for animal tissues, and play a critical role in wound healing.

Fibrogenic promoting the development of fibres.

Fibromyalgia a common and complex chronic pain disorder that affects people physically, mentally and socially. Symptoms include debilitating fatigue, sleep disturbance, and joint stiffness. Also referred to as FM or FMS.

Fibrosarcoma a malignant tumour derived from fibrous connective tissue and characterized by immature proliferating fibroblasts or undifferentiated anaplastic spindle cells.

Fibrosis the formation of fibrous tissue as a reparative or reactive process.

Filarial pertaining to a thread-like nematode worm.

Filariasis a parasitic and infectious tropical disease that is caused by thread-like filarial nematode worms in the superfamily Filarioidea.

Fistula an abnormal connection between two parts inside of the body.

Fistula-in-ano a track connecting the internal anal canal to the skin surrounding the anal orifice.

Flatulence is the presence of a mixture of gases known as flatus in the digestive tract of mammals expelled from the rectum. Excessive flatulence can be caused by lactose intolerance, certain foods or a sudden switch to a high fibre.

Flavans a subgroup of flavonoids. See flavonoids.

Flavanols a subgroup of flavonoids, are a class of flavonoids that use the 2-phenyl-3,4-dihydro-2H-chromen-3-ol skeleton. These compounds include the catechins and the catechin gallates. They are found in chocolate, fruits and vegetables. See flavonoids.

Flavanones a subgroup of flavonoids, constitute >90% of total flavonoids in citrus. The major dietary flavanones are hesperetin, naringenin and eriodictyol.

Flavivirus A family of viruses transmitted by mosquitoes and ticks that cause some important diseases, including dengue, yellow fever, tick-borne encephalitis and West Nile fever.

Flavones a subgroup of flavonoids based on the backbone of 2-phenylchromen-4-one (2-phenyl-1-benzopyran-4-one). Flavones are mainly found in cereals and herbs.

Flavonoids (or bioflavonoids) are a group of polyphenolic antioxidant compounds in that are occur in plant as secondary metabolites. They are responsible for the colour of fruit and vegetables. Twelve basic classes (chemical types) of flavonoids have been recognized flavones, isoflavones, flavans, flavanones, flavanols, flavanolols, anthocyanidins, catechins (including proanthocyanidins), leukoanthocyanidins, chalcones, dihydrochalcones, and aurones. Apart from their antioxidant activity, flavonoids are known for their ability to strengthen capillary walls, thus assisting circulation and helping to prevent and treat bruising, varicose veins, bleeding gums and nosebleeds, heavy menstrual bleeding and are also anti-inflammatory.

Flourine F is an essential chemical element that is required for maintenance of healthy bones and teeth and to reduce tooth decay. It is found in sea weeds, tea, water, seafood and dairy products.

Fluorosis a dental health condition caused by a child receiving too much fluoride during tooth development.

Flux an excessive discharge of fluid.

FMD (Flow Mediated Dilation) a measure of endothelial dysfunction which is used to evaluate cardiovascular risk.

Follicle stimulating hormone (FSH) a hormone produced by the pituitary gland.

In women, it helps control the menstrual cycle and the production of eggs by the ovaries.

Follicular atresia the break-down of the ovarian follicles.

Fomentation treatment by the application of war, moist substance.

Fontanelle soft spot on an infant's skull.

Framboesia see yaws.

FRAP ferric reducing ability of plasma, an assay used to assess antioxidant property.

Friedreich's ataxia is a genetic inherited disorder that causes progressive damage to the nervous system resulting in symptoms ranging from muscle weakness and speech problems to heart disease. *cf.* ataxia.

Fulminant hepatitis acute liver failure.

Functional food is any fresh or processed food claimed to have a health-promoting or disease-preventing property beyond the basic function of supplying nutrients. Also called medicinal food.

Furuncle is a skin disease caused by the infection of hair follicles usually caused by *Staphylococcus aureus,* resulting in the localized accumulation of pus and dead tissue.

Furunculosis skin condition characterized by persistent, recurring boils.

G2-M cell cycle the phase where the cell prepare for mitosis and where chromatids and daughter cells separate.

GABA gamma aminobutyric acid, required as an inhibitory neurotransmitter to block the transmission of an impulse from one cell to another in the central nervous system, which prevents over-firing of the nerve cells. It is used to treat both epilepsy and hypertension.

GADD 152 a pro-apoptotic gene.

Galctifuge or lactifuge, casuing the arrest of milk secretion.

Galactogogue a substance that promotes the flow of milk.

Galactophoritis inflammation of the milk ducts.

Galactopoietic increasing the flow of milk; milk-producing.

Gall bladder a small, pear-shaped muscular sac, located under the right lobe of the liver, in which bile secreted by the liver is stored until needed by the body for digestion. Also called cholecyst, cholecystis.

Gallic Acid Equivalent (GAE) measures the total phenol content in terms of the standard Gallic acid by the Folin-Ciocalteau assay.

Gamma GT (GGT) Gamma-glutamyl transpeptidase, a liver enzyme.

Gastralgia (heart burn) – pain in the stomach or abdominal region. It is caused by excess of acid, or an accumulation of gas, in the stomach.

Gastric pertaining to or affecting the stomach.

Gastric emptying refers to the speed at which food and drink leave the stomach.

Gastritis inflammation of the stomach.

Gastrocnemius muscle the big calf muscle at the rear of the lower leg.

Gastrotonic (Gastroprotective) substance that strengthens, tones, or regulates gastric functions (or protects from injury) without overt stimulation or depression.

Gavage forced feeding.

Gene silencing suppression of the expression of a gene.

Genotoxin a chemical or other agent that damages cellular DNA, resulting in mutations or cancer.

Genotoxic describes a poisonous substance which harms an organism by damaging its DNA thereby capable of causing mutations or cancer.

Geriatrics is a sub-specialty of internal medicine that focuses on health care of elderly people.

Ghrelin a gastrointestinal peptide hormone secreted by epithelial cells in the stomach lining, it stimulates appetite, gastric emptying, and increases cardiac output.

Gingival Index an index describing the clinical severity of gingival inflammation as well as its location.

Gingivitis refers to gingival inflammation induced by bacterial biofilms (also called plaque) adherent to tooth surfaces.

Gin-nan sitotoxism toxicity caused by ingestion of ginkgotoxin and characterised mainly by epileptic convulsions, paralysis of the legs and loss of consciousness.

Glaucoma a group of eye diseases in which the optic nerve at the back of the eye is slowly destroyed, leading to impaired vision and blindness.

Gleet a chronic inflammation (as gonorrhea) of a bodily orifice usually accompanied by an abnormal discharge.

Glial cells support, non-neuronal cells in the central nervous system that maintain homeostasis, form myelin and provide protection for the brain's neurons.

Glioma is a type of tumour that starts in the brain or spine. It is called a glioma because it arises from glial cells.

Glioblastoma multiforme most common and most aggressive type of primary brain tumour in humans, involving glial cells.

Glomerulonephritis (GN) a renal disease characterized by inflammation of the glomeruli, or small blood vessels in the kidneys. Also known as glomerular nephritis. *adj*. glomerulonephritic.

Glomerulosclerosis a hardening of the glomerulus in the kidney.

Glossal pertaining to the tongue**.**

GLP-1 glucagon-like peptide-1 is derived from the transcription product of the proglucagon gene, associate with type 2-diabetes therapy.

Gluconeogenesis a metabolic pathway that results in the generation of glucose from non-carbohydrate carbon substrates such as lactate. *adj*. gluconeogenic.

Glucose transporters (GLUT or SLC2A family) are a family of membrane proteins found in most mammalian cells.

Glucosyltranferase an enzyme that enable the transfer of glucose.

Glucuronidation a phase II detoxification pathway occurring in the liver in which glucuronic acid is conjugated with toxins.

Glutamic Oxaloacetate Transaminase (GOT) catalyzes the transfer of an amino group from an amino acid (Glu) to a 2-keto-acid to generate a new amino acid and the residual 2-keto-acid of the donor amino acid.

Glutamic pyruvate transaminase (GPT) see Alanine aminotransferase.

Glutathione (GSH) a tripeptide produced in the human liver and plays a key role in intermediary metabolism, immune response and health. It plays an important role in scavenging free radicals and protects cells against several toxic oxygen-derived chemical species.

Glutathione peroxidase (GPX) the general name of an enzyme family with peroxidase activity whose main biological role is to protect the organism from oxidative damage.

Glutathione S-transferase (GST) a major group of detoxification enzymes that participate in the detoxification of reactive electrophilic compounds by catalysing their conjugation to glutathione.

Glycation or glycosylation a chemical reaction in which glycosyl groups are added to a protein to produce a glycoprotein.

Glycogenolysis is the catabolism of glycogen by removal of a glucose monomer through cleavage with inorganic phosphate to produce glucose-1-phosphate.

Glycometabolism metabolism (oxidation) of glucose to produce energy.

Glycosuria or glucosuria is an abnormal condition of osmotic diuresis due to excretion of glucose by the kidneys into the urine.

Glycosylases a family of enzymes involved in base excision repair.

Goitre an enlargement of the thyroid gland leading to swelling of the neck or larynx.

Goitrogen substance that suppresses the function of the thyroid gland by interfering with iodine uptake, causing enlargement of the thyroid, i.e. goiter.

Goitrogenic *adj*. causing goiter.

Gonadotroph a basophilic cell of the anterior pituitary specialized to secrete follicle-stimulating hormone or luteinizing hormone.

Gonatropins protein hormones secreted by gonadotrope cells of the pituitary gland of vertebrates.

Gonorrhoea a common sexually transmitted bacterial infection caused by the bacterium *Neisseria gonorrhoeae*.

Gout a disorder caused by a build-up of a waste product, uric acid, in the bloodstream. Excess

uric acid settles in joints causing inflammation, pain and swelling.

G-protein-coupled receptors (GPCRs) comprise a large and diverse family of proteins whose primary function is to transduce extracellular stimuli into cells.

Granulation the condition or appearance of being granulated (becoming grain-like).

Gravel sand-like concretions of uric acid, calcium oxalate, and mineral salts formed in the passages of the biliary and urinary tracts.

Gripe water is a home remedy for babies with colic, gas, teething pain or other stomach ailments. Its ingredients vary, and may include alcohol, bicarbonate, ginger, dill, fennel and chamomile.

Grippe an epidemic catarrh; older term for influenza.

GSH see Glutathione.

GSH-Px Glutathione peroxidase, general name of an enzyme family with peroxidase activity whose main biological role is to protect the organism from oxidative damage.

GSSG glutathione disulfides are biologically important intracellular thiols, and alterations in the GSH/GSSG ratio are often used to assess exposure of cells to oxidative stress.

GSTM glutathione S transferase M1, a major group of detoxification enzymes.

GSTM 2 glutathione S transferase M2, a major group of detoxification enzymes.

Gynecopathy any or various diseases specific to women.

Gynoid adiposity fat distribution mainly to the hips and thighs, pear shaped.

Haemagogic promoting a flow of blood.

Haematemesis, Hematemesis is the vomiting of blood.

Haematinic improving the quality of the blood, its haemoglobin level and the number of erythrocytes.

Haematochezia passage of stools containing blood.

Haematochyluria, hematochyluria the discharge of blood and chyle (emulsified fat) in the urine, see also chyluria.

Haematoma, hematoma a localized accumulation of blood in a tissue or space composed of clotted blood.

Haematometra, hematometra a medical condition involving bleeding of or near the uterus.

Haematopoiesis, hematopoiesis formation of blood cellular components from the haematopoietic stem cells.

Haematopoietic *adj.* relating to the formation and development of blood cells.

Haematuria, Hematuria is the presence of blood in the urine. Hematuria is a sign that something is causing abnormal bleeding in a person's genitourinary tract.

Haeme oxygenase (HO-1, encoded by Hmox1) is an inducible protein activated in systemic inflammatory conditions by oxidant stress, an enzyme that catalyzes degradation of heme.

Haemochromatosis is a condition in which the body takes in too much iron.

Haemodialysis, Hemodialysis a method for removing waste products such as potassium and urea, as well as free water from the blood when the kidneys are in renal failure.

Haemolyis lysis of red blood cells and the release of haemoglobin into the surrounding fluid (plasma). *adj.* haemolytic.

Haemoptysis, hemoptysis is the coughing up of blood from the respiratory tract. The blood can come from the nose, mouth, throat, and the airway passages leading to the lungs.

Haemorrhage, hemaorrhage bleeding, discharge of blood from blood vessels.

Haemorrhoids, Hemorrhoids a painful condition in which the veins around the anus or lower rectum are enlarged, swollen and inflamed. Also called piles.

Haemostasis, hemostasis a complex process which causes the bleeding process to stop.

Haemostatic, hemostatic something that stops bleeding.

Halitosis (bad breath) a common condition caused by sulfur-producing bacteria that live within the surface of the tongue and in the throat.

Hallucinogen drug that produces hallucinogen.

Hallucinogenic inducing hallucinations.

Haplotype a set of alleles of closely linked loci on a chromosome that tend to be inherited together.

Hapten a small molecule that can elicit an immune response only when attached to a large carrier such as a protein.

HBeAg hepatitis B e antigen.

HBsAg hepatitis B s antigen.

Heartburn burning sensation in the stomach and esophagus caused by excessive acidity of the stomach fluids.

Heat rash any condition aggravated by heat or hot weather such as intertrigo.

Heat Shock Chaperones (HSC) ubiquitous molecules involved in the modulation of protein conformational and complexation states, associated with heat stress or other cellular stress response.

Heat Shock Proteins (HSP) a group of functionally related proteins the expression of which is increased when the cells are exposed to elevated temperatures or other cellular stresses.

Helminthiasis a disease in which a part of the body is infested with worms such as pinworm, roundworm or tapeworm.

Hemagglutinin refers to a substance that causes red blood cells to agglutinate.

Hemagglutination a specific form of agglutination that involves red blood cells.

Hemagglutination–inhibition test measures of the ability of soluble antigen to inhibit the agglutination of antigen-coated red blood cells by antibodies.

Hemangioma blood vessel.

Hematocrit is a blood test that measures the percentage of the volume of whole blood that is made up of red blood cells.

Hematopoietic pertaining to the formation of blood or blood cells.

Hematopoietic stem cell is a cell isolated from the blood or bone marrow that can renew itself, and can differentiate to a variety of specialized cells.

Heme oxygenase-1 (HO-1) an enzyme that catalyses the degradation of heme; an inducible stress protein, confers cytoprotection against oxidative stress in vitro and in vivo.

Hemoglobinopathies genetic defects that produce abnormal hemoglobins and anemia.

Hemolytic anemia anemia due to hemolysis, the breakdown of red blood cells in the blood vessels or elsewhere in the body.

Hemorheology study of blood flow and its elements in the circulatory system. *adj*. hemorheological.

Hemorrhagic colitis an acute gasteroenteritis characterized by overtly bloody diarrhea that is caused by *Escherichia coli* infection.

Hemolytic-uremic syndrome is a disease characterized by hemolytic anemia, acute renal failure (uremia) and a low platelet count.

Hepa-1c1c7 a type of hepatoma cells.

Hepatalgia pain or discomfort in the liver area.

Heptalgia pain in the liver and spleen.

Hepatectomy the surgical removal of part or all of the liver.

Hepatic relating to the liver.

Hepatic cirrhosis affecting the liver, characterize by hepatic fibrosis and regenerative nodules.

Hepatitis inflammation of the liver.

Hepatitis A (formerly known as infectious hepatitis) is an acute infectious disease of the liver caused by the hepatovirus hepatitis A virus.

Hepatocarcinogenesis represents a linear and progressive cancerous process in the liver in which successively more aberrant monoclonal populations of hepatocytes evolve.

Hepatocellular carcinoma (HCC) also called malignant hepatoma, is a primary malignancy (cancer) of the liver.

Hepatocytolysis cytotoxicity (dissolution) of liver cells.

Hepatoma cancer of the liver.

Hepatopathy a disease or disorder of the liver.

Hepatoprotective (liver protector) a substance that helps protect the liver from damage by toxins, chemicals or other disease processes.

Hepatoregenerative a compound that promotes hepatocellular regeneration, repairs and restores liver function to optimum performance.

Hepatotonic (liver tonic) a substance that is tonic to the liver - usually employed to normalize liver enzymes and function.

HER-2 human epidermal growth factor receptor 2, a protein giving higher aggressiveness in breast cancer, also known as ErbB-2, ERBB2.

Herpes a chronic inflammation of the skin or mucous membrane characterized by the development of vesicles on an inflammatory base.

Herpes simplex virus 1 and 2 – (HSV-1 and HSV-2) are two species of the herpes virus family which cause a variety of illnesses/infections in humans such cold sores, chickenpox or varicella, shingles or herpes zoster (VZV), cytomegalovirus (CMV), and various cancers, and can cause brain inflammation (encephalitis). HSV-1 is commonly associated with herpes outbreaks of the face known as cold sores or fever blisters, whereas HSV-2 is more often associated with genital herpes. They are also called Human Herpes Virus 1 and 2 (HHV-1 and HHV-2) and are neurotropic and neuroinvasive viruses; they enter and hide in the human nervous system, accounting for their durability in the human body.

Herpes zoster or simply zoster, commonly known as shingles and also known as zona, is a viral disease characterized by a painful skin rash with blisters.

Hernia occurs when part of an internal organ bulges through a weak area of muscle.

Heterophobia term used to describe irrational fear of, aversion to, or discrimination against heterosexuals.

HDL-C (HDL Cholesterol) high density lipoprotein-cholesterol, also called "good cholesterol". See also high-density lipoprotein.

Hiatus hernia occurs when the upper part of the stomach pushes its way through a tear in the diaphragm.

High-density lipoprotein (HDL) is one of the five major groups of lipoproteins which enable cholesterol and triglycerides to be transported within the water based blood stream. HDL can remove cholesterol from atheroma within arteries and transport it back to the liver for excretion or re-utilization—which is the main reason why HDL-bound cholesterol is sometimes called "good cholesterol", or HDL-C. A high level of HDL-C seems to protect against cardiovascular diseases. cf. LDL.

HGPRT, HPRT (hypoxanthine-guanine phosphoribosyl transferase) an enzyme that catalyzes the conversion of 5-phosphoribosyl-1-pyrophosphate and hypoxanthine, guanine, or 6-mercaptopurine to the corresponding 5'-mononucleotides and pyrophosphate. The enzyme is important in purine biosynthesis as well as central nervous system functions.

Hippocampus a ridge in the floor of each lateral ventricle of the brain that consists mainly of gray matter.

Hippocampal pertaining to the hippocampus.

Histaminergic liberated or activated by histamine, relating to the effects of histamine at histamine receptors of target tissues.

Histaminergic receptors are types of G-protein coupled receptors with histamine as their endogenous ligand.

HIV see Human immunodeficiency virus.

Hives (urticaria) is a skin rash characterised by circular wheals of reddened and itching skin.

HMG-CoAr 3-hydroxy-3-methyl-glutaryl-CoA reductase or (HMGCR) is the rate-controlling enzyme (EC 1.1.1.88) of the mevalonate pathway.

HMG-CoA 3-hydroxy-3-methylglutaryl-coenzyme A, an intermediate in the mevalonate pathway.

Hodgkin's disease disease characterized by enlargement of the lymph glands, spleen and anemia.

Homeodomain transcription factor a protein domain encoded by a homeobox. Homeobox genes encode transcription factors which typically switch on cascades of other genes.

Homeostasis the maintenance of a constant internal environment of a cell or an organism, despite fluctuations in the external.

Homeotherapy treatment or prevention of disease with a substance similar but not identical to the causative agent of the disease.

Homocysteine an amino acid in the blood.

Homograft see allograft.

Hormonal (female) substance that has a hormone-like effect similar to that of estrogen and/or a substance used to normalize female hormone levels.

Hormonal (male) substance that has a hormone-like effect similar to that of testosterone and/or a substance used to normalize male hormone levels.

HRT hormone replacement therapy, the administration of the female hormones,

oestrogen and progesterone, and sometimes testosterone.

HSP27 is an ATP-independent, 27 kDa heat shock protein chaperone that confers protection against apoptosis.

HSP90 a 90 kDa heat shock protein chaperone that has the ability to regulate a specific subset of cellular signaling proteins that have been implicated in disease processes.

HT29 cells are human intestinal epithelial cells which produce the secretory component of Immunoglobulin A (IgA), and carcinoembryonic antigen (CEA).

Human cytomegalovirus (HCMV) a DNA herpes virus which is the leading cause of congenital viral infection and mental retardation.

Human factor X a coagulation factor also known by the eponym Stuart-Prower factor or as thrombokinase, is an enzyme involved in blood coagulation. It synthesized in the liver and requires vitamin K for its synthesis.

Human immunodeficiency virus (HIV) a retrovirus that can lead to acquired immunodeficiency syndrome (AIDS), a condition in humans in which the immune system begins to fail, leading to life-threatening opportunistic infections.

Humoral Immune Response (HIR) is the aspect of immunity that is mediated by secreted antibodies (as opposed to cell-mediated immunity, which involves T lymphocytes) produced in the cells of the B lymphocyte lineage (B cell).

HUVEC human umbilical vein endothelial cells.

hTERT – (TERT) telomerase reverse transcriptase is a catalytic subunit of the enzyme telomerase in humans. It exerts a novel protective function by binding to mitochondrial DNA, increasing respiratory chain activity and protecting against oxidative stress–induced damage.

Hyaluronidase enzymes that catalyse the hydrolysis of certain complex carbohydrates like hyaluronic acid and chondroitin sulfates.

Hydatidiform a rare mass or growth that forms inside the uterus at the beginning of a pregnancy.

Hydrocholeretic an agent that stimulates an increased output of bile of low specific gravity.

Hydrogogue a purgative that causes an abundant watery discharge from the bowel.

Hydronephrosis is distension and dilation of the renal pelvis and calyces, usually caused by obstruction of the free flow of urine from the kidney.

Hydrophobia a viral neuroinvasive disease that causes acute encephalitis (inflammation of the brain) in warm-blooded animals. Also called rabies.

Hydropsy see dropsy.

Hyperaemia the increase of blood flow to different tissues in the body.

Hyperammonemia, hyperammonaemia a metabolic disturbance characterised by an excess of ammonia in the blood.

Hyperalgesia an increased sensitivity to pain (enhanced pricking pain), which may be caused by damage to nociceptors or peripheral nerves.

Hypercholesterolemia high levels of cholesterol in the blood that increase a person's risk for cardiovascular disease leading to stroke or heart attack.

Hyperemia is the increased blood flow that occurs when tissue is active.

Hyperemesis severe and persistent nausea and vomiting (morning sickness) during pregnancy.

Hyperglycemic, hyperglycaemia high blood sugar; is a condition in which an excessive amount of glucose circulates in the blood plasma.

Hyperglycemic a substance that raises blood sugar levels.

Hyperhomocysteinemia is a medical condition characterized by an abnormally large level of homocysteine in the blood.

Hyperinsulinemia a condition in which there are excess levels of circulating insulin in the blood; also known as pre-diabetes.

Hyperkalemia is an elevated blood level of the electrolyte potassium.

Hyperknesis enhanced itch to pricking.

Hyperleptinemia increased serum leptin level.

Hypermethylation an increase in the inherited methylation of cytosine and adenosine residues in DNA.

Hyperpiesia persistent and pathological high blood pressure for which no specific cause can be found.

Hyperplasia increased cell production in a normal tissue or organ.

Hyperprolactinaemia the presence of abnormally high levels of prolactin in the blood.

Hyperpropulsion using water pressure as a force to move objects; used to dislodge calculi in the urethra.

Hyperpyrexia is an abnormally high fever.

Hypertension commonly referred to as "high blood pressure" or HTN, is a medical condition in which the arterial blood pressure is chronically elevated.

Hypertensive characterized or caused by increased tension or pressure as abnormally high blood pressure.

Hypertriglyceridaemia or hypertriglycemia a disorder that causes high triglycerides in the blood.

Hypertrophy enlargement or overgrowth of an organ.

Hyperuricemia is a condition characterized by abnormally high level of uric acid in the blood.

Hypoadiponectinemia low plasma adiponectin concentrations associated with obesity and type 2 diabetes; that is closely related to the degree of insulin resistance and hyperinsulinemia than to the degree of adiposity and glucose tolerance.

Hypoalbuminemia a medical condition where levels of albumin in blood serum are abnormally low.

Hypocalcemic tetany a disease caused by an abnormally low level of calcium in the blood and characterized by hyperexcitability of the neuromuscular system and results in carpopedal spasms.

Hypochlorhydria refer to states where the production of gastric acid in the stomach is absent or low.

Hypocholesterolemic (cholesterol-reducer), a substance that lowers blood cholesterol levels.

Hypocorticism see Addison's disease.

Hypocortisolism see Addison's disease.

Hypoglycemic an agent that lowers the concentration of glucose (sugar) in the blood.

Hypoperfusion decreased blood flow through an organ, characterized by an imbalance of oxygen demand and oxygen delivery to tissues.

Hypophagic under-eating.

Hypotensive characterised by or causing diminished tension or pressure, as abnormally low blood pressure.

Hypothermia a condition in which an organism's temperature drops below that required for normal metabolism and body functions.

Hypothermic relating to hypothermia, with subnormal body temperature.

Hypoxaemia is the reduction of oxygen specifically in the blood.

Hypoxia a shortage of oxygen in the body. *adj.* hypoxic.

ICAM-1 (Inter-Cellular Adhesion Molecule 1) also known as CD54 (Cluster of Differentiation 54), is a protein that in humans is encoded by the ICAM1 gene.

IC 50 the median maximal inhibitory concentration; a measure of the effectiveness of a compound in inhibiting biological or biochemical function.

I.C.V. (intra-cerebroventricular) injection of chemical into the right lateral ventricle of the brain.

Ichthyotoxic a substance which is poisonous to fish.

Iceterus jaundice, yellowish pigmentation of the skin.

Icteric hepatitis an infectious syndrome of hepatitis characterized by jaundice, nausea, fever, right-upper quadrant pain, enlarged liver and transaminitis (increase in alanine aminotransferase (ALT) and/or aspartate aminotransferase (AST)).

Icterus neonatorum jaundice in newborn infants.

Idiopathic of no apparent physical cause.

Idiopathic sudden sensorineural hearing loss (ISSHL) is sudden hearing loss where clinical assessment fails to reveal a cause.

IgE Immunoglobin E – a class of antibody that plays a role in allergy.

IGFs insulin-like growth factors, polypeptides with high sequence similarity to insulin.

IgG Immunoglobin G – the most abundant immunoglobin (antibody) and is one of the major activators of the complement pathway.

IgM Immunoglobin M – primary antibody against A and B antigens on red blood cells.

IKAP is a scaffold protein of the IvarKappaBeta kinase complex and a regulator for kinases involved in pro-inflammatory cytokine signaling.

IKappa B or IkB-beta, a protein of the NF-Kappa-B inhibitor family.

Ileus a temporary disruption of intestinal peristalsis due to non-mechanical causes.

Immune modulator a substance that affects or modulates the functioning of the immune system.

Immunodeficiency a state in which the immune system's ability to fight infectious disease is compromised or entirely absent.

Immunogenicity the property enabling a substance to provoke an immune response.

Immunomodulatory capable of modifying or regulating one or more immune functions.

Immunoreactive reacting to particular antigens or haptens.

Immunostimulant agent that stimulates an immune response.

Immunosuppression involves a process that reduces the activation or efficacy of the immune system.

Immunotoxin a man-made protein that consists of a targeting portion linked to a toxin.

Impetigo a contagious, bacterial skin infection characterized by blisters that may itch, caused by a *Streptoccocus* bacterium or *Staphylococcus aureus* and mostly seen in children.

Impotence a sexual dysfunction characterized by the inability to develop or maintain an erection of the penis.

Incontinence (fecal) the inability to control bowel's movement.

Incontinence (Urine) the inability to control urine excretion.

Index of structural atypia (ISA) index of structural abnormality.

Induration hardened, as a soft tissue that becomes extremely firm.

Infarct an area of living tissue that undergoes necrosis as a result of obstruction of local blood supply.

Infarction is the process of tissue death (necrosis) caused by blockage of the tissue's blood supply.

Inflammation a protective response of the body to infection, irritation or other injury, aimed at destroying or isolating the injuries and characterized by redness, pain, warmth and swelling.

Influenza a viral infection that affects mainly the nose, throat, bronchi and occasionally, lungs.

Infusion a liquid extract obtained by steeping something (e.g. herbs) that are more volatile or dissolve readily in water, to release their active ingredients without boiling.

Inguinal hernia a hernia into the inguinal canal of the groin.

Inhalant a medicinal substance that is administered as a vapor into the upper respiratory passages.

iNOS, Inducible Nitric oxide Synthases through its product, nitric oxide (NO), may contribute to the induction of germ cell apoptosis. It plays a crucial role in early sepsis-related microcirculatory dysfunction.

Inotropic affecting the force of muscle contraction.

Insecticide an agent that destroys insects. *adj*. insecticidal.

Insomnia a sleeping disorder characterized by the inability to fall asleep and/or the inability to remain asleep for a reasonable amount of time.

Insulin a peptide hormone composed of 51 amino acids produced in the islets of Langerhans in the pancreas causes cells in the liver, muscle, and fat tissue to take up glucose from the blood, storing it as glycogen in the liver and muscle. Insulin deficiency is often the cause of diabetes and exogenous insulin is used to control diabetes.

Insulin-like growth factors (IGFs) polypeptides with high sequence similarity to insulin. They are part of a complex system that cells employ to communicate with their physiologic environment.

Insulin-mimetic to act like insulin.

Insulinotropic changing the action of insulin.

Integrase an enzyme produced by a retrovirus (such as HIV) that enables its genetic material to be integrated into the DNA of the infected cell.

Interferons (IFNs) are natural cell-signaling glycoproteins known as cytokines produced by the cells of the immune system of most vertebrates in response to challenges such as viruses, parasites and tumour cells.

Interleukins a group of naturally occurring proteins and is a subset of a larger group of cellular messenger molecules called cytokines, which are modulators of cellular behavior.

Interleukin-1 (IL-1) a cytokine that could induce fever, control lymphocytes, increase the number of bone marrow cells and cause degeneration of bone joints. Also called endogenous pyrogen, lymphocyte activating factor, haemopoetin-1 and mononuclear cell factor, amongst others that IL-1 is composed of two distinct proteins, now called IL-1α and IL-1β.

Interleukin 1 Beta (IL 1B) a cytokine protein produced by activated macrophages. cytokine is an important mediator of the inflammatory response, and is involved in a variety of cellular activities, including cell proliferation, differentiation, and apoptosis.

Interleukin 2 (IL-2) a type of cytokine immune system signaling molecule that is instrumental in the body's natural response to microbial infection.

Interleukin-2 receptor (IL-2R) a heterotrimeric protein expressed on the surface of certain immune cells, such as lymphocytes, that binds and responds to a cytokine called IL-2.

Interleukin-6 (IL-6) an interleukin that acts as both a pro-inflammatory and anti-inflammatory cytokine.

Interleukin 8 (IL 8) a cytokine produced by macrophages and other cell types such as epithelial cells and is one of the major mediators of the inflammatory response.

Intermediate-density lipoproteins (IDL) is one of the five major groups of lipoproteins (chylomicrons, VLDL, IDL, LDL, and HDL) that enable fats and cholesterol to move within the water-based solution of the bloodstream. IDL is further degraded to form LDL particles and, like LDL, can also promote the growth of atheroma and increase cardiovascular diseases.

Intermittent claudication an aching, crampy, tired, and sometimes burning pain in the legs that comes and goes, caused by peripheral vascular disease. It usually occurs with walking and disappears after rest.

Interstitium the space between cells in a tissue.

Interstitial pertaining to the interstitium.

Intertrigo an inflammation (rash) caused by microbial infection in skin folds.

Intima innermost layer of an artery or vein.

Intoxicant substance that produce drunkenness or intoxication.

Intraperitoneal (i.p.) the term used when a chemical is contained within or administered through the peritoneum (the thin, transparent membrane that lines the walls of the abdomen).

Intrathecal (i.t.) through the theca of the spinal cord into the subarachnoid space.

Intromission the act of putting one thing into another.

Intubation refers to the placement of a tube into an external or internal orifice of the body.

Iodine (I) is an essential chemical element that is important for hormone development in the human body. Lack of iodine can lead to an enlarged thyroid gland (goitre) or other iodine deficiency disorders including mental retardation and stunted growth in babies and children. Iodine is found in dairy products, seafood, kelp, seaweeds, eggs, some vegetables and iodized salt.

IP see Intraperitoneal.

Iron (Fe) is essential to most life forms and to normal human physiology. In humans, iron is an essential component of proteins involved in oxygen transport and for haemoglobin. It is also essential for the regulation of cell growth and differentiation. A deficiency of iron limits oxygen delivery to cells, resulting in fatigue, poor work performance, and decreased immunity. Conversely, excess amounts of iron can result in toxicity and even death. Dietary sources include, certain cereals, dark green leafy vegetables, dried fruit, legumes, seafood, poultry and meat.

Ischemia an insufficient supply of blood to an organ, usually due to a blocked artery.

Ischuria retention or suppression of urine.

Isoflavones a subgroup of flavonoids in which the basic structure is a 3-phenyl chromane skeleton. They act as phytoestrogens in mammals. See flavonoids.

Isomers substances that are composed of the same elements in the same proportions and hence have the same molecular formula but differ in properties because of differences in the arrangement of atoms.

Isoprostanes unique prostaglandin-like compounds generated in vivo from the free radical-catalysed peroxidation of essential fatty acids.

Jamu traditional Indonesian herbal medicine.

Jaundice refers to the yellow color of the skin and whites of the eyes caused by excess bilirubin in the blood.

JNK (Jun N-terminal Kinase), also known as Stress Activated Protein Kinase (SAPK), belongs to the family of MAP kinases.

Jurkat cells a line of T lymphocyte cells that are used to study acute T cell leukemia.

KB cell a cell line derived from a human carcinoma of the nasopharynx, used as an assay for antineoplastic (anti-tumour) agents.

Kallikreins peptidases (enzymes that cleave peptide bonds in proteins), a subgroup of the serine protease family; they liberate kinins from kininogens. Kallikreins are targets of active investigation by drug researchers as possible biomarkers for cancer.

Kaposi sarcoma a cancerous tumour of the connective tissues caused by the huma herpesvirus 8 and is often associated with AIDS.

Kaposi sarcoma herpes virus (KSHV) also known as human herpesvirus-8, is a gamma 2 herpesvirus or rhadinovirus. It plays an important role in the pathogenesis of Kaposi sarcoma (KS), multicentric Castleman disease (MCD) of the plasma cell type, and primary effusion lymphoma and occurs in HIV patients.

Keratin a sulphur-containing protein which is a major component in skin, hair, nails, hooves, horns, and teeth.

Keratinocyte is the major constituent of the epidermis, constituting 95% of the cells found there.

Keratinophilic having an affinity for keratin.

Keratitis inflammation of the cornea.

Keratomalacia an eye disorder that leads to a dry cornea.

Kidney stones (calculi) are hardened mineral deposits that form in the kidney.

Kinin is any of various structurally related polypeptides, such as bradykinin, that act locally to induce vasodilation and contraction of smooth muscle.

Kininogen either of two plasma α2-globulins that are kinin precursors.

Knockout gene knockout is a genetic technique in which an organism is engineered to carry genes that have been made inoperative.

Kunitz protease inhibitors a type of protein contained in legume seeds which functions as a protease inhibitor.

Kupffer cells are resident macrophages of the liver and play an important role in its normal physiology and homeostasis as well as participating in the acute and chronic responses of the liver to toxic compounds.

L-Dopa (L-3,4-dihydroxyphenylalanine) is an amino acid that is formed in the liver and converted into dopamine in the brain.

Labour process of childbirth involving muscular contractions.

Lacrimation secretion and discharge of tears.

Lactation secretion and production of milk.

Lactagogue an agent that increases or stimulates milk flow or production. Also called a galactagogue.

Lactate dehydrogenase (LDH) enzyme that catalyzes the conversion of lactate to pyruvate.

LAK cell a lymphokine-activated killer cell i.e. a white blood cell that has been stimulated to kill tumour cells.

Larvacidal an agent which kills insect or parasite larva.

Laryngitis is an inflammation of the larynx.

Lactic acidosis is a condition caused by the buildup of lactic acid in the body. It leads to acidification of the blood (acidosis), and is considered a distinct form of metabolic acidosis.

Laminin a glycoprotein component of connective tissue basement membrane that promotes cell adhesion.

Laparotomy a surgical procedure involving an incision through the abdominal wall to gain access into the abdominal cavity. *adj.* laparotomized.

Laxation bowel movement.

Laxatives substances that are used to promote bowel movement.

LC 50 median lethal concentration, see LD 50.

LD 50 median lethal dose – the dose required to kill half the members of a tested population. Also called LC 50 (median lethal concentration).

LDL see low-density lipoprotein.

LDL Cholesterol see low-density lipoprotein.

LDL receptor (LDLr) a low-density lipoprotein receptor gene.

Lectins are sugar-binding proteins that are highly specific for their sugar moieties, that agglutinate cells and/or precipitate glycoconjugates. They play a role in biological recognition phenomena involving cells and proteins.

Leishmaniasis a disease caused by protozoan parasites that belong to the genus *Leishmania* and is transmitted by the bite of certain species of sand fly.

Lenticular opacity also known as or related to cataract.

Leprosy a chronic bacterial disease of the skin and nerves in the hands and feet and, in some cases, the lining of the nose. It is caused by the *Mycobacterium leprae.* Also called Hansen's disease.

Leptin is a 16 kDa protein hormone with important effects in regulating body weight, metabolism and reproductive function.

Lequesne Algofunctional Index is a widespread international instrument (10 questions survey) and recommended by the World Health Organization (WHO) for outcome measurement in hip and knee diseases such as osteoarthritis.

Leucocyte white blood corpuscles, colourless, without haemoglobin that help to combat infection.

Leucoderma a skin abnormality characterized by white spots, bands and patches on the skin; they can also be caused by fungus and tinea. Also see vitiligo.

Leucorrhoea commonly known as whites, refers to a whitish discharge from the female genitals

Leukemia, leukaemia a cancer of the blood or bone marrow and is characterized by an abnormal proliferation (production by multiplication) of blood cells, usually white blood cells (leukocytes).

Leukocytopenia abnormal decrease in the number of leukocytes (white blood cells) in the blood.

Leukomyelopathy any diseases involving the white matter of the spinal cord.

Leukopenia a decrease in the number of circulating white blood cells.

Leukoplakia condition characterized by white spots or patches on mucous membranes, especially of the mouth and vulva.

Leukotriene a group of hormones that cause the inflammatory symptoms of hay-fever and asthma.

Levarterenol see Norepinephrine.

LexA repressor or Repressor LexA is repressor enzyme that represses SOS response genes coding for DNA polymerases required for repairing DNA damage

Libido sexual urge.

Lichen planus a chronic mucocutaneous disease that affects the skin, tongue, and oral mucosa.

Ligroin a volatile,, inflammable fraction of petroleum, obtained by distillation and used as a solvent.

Liniment liquid preparation rubbed on skin, used to relieve muscular aches and pains.

Lipodiatic having lipid and lipoprotein lowering property.

Lipodystrophy a medical condition characterized by abnormal or degenerative conditions of the body's adipose tissue.

Lipogenesis is the process by which acetyl-CoA is converted to fats.

Lipolysis is the breakdown of fat stored in fat cells in the body.

Liposomes artificially prepared vesicles made of lipid bilayer.

Lipotoxicity refers to tissues diseases that may occur when fatty acids spillover in excess of the oxidative needs of those tissues and

enhances metabolic flux into harmful pathways of nonoxidative metabolism.

Lipotropic refers to compounds that help catalyse the breakdown of fat during metabolism in the body. e.g. chlorine and lecithin.

Lipoxygenase a family of iron-containing enzymes that catalyse the dioxygenation of polyunsaturated fatty acids in lipids containing a cis,cis-1,4-pentadiene structure.

Lithiasis formation of urinary calculi (stones).

Lithogenic promoting the formation of calculi (stones).

Lithontripic removes stones from kidney, gall bladder.

Liver X receptors nuclear hormones that function as central transcriptional regulators for lipid homeostasis.

Lotion a liquids suspension or dispersion of chemicals for external application to the body.

Lovo cells colon cancer cells.

Low-density lipoprotein (LDL) is a type of lipoprotein that transports cholesterol and triglycerides from the liver to peripheral tissues. High levels of LDL cholesterol can signal medical problems like cardiovascular disease, and it is sometimes called "bad cholesterol".

LRP1 low-density lipoprotein receptor-related protein-1, plays a role in intracellular signaling functions as well as in lipid metabolism .

LTB4 a type of leukotriene, a major metabolite in neutrophil polymorphonuclear leukocytes. It stimulates polymorphonuclear cell function (degranulation, formation of oxygen-centered free radicals, arachidonic acid release, and metabolism). It induces skin inflammation.

Luciferase is a generic name for enzymes commonly used in nature for bioluminescence.

Lumbago is the term used to describe general lower back pain.

Lung abscess necrosis of the pulmonary tissue and formation of cavities containing necrotic debris or fluid caused by microbial infections.

Lusitropic an agent that affects diastolic relaxation.

Lutein a carotenoid, occurs naturally as yellow or orange pigment in some fruits and leafy vegetables. It is one of the two carotenoids contained within the retina of the eye. Within the central macula, zeaxanthin predominates, whereas in the peripheral retina, lutein predominates. Lutein is necessary for good vision and may also help prevent or slow down atherosclerosis, the thickening of arteries, which is a major risk for cardiovascular disease.

Luteinising hormone (LH) a hormone produced by the anterior pituitary gland. In females, it triggers ovulation. In males, it stimulates the production of testosterone to aid sperm maturation.

Luteolysis is the structural and functional degradation of the corpus luteum (CL) that occurs at the end of the luteal phase of both the estrous and menstrual cycles in the absence of pregnancy.

Lymphadenitis-cervical inflammation of the lymph nodes in the neck, usually caused by an infection.

Lymphatitis inflammation of lymph vessels and nodes.

Lymphadenopathy a term meaning disease of the lymph nodes – lymph node enlargement.

Lymphoblastic pertaining to the production of lymphocytes.

Lymphocyte a small white blood cell (leucocyte) that plays a large role in defending the body against disease. Lymphocytes are responsible for immune responses. There are two main types of lymphocytes: B cells and T cells. Lymphocytes secrete products (lymphokines) that modulate the functional activities of many other types of cells and are often present at sites of chronic inflammation.

Lymphocyte B cells the B cells make antibodies that attack bacteria and toxins.

Lymphocyte T cells T cells attack body cells themselves when they have been taken over by viruses or have become cancerous.

Lymphoma a type of cancer involving cells of the immune system, called lymphocytes.

Lymphopenia abnormally low number of lymphocytes in the blood.

Lysosomes are small, spherical organelles containing digestive enzymes (acid hydrolases) and other proteases (cathepsins).

Maceration softening or separating of parts by soaking in a liquid.

Macrophage a type of large leukocyte that travels in the blood but can leave the bloodstream and enter tissue; like other leukocytes it protects the body by digesting debris and foreign cells.

Macular degeneration a disease that gradually destroys the macula, the central portion of the retina, reducing central vision.

Macules small circumscribed changes in the color of skin that are neither raised (elevated) nor depressed.

Maculopapular describes a rash characterized by raised, spotted lesions.

Magnesium (M g) is the fourth most abundant mineral in the body and is essential to good health. It is important for normal muscle and nerve function, steady heart rhythm, immune system, and strong bones. Magnesium also helps regulate blood sugar levels, promotes normal blood pressure, and is known to be involved in energy metabolism and protein synthesis and plays a role in preventing and managing disorders such as hypertension, cardiovascular disease, and diabetes. Dietary sources include legumes (e.g. soya bean and by-products), nuts, whole unrefined grains, fruit (e.g. banana, apricots), okra and green leafy vegetables.

MAK cell macrophage-activated killer cell, activated nacrophage that is much more phagocytic than monocytes.

Malaise a feeling of weakness, lethargy or discomfort as of impending illness.

Malaria is an infection of the blood by *Plasmodium* parasite that is carried from person to person by mosquitoes. There are four species of malaria parasites that infect man: *Plasmodium falciparum*, so called 'malignant tertian fever', is the most serious disease, *Plasmodium vivax*, causing a relapsing form of the disease, *Plasmodium malariae*, and *Plasmodium ovale*.

Malassezia a fungal genus (previously known as *Pityrosporum*) classified as yeasts, naturally found on the skin surfaces of many animals including humans. It can cause hypopigmentation on the chest or back if it becomes an opportunistic infection.

Mammalian target of rapamycin (mTOR) pathway that regulates mitochondrial oxygen consumption and oxidative capacity.

Mammogram an x-ray of the breast to detect tumours.

Mandibular relating to the mandible, the human jaw bone.

Manganese is an essential element for heath. It is an important constituent of some enzymes and an activator of other enzymes in physiologic processes. Manganese superoxide dismutase (MnSOD) is the principal antioxidant enzyme in the mitochondria. Manganese-activated enzymes play important roles in the metabolism of carbohydrates, amino acids, and cholesterol. Manganese is the preferred cofactor of enzymes called glycosyltransferases which are required for the synthesis of proteoglycans that are needed for the formation of healthy cartilage and bone. Dietary source include whole grains, fruit, legumes (soybean and by-products), green leafy vegetables, beetroot and tea.

MAO activity monoamine oxidase activity.

MAPK (Mitogen-activated protein kinase) these kinases are strongly activated in cells subjected to osmotic stress, UV radiation, disregulated K^+ currents, RNA-damaging agents, and a multitude of other stresses, as well as inflammatory cytokines, endotoxin, and withdrawal of a trophic factor. The stress-responsive MAPKs mediate a plethora of cellular responses to such stressful stimuli, including apoptosis and production of inflammatory and immunoregulatory cytokines in diverse cell systems.

Marasmus is one of the three forms of serious protein-energy malnutrition.

Mastectomy surgery to remove a breast.

Masticatory a substance chewed to increase salivation. Also called Sialogue.

Mastitis a bacterial infection of the breast which usually occurs in breastfeeding mothers.

Matrix metalloproteinases (MMP) a member of a group of enzymes that can break down proteins, such as collagen, that are normally found in the spaces between cells in tissues

(i.e., extracellular matrix proteins). Matrix metalloproteinases are involved in wound healing, angiogenesis, and tumour cell metastasis. See also metalloproteinase.

MBC minimum bacterial concentration – the lowest concentration of antibiotic required to kill an organism.

MDA Malondialdehyde is one of the most frequently used indicators of lipid peroxidation.

Measles an acute, highly communicable rash illness due to a virus transmitted by direct contact with infectious droplets or, less commonly, by airborne spread.

Medial Preoptic Area is located at the rostral end of the hypothalamus, it is important for the regulation of male sexual behavior.

Megaloblastic anemia an anemia that results from inhibition of DNA synthesis in red blood cell production, often due to a deficiency of vitamin B12 or folate and is characterized by many large immature and dysfunctional red blood cells (megaloblasts) in the bone marrow.

Melaene (melena) refers to the black, "tarry" feces that are associated with gastrointestinal hemorrhage.

Melanogenesis production of melanin by living cells.

Melanoma malignant tumour of melanocytes which are found predominantly in skin but also in the bowel and the eye and appear as pigmented lesions.

Melatonin a hormone produced in the brain by the pineal gland, it is important in the regulation of the circadian rhythms of several biological functions.

Menarche the first menstrual cycle, or first menstrual bleeding, in female human beings.

Menorrhagia heavy or prolonged menstruation, too-frequent menstrual periods.

Menopausal refer to permanent cessation of menstruation.

Menses see menstruation.

Menstruation the approximately monthly discharge of blood from the womb in women of childbearing age who are not pregnant. Also called menses. *adj.* menstrual.

Mesangial cells are specialized cells around blood vessels in the kidneys, at the mesangium.

Metabonome complete set of metabolically regulated elements in cells.

Metalloproteinase enzymes that breakdown proteins and requiring zinc or calcium atoms for proper function.

Meta-analysis a statistical procedure that combines the results of several studies that address a set of related research hypotheses.

Metaphysis is the portion of a long bone between the epiphyses and the diaphysis of the femur.

Metaphyseal pertaining to the metaphysis.

Metaplasia transformation of one type of one mature differentiated cell type into another mature differentiated cell type.

Metastasis is the movement or spreading of cancer cells from one organ or tissue to another.

Metetrus the quiescent period of sexual inactivity between oestrus cycles.

Metroptosis the slipping or falling out of place of an organ (as the uterus)

Metrorrhagia uterine bleeding at irregular intervals, particularly between the expected menstrual periods.

Mevinolin a potent inhibitor of 3-hydroxy-3-methylglutaryl coenzyme A reductase (HMG-CoA reductase).

MHC acronym for major histocompatibility complex, a large cluster of genes found on the short arm of chromosome 6 in most vertebrates that encodes MHC molecules. MHC molecules play an important role in the immune system and autoimmunity.

MIC minimum inhibitory concentration – lowest concentration of an antimicrobial that will inhibit the visible growth of a microorganism.

Micelle a submicroscopic aggregation of molecules.

Micellization formation process of micelles.

Microangiopathy (or microvascular disease) is an angiopathy affecting small blood vessels in the body

Microfilaria a pre-larval parasitic worm of the family Onchocercidae, found in the vector and in the blood or tissue fluid of human host.

Micronuclei small particles consisting of acentric fragments of chromosomes or entire chromosomes, which lag behind at anaphase of cell division.

Microsomal PGE2 synthase is the enzyme that catalyses the final step in prostaglandin E2 (PGE2) biosynthesis.

Microvasculature the finer vessels of the body, as the arterioles, capillaries, and venules.

Micturition urination, act of urinating.

Migraine a neurological syndrome characterized by altered bodily perceptions, severe, painful headaches, and nausea.

Mimosine is an alkaloid, β-3-hydroxy-4 pyridone amino acid, it is a toxic non-protein free amino acid and is an antinutrient.

Mineral apposition rate MAR, rate of addition of new layers of mineral on the trabecular surfaces of bones.

Miscarriage spontaneous abortion.

Mitochondrial Complex I the largest enzyme in the mitochondrial respiratory oxidative phosphorylation system.

Mitochondrial permeability transition (MPT) is an increase in the permeability of the mitochondrial membranes to molecules of less than 1,500 Da in molecular weight. MPT is one of the major causes of cell death in a variety of conditions.

Mitogen an agent that triggers mitosis, elicit all the signals necessary to induce cell proliferation.

Mitogenic able to induce mitosis or transformation.

Mitomycin a chemotherapy drug that is given as a treatment for several different types of cancer, including breast, stomach, oesophagus and bladder cancers.

Mitosis cell division in which the nucleus divides into nuclei containing the same number of chromosomes.

Mitogenicity process of induction of mitosis.

MMP matrix metalloproteinases, a group of peptidases involved in degradation of the extracellular matrix (ECM).

Mnestic pertaining to memory.

Molecular docking is a key tool in structural molecular biology and computer-assisted drug design.

Molluscidal destroying molluscs like snails.

Molt 4 cells MOLT4 cells are lymphoblast-like in morphology and are used for studies of apoptosis, tumour cytotoxicity, tumourigenicity, as well as for antitumour testing.

Molybdenum (Mo) is an essential element that forms part of several enzymes such as xanthine oxidase involved in the oxidation of xanthine to uric acid and use of iron. Molybdenum concentrations also affect protein synthesis, metabolism, and growth. Dietary sources include meat, green beans, eggs, sunflower seeds, wheat flour, lentils, and cereal grain.

Monoamine oxidase A (MAOA) is an isozyme of monoamine oxidase. It preferentially deaminates norepinephrine (noradrenaline), epinephrine (adrenaline), serotonin, and dopamine.

Monoaminergic of or pertaining to neurons that secrete monoamine neurotransmitters (e.g., dopamine, serotonin).

Monoclonal antibodies are produced by fusing single antibody-forming cells to tumour cells grown in culture.

Monocyte large white blood cell that ingest microbes, other cells and foreign matter.

Monogalactosyl diglyceride are the major lipid components of chloroplasts.

Monorrhagia is heavy bleeding and that's usually defined as periods lasting longer than 7 days or excessive bleeding.

Morbidity a diseased state or symptom or can refer either to the incidence rate or to the prevalence rate of a disease.

Morelloflavone a biflavonoid extracted from *Garcinia dulcis*, has shown antioxidative, antiviral, and anti-inflammatory properties.

Morphine the major alkaloid of opium and a potent narcotic analgesic.

MTTP microsomal triglyceride transfer protein that is required for the assembly and secretion of triglyceride – rich lipoproteins from both enterocytes and hepatocytes.

MUC 5 AC mucin 5 AC, a secreted gel-forming protein mucin with a high molecular weight of about 641 kDa.

Mucositis painful inflammation and ulceration of the mucous membranes lining the digestive tract.

Mucous relating to mucus.

Mucolytic capable of reducing the viscosity of mucus, or an agent that so acts.

Mucus viscid secretion of the mucous membrane.

Multidrug resistance (MDR) ability of a living cell to show resistance to a wide variety of structurally and functionally unrelated compounds.

Muscarinic receptors are G protein-coupled acetylcholine receptors found in the plasma membranes of certain neurons and other cells.

Mutagen an agent that induces genetic mutation by causing changes in the DNA.

Mutagenic capable of inducing mutation (used mainly for extracellular factors such as X-rays or chemical pollution).

Myc codes for a protein that binds to the DNA of other genes and is therefore a transcription factor, found on chromosome 8 in human.

Mycosis an infection or disease caused by a fungus.

Myelocyte is a young cell of the granulocytic series, occurring normally in bone marrow, but not in circulating blood.

Myeloid Leukaemia (Chronic) a type of cancer that affects the blood and bone marrow, characterized by excessive number of white blood cells.

Myeloma cancer that arise in the plasma cells a type of white blood cells.

Myeloperoxidase (MPO) is a peroxidase enzyme most abundantly present in neutrophil granulocytes (a subtype of white blood cells). It is an inflammatory enzyme produced by activated leukocytes that predicts risk of coronary heart disease.

Myeloproliferative disorder disease of the bone marrow in which excess cells are produced.

Myocardial relating to heart muscles tissues.

Myocardial infarction (MI) is the rapid development of myocardial necrosis caused by a critical imbalance between oxygen supply and demand of the myocardium.

Myocardial ischemia an intermediate condition in coronary artery disease during which the heart tissue is slowly or suddenly starved of oxygen and other nutrients.

Myogenesis the formation of muscular tissue, especially during embryonic development.

Myopia near – or short-sightedness.

Myosarcoma a malignant muscle tumour.

Myringosclerosis also known as tympanosclerosis or intratympanic tympanosclerosis, is a condition caused by calcification of collagen tissues in the tympanic membrane of the middle ear.

Mytonia a symptom of certain neuromuscular disorders characterized by the slow relaxation of the muscles after voluntary contraction or electrical stimulation.

Myotonia dystrophica an inherited disorder of the muscles and other body systems characterized by progressive muscle weakness, prolonged muscle contractions (myotonia), clouding of the lens of the eye (cataracts), cardiac abnormalities, balding, and infertility.

Myotube a developing skeletal muscle fibre with a tubular appearance.

N-nitrosmorpholine a human carcinogen.

N-Nitrosoproline an indicator for N-nitrosation of amines.

NADPH The reduced form of nicotinamide adenine dinucleotide phosphate that serves as an electron carrier.

NAFLD Non-alcoholic fatty liver disease.

Narcotic an agent that produces narcosis, in moderate doses it dulls the senses, relieves pain and induces sleep; in excessive dose it cause stupor, coma, convulsions and death.

Nasopharynx upper part of the alimentary continuous with the nasal passages.

Natriuresis the discharge of excessive large amount of sodium through urine. *adj.* natriuretic.

Natural killer cells (NK cells) a type of cytotoxic lymphocyte that constitute a major component of the innate immune system.

Natural killer T (NKT) cells a heterogeneous group of T cells that share properties of both T cells and natural killer (NK) cells.

Nausea sensation of unease and discomfort in the stomach with an urge to vomit.

Necropsy see autopsy.

Necrosis morphological changes that follow cell death, usually involving nuclear and cytoplasmic changes.

Neonatal *adj.* of or relating to newborn infants or an infant.

Neoplasia abnormal growth of cells, which may lead to a neoplasm, or tumour.

Neoplasm tumour; any new and abnormal growth, specifically one in which cell multiplication is uncontrolled and progressive. Neoplasms may be benign or malignant.

Neoplastic transformation conversion of a tissue with a normal growth pattern into a malignant tumour.

Neointima a new or thickened layer of arterial intima formed especially on a prosthesis or in atherosclerosis by migration and proliferation of cells from the media.

Neovasculature formation of new blood vessels.

Nephrectomised kidneys surgically removed.

Nephrectomy surgical removal of the kidney.

Nephric relating to or connected with a kidney.

Nephrin is a protein necessary for the proper functioning of the renal filtration barrier.

Nephritic syndrome is a collection of signs (known as a syndrome) associated with disorders affecting the kidneys, more specifically glomerular disorders.

Nephritis is inflammation of the kidney.

Nephrolithiasis process of forming a kidney stone in the kidney or lower urinary tract.

Nephropathy a disorder of the kidney.

Nephrotic syndrome nonspecific disorder in which the kidneys are damaged, causing them to leak large amounts of protein from the blood into the urine.

Nephrotoxicity poisonous effect of some substances, both toxic chemicals and medication, on the kidney.

Nerve growth factor (NGF) a small protein that induces the differentiation and survival of particular target neurons (nerve cells).

Nervine a nerve tonic that acts therapeutically upon the nerves, particularly in the sense of a sedative that serves to calm ruffled nerves.

Neuralgia is a sudden, severe painful disorder of the nerves.

Neuraminidase glycoside hydrolase enzymes that cleaves the glycosidic linakges of neuraminic acids.

Neuraminidase inhibitors a class of antiviral drugs targeted at the influenza viruses whose mode of action consists of blocking the function of the viral neuraminidase protein, thus preventing the virus from reproducing.

Neurasthenia a condition with symptoms of fatigue, anxiety, headache, impotence, neuralgia and impotence.

Neurasthenic a substance used to treat nerve pain and/or weakness. (i.e. neuralgia, sciatica, etc.)

Neurite refers to any projection from the cell body of a neuron.

Neuritis an inflammation of the nerve characterized by pain, sensory disturbances and impairment of reflexes. *adj*. neuritic.

Neuritogenesis the first step of neuronal differentiation, takes place as nascent neurites bud from the immediate postmitotic neuronal soma.

Neuroblastoma a common extracranial cancer that forms in nerve tissues, common in infancy.

Neuroendocrine *adj*. of, relating to, or involving the interaction between the nervous system and the hormones of the endocrine glands.

Neuroleptic refers to the effects on cognition and behavior of antipsychotic drugs that reduce confusion, delusions, hallucinations, and psychomotor agitation in patients with psychoses.

Neuropharmacological relating the effects of drugs on the neurosystem.

Neuroradiology is a subspecialty of radiology focusing on the diagnosis and characterization of abnormalities of the central and peripheral nervous system. *adj*. neuroradiologic.

Neurotrophic relating to neutrophy i.e. the nutrition and maintenance of nervous tissue.

Neutrophin protein that induce the survival, development and function of neurons.

Neutropenia a disorder of the blood, characterized by abnormally low levels of neutrophils.

Neutrophil a type of white blood cell, specifically a form of granulocyte.

NF-kappa B (NF-kB) nuclear factor kappa B, is an ubiquitous rapid response transcription factor in cells involved in immune and inflammatory reactions.

Niacin vitamin B3. See vitamin B3.

Niacinamide an amide of niacin, also known as nicotinamide. See vitamin B3.

NIH3T3 cells a mouse embryonic fibroblast cell line used in the cultivation of keratinocytes.

Nitrogen (N) is an essential building block of amino and nucleic acids and proteins and is essential to all living organisms. Protein rich vegetables like legumes are rich food sources of nitrogen.

NK cells Natural killer cells, a type of cytotoxic lymphocyte that constitute a major component of the innate immune system.

NMDA receptor N-methyl-D-aspartate receptor, the predominant molecular device for controlling synaptic plasticity and memory function. A brain receptor activated by the amino acid glutamate, which when excessively stimulated may cause cognitive defects in Alzheimer's disease.

Nociceptive causing pain, responding to a painful stimulus.

Non-osteogenic fibromata of bone.

Nootropics are substances which are claimed to boost human cognitive abilities (the functions and capacities of the brain). Also popularly referred to as "smart drugs", "smart nutrients", "cognitive enhancers" and "brain enhancers".

Noradrenalin see Norepinephrine.

Norepinephrine a substance, both a hormone and neurotransmitter, secreted by the adrenal medulla and the nerve endings of the sympathetic nervous system to cause vasoconstriction and increases in heart rate, blood pressure, and the sugar level of the blood. Also called levarterenol, noradrenalin.

Normoglycaemic having the normal amount of glucose in the blood.

Nosocomial infections infections which are a result of treatment in a hospital or a healthcare service unit, but secondary to the patient's original condition.

NK1.1+ T (NKT) cells a type of natural killer T (NKT) cells. See natural killer T cells.

Nuclear factor erythroid 2-related factor 2 (Nrf2) a transcription factor that plays a major role in response to oxidative stress by binding to antioxidant-responsive elements that regulate many hepatic phase I and II enzymes as well as hepatic efflux transporters.

Nucleosomes fundamental repeating subunits of all eukaryotic chromatin, consisting of a DNA chain coiled around a core of histones.

5'-Nucleotidase (5'-ribonucleotide phosphohydrolase), an intrinsic membrane glycoprotein present as an ectoenzyme in a wide variety of mammalian cells, hydrolyzes 5'-nucleotides to their corresponding nucleosides.

Nulliparous term used to describe a woman who has never given birth.

Nyctalopia night blindness, impaired vision in dim light and in the dark, due to impaired function of certain specialized vision cells.

Nycturia excessive urination at night; especially common in older men.

Occulsion closure or blockage (as of a blood vessel).

Occlusive peripheral arterial disease (PAOD) also known as peripheral vascular disease (PVD), or peripheral arterial disease (PAD) refers to the obstruction of large arteries not within the coronary, aortic arch vasculature, or brain. PVD can result from atherosclerosis, inflammatory processes leading to stenosis, an embolism, or thrombus formation.

Oculomotor nerve the third of 12 paired cranial nerves.

Odds ratio a statistical measure of effect size, describing the strength of association or non-independence between two binary data values.

Odontalgia toothache. *adj.* odontalgic.

Odontopathy any disease of the teeth.

Oedema see edema.

Oligoarthritis an inflammation of two, three or four joints.

Oligonucleosome a series of nucleosomes.

Oligospermia or oligozoospermia refers to semen with a low concentration of sperm, commonly associated with male infertility.

Oliguria decreased production of urine.

Oligoanuria insufficient urine volume to allow for administration of necessary fluids, etc.

Omega 3 fatty acids are essential polyunsaturated fatty acids that have in common a final carbon–carbon double bond in the n−3 position. Dietary sources of omega-3 fatty acids

include fish oil and certain plant/nut oils. The three most nutritionally important omega 3 fatty acids are alpha-linolenic acid, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Research indicates that omega 3 fatty acids are important in health promotion and disease and can help prevent a wide range of medical problems, including cardiovascular disease, depression, asthma, and rheumatoid arthritis.

Omega 6 fatty acids are essential polyunsaturated fatty acids that have in common a final carbon–carbon double bond in the n−6 position. Omega-6 fatty acids are considered essential fatty acids (EFAs) found in vegetable oils, nuts and seeds. They are essential to human health but cannot be made in the body. Omega-6 fatty acids – found in vegetable oils, nuts and seeds – are a beneficial part of a heart-healthy eating. Omega-6 and omega-3 PUFA play a crucial role in heart and brain function and in normal growth and development. Linoleic acid (LA) is the main omega-6 fatty acid in foods, accounting for 85–90 % of the dietary omega-6 PUFA. Other omega 6 acids include gamma-linolenic acid or GLA, sometimes called gamoleic acid, eicosadienoic acid, arachidonic acid and docosadienoic acid.

Omega 9 fatty acids are not essential polyunsaturated fatty acids that have in common a final carbon–carbon double bond in the n−9 position. Some n−9s are common components of animal fat and vegetable oil. Two n−9 fatty acids important in industry are: oleic acid (18:1, n−9), which is a main component of olive oil and erucic acid (22:1, n−9), which is found in rapeseed, wallflower seed, and mustard seed.

Oncogenes genes carried by tumour viruses that are directly and solely responsible for the neoplastic (tumorous) transformation of host cells.

Ophthalmia severe inflammation of eye, or the conjunctiva or deeper structures of the eye . Also called ophthalmitis.

Ophthalmia (Sympathetic) inflammation of both eyes following trauma to one eye.

Opiate drug derived from the opium plant.

Opioid receptors a group of G-protein coupled receptors located in the brain and various organs that bind opiates or opioid substances.

Optic placode an ectodermal placode from which the lens of the embryonic eye develops; also called lens placode.

ORAC (Oxygen radical absorbance capacity) a method of measuring antioxidant capacities in biological samples.

Oral submucous fibrosis a chronic debilitating disease of the oral cavity characterized by inflammation and progressive fibrosis of the submucosa tissues.

Oral thrush an infection of yeast fungus, *Candida albicans*, in the mucous membranes of the mouth.

Orchidectomy surgery to remove one or both testicles.

Orchidectomised with testis removed.

Orchitis an acute painful inflammatory reaction of the testis secondary to infection by different bacteria and viruses.

Orexigenic increasing or stimulating the appetite.

Orofacial dyskinesia abnormal involuntary movements involving muscles of the face, mouth, tongue, eyes, and occasionally, the neck—may be unilateral or bilateral, and constant or intermittent.

Oropharyngeal relating to the oropharynx.

Oropharynx part of the pharynx between the soft palate and the epiglottis.

Ostalgia, Ostealgia pain in the bones. Also called osteodynia.

Osteoarthritis is the deterioration of the joints that becomes more common with age.

Osteoarthrosis chronic noninflammatory bone disease.

Osteoblast a mononucleate cell that is responsible for bone formation.

Osteoblastic relating to osteoblasts.

Osteocalcin a noncollagenous protein found in bone and dentin, also refer to as bone gamma-carboxyglutamic acid-containing protein.

Osteoclasts a kind of bone cell that removes bone tissue by removing its mineralized matrix.

Osteoclastogenesis the production of osteoclasts.

Osteodynia pain in the bone.

Osteogenic derived from or composed of any tissue concerned in bone growth or repair.

Osteomalacia refers to the softening of the bones due to defective bone mineralization.

Osteomyelofibrosis a myeloproliferative disorder in which fibrosis and sclerosis finally lead to bone marrow obliteration.

Osteopenia reduction in bone mass, usually caused by a lowered rate of formation of new bone that is insufficient to keep up with the rate of bone destruction.

Osteoporosis a disease of bone that leads to an increased risk of fracture.

Osteoprotegerin also called osteoclastogenesis inhibitory factor (OCIF), a cytokine, which can inhibit the production of osteoclasts.

Osteosacrcoma a malignant bone tumour. Also called osteogenic sarcoma.

Otalgia earache, pain in the ear.

Otic placode a thickening of the ectoderm on the outer surface of a developing embryo from which the ear develops.

Otitis inflammation of the inner or outer parts of the ear.

Otorrhea running drainage (discharge) exiting the ear.

Ovariectomised with one or two ovaries removed.

Ovariectomy surgical removal of one or both ovaries.

Oxidation the process of adding oxygen to a compound, dehydrogenation or increasing the electro-negative charge.

Oxidoreductase activity catalysis of an oxidation-reduction (redox) reaction, a reversible chemical reaction. One substrate acts as a hydrogen or electron donor and becomes oxidized, while the other acts as hydrogen or electron acceptor and becomes reduced.

Oxytocic *adj*. hastening or facilitating childbirth, especially by stimulating contractions of the uterus.

Oxytocin is a mammalian hormone that also acts as a neurotransmitter in the brain. It is best known for its roles in female reproduction: it is released in large amounts after distension of the cervix and vagina during labor, and after stimulation of the nipples, facilitating birth and breastfeeding, respectively.

Oxygen radical absorbance capacity (ORAC) a method of measuring antioxidant capacities in biological samples.

Oxyuriasis infestation by pinworms.

Ozoena discharge of the nostrils caused by chronic inflammation of the nostrils.

p.o. per os, oral administration.

P21 also known as cyclin-dependent kinase inhibitor 1 or CDK-interacting protein 1, is a potent cyclin-dependent kinase inhibitor.

P53 also known as protein 53 or tumour protein 53, is a tumour suppressor protein that in humans is encoded by the TP53 gene.

P-Selectin also known as CD62P, GMP-140, LLECAM-3, PADGEM, a member of the selectin family. It is expressed by activated platelets and endothelial cells.

P-glycoprotein (P-gp, ABCB1, MDR1) a cell membrane-associated drug-exporting protein that transports a variety of drug substrates from cancer cells.

Palpebral ptosis the abnormal drooping of the upper lid, caused by partial or total reduction in levator muscle function.

Palpitation rapid pulsation or throbbing of the heart.

Paludism state of having symptoms of malaria characterized by high fever and chills.

Pancreatectomized having undergone a pancreatectomy.

Pancreatectomy surgical removal of all or part of the pancreas.

Pancreatitis inflammation of the pancreas.

Pantothenic acid vitamin B5. See vitamin B5.

Papain a protein degrading enzyme used medicinally and to tenderize meat.

Papilloma a benign epithelial tumour growing outwardly like in finger-like fronds.

Papule a small, solid, usually inflammatory elevation of the skin that does not contain pus.

Paralytic person affected with paralysis, pertaining to paralysis.

Parasitemia presence of parasites in blood. *adj*. parasitemic.

Parasympathetic nervous system subsystem of the nervous systems that slows the heart

rate and increases intestinal and gland activity and relaxes the sphincter muscles.

Parasympathomimetic having an action resembling that caused by stimulation of the parasympathetic nervous system.

Parenteral administration administration by intravenous, subcutaneous or intramuscular route**s.**

Paresis a condition characterised by partial loss of movement, or impaired movement.

Paresthesia is an abnormal sensation of the skin, such as burning, numbness, itching, hyperesthesia (increased sensitivity) or tingling, with no apparent physical cause.

Paradontosis is the inflammation of gums and other deeper structures, including the bone.

Parenteral is a route of administration via the veins that involves piercing the skin or mucous membrane.

Parotitis inflammation of salivary glands.

Paroxysm a sudden outburst of emotion or action, a sudden attack, recurrence or intensification of a disease.

Paroxystic relating to an abnormal event of the body with an abrupt onset and an equally sudden return to normal.

PARP see poly (ADP-ribose) polymerase.

Parturition act of child birth.

PCE/PCN ratio polychromatic erythrocyte/normochromatic erythrocyte ratio use as a measure of cytotoxic effects.

pCREB phosphorylated cAMP (adenosine 3'5' cyclic monophosphate)-response element binding protein.

PDEF acronym for prostate-derived ETS factor, an ETS (epithelial-specific E26 transforming sequence) family member that has been identified as a potential tumour suppressor.

pERK phosphorylated extracellular signal-regulated kinase, protein kinases involved in many cell functions.

p53 also known as protein 53 or tumour protein 53, is a tumour suppressor protein that in humans is encoded by the TP53 gene.

Pectoral pertaining to or used for the chest and respiratory tract.

Peliosis see purpura.

Pellagra is a systemic nutritional wasting disease caused by a deficiency of vitamin B3 (niacin).

Pemphigus neonatorum Staphylococcal scalded skin syndrome, a bacterial disease of infants, characterized by elevated vesicles or blebs on a normal or reddened skin .

Peptic ulcer a sore in the lining of the stomach or duodenum, the first part of the small intestine.

Percutanous pertains to a medical procedure where access to inner organs or tissues is done via needle puncture of the skin.

Perfusion to force fluid through the lymphatic system or blood vessels to an organ or tissue.

Periapical periodontitis is the inflammation of the tissue adjacent to the tip of the tooth's root.

Perifuse to flush a fresh supply of bathing fluid around all of the outside surfaces of a small piece of tissue immersed in it.

Perilipins highly phosphorylated adipocyte proteins that are localized at the surface of the lipid droplet.

Perimenopause is the phase before menopause actually takes place, when ovarian hormone production is declining and fluctuating. *adj*. perimenopausal.

Periodontal ligament (PDL) is a group of specialized connective tissue fibers that essentially attach a tooth to the bony socket.

Periodontitis is a severe form of gingivitis in which the inflammation of the gums extends to the supporting structures of the tooth. Also called pyorrhea.

Peripheral arterial disease (PAD) see peripheral artery occlusive disease.

Peripheral neuropathy refers to damage to nerves of the peripheral nervous system.

Peripheral vascular disease (PVD) see peripheral artery occlusive disease .

Peristalsis a series of organized, wave-like muscle contractions that occur throughout the digestive tract.

Perlingual through or by way of the tongue.

Perniosis an abnormal reaction to cold that occurs most frequently in women, children, and the elderly. Also called chilblains.

Per so (P.O.) oral administration.

Peroxisome proliferator-activated receptors (PPARs) a family of nuclear receptors that are involved in lipid metabolism, differentiation, proliferation, cell death, and inflammation.

Peroxisome proliferator-activated receptor alpha (PPAR-alpha) a nuclear receptor protein, transcription factor and a major regulator of lipid metabolism in the liver.

Peroxisome proliferator-activated receptor gamma (PPAR-γ) a type II nuclear receptor protein that regulates fatty acid storage and glucose metabolism.

Pertussis whooping cough, sever cough.

Peyers Patches patches of lymphoid tissue or lymphoid nodules on the walls of the ileal-small intestine.

PGE-2 Prostaglandin E2, a hormone-like substance that is released by blood vessel walls in response to infection or inflammation that acts on the brain to induce fever.

Phagocytes are the white blood cells that protect the body by ingesting (phagocytosing) harmful foreign particles, bacteria and dead or dying cells. *adj.* phagocytic.

Phagocytosis is process the human body uses to destroy dead or foreign cells.

Pharmacognosis the branch of pharmacology that studies the composition, use, and history of drugs.

Pharmacopoeia authoritative treatise containing directions for the identification of drug samples and the preparation of compound medicines, and published by the authority of a government or a medical or pharmaceutical society and in a broader sense is a general reference work for pharmaceutical drug specifications.

Pharyngitis, Pharyngolaryngitis inflammation of the pharynx and the larynx.

Pharyngolaryngeal pertaining to the pharynx and larynx.

Phenolics class of chemical compounds consisting of a hydroxyl group (–OH) bonded directly to an aromatic hydrocarbon group.

Pheochromocytoma is a rare neuroendocrine tumour that usually originates from the adrenal glands' chromaffin cells, causing over-production of catecholamines, powerful hormones that induce high blood pressure and other symptoms.

Phlebitis is an inflammation of a vein, usually in the legs.

Phlegm abnormally viscid mucus secreted by the mucosa of the respiratory passages during certain infectious processes.

Phlegmon a spreading, diffuse inflammation of the soft or connective tissue due to infection by Streptococci bacteria.

Phoroglucinol a white, crystalline compound used as an antispasmodic, analytical reagent, and decalcifier of bone specimens for microscopic examination.

Phosphatidylglycerol is a glycerophospholipid found in pulmonary active surface lipoprotein and consists of a L-glycerol 3-phosphate backbone ester-bonded to either saturated or unsaturated fatty acids on carbons 1 and 2.

Phosphatidylinositol 3-kinases (PI 3-kinases or PI3Ks) a group of enzymes involved in cellular functions such as cell growth, proliferation, differentiation, motility, survival and intracellular trafficking, which in turn are involved in cancer.

Phosphatidylserine a phosphoglyceride phospholipid that is one of the key building blocks of cellular membranes, particularly in the nervous system. It is derived from soy lecithin

Phosphodiesterases a diverse family of enzymes that hydrolyse cyclic nucleotides and thus play a key role in regulating intracellular levels of the second messengers cAMP and cGMP, and hence cell function.

Phospholipase an enzyme that hydrolyzes phospholipids into fatty acids and other lipophilic substances.

Phospholipase A2 (PLA2) a small lipolytic enzyme that releases fatty acids from the second carbon group of glycerol. Plays an essential role in the synthesis of prostaglandins and leukotrienes.

Phospholipase C enzymes that cleaves phospholipase.

Phospholipase C gamma (PLC gamma) enzymes that cleaves phospholipase in cellular proliferation and differentiation, and its enzymatic

activity is upregulated by a variety of growth factors and hormones.

Phosphorus (P) is an essential mineral that makes up 1% of a person's total body weight and is found in the bones and teeth. It plays an important role in the body's utilization of carbohydrates and fats; in the synthesis of protein for the growth, maintenance, and repair of cells and tissues. It is also crucial for the production of ATP, a molecule the body uses to store energy. Main sources are meat and milk; fruits and vegetables provides small amounts.

Photoaging is the term that describes damage to the skin caused by intense and chronic exposure to sunlight resulting in premature aging of the skin.

Photocarcinogenesis represents the sum of a complex of simultaneous and sequential biochemical events that ultimately lead to the occurrence of skin cancer.

Photophobia abnormal visual intolerance to light.

Photopsia an affection of the eye, in which the patient perceives luminous rays, flashes, coruscations, etc.

Photosensitivity sensitivity toward light.

Phthisis an archaic name for tuberculosis.

Phytohemagglutinin a lectin found in plant that is involved in the stimulation of lymphocyte proliferation.

Phytonutrients certain organic components of plants, that are thought to promote human health. Fruits, vegetables, grains, legumes, nuts and teas are rich sources of phytonutrients. Phytonutrients are not 'essential' for life. Also called phytochemicals.

Phytosterols a group of steroid alcohols, cholesterol-like phytochemicals naturally occurring in plants like vegetable oils, nuts and legumes.

Piebaldism rare autosomal dominant disorder of melanocyte development characterized by distinct patches of skin and hair that contain no pigment.

Piles see haemorrhoids.

Pityriasis lichenoides is a rare skin disorder of unknown aetiology characterised by multiple papules and plaques.

PKC protein kinase C, a membrane bound enzyme that phosphorylates different intracellular proteins and raised intracellular Ca levels.

PKC Delta inhibitors Protein Kinase C delta inhibitors that induce apoptosis of haematopoietic cell lines.

Placebo a sham or simulated medical intervention.

Placode a plate like epithelial thickening in the embryo where some organ or structure later develops.

Plasma the yellow-colored liquid component of blood, in which blood cells are suspended.

Plasmalemma plasma membrane.

Plasma Kallikrien a serine protease, synthesized in the liver and circulates in the plasma.

Plasmin a proteinase enzyme that is responsible for digesting fibrin in blood clots.

Plasminogen the proenzyme of plasmin, whose primary role is the degradation of fibrin in the vasculature.

Plaster poultice.

Platelet Activating Factor PAF is an acetylated derivative of glycerophosphorylcholine, released by basophils and mast cells in immediate hypersensitive reactions and macrophages and neutrophils in other inflammatory reactions. One of its main effects is to induce platelet aggregation.

PLC gamma phospholipase C gamma plays a central role in signal transduction.

Pleurisy is an inflammation of the pleura, the lining of the pleural cavity surrounding the lungs, which can cause painful respiration and other symptoms. Also known as pleuritis.

Pneumonia an inflammatory illness of the lung caused by bacteria or viruses.

Pneumotoxicity damage to lung tissues.

Poliomyelitis is a highly infectious viral disease that may attack the central nervous system and is characterized by symptoms that range from a mild non-paralytic infection to total paralysis in a matter of hours; also called polio or infantile paralysis.

Poly (ADP-ribose) polymerase (PARP) a protein involved in a number of cellular processes especially DNA repair and programmed cell death.

Polyarthritis is any type of arthritis which involves five or more joints.

Polychromatic erythrocyte (PCE) an immature red blood cell containing RNA, that can be differentiated by appropriate staining techniques from a normochromatic erythrocyte (NCE), which lacks RNA.

Polycystic kidney disease is a kidney disorder passed down through families in which multiple cysts form on the kidneys, causing them to become enlarged.

Polycythaemia a type of blood disorder characterised by the production of too many red blood cells.

Polymorphnuclear having a lobed nucleus. Used especially of neutrophilic white blood cells.

Polyneuritis widespread inflammation of the nerves.

Polyneuritis gallinarum a nervous disorder in birds and poultry.

Polyp a growth that protrudes from a mucous membrane.

Polyphagia medical term for excessive hunger or eating.

Polyuria a condition characterized by the passage of large volumes of urine with an increase in urinary frequency.

Pomade a thick oily dressing.

Porphyrin any of a class of water-soluble, nitrogenous biological pigments.

Postpartum (Depression) depression after pregnancy; also called peripartum depression.

Postprandial after mealtime.

Potassium (K) is an element that's essential for the body's growth and maintenance. It's necessary to keep a normal water balance between the cells and body fluids, for cellular enzyme activities and plays an essential role in the response of nerves to stimulation and in the contraction of muscles. Potassium is found in many plant foods and fish (tuna, halibut): chard, mushrooms, spinach, fennel, kale, mustard greens, Brussels sprouts, broccoli, cauliflower, cabbage winter squash, eggplant, cantaloupe, tomatoes, parsley, cucumber, bell pepper, turmeric, ginger root, apricots, strawberries, avocado and banana.

Poultice is a soft moist mass, often heated and medicated, that is spread on cloth over the skin to treat an aching, inflamed, or painful part of the body. Also called cataplasm.

PPARs peroxisome proliferator-activated receptors – a group of nuclear receptor proteins that function as transcription factors regulating the expression of genes.

Prebiotics a category of functional food, defined as non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon, and thus improve host health. *cf.* probiotics.

Prepubertal before puberty; pertaining to the period of accelerated growth preceding gonadal maturity.

Pre-eclampsia see toxemia.

Pregnane X receptor (PXR; NR1I2) is a ligand-activated transcription factor that plays a role not only in drug metabolism and transport but also in various other biological processes**.**

Prenidatory referring to the time period between fertilization and implantation.

Prenylated flavones flavones with an isoprenyl group in the 8-position, has been reported to have good anti-inflammatory properties.

Proangiogenic promote angiogensis (formation and development of new blood vessels)..

Probiotics are dietary supplements and live microorganisms containing potentially beneficial bacteria or yeasts that are taken into the alimentary system for healthy intestinal functions. *cf.* prebiotics.

Procyanidin also known as proathocyanidin, oligomeric proathocyanidin, leukocyanidin, leucoanthocyanin, is a class of flavanols found in many plants. It has antioxidant activity and plays a role in the stabilization of collagen and maintenance of elastin.

Progestational of or relating to the phase of the menstrual cycle immediately following ovulation, characterized by secretion of progesterone.

Proglottid one of the segments of a tapeworm.

Prognosis medical term to describe the likely outcome of an illness.

Prolactin a hormone produced by the pituitary gland, it stimulates the breasts to produce milk in pregnant women. It is also present in males but its role is not well understood.

Prolapsus to fall or slip out of place.

Prolapus ani eversion of the lower portion of the rectum, and protruding through the anus, common in infancy and old age.

Proliferating cell nuclear antigen (PCNA) a new marker to study human colonic cell proliferation.

Proliferative Vitreoretinopathy (PVR) a most common cause of failure in retinal reattachment surgery, characterised by the formation of cellular membrane on both surfaces of the retina and in the vitreous.

Promastigote the flagellate stage in the development of trypanosomatid protozoa, characterized by a free anterior flagellum.

Promyelocytic leukemia a subtype of acute myelogenous leukemia (AML), a cancer of the blood and bone marrow.

Pro-oxidants chemicals that induce oxidative stress, either through creating reactive oxygen species or inhibiting antioxidant systems.

Prophylaxis prevention or protection against disease.

Prostacyclin a prostaglandin that is a metabolite of arachidonic acid, inhibits platelet aggregation, and dilates blood vessels.

Prostaglandins a family of C 20 lipid compounds found in various tissues, associated with muscular contraction and the inflammation response such as swelling, pain, stiffness, redness and warmth.

Prostaglandin E2 (PEG –2) one of the prostaglandins, a group of hormone-like substances that participate in a wide range of body functions such as the contraction and relaxation of smooth muscle, the dilation and constriction of blood vessels, control of blood pressure, and modulation of inflammation.

Prostaglandin E synthase an enzyme that in humans is encoded by the glutathione-dependent PTGES gene.

Prostanoids term used to describe a subclass of eicosanoids (products of COX pathway) consisting of the prostaglandins (mediators of inflammatory and anaphylactic reactions), the thromboxanes (mediators of vasoconstriction) and the prostacyclins (active in the resolution phase of inflammation.)

Prostate a gland that surround the urethra at the bladder in the male.

Prostate cancer a disease in which cancer develops in the prostate, a gland in the male reproductive system. Symptoms include pain, difficulty in urinating, erectile dysfunction and other symptoms.

Prostate –specific antigen (PSA) a protein produced by the cells of the prostate gland.

Protein kinase C (PKC) a family of enzymes involved in controlling the function of other proteins through the phosphorylation of hydroxyl groups of serine and threonine amino acid residues on these proteins. PKC enzymes play important roles in several signal transduction cascades.

Proteinase a protease (enzyme) involved in the hydrolytic breakdown of proteins, usually by splitting them into polypeptide chains.

Proteomics the large-scale study of proteins, particularly their structures and functions.

Prothyroid good for thyroid function.

Prothrombin blood-clotting protein that is converted to the active form, factor IIa, or thrombin, by cleavage.

Protein tyrosine phosphatase (PTP) a group of enzymes that remove phosphate groups from phosphorylated tyrosine residues on proteins.

Proteinuria means the presence of an excess of serum proteins in the urine.

Proteolysis cleavage of the peptide bonds in protein forming smaller polypeptides. *adj*. proteolytic.

Protheolithic proteolytic see proteolysis.

Proto-oncogene A normal gene which, when altered by mutation, becomes an oncogene that can contribute to cancer.

Proptosis see exophthalmos.

Prurigo a general term used to describe itchy eruptions of the skin.

Pruritis defined as an unpleasant sensation on the skin that provokes the desire to rub or scratch the area to obtain relief; itch, itching. *adj*. pruritic.

PSA Prostate Specific Antigen, a protein which is secreted into ejaculate fluid by the healthy prostate. One of its functions is to aid sperm movement.

Psoriasis a common chronic, non-contagious autoimmune dermatosis that affects the skin and joints.

Psychoactive having effects on the mind or behavior.

Psychonautics exploration of the psyche by means of approaches such as meditation, prayer, lucid dreaming, brain wave entrainment etc.

Psychotomimetic hallucinogenic.

Psychotropic capable of affecting the mind, emotions, and behavior.

Ptosis also known as drooping eyelid; caused by weakness of the eyelid muscle and damage to the nerves that control the muscles or looseness of the skin of the upper eyelid..

PTP protein tyrosine phosphatase.

PTPIB protein tyrosine phosphatase 1B.

P13-K is a lipid kinase enzyme involved in the regulation of a number of cellular functions such as cell growth, proliferation, differentiation, motility, survival and intracellular trafficking, which in turn are involved in cancer.

P13-K/AKT signaling pathway shown to be important for an extremely diverse array of cellular activities – most notably cellular proliferation and survival.

Pthysis silicosis with tuberculosis.

Prurigo a general term used to describe itchy eruptions of the skin.

Puerperal pertaining to child birth.

Pulmonary embolism a blockage (blood clot) of the main artery of the lung.

Purgative a substance used to cleanse or purge, especially causing the immediate evacuation of the bowel.

Purpura is the appearance of red or purple discolorations on the skin that do not blanch on applying pressure. Also called peliosis.

Purulent containing pus discharge.

Purulent sputum sputum containing, or consisting of, pus.

Pustule small, inflamed, pus-filled lesions.

Ptosis drooping of the upper eye lid.

Pyelonephritis an ascending urinary tract infection that has reached the pyelum (pelvis) of the kidney.

Pyodermatitis refers to inflammation of the skin.

Pyorrhea see periodontitis.

Pyretic referring to fever.

Pyrexia fever of unknown origin.

Pyridoxal a chemical form of vitamin B6. See vitamin B6.

Pyridoxamine a chemical form of vitamin B6. See vitamin B6.

Pyridoxine a chemical form of vitamin B6. See vitamin B6.

Pyrolysis decomposition or transformation of a compound caused by heat. *adj.* pyrolytic.

PYY Peptide a 36 amino acid peptide secreted by L cells of the distal small intestine and colon that inhibits gastric and pancreatic secretion.

QT interval is a measure of the time between the start of the Q wave and the end of the T wave in the heart's electrical cycle. A prolonged QT interval is a biomarker for ventricular tachyarrhythmias and a risk factor for sudden death.

Quorum sensing (QS) the control of gene expression in response to cell density, is used by both gram-negative and gram-positive bacteria to regulate a variety of physiological functions.

Radiolysis the dissociation of molecules by radiation.

Radioprotective serving to protect or aiding in protecting against the injurious effect of radiations.

RAGE is the receptor for advanced glycation end products, a multiligand receptor that propagates cellular dysfunction in several inflammatory disorders, in tumours and in diabetes.

RAS see renin-angiotensin system or recurrent aphthous stomatitis.

Rash a temporary eruption on the skin, see uticaria.

Reactive oxygen species species such as superoxide, hydrogen peroxide, and hydroxyl radical. At low levels, these species may function in cell signaling processes. At higher levels, these species may damage cellular macromol-

ecules (such as DNA and RNA) and participate in apoptosis (programmed cell death).

Rec A is a 38 kDa *Escherichia coli* protein essential for the repair and maintenance of DNA.

Receptor for advanced glycation end products (RAGE) is a member of the immunoglobulin superfamily of cell surface molecules; mediates neurite outgrowth and cell migration upon stimulation with its ligand, amphoterin.

Recticulocyte non-nucleated stage in the development of the red blood cell.

Recticulocyte lysate cell lysate produced from reticulocytes, used as an in-vitro translation system.

Recticuloendothelial system part of the immune system, consists of the phagocytic cells located in reticular connective tissue, primarily monocytes and macrophages.

Recurrent aphthous stomatitis, or RAS is a common, painful condition in which recurring ovoid or round ulcers affect the oral mucosa.

Redox homeostasis is considered as the cumulative action of all free radical reactions and antioxidant defenses in different tissues.

Refrigerant a medicine or an application for allaying heat, fever or its symptoms.

Renal calculi kidney stones.

Renal interstitial fibrosis damage sustained by the kidneys' renal tubules and interstitial capillaries due to accumulation of extracellular waste in the wall of the small arteries and arterioles.

Renin also known as an angiotensinogenase, is an enzyme that participates in the body's renin-angiotensin system (RAS).

Renin-angiotensin system (RAS) also called the renin-angiotensin-aldosterone system (RAAS) is a hormone system that regulates blood pressure and water (fluid) balance.

Reperfusion the restoration of blood flow to an organ or tissue that has had its blood supply cut off, as after a heart attack.

Reporter gene a transfected gene that produces a signal, such as green fluorescence, when it is expressed.

Resistin a cysteine-rich protein secreted by adipose tissue of mice and rats.

Resolutive a substance that induces subsidence of inflammation.

Resolvent reduce inflammation or swelling.

Resorb to absorb or assimilate a product of the body such as an exudates or cellular growth.

Restenosis is the reoccurrence of stenosis, a narrowing of a blood vessel, leading to restricted blood flow.

Resveratrol is a phytoalexin produced naturally by several plants when under attack by pathogens such as bacteria or fungi. It is a potent antioxidant found in red grapes and other plants.

Retinol a form of Vitamin A, see vitamin A.

Retinopathy a general term that refers to some form of non-inflammatory damage to the retina of the eye.

Revulsive counterirritant, used for swellings.

Rheumatic pertaining to rheumatism or to abnormalities of the musculoskeletal system.

Rheumatism, Rheumatic disorder, Rheumatic diseases refers to various painful medical conditions which affect bones, joints, muscles, tendons. Rheumatic diseases are characterized by the signs of inflammation – redness, heat, swelling, and pain.

Rheumatoid arthritis (RA) is a chronic, systemic autoimmune disorder that most commonly causes inflammation and tissue damage in joints (arthritis) and tendon sheaths, together with anemia.

Rhinorrhea commonly known as a runny nose, characterized by an unusually significant amount of nasal discharge.

Rhinoplasty is surgery to repair or reshape the nose.

Rhinosinusitis inflammation of the nasal cavity and sinuses.

Rhinitis irritation and inflammation of some internal areas of the nose and the primary symptom of rhinitis is a runny nose.

Rho GTPases Rho-guanosine triphosphate hydrolase enzymes are molecular switches that regulate many essential cellular processes, including actin dynamics, gene transcription, cell-cycle progression and cell adhesion.

Ribosome inactivating proteins protein that are capable of inactivating ribosomes.

Rickets is a softening of the bones in children potentially leading to fractures and deformity.

Ringworm dermatophytosis, a skin infection caused by fungus.

Roborant restoring strength or vigour, a tonic.

Rotavirus the most common cause of infectious diarrhea (gastroenteritis) in young children and infants, one of several viruses that causes infections called stomach flu.

Rubefacient a substance for external application that produces redness of the skin e.g. by causing dilation of the capillaries and an increase in blood.

S-T segment the portion of an electrocardiogram between the end of the QRS complex and the beginning of the T wave. Elevation or depression of the S-T segment is the characteristics of myocardial ischemia or injury and coronary artery disease.

Sapraemia see septicaemia.

Sarcoma cancer of the connective or supportive tissue (bone, cartilage, fat, muscle, blood vessels) and soft tissues.

Sarcopenia degenerative loss of skeletal muscle mass and strength associated with aging.

Sarcoplasmic reticulum a special type of smooth endoplamic reticulum found in smooth and striated muscle.

SARS Severe acute respiratory syndrome, the name of a potentially fatal new respiratory disease in humans which is caused by the SARS coronavirus (SARS-CoV)

Satiety state of feeling satiated, fully satisfied (appetite or desire).

S.C. abbreviation for sub-cutaneous, beneath the layer of skin.

Scabies a transmissible ectoparasite skin infection characterized by superficial burrows, intense pruritus (itching) and secondary infection.

Scarlatina scarlet fever, an acute, contagious disease caused by infection with group A streptococcal bacteria.

Schwann cells or neurolemmocytes, are the principal supporing cells of the peripheral nervous system, they form the myelin sheath of a nerve fibre.

Schistosomiasis is a parasitic disease caused by several species of fluke of the genus *Schistosoma*. Also known as bilharzia, bilharziosis or snail fever.

Schizophrenia a psychotic disorder (or a group of disorders) marked by severely impaired thinking, emotions, and behaviors.

Sciatica a condition characterised by pain deep in the buttock often radiating down the back of the leg along the sciatic nerve.

Scleroderma a disease of the body's connective tissue. The most common symptom is a thickening and hardening of the skin, particularly of the hands and face.

Scrofula a tuberculous infection of the skin on the neck caused by the bacterium *Mycobacterium tuberculosis*.

Scrophulosis see scrofula.

Scurf abnormal skin condition in which small flakes or sales become detached.

Scurvy a state of dietary deficiency of vitamin C (ascorbic acid) which is required for the synthesis of collagen in humans.

Secretagogue a substance that causes another substance to be secreted.

Sedative having a soothing, calming, or tranquilizing effect; reducing or relieving stress, irritability, or excitement.

Seizure the physical findings or changes in behavior that occur after an episode of abnormal electrical activity in the brain.

Selectins are a family of cell adhesion molecules; e.g. selectin-E, selectin-L, selectin-P.

Selenium (Se) a trace mineral that is essential to good health but required only in tiny amounts; it is incorporated into proteins to make selenoproteins, which are important antioxidant enzymes. It is found in avocado, brazil nut, lentils, sunflower seeds, tomato, whole grain cereals, seaweed, seafood and meat.

Sensorineural bradyacuasia hearing impairment of the inner ear resulting from damage to the sensory hair cells or to the nerves that supply the inner ear**.**

Sepsis a condition in which the body is fighting a severe infection that has spread via the bloodstream.

Sequela an abnormal pathological condition resulting from a disease, injury or trauma.

Serine proteinase peptide hydrolases which have an active centre histidine and serine involved in the catalytic process.

Serotonergic liberating, activated by, or involving serotonin in the transmission of nerve impulses.

Serotonin a monoamine neurotransmitter synthesized in serotonergic neurons in the central nervous system.

Septicaemia a **s**ystemic disease associated with the presence and persistence of pathogenic microorganisms or their toxins in the blood.

Sequelae a pathological condition resulting from a prior disease, injury, or attack.

Sexual potentiator increases sexual activity and potency, enhances sexual performance due to increased blood flow and efficient metabolism.

Sexually transmitted diseases (STD) infections that are transmitted through sexual activity.

SGOT, Serum glutamic oxaloacetic transaminase an enzyme that is normally present in liver and heart cells. SGOT is released into blood when the liver or heart is damaged. Also called aspartate transaminase (AST).

SGPT, Serum glutamic pyruvic transaminase an enzyme normally present in serum and body tissues, especially in the liver; it is released into the serum as a result of tissue injury, also called Alanine transaminase (ALT),

Shiga – like toxin a toxin produced by the bacterium *Escherichia coli* which disrupts the function of ribosomes, also known as verotoxin.

Shiga toxigenic *Escherichia coli* **(STEC)** comprises a diverse group of organisms capable of causing severe gastrointestinal disease in humans.

Shiga toxin a toxin produced by the bacterium *Shigella dysenteriae*, which disrupts the function of ribosomes.

Shingles skin rash caused by the Zoster virus (same virus that causes chicken pox) and is medically termed Herpes zoster.

Sialogogue salivation-promoter, a substance used to increase or promote the excretion of saliva.

Sialoproteins glycoproteins that contain sialic acid as one of their carbohydrates.

Sialyation reaction with sialic acid or its derivatives; used especially with oligosaccharides.

Sialyltransferases enzymes that transfer sialic acid to nascent oligosaccharide.

Sickle cell disease is an inherited blood disorder that affects red blood cells. People with sickle cell disease have red blood cells that contain mostly hemoglobin S, an abnormal type of hemoglobin. Sometimes these red blood cells become sickle-shaped (crescent shaped) and have difficulty passing through small blood vessels.

Side stitch is an intense stabbing pain under the lower edge of the ribcage that occurs while exercising.

Signal transduction cascade refers to a series of sequential events that transfer a signal through a series of intermediate molecules until final regulatory molecules, such as transcription factors, are modified in response to the signal.

Silicon (Si) is required in minute amounts by the body and is important for the development of healthy hair and the prevention of nervous disorders. Lettuce is the best natural source of Silicon.

Sinapism signifies an external application, in the form of a soft plaster, or poultice.

Sinusitis inflammation of the nasal sinuses.

SIRC cells Statens Seruminstitut Rabbit Cornea (SIRC) cell line.

SIRT 1 stands for sirtuin (silent mating type information regulation 2 homolog) 1. It is an enzyme that deacetylates proteins that contribute to cellular regulation.

6-Keto-PGF1 alpha a physiologically active and stable hydrolysis product of Epoprostenol, found in nearly all mammalian tissues.

Skp1 (S-phase kinase-associated protein 1) is a core component of SCF ubiquitin ligases and mediates protein degradation.

Smads a family of intracellular proteins that mediate signaling by members of the TGF-beta (transforming growth factor beta) superfamily.

Smad2/3 a key signaling molecule for TGF-beta.

Smad7 a TGFβ type 1 receptor antagonist.

Smallpox is an acute, contagious and devastating disease in humans caused by *Variola* virus and have resulted in high mortality over the centuries.

Snuff powder inhaled through the nose.

SOD superoxide dismutase, is an enzyme that repairs cells and reduces the damage done to them by superoxide, the most common free radical in the body.

Sodium (Na) is an essential nutrient required for health. Sodium cations are important in neuron (brain and nerve) function, and in influencing osmotic balance between cells and the interstitial fluid and in maintenance of total body fluid homeostasis. Extra intake may cause a harmful effect on health. Sodium is naturally supplied by salt intake with food.

Soleus muscle smaller calf muscle lower down the leg and under the gastrocnemius muscle.

Somites mesodermal structures formed during embryonic development that give rise to segmented body parts such as the muscles of the body wall.

Soporific a sleep inducing drug.

SOS response a global response to DNA damage in which the cell cycle is arrested and DNA repair and mutagenesis are induced.

Soyasaponins bioactive saponin compounds found in many legumes.

Soyasapogenins triterpenoid products obtained from the acid hydrolysis of soyasaponins, designated soyasapogenols A, B, C, D and E.

Spasmolytic checking spasms, see antispasmodic.

Splenomegaly an enlargement of the spleen.

Spermatorrhoea medically an involuntary ejaculation/drooling of semen usually nocturnal emissions.

Spermidine an important polyamine in DNA synthesis and gene expression.

Sphingolipid a member of a class of lipids derived from the aliphatic amino alcohol, sphingosine.

Spleen organ that filters blood and prevents infection.

Spleen tyrosine kinase (SYK) is an enigmatic protein tyrosine kinase functional in a number of diverse cellular processes such as the regulation of immune and inflammatory responses.

Splenitis inflammation of the spleen.

Splenocyte is a monocyte, one of the five major types of white blood cell, and is characteristically found in the splenic tissue.

Splenomegaly is an enlargement of the spleen.

Sprain to twist a ligament or muscle of a joint without dislocating the bone.

Sprue is a chronic disorder of the small intestine caused by sensitivity to gluten, a protein found in wheat and rye and to a lesser extent oats and barley . It causes poor absorption by the intestine of fat, protein, carbohydrates, iron, water, and vitamins A, D, E, and K.

Sputum matter coughed up and usually ejected from the mouth, including saliva, foreign material, and substances such as mucus or phlegm, from the respiratory tract.

SREBP-1 see sterol regulatory element-binding protein-1.

Stanch to stop or check the flow of a bodily fluid like blood from a wound.

Statin a type of lipid-lowering drug.

Status Epilepticus refers to a life-threatening condition in which the brain is in a state of persistent seizure.

STD sexually transmitted disease.

Steatorrhea is the presence of excess fat in feces which appear frothy, foul smelling and floats because of the high fat content.

Steatohepatitis liver disease, characterized by inflammation of the liver with fat accumulation in the liver.

Steatosis refer to the deposition of fat in the interstitial spaces of an organ like the liver, fatty liver disease.

Sterility inability to produce offspring, also called asepsis.

Steroidogenisis the production of steroids.

Steroidogenic relating to steroidogenisis.

Sterol regulatory element-binding protein-1 (SREBP1) is a key regulator of the transcription of numerous genes that function in the metabolism of cholesterol and fatty acids.

Stimulant a substance that promotes the activity of a body system or function.

Stomachic (digestive stimulant), an agent that stimulates or strengthens the activity of the stomach; used as a tonic to improve the appetite and digestive processes.

Stomatitis oral inflammation and ulcers, may be mild and localized or severe, widespread, and painful.

Stomatology medical study of the mouth and its diseases.

Stool faeces.

Straub tail condition in which an animal carries its tail in an erect (vertical or nearly vertical) position.

Strangury is the painful passage of small quantities of urine which are expelled slowly by straining with severe urgency; it is usually accompanied with the unsatisfying feeling of a remaining volume inside and a desire to pass something that will not pass.

STREPs sterol regulatory element binding proteins, a family of transcription factors that regulate lipid homeostasis by controlling the expression of a range of enzymes required for endogenous cholesterol, fatty acid, triacylglycerol and phospholipid synthesis.

Stria terminalis a structure in the brain consisting of a band of fibres running along the lateral margin of the ventricular surface of the thalamus.

Striae gravidarum a cutaneous condition characterized by stretch marks on the abdomen during and following pregnancy.

Stricture an abnormal constriction of the internal passageway within a tubular structure such as a vessel or duct

Strongyloidiasis an intestinal parasitic infection in humans caused by two species of the parasitic nematode *Strongyloides.* The nematode or round worms are also called thread worms.

Styptic a short stick of medication, usually anhydrous aluminum sulfate (a type of alum) or titanium dioxide, which is used for stanching blood by causing blood vessels to contract at the site of the wound. Also called hemostatic pencil. see antihaemorrhagic.

Subarachnoid hemorrhage is bleeding in the area between the brain and the thin tissues that cover the brain.

Sudatory medicine that causes or increases sweating. Also see sudorific.

Sudorific a substance that causes sweating.

Sulfur Sulfur is an essential component of all living cells. Sulfur is important for the synthesis of sulfur-containing amino acids, all polypeptides, proteins, and enzymes such as glutathione an important sulfur-containing tripeptide which plays a role in cells as a source of chemical reduction potential. Sulfur is also important for hair formation. Good plant sources are garlic, onion, leeks and other Alliaceous vegetables, Brassicaceous vegetables like cauliflower, cabbages, Brussels sprout, Kale; legumes – beans, green and red gram, soybeans; horse radish, water cress, wheat germ.

Supraorbital located above the orbit of the eye.

Superoxidae mutase (SOD) antioxidant enzyme.

Superior mesenteric artery (SMA) arises from the anterior surface of the abdominal aorta, just inferior to the origin of the celiac trunk, and supplies the intestine from the lower part of the duodenum to the left colic flexure and the pancreas.

Suppuration the formation of pus, the act of becoming converted into and discharging pus.

SYK, Spleen tyrosine kinase is a human protein and gene. Syk plays a similar role in transmitting signals from a variety of cell surface receptors including CD74, Fc Receptor, and integrins.

Sympathetic nervous system the part of the autonomic nervous system originating in the thoracic and lumbar regions of the spinal cord that in general inhibits or opposes the physiological effects of the parasympathetic nervous system, as in tending to reduce digestive secretions or speed up the heart.

Synaptic plasticity the ability of neurons to change the number and strength of their synapses.

Synaptogenesis the formation of synapses.

Synaptoneurosomes purified synapses containing the pre- and postsynaptic termini.

Synaptosomes isolated terminal of a neuron.

Syncope fainting, sudden loss of consciousness followed by the return of wakefulness.

Syndactyly webbed toes, a condition where two or more digits are fused together.

Syneresis expulsion of liquid from a gel, as contraction of a blood clot and expulsion of liquid.

Syngeneic genetically identical or closely related, so as to allow tissue transplant; immunologically compatible.

Synovial lubricating fluid secreted by synovial membranes, as those of the joints.

Synoviocyte located in the synovial membrane, there are two types. Type A cells are more numerous, have phagocytic characteristics and produce degradative enzymes. Type B cells produce synovial fluid, which lubricates the joint and nurtures nourishes the articular cartilage.

Syphilis is perhaps the best known of all the STD's. Syphilis is transmitted by direct contact with infection sores, called chancres, syphitic skin rashes, or mucous patches on the tongue and mouth during kissing, necking, petting, or sexual intercourse. It can also be transmitted from a pregnant woman to a fetus after the fourth month of pregnancy.

Systolic the blood pressure when the heart is contracting. It is specifically the maximum arterial pressure during contraction of the left ventricle of the heart.

T cells or T lymphocytes, a type of white blood cell that play a key role in the immune system.

Tachyarrhythmia any disturbance of the heart rhythm in which the heart rate is abnormally increased.

Tachycardia a false heart rate applied to adults to rates over 100 beats per minute.

Tachyphylaxia a decreased response to a medicine given over a period of time so that larger doses are required to produce the same response.

Tachypnea abnormally fast breathing.

Taenia a parasitic tapeworm or flatworm of the genus, *Taenia.*

Taeniacide an agent that kills tapeworms.

TBARS see thiobarbituric acid reactive substances.

TCA cycle see Tricarboxylic acid cycle**.**

T-cell a type of white blood cell that attacks virus-infected cells, foreign cells and cancer cells.

TCID50 median tissue culture infective dose; that amount of a pathogenic agent that will produce pathological change in 50% of cell cultures.

Telencephalon the cerebral hemispheres, the largest divisions of the human brain.

Telomerase enzyme that acts on parts of chromosomes known as telomeres.

Tendonitis is inflammation of a tendon.

Tenesmus a strong desire to defaecate.

Teratogen is an agent that can cause malformations of an embryo or fetus. *adj*. teratogenic.

Tetanus an acute, potentially fatal disease caused by tetanus bacilli multiplying at the site of an injury and producing an exotoxin that reaches the central nervous system producing prolonged contraction of skeletal muscle fibers. Also called lockjaw.

Testicular torsion twisting of the spermatic cord, which cuts off the blood supply to the testicle and surrounding structures within the scrotum.

Tete acute dermatitis caused by both bacterial and fungal infection

Tetter any of a number of skin diseases.

TGF-beta transforming growth factor beta is a protein that controls proliferation, cellular differentiation, and other functions in most cells.

Th cells or T helper cells a subgroup of lymphocytes that helps other white blood cells in immunologic processes.

Thermogenic tending to produce heat, applied to drugs or food (fat burning food)

Thiobarbituric acid reactive substances (TBARS) a well-established method for screening and monitoring lipid peroxidation.

Thixotropy the property exhibited by certain gels of becoming fluid when stirred or shaken and returning to the semisolid state upon standing**.**

Thrombocythaemia a blood condition characterize by a high number of platelets in the blood.

Thrombocytopenia a condition when the bone marrow does not produce enough platelets (thrombocytes) like in leukaemia.

Thromboembolism formation in a blood vessel of a clot (thrombus) that breaks loose and is carried by the blood stream to plug another vessel.

Thrombogenesis formation of a thrombus or blood clot.

Thrombophlebitis occurs when there is inflammation and clot in a surface vein.

Thromboplastin an enzyme liberated from blood platelets that converts prothrombin into thrombin as blood starts to clot, also called thrombokinase.

Thrombosis the formation or presence of a thrombus (clot).

Thromboxanes any of several compounds, originally derived from prostaglandin precursors in platelets that stimulate aggregation of platelets and constriction of blood vessels.

Thromboxane B2 the inactive product of thromboxane.

Thrombus a fibrinous clot formed in a blood vessel or in a chamber of the heart.

Thrush a common mycotic infection caused by yeast, *Candida albicans*, in the digestive tract or vagina. In children it is characterized by white spots on the tongue.

Thymocytes are T cell precursors which develop in the thymus.

Thyrotoxicosis or hyperthyroidism – an overactive thyroid gland, producing excessive circulating free thyroxine and free triiodothyronine, or both.

TIMP-3 a human gene belongs to the tissue inhibitor of matrix metalloproteinases (MMP) gene family. see MMP.

Tincture solution of a drug in alcohol.

Tinea ringworm, fungal infection on the skin.

Tinea favosa See favus.

Tinnitus a noise in the ears, as ringing, buzzing, roaring, clicking, etc.

Tisane a herbal infusion used as tea or for medicinal purposes.

Tissue plasminogen activator a serine protease involved in the breakdown of blood clots.

TNF alpha cachexin or cachectin and formally known as tumour necrosis factor-alpha, a cytokine involved in systemic inflammation. primary role of TNF is in the regulation of immune cells. TNF is also able to induce apoptotic cell death, to induce inflammation, and to inhibit tumourigenesis and viral replication.

Tocolytics medications used to suppress premature labor.

Tocopherol fat soluble organic compounds belonging to vitamin E group**.** See vitamin E.

Tocotrienol fat soluble organic compounds belonging to vitamin E group**.** See vitamin E.

Toll-like receptors (TLRs) a class of proteins that play a key role in the innate immune system.

Tonic substance that acts to restore, balance, tone, strengthen, or invigorate a body system without overt stimulation or depression

Tonic clonic seizure a type of generalized seizure that affects the entire brain.

Tonsillitis an inflammatory condition of the tonsils due to bacteria, allergies or respiratory problems.

Topoisomerases a class of enzymes involved in the regulation of DNA supercoiling.

Topoiosmerase inhibitors a new class of anticancer agents with a mechanism of action aimed at interrupting DNA replication in cancer cells.

Total parenteral nutrition (TPN) is a method of feeding that bypasses the gastrointestinal tract.

Toxemia is the presence of abnormal substances in the blood, but the term is also used for a serious condition in pregnancy that involves hypertension and proteinuria. Also called pre-eclampsia.

Tracheitis is a bacterial infection of the trachea; also known as bacterial tracheitis or acute bacterial tracheitis.

Trachoma a contagious disease of the conjunctiva and cornea of the eye, producing painful sensitivity to strong light and excessive tearing.

TRAIL acronym for tumour necrosis factor-related apoptosis-inducing ligand, is a cytokine that preferentially induces apoptosis in tumour cells.

Tranquilizer a substance drug used in calming person suffering from nervous tension or anxiety.

Transaminase also called aminotransferase is an enzyme that catalyzes a type of reaction between an amino acid and an α-keto acid.

Transaminitis increase in alanine aminotransferase (ALT) and/or aspartate aminotransferase (AST) to >5 times the upper limit of normal.

Transcatheter arterial chemoembolization (TACE) is an interventional radiology procedure involving percutaneous access of to the hepatic artery and passing a catheter through the abdominal artery aorta followed by radiology. It is used extensively in the palliative treatment of unresectable hepatocellular carcinoma (HCC)

Transcriptional activators are proteins that bind to DNA and stimulate transcription of nearby genes.

Transcriptional coactivator PGC-1 a potent transcriptional coactivator that regulates oxidative metabolism in a variety of tissues.

Transcriptome profiling to identify genes involved in peroxisome assembly and function.

Transforming growth factor beta (TGF-β) a protein that controls proliferation, cellular differentiation, and other functions in most cells.

TRAP 6 thrombin receptor activating peptide with 6 amino acids.

Tremorine a chemical that produces a tremor resembling Parkinsonian tremor.

Tremulous marked by trembling, quivering or shaking.

Triacylglycerols or triacylglyceride, is a glyceride in which the glycerol is esterified with three fatty acids.

Tricarboxylic acid cycle (TCA cycle) a series of enzymatic reactions in aerobic organisms involving oxidative metabolism of acetyl units and producing high-energy phosphate compounds, which serve as the main source of cellular energy. Also called citric acid cycle, Krebs cycle.

Trichophytosis infection by fungi of the genus *Trichophyto*n.

Trigeminal neuralgia (TN) is a neuropathic disorder of one or both of the facial trigeminal nerves, also known as prosopalgia.

Triglycerides a type of fat (lipids) found in the blood stream.

Trismus continuous contraction of the muscles of the jaw, specifically as a symptom of tetanus, or lockjaw; inability to open mouth fully.

TrKB receptor also known as TrKB tyrosine kinase, a protein in humans that acts as a catalytic receptor for several neutrophins.

Trolox Equivalent measures the antioxidant capacity of a given substance, as compared to the standard, Trolox also referred to as TEAC (Trolox equivalent antioxidant capacity).

Trypanocidal destructive to trypanosomes.

Trypanosomes protozoan of the genus *Trypanosoma.*

Trypanosomiasis human disease or an infection caused by a trypanosome.

Trypsin an enzyme of pancreatic juice that hydrolyzes proteins into smaller polypeptide units.

Trypsin inhibitor small protein synthesized in the exocrine pancreas which prevents conversion of trypsinogen to trypsin, so protecting itself against trypsin digestion.

Tuberculosis (TB) is a bacterial infection of the lungs caused by a bacterium called *Mycobacterium tuberculosis,* characterized by the formation of lesions (tubercles) and necrosis in the lung tissues and other organs.

Tumourigenesis formation or production of tumours**.**

Tumour an abnormal swelling of the body other than those caused by direct injury.

Tussis a cough.

Tympanic membrane ear drum.

Tympanitis infection or inflammation of the inner ear.

Tympanophonia increased resonance of one's own voice, breath sounds, arterial murmurs, etc., noted especially in disease of the middle ear.

Tympanosclerosis see myringoslcerosis.

Tyrosinase a copper containing enzyme found in animals and plants that catalyses the oxidation of phenols (such as tyrosine) and the production of melanin and other pigments from tyrosine by oxidation.

UCP1 an uncoupling protein found in the mitochondria of brown adipose tissue used to generate heat by non-shivering thermogenesis**.**

UCP – 2 enzyme uncoupling protein 2 enzyme, a mitochondrial protein expressed in adipocytes.

Ulcer an open sore on an external or internal body surface usually accompanied by disintegration of tissue and pus.

Ulcerative colitis is one of two types of inflammatory bowel disease – a condition that causes the bowel to become inflamed and red.

Ulemorrhagia bleeding of the gums.

Ulitis inflammation of the gums.

Unguent ointment.

Unilateral ureteral obstruction unilateral blockage of urine flow through the ureter of one kidney, resulting in a backup of urine, distension of the renal pelvis and calyces, and hydronephrosis.

Uraemia an excess in the blood of urea, creatinine and other nitrogenous end products of protein and amino acids metabolism, more correctly referred to as azotaemia.

Uraemic of or involving excess nitrogenous waste products in the urine (usually due to kidney insufficiency).

Urethra tube conveying urine from the bladder to the external urethral orifice.

Urethritis is an inflammation of the urethra caused by infection.

Urinary pertaining to the passage of urine.

Urinogenital relating to the genital and urinary organs or functions.

Urodynia pain on urination.

Urokinase a serine protease enzyme in human urine that catalyzes the conversion of plasminogen to plasmin.

Urolithiasis formation of stone in the urinary tract (kidney bladder or urethra).

Urticant a substance that causes wheals to form.

Urticaria (or hives) is a skin condition, commonly caused by an allergic reaction, that is characterized by raised red skin welts.

Uterine relating to the uterus.

Uterine relaxant an agent that relaxes the muscles in the uterus.

Uterine stimulant an agent that stimulates the uterus (and often employed during active childbirth).

Uterotonic giving muscular tone to the uterus.

Uterotrophic causing an effect on the uterus.

Uterus womb.

Vagotomy the surgical cutting of the vagus nerve to reduce acid secretion in the stomach.

Vagus nerve a cranial nerve, that is, a nerve connected to the brain. The vagus nerve has branches to most of the major organs in the body, including the larynx, throat, windpipe, lungs, heart, and most of the digestive system

Variola or smallpox, a contagious disease unique to humans, caused by either of two virus variants, *Variola major* and *Variola minor.* The disease is characterised by fever, weakness and skin eruption with pustules that form scabs that leave scars.

Varicose veins are veins that have become enlarged and twisted.

Vasa vasorum is a network of small blood vessels that supply large blood vessels. *plur.* vasa vasori.

Vascular endothelial growth factor (VEGF) a polypeptide chemical produced by cells that stimulates the growth of new blood vessels.

Vasculogenesis the process of blood vessel formation occurring by a de novo production of endothelial cells.

Vasoconstrictor drug that causes constriction of blood vessels.

Vasodilator drug that causes dilation or relaxation of blood vessels.

Vasodilatory causing the widening of the lumen of blood vessels.

Vasomotor symptoms menopausal symptoms characterised by hot flushes and night sweats.

Vasospasm refers to a condition in which blood vessels spasm, leading to vasoconstriction and subsequently to tissue ischemia and death (necrosis).

Vasculogenesis process of blood vessel formation occurring by a de novo production of endothelial cells.

VCAM-1 (vascular cell adhesion molecule-1) also known as CD106, contains six or seven immunoglobulin domains and is expressed on both large and small vessels only after the endothelial cells are stimulated by cytokines.

VEGF Vascular endothelial growth factor.

Venereal disease (VD) term given to the diseases syphilis and gonorrhoea.

Venule a small vein, especially one joining capillaries to larger veins.

Vermifuge a substance used to expel worms from the intestines.

Verotoxin a Shiga-like toxin produced by *Escherichia coli,* which disrupts the function of ribosomes, causing acute renal failure.

Verruca plana is a reddish-brown or flesh-colored, slightly raised, flat-surfaced, well-demarcated papule on the hand and face, also called flat wart.

Vertigo an illusory, sensory perception that the surroundings or one's own body are revolving; dizziness.

Very-low-density lipoprotein (VLDL) a type of lipoprotein made by the liver. VLDL is one of the five major groups of lipoproteins (chylomicrons, VLDL, intermediate-density lipoprotein, low-density lipoprotein, high-density lipoprotein (HDL)) that enable fats and cholesterol to move within the water-based solution of the bloodstream. VLDL is converted in the bloodstream to low-density lipoprotein (LDL).

Vesical calculus calculi (stones) in the urinary bladder

Vesicant a substance that causes tissue blistering.

Vestibular relating to the sense of balance.

Vestibular disorders includes symptoms of dizziness, vertigo, and imbalance; it can be result from or worsened by genetic or environmental conditions.

Vestibular system includes parts of the inner ear and brain that process sensory information involved with controlling balance and eye movement.

Vibrissa stiff hairs that are located especially about the nostrils.

Viremia a medical condition where viruses enter the bloodstream and hence have access to the rest of the body.

Visceral fat intra-abdominal fat, is located inside the peritoneal cavity, packed in between internal organs and torso.

Vitamin any complex, organic compound, found in various food or sometimes synthesized in the body, required in tiny amounts and are essential for the regulation of metabolism, normal growth and function of the body.

Vitamin A retinol, fat-soluble vitamins that play an important role in vision, bone growth, reproduction, cell division, and cell differentiation, helps regulate the immune system in preventing or fighting off infections. Vitamin A that is found in colorful fruits and vegetables is called provitamin A carotenoid. They can be made into retinol in the body. Deficiency of vitamin A results in night blindness and keratomalacia.

Vitamin B1 also called thiamine, water-soluble vitamins, dissolve easily in water, and in general, are readily excreted from the body they are not readily stored, consistent daily intake is important. It functions as coenzyme in the metabolism of carbohydrates and branched chain amino acids, and other cellular processes. Deficiency results in beri-beri disease.

Vitamin B2 also called riboflavin, an essential water-soluble vitamin that functions as coenzyme in redox reactions. Deficiency causes ariboflavinosis.

Vitamin B3 comprises niacin and niacinamide, water-soluble vitamin that function as coenzyme or co-substrate for many redox reactions and is required for energy metabolism. Deficiency causes pellagra.

Vitamin B5 also called pantothenic acid, a water-soluble vitamin that function as coenzyme in fatty acid metabolism. Deficiency causes paresthesia.

Vitamin B6 water-soluble vitamin, exists in three major chemical forms: pyridoxine, pyridoxal, and pyridoxamine. Vitamin B6 is needed in enzymes involved in protein metabolism, red blood cell metabolism, efficient functioning of nervous and immune systems and hemoglobin formation. Deficiency causes anaemia and peripheral neuropathy.

Vitamin B 7 also called biotin or vitamin H, an essential water-soluble vitamin, is involved in the synthesis of fatty acids amino acids and glucose, in energy metabolism. Biotin

promotes normal health of sweat glands, bone marrow, male gonads, blood cells, nerve tissue, skin and hair, Deficiency causes dermatitis and enteritis.

Vitamin B9 also called folic acid, an essential water-soluble vitamin. Folate is especially important during periods of rapid cell division and growth such as infancy and pregnancy. Deficiency during pregnancy is associated with birth defects such as neural tube defects. Folate is also important for production of red blood cells and prevent anemia. Folate is needed to make DNA and RNA, the building blocks of cells. It also helps prevent changes to DNA that may lead to cancer.

Vitamin B12 a water-soluble vitamin, also called cobalamin as it contains the metal cobalt. It helps maintain healthy nerve cells and red blood cells, and DNA production. Vitamin B12 is bound to the protein in food. Deficiency causes megaloblastic anaemia.

Vitamin C also known as ascorbic acid is an essential water-soluble vitamin. It functions as cofactor for reactions requiring reduced copper or iron metallonzyme and as a protective antioxidant. Deficiency of vitamin C causes scurvy.

Vitamin D a group of fat-soluble, prohormone vitamin, the two major forms of which are vitamin D2 (or ergocalciferol) and vitamin D3 (or cholecalciferol). Vitamin D obtained from sun exposure, food, and supplements is biologically inert and must undergo two hydroxylations in the body for activation. Vitamin D is essential for promoting calcium absorption in the gut and maintaining adequate serum calcium and phosphate concentrations to enable normal growth and mineralization of bone and prevent hypocalcemic tetany. Deficiency causes rickets and osteomalacia. Vitamin D has other roles in human health, including modulation of neuromuscular and immune function, reduction of inflammation and modulation of many genes encoding proteins that regulate cell proliferation, differentiation, and apoptosis.

Vitamin E is the collective name for a group of fat-soluble compounds and exists in eight chemical forms (alpha-, beta-, gamma-, and delta-tocopherol and alpha-, beta-, gamma-, and delta-tocotrienol). It has pronounced antioxidant activities stopping the formation of Reactive Oxygen Species when fat undergoes oxidation and help prevent or delay the chronic diseases associated with free radicals. Besides its antioxidant activities, vitamin E is involved in immune function, cell signaling, regulation of gene expression, and other metabolic processes. Deficiency is very rare but can cause mild hemolytic anemia in newborn infants.

Vitamin K a group of fat soluble vitamin and consist of vitamin K_1 which is also known as phylloquinone or phytomenadione (also called phytonadione) and vitamin K_2 (menaquinone, menatetrenone). Vitamin K plays an important role in blood clotting. Deficiency is very rare but can cause bleeding diathesis.

Vitamin P a substance or mixture of substances obtained from various plant sources, identified as citrin or a mixture of bioflavonoids, thought to but not proven to be useful in reducing the extent of hemorrhage.

Vitiligo a chronic skin disease that causes loss of pigment, resulting in irregular pale patches of skin. It occurs when the melanocytes, cells responsible for skin pigmentation, die or are unable to function**.** Also called leucoderma.

Vitreoretinopathy see proliferative vitreoretinopathy.

VLDL see very low density lipoproteins.

Vomitive substance that causes vomiting.

Vulnerary (wound healer), a substance used to heal wounds and promote tissue formation.

Wart an infectious skin tumour caused by a viral infection.

Welt see wheal.

Wheal a firm, elevated swelling of the skin. Also called a weal or welt.

White Fat White adipose tissue (WAT) in mammals, store of energy . cf. brown fat.

Whitlow painful infection of the hand involving one or more fingers that typically affects the terminal phalanx.

Whooping cough acute infectious disease usually in children caused by a *Bacillus* bacterium

and accompanied by catarrh of the respiratory passages and repeated bouts of coughing.

Wnt signaling pathway is a network of proteins involved in embryogenesis and cancer, and also in normal physiological processes.

X-linked agammaglobulinemia also known as X-linked hypogammaglobulinemia, XLA, Bruton type agammaglobulinemia, Bruton syndrome, or sex-linked agammaglobulinemia; a rare x-linked genetic disorder that affects the body's ability to fight infection.

Xanthine oxidase A flavoprotein enzyme containing a molybdenum cofactor (Moco) and (Fe_2S_2) clusters, involved in purine metabolism. In humans, inhibition of xanthine oxidase reduces the production of uric acid, and prevent hyperuricemia and gout.

Xanthones Unique class of biologically active phenol compounds with the molecular formula $C1_3H_8O_2$ possessing antioxidant properties, discovered in the mangosteen fruit.

Xenobiotics a chemical (as a drug, pesticide, or carcinogen) that is foreign to a living organism.

Xenograft a surgical graft of tissue from one species to an unlike species.

Xerophthalmia a medical condition in which the eye fails to produce tears.

Yaws an infectious tropical infection of the skin, bones and joints caused by the spirochete bacterium *Treponema pertenue,* characterized by papules and pappiloma with subsequent deformation of the skins, bone and joints; also called framboesia.

Yellow fever is a viral disease that is transmitted to humans through the bite of infected mosquitoes. Illness ranges in severity from an influenza-like syndrome to severe hepatitis and hemorrhagic fever. Yellow fever virus (YFV) is maintained in nature by mosquito-borne transmission between nonhuman primates.

Zeaxanthin a common carotenoid, found naturally as coloured pigments in many fruit vegetables and leafy vegetables. It is important for good vision and is one of the two carotenoids contained within the retina of the eye. Within the central macula, zeaxanthin predominates, whereas in the peripheral retina, lutein predominates.

Zinc (Zn) is an essential mineral for health. It is involved in numerous aspects of cellular metabolism: catalytic activity of enzymes, immune function, protein synthesis, wound healing, DNA synthesis, and cell division. It also supports normal growth and development during pregnancy, childhood, and adolescence and is required for proper sense of taste and smell. Dietary sources include beans, nuts, pumpkin seeds, sunflower seeds, whole wheat bread and animal sources.

Scientific Glossary

Abaxial facing away from the axis, as of the surface of an organ.

Abscission shedding of leaves, flowers, or fruits following the formation of the abscission zone.

Acaulescent lacking a stem, or stem very much reduced.

Accrescent increasing in size after flowering or with age.

Achene a dry, small, one-seeded, indehiscent one-seeded fruit formed from a superior ovary of one carpel as in sunflower.

Acid soil soil that maintains a pH of less than 7.0.

Acidulous acid or sour in taste.

Actinomorphic having radial symmetry, capable of being divided into symmetrical halves by any plane, refers to a flower, calyx or corolla.

Aculeate having sharp prickles.

Acuminate tapering gradually to a sharp point.

Acute (Botany) tapering at an angle of less than 90° before terminating in a point as of leaf apex and base.

Adaxial side closest to the stem axis.

Aldephous having stamens united together by their filaments.

Adherent touching without organic fusion as of floral parts of different whorls.

Adnate united with another unlike part as of stamens attached to petals.

Adpressed lying close to another organ but not fused to it.

Adventive Not native to and not fully established in a new habitat or environment; locally or temporarily naturalized. e.g. an adventive weed.

Adventitious arising in abnormal positions, e.g. roots arising from the stem, branches or leaves, buds arising elsewhere than in the axils of leaves

Aestivation refers to positional arrangement of the floral parts in the bud before it opens.

Akinete a thick-walled dormant cell derived from the enlargement of a vegetative cell. It serves as a survival structure.

Alfisols have a clay-enriched subsoil and relatively high native fertility, having undergone only moderate leaching, containing aluminium, iron and with at least 35% base saturation, meaning that calcium, magnesium, and potassium are relatively abundant.

Alkaline soil soil that maintains a pH above 7.0, usually containing large amounts of calcium, sodium, and magnesium, and is less soluble than acidic soils.

Alkaloids naturally occurring bitter, complex organic-chemical compounds containing basic nitrogen and oxygen atoms and having various pharmacological effects on humans and other animals.

Alternate leaves or buds that are spaced along opposite sides of stem at different levels.

Allomorphic with a shape or form different from the typical.

Alluvium soil or sediments deposited by a river or other running water.

Alluvial soil a fine-grained fertile soil deposited by water flowing over flood plains or in river beds.

Amplexicaul clasping the stem as base of certain leaves.

Anatomizing interconnecting network as applied to leaf veins.

Andisols are soils formed in volcanic ash and containing high proportions of glass and amorphous colloidal materials.

Androdioecious with male flowers and bisexual flowers on separate plants.

Androecium male parts of a flower; comprising the stamens of one flower.

Androgynous with male and female flowers in distinct parts of the same inflorescence.

Andromonoecious having male flowers and bisexual flowers on the same plant.

Angiosperm a division of seed plants with the ovules borne in an ovary.

Annual a plant which completes its life cycle within a year.

Annular shaped like or forming a ring.

Annulus circle or ring-like structure or marking; the portion of the corolla which forms a fleshy, raised ring.

Anther the part of the stamen containing pollen sac which produces the pollen.

Anthelate an open, paniculate cyme.

Antheriferous containing anthers.

Anthesis the period between the opening of the bud and the onset of flower withering.

Anthocarp a false fruit consisting of the true fruit and the base of the perianth.

Anthocyanidins are common plant pigments. They are the sugar-free counterparts of anthocyanins.

Anthocyanins a subgroup of antioxidant flavonoids, are glucosides of anthocyanidins. They occur as water-soluble vacuolar pigments that may appear red, purple, or blue according to pH in plants.

Antipetala situated opposite petals.

Antisepala situated opposite sepals.

Antrorse directed forward upwards.

Apetalous lacking petals as of flowers with no corolla.

Apical meristem active growing point. A zone of cell division at the tip of the stem or the root.

Apically towards the apex or tip of a structure.

Apiculate ending abruptly in a short, sharp, small point.

Apiculum a short, pointed, flexible tip.

Apocarpous carpels separate in single individual pistils.

Apopetalous with separate petals, not united to other petals.

Aposepalous with separate sepals, not united to other sepals.

Appressed pressed closely to another structure but not fused or united.

Aquatic a plant living in or on water for all or a considerable part of its life span.

Arachnoid (Botany) formed of or covered with long, delicate hairs or fibers.

Arborescent resembling a tree; applied to non-woody plants attaining tree height and to shrubs tending to become tree-like in size.

Arbuscular mycorrhiza (AM) a type of mycorrhiza in which the fungus (of the phylum Glomeromycota) penetrates the cortical cells of the roots of a vascular plant and form unique structures such as arbuscules and vesicles. These fungi help plants to capture nutrients such as phosphorus and micronutrients from the soil.

Archegonium a flask-shaped female reproductive organ in mosses, ferns, and other related plants.

Areole (Botany) a small, specialized, cushion-like area on a cactus from which hairs, glochids, spines, branches, or flowers may arise; an irregular angular specs marked out on a surface e.g. fruit surface. *pl.* areolea.

Areolate with areolea.

Aril specialized outgrowth from the funiculus (attachment point of the seed) (or hilum) that encloses or is attached to the seed. *adj.* arillate.

Arillode a false aril; an aril originating from the micropyle instead of from the funicle or chalaza of the ovule, e.g. mace of nutmeg.

Aristate bristle-like part or appendage, e.g. awns of grains and grasses.

Aristulate having a small, stiff, bristle-like part or appendage; a diminutive of aristate

Articulate jointed; usually breaking easily at the nodes or point of articulation into segments.

Ascending arched upwards in the lower part and becoming erect in the upper part.

Ascus is the sexual spore-bearing cell produced in Ascomycete fungi. *pl.* asci.

Ascospore spore produced in the ascus in Ascomycete fungi.

Asperulous refers to a rough surface with short, hard projections.

Attenuate tapered or tapering gradually to a point.

Auricle an ear-like appendage that occurs at the base of some leaves or corolla.

Auriculate having auricles.

Awn a hair-like or bristle-like appendage on a larger structure.

Axil upper angle between a lateral organ, such as a leaf petiole and the stem that bears it.

Axile situated along the central axis of an ovary having two or more locules, as in axile placentation.

Axillary arising or growing in an axil.

Baccate beery-like, pulpy or fleshy.

Barbate bearded, having tufts of hairs.

Barbellae short, stiff, hair-like bristles. *adj*. barbellate.

Bark is the outermost layers of stems and roots of woody plants.

Basal relating to, situated at, arising from or forming the base.

Basaltic soil soil derived from basalt, a common extrusive volcanic rock.

Basidiospore a reproductive spore produced by Basidiomycete fungi.

Basidium a microscopic, spore-producing structure found on the hymenophore of fruiting bodies of Basidiomycete fungi.

Basifixed attached by the base, as certain anthers are to their filaments.

Basionym the synonym of a scientific name that supplies the epithet for the correct name.

Beak a prominent apical projection, especially of a carpel or fruit. *adj*. beaked.

Bearded having a tuft of hairs.

Berry a fleshy or pulpy indehiscent fruit from a single ovary with the seed(s) embedded in the fleshy tissue of the pericarp.

Biconvex convex on both sides.

Biennial completing the full cycle from germination to fruiting in more than one, but not more than 2 years.

Bifid forked, divided into two parts.

Bifoliolate having two leaflets.

Bilabiate having two lips as of a corolla or calyx with segments fused into an upper and lower lip.

Bipinnate twice pinnate; the primary leaflets being again divided into secondary leaflets.

Bipinnatisect refers to a pinnately compound leaf, in which each leaflet is again divided into pinnae.

Biserrate doubly serrate; with smaller regular, asymmetric teeth on the margins of larger teeth.

Bisexual having both sexes, as in a flower bearing both stamens and pistil, hermaphrodite or perfect.

Biternate Twice ternate; with three pinnae each divided into three pinnules.

Blade lamina; part of the leaf above the sheath or petiole.

Blotched see variegated.

Bole main trunk of tree from the base to the first branch.

Brachyblast a short, axillary, densely crowded branchlet or shoot of limited growth, in which the internodes elongate little or not at all.

Bracket fungus shelf fungus.

Bract a leaf-like structure, different in form from the foliage leaves, associated with an inflorescence or flower. *adj*. bracteate.

Bracteate possessing bracts.

Bracteolate having bracteoles.

Bracteole a small, secondary, bract-like structure borne singly or in a pair on the pedicel or calyx of a flower. *adj*. bracteolate.

Bristle a stiff hair.

Bulb a modified underground axis that is short and crowned by a mass of usually fleshy, imbricate scales. *adj*. bulbous.

Bulbil A small bulb or bulb-shaped body, especially one borne in the leaf axil or an inflorescence, and usually produced for asexual reproduction.

Bullate puckered, blistered.

Burr type of seed or fruit with short, stiff bristles or hooks or may refer to a deformed type of wood in which the grain has been misformed.

Bush low, dense shrub without a pronounced trunk.

Buttress supporting, projecting outgrowth from base of a tree trunk as in some Rhizophoraceae and Moraceae.

Caducous shedding or falling early before maturity refers to sepals and petals.

Caespitose growing densely in tufts or clumps; having short, closely packed stems.

Calcareous composed of or containing lime or limestone.

Calcrete a hardpan consisting gravel and sand cemented by calcium.

Callus a condition of thickened raised mass of hardened tissue on leaves or other plant parts often formed after an injury but sometimes a normal feature. A callus also can refer to an undifferentiated plant cell mass grown on a culture medium. *n.* callosity**.** *pl.* calli, callosities. *adj.* callose.

Calyptra the protective cap or hood covering the spore case of a moss or related plant.

Calyptrate operculate, having a calyptra.

Calyx outer floral whorl usually consisting of free sepals or fused sepals (calyx tube) and calyx lobes. It encloses the flower while it is still a bud. *adj.* calycine.

Calyx lobe one of the free upper parts of the calyx which may be present when the lower part is united into a tube.

Calyx tube the tubular fused part of the calyx, often cup shaped or bell shaped, when it is free from the corolla.

Campanulate shaped like a bell refers to calyx or corolla.

Canaliculate having groove or grooves.

Candelabriform having the shape of a tall branched candle-stick.

Canescent covered with short, fine whitish or grayish hairs or down.

Canopy uppermost leafy stratum of a tree.

Cap see pileus.

Capitate growing together in a head. Also means enlarged and globular at the tip.

Capitulum a flower head or inflorescence having a dense cluster of sessile, or almost sessile, flowers or florets.

Capsule a dry, dehiscent fruit formed from two or more united carpels and dehiscing at maturity by sections called valves to release the seeds. *adj.* capsular.

Carinate keeled.

Carpel a simple pistil consisting of ovary, ovules, style and stigma. *adj.* carpellary.

Carpogonium female reproductive organ in red algae. *pl.* carpogonia.

Carpophore part of the receptacle which is lengthened between the carpels as a central axis; any fruiting body or fruiting structure of a fungus.

Cartilaginous sinewy, having a firm, tough, flexible texture (in respect of leaf margins).

Caryopsis a simple dry, indehiscent fruit formed from a single ovary with the seed coat united with the ovary wall as in grasses and cereals.

Cataphyll a reduced or scarcely developed leaf at the start of a plant's life (i.e., cotyledons) or in the early stages of leaf development.

Catkin a slim, cylindrical, pendulous flower spike usually with unisexual flowers.

Caudate having a narrow, tail-like appendage.

Caudex thickened, usually underground base of the stem.

Caulescent having a well developed aerial stem.

Cauliflory botanical term referring to plants which flower and fruit from their main stems or woody trunks. *adj.* cauliflorus.

Cauline borne on the aerial part of a stem.

Chaffy having thin, membranous scales in the inflorescence as in the flower heads of the sunflower family.

Chalaza the basal region of the ovule where the stalk is attached.

Chartaceous papery, of paper-like texture.

Chasmogamous describing flowers in which pollination takes place while the flower is open.

Chloroplast a chlorophyll-containing organelle (plastid) that gives the green colour to leaves and stems. Plastids harness light energy that is used to fix carbon dioxide in the process called photosynthesis.

Chromoplast plastid containing colored pigments apart from chlorophyll.

Chromosomes thread-shaped structures that occur in pairs in the nucleus of a cell, containing the genetic information of living organisms.

Cilia hairs along the margin of a leaf or corolla lobe.

Ciliate with a fringe of hairs on the margin as of the corolla lobes or leaf.

Ciliolate minutely ciliate.

Cilium a straight, usually erect hair on a margin or ridge. *pl.* cilia.

Cincinnus a monochasial cyme in which the lateral branches arise alternately on opposite sides of the false axis.

Circinnate spirally coiled, with the tip innermost.

Circumscissile opening by a transverse line around the circumference as of a fruit.

Cladode the modified photosynthetic stem of a plant whose foliage leaves are much reduced or absent. *cf.* cladophyll, phyllode.

Cladophyll A photosynthetic branch or portion of a stem that resembles and functions as a leaf, like in asparagus. *cf.* cladode, phyllode.

Clamp connection In the Basidiomycetes fungi, a lateral connection or outgrowth formed between two adjoining cells of a hypha and arching over the septum between them.

Clavate club shaped thickened at one end refer to fruit or other organs.

Claw the conspicuously narrowed basal part of a flat structure.

Clay a naturally occurring material composed primarily of fine-grained minerals like kaolinite, montmorrillonite-smectite or illite which exhibit plasticity through a variable range of water content, and which can be hardened when dried and/or fired.

Clayey resembling or containing a large proportion of clay.

Cleft incised halfway down.

Cleistogamous refers to a flower in which fertilization occurs within the bud i.e. without the flower opening. *cf.* chasmogamous.

Climber growing more or less upwards by leaning or twining around another structure.

Clone all the plants reproduced, vegetatively, from a single parent thus having the same genetic make-up as the parent.

Coccus one of the sections of a distinctly lobed fruit which becomes separate at maturity; sometimes called a mericarp. *pl.* cocci.

Coenocarpium a fleshy, multiple pseudocarp formed from an inflorescence rather than a single flower.

Coherent touching without organic fusion, referring to parts normally together, e.g. floral parts of the same whorl. *cf.* adherent, adnate, connate.

Collar boundary between the above and below ground parts of the plant axis.

Colliculate having small elevations.

Column a structure formed by the united style, stigma and stamen(s) as in Asclepiadaceae and Orchidaceae.

Comose tufted with hairs at the ends as of seeds.

Composite having two types of florets as of the flowers in the sunflower family, Asteraceae.

Compost organic matter (like leaves, mulch, manure, etc.) that breaks down in soil releasing its nutrients.

Compound describe a leaf that is further divided into leaflets or pinnae or flower with more than a single floret.

Compressed flattened in one plane.

Conceptacles specialised cavities of marine algae that contain the reproductive organs.

Concolorous uniformly coloured, as in upper and lower surfaces. *cf.* discolorous

Conduplicate folded together lengthwise.

Cone a reproductive structure composed of an axis (branch) bearing sterile bract-like organs and seed or pollen bearing structures. Applied to Gymnospermae, Lycopodiaceae, Casuarinaceae and also in some members of Proteaceae.

Conic cone shaped, attached at the broader end.

Conic-capitate a cone-shaped head of flowers.

Connate fused to another structure of the same kind. *cf.* adherent, adnate, coherent.

Connective the tissue separating two lobes of an anther.

Connivent converging.

Conspecific within or belonging to the same species.

Contorted twisted.

Convolute refers to an arrangement of petals in a bud where each has one side overlapping the adjacent petal.

Cordate heart-shaped as of leaves.

Core central part.

Coriaceous leathery texture as of leaves.

Corm a short, swollen, fleshy, underground plant stem that serves as a food storage organ

used by some plants to survive winter or other adverse conditions

Cormel a miniature, new corm produced on a mature corm.

Corolla the inner floral whorl of a flower, usually consisting of free petals or a petals fused forming a corolla tube and corolla lobes. *adj.* corolline.

Corona a crown-like section of the staminal column, usually with the inner and outer lobes as in the **Stapelieae**.

Coroniform crown shaped, as in the pappus of Asteraceae.

Cortex the outer of the stem or root of a plant, bounded on the outside by the epidermis and on the inside by the endodermis containing undifferentiated cells.

Corymb a flat-topped, short, broad inflorescence, in which the flowers, through unequal pedicels, are in one horizontal plane and the youngest in the centre. *adj.* corymbose

Costa a thickened, linear ridge or the midrib of the pinna in ferns. *adj.* costate.

Costapalmate having definite costa (midrib) unlike the typical palmate leaf, but the leaflets are arranged radially like in a palmate leaf.

Cotyledon the primary seed leaf within the embryo of a seed.

Cover crop crop grown in between trees or in fields primarily to protect the soil from erosion, to improve soil fertility and to keep off weeds.

Crenate round-toothed or scalloped as of leaf margins.

Crenulate minutely crenate, very strongly scalloped.

Crisped with a curled or twisted edge.

Cristate having or forming a crest or crista.

Crozier shaped like a shepherd's crook.

Crustaceous like a crust; having a hard crust or shell.

Cucullate having the shape of a cowl or hood, hooded.

Culm the main aerial stem of the Graminae (grasses, sedges, rushes and other monocots).

Culm sheath the plant casing (similar to a leaf) that protects the young bamboo shoot during growth, attached at each node of culm.

Cultigen plant species or race known only in cultivation.

Cultivar cultivated variety; an assemblage of cultivated individuals distinguished by any characters significant for the purposes of agriculture, forestry or horticulture, and which, when reproduced, retains its distinguishing features.

Cuneate wedge-shaped, obtriangular.

Cupular cup-shaped, having a cupule.

Cupule a small cup-shaped structure or organ, like the cup at the base of an acorn.

Cusp an elongated, usually rigid, acute point. *cf.* mucro.

Cuspidate terminating in or tipped with a sharp firm point or cusp. *cf.* mucronate.

Cuspidulate constricted into a minute cusp. *cf.* cuspidate.

Cyathiform in the form of a cup, a little widened at the top.

Cyathium a specialised type of inflorescence of plants in the genus Euphorbia and Chamaesyce in which the unisexual flowers are clustered together within a bract-like envelope. *pl.* cyathia.

Cylindric tubular or rod shaped.

Cylindric-acuminate elongated and tapering to a point.

Cymbiform boat shaped, elongated and having the upper surface decidedly concave.

Cyme an inflorescence in which the lateral axis grows more strongly than the main axis with the oldest flower in the centre or at the ends. *adj.* cymose

Cymule a small cyme or one or a few flowers.

Cystidium a relatively large cell found on the hymenium of a Basidiomycete, for example, on the surface of a mushroom.

Cystocarp fruitlike structure (sporocarp) developed after fertilization in the red algae.

Deciduous falling off or shedding at maturity or a specific season or stage of growth.

Decorticate to remove the bark, rind or husk from an organ; to strip of its bark; to come off as a skin.

Decompound as of a compound leaf; consisting of divisions that are themselves compound.

Decumbent prostrate, laying or growing on the ground but with ascending tips. *cf.* ascending, procumbent.

Decurrent having the leaf base tapering down to a narrow wing that extends to the stem.

Decussate having paired organs with successive pairs at right angles to give four rows as of leaves.

Deflexed bent downwards.

Dehisce to split open at maturity, as in a capsule.

Dehiscent splitting open at maturity to release the contents. *cf.* indehiscent.

Deltate triangular shape.

Deltoid shaped like an equilateral triangle.

Dendritic branching from a main stem or axis like the branches of a tree.

Dentate with sharp, rather coarse teeth perpendicular to the margin.

Denticulate finely toothed.

Diageotropic the tendency of growing parts, such as roots, to grow at right angle to the line of gravity.

Diadelphous having stamens in two bundles as in Papilionaceae flowers.

Dichasium a cymose inflorescence in which the branches are opposite and approximately equal. *pl.* dichasia. *adj.* dichasial.

Dichotomous divided into two parts.

Dicotyledon angiosperm with two cotyledons.

Didymous arranged or occurring in pairs as of anthers, having two lobes.

Digitate having digits or fingerlike projections.

Dikaryophyses or dendrophydia, irregularly, strongly branched terminal hyphae in the Hymenomycetes (class of Basidiomycetes) fungi.

Dimorphic having or occurring in two forms, as of stamens of two different lengths or a plant having two kinds of leaves.

Dioecious with male and female unisexual flowers on separate plants. *cf.* monoecious.

Diploid a condition in which the chromosomes in the nucleus of a cell exist as pairs, one set being derived from the female parent and the other from the male.

Diplobiontic life cycle life cycle that exhibits alternation of generations, which features of spore-producing multicellular sporophytes and gamete-producing multicellular gametophytes. mitoses occur in both the diploid and haploid phases.

Diplontic life cycle or gametic meiosis, wherein instead of immediately dividing meiotically to produce haploid cells, the zygote divides mitotically to produce a multicellular diploid individual or a group of more diploid cells.

Dipterocarpous trees of the family Dipterocarpaceae, with two-winged fruit found mainly in tropical lowland rainforest.

Disc (Botany) refers to the usually disc shaped receptacle of the flower head in Asteraceae; also the fleshy nectariferous organ usually between the stamens and ovary; also used for the enlarged style-end in Proteaceae.

Disc floret the central, tubular 4 or 5-toothed or lobed floret on the disc of an inflorescence, as of flower head of Asteraceae.

Disciform flat and rounded in shaped. *cf.* discoid, radiate.

Discoid resembling a disc; having a flat, circular form; disk-shaped *cf.* disciform, radiate.

Discolorous having two colours, as of a leaf which has different colors on the two surfaces. *cf.* concolorous.

Dispersal dissemination of seeds.

Distal site of any structure farthest from the point of attachment. *cf.* proximal.

Distichous referring to two rows of upright leaves in the same plane.

Dithecous having two thecae.

Divaricate diverging at a wide angle.

Domatium a part of a plant (e.g., a leaf) that has been modified to provide protection for other organisms. *pl.* domatia.

Dormancy a resting period in the life of a plant during which growth slows or appears to stop.

Dorsal referring to the back surface.

Dorsifixed attached to the back as of anthers.

Drupaceous resembling a drupe.

Drupe a fleshy fruit with a single seed enclosed in a hard shell (endocarp) which is tissue embedded in succulent tissue (mesocarp) surrounded by a thin outer skin (epicarp). *adj.* drupaceous.

Drupelet a small drupe.

Ebracteate without bracts.

Echinate bearing stiff, stout, bristly, prickly hairs.

Edaphic refers to plant communities that are distinguished by soil conditions rather than by the climate.

Eglandular without glands. *cf.* glandular.

Ellipsoid a 3-dimensional shape; elliptic in outline.

Elliptic having a 2-dimensional shape of an ellipse or flattened circle.

Elongate extended, stretched out.

Emarginate refers to leaf with a broad, shallow notch at the apex. *cf.* retuse.

Embryo (Botany) a minute rudimentary plant contained within a seed or an archegonium, composed of the embryonic axis (shoot end and root end).

Endemic prevalent in or peculiar to a particular geographical locality or region.

Endocarp The hard innermost layer of the pericarp of many fruits.

Endosperm tissue that surrounds and nourishes the embryo in the angiosperm seed.

Endospermous refers to seeds having an endosperm.

Endotrophic as of mycorrhiza obtaining nutrients from inside.

Ensilage the process of preserving green food for livestock in an undried condition in airtight conditions. Also called silaging.

Entire having a smooth, continuous margin without any incisions or teeth as of a leaf.

Entisols soils that do not show any profile development other than an A horizon.

Ephemeral transitory, short-lived.

Epicalyx a whorl of bracts, subtending and resembling a calyx.

Epicarp outermost layer of the pericarp of a fruit.

Epicormic attached to the corm.

Epicotyl the upper portion of the embryonic axis, above the cotyledons and below the first true leaves.

Epigeal above grounds with cotyledons raised above ground.

Epiparasite an organism parasitic on another that parasitizes a third.

Epipetalous borne on the petals, as of stamens.

Epiphyte a plant growing on, but not parasitic on, another plant, deriving its moisture and nutrients from the air and rain e.g. some Orchidaceae. *adj.* epiphytic.

Erect upright, vertical.

Essential oils volatile products obtained from a natural source; refers to volatile products obtained by steam or water distillation in a strict sense.

Etiolation to cause (a plant) to develop without chlorophyll by preventing exposure to sunlight.

Eutrophic having waters rich in mineral and organic nutrients that promote a proliferation of plant life, especially algae, which reduces the dissolved oxygen content and often causes the extinction of other organisms.

Excentric off the true centre.

Excrescence abnormal outgrowth.

Excurrent projecting beyond the tip, as the midrib of a leaf or bract.

Exserted sticking out, protruding beyond some enclosing organ, as of stamens which project beyond the corolla or perianth.

Exstipulate without stipules. *cf.* stipulate.

Extra-floral outside the flower.

Extrose turned outwards or away from the axis as of anthers. *cf.* introrse, latrorse.

Falcate sickle shaped, crescent-shaped.

Fascicle a cluster or bundle of stems, flowers, stamens. *adj.* fasciculate.

Fasciclode staminode bundles.

Fastigiate a tree in which the branches grow almost vertically.

Ferrosols soils with an iron oxide content of greater than 5%.

Ferruginous rust coloured, reddish-brown.

Fertile having functional sexual parts which are capable of fertilisation and seed production. *cf.* sterile.

Filament the stalk of a stamen supporting and subtending the anther.

Filiform Having the form of or resembling a thread or filament.

Fimbriate fringed.
Fixed oils non volatile oils, triglycerides of fatty acids.
Flaccid limp and weak.
Flag leaf the uppermost leaf on the stem.
Flaky in the shape of flakes or scales.
Flexuous zig-zagging, sinuous, bending, as of a stem.
Floccose covered with tufts of soft woolly hairs.
Floral tube a flower tube usually formed by the basal fusion of the perianth and stamens.
Floret one of the small individual flowers of sunflower family or the reduced flower of the grasses, including the lemma and palea.
Flower the sexual reproductive organ of flowering plants, typically consisting of gynoecium, androecium and perianth or calyx and/or corolla and the axis bearing these parts.
Fluted as of a trunk with grooves and folds.
Fodder plant material, fresh or dried fed to animals.
Foliaceous leaf-like.
Foliar pertaining to a leaf.
Foliolate pertaining to leaflets, used with a number prefix to denote the number of leaflets.
Foliose leaf-like.
Follicle (Botany) a dry fruit, derived from a single carpel and dehiscing along one suture.
Forb any herb that is not grass or grass-like.
Free central placentation The arrangement of ovules on a central column that is not connected to the ovary wall by partitions, as in the ovaries of the carnation and primrose.
Frond the leaf of a fern or cycad.
Fruit ripened ovary with adnate parts.
Fugacious shedding off early.
Fulvous yellow, tawny.
Funiculus (Botany) short stalk which attaches the ovule to the ovary wall.
Fusiform a 3-dimensional shape; spindle shaped, i.e. broad in the centre and tapering at both ends thick, but tapering at both ends.
Gamete a reproductive cell that fuses with another gamete to form a zygote. Gametes are haploid, (they contain half the normal (diploid) number of chromosomes); thus when two fuse, the diploid number is restored.
Gametophyte The gamete-producing phase in a plant characterized by alternation of generations.
Gamosepalous with sepals united or partially united.
Gall-flower short styled flower that do not develop into a fruit but are adapted for the development of a specific wasp within the fruit e.g. in the fig.
Geniculate bent like a knee, refer to awns and filaments.
Geocarpic where the fruit are pushed into the soil by the gynophore and mature.
Geophyte a plant that stores food in an underground storage organ e.g. a tuber, bulb or rhizome and has subterranean buds which form aerial growth.
Geotextile are permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain.
Glabrescent becoming glabrous.
Glabrous smooth, hairless without pubescence.
Gland a secretory organ, e.g. a nectary, extrafloral nectary or a gland tipped, hair-like or wart-like organ. *adj.* glandular. *cf.* eglandular.
Glaucous pale blue-green in colour, covered with a whitish bloom that rubs off readily.
Gley soils a hydric soil which exhibits a greenish-blue-grey soil color due to wetland conditions.
Globose spherical in shape.
Globular a three-dimensional shape; spherical or orbicular; circular in outline.
Glochids tiny, finely barbed hair-like spines found on the areoles of some cacti and other plants.
Glochidiate having glochids.
Glochidote plant having glochids.
Glume one of the two small, sterile bracts at the base of the grass spikelet, called the lower and upper glumes, due to their position on the rachilla. Also used in Apiaceae, Cyperaceae for the very small bracts on the spikelet in which each flower is subtended by one floral glume. *adj.* glumaceous.
Guttation the appearance of drops of xylem sap on the tips or edges of leaves of some vascular plants, such as grasses and bamboos.

Guttule small droplet.

Gymnosperm a group of spermatophyte seed-bearing plants with ovules on scales, which are usually arranged in cone-like structures and not borne in an ovary. *cf.* angiosperm.

Gynoecium the female organ of a flower; a collective term for the pistil, carpel or carpels.

Gynomonoecious having female flowers and bisexual flowers on the same plant. *cf.* andromonoecious.

Gynophore stalk that bears the pistil/carpel.

Habit the general growth form of a plant, comprising its size, shape, texture and stem orientation, the locality in which the plant grows.

Halophyte a plant adapted to living in highly saline habitats. Also a plant that accumulates high concentrations of salt in its tissues. *adj.* halophytic.

Hapaxanthic refer to palms which flowers only once and then dies. c.f. pleonanthic.

Haploid condition where nucleus or cell has a single set of unpaired chromosomes, the haploid number is designated as n.

Haplontic life cycle or zygotic meiosis wherein meiosis of a zygote immediately after karyogamy, produces haploid cells which produces more or larger haploid cells ending its diploid phase.

Hastate having the shape of an arrowhead but with the basal lobes pointing outward at right angles as of a leaf.

Hastula a piece of plant material at the junction of the petiole and the leaf blade; the hastula can be found on the top of the leaf, adaxial or the bottom, abaxial or both sides.

Heartwood wood from the inner portion of a tree.

Heliophilous sun-loving, tolerates high level of sunlight.

Heliotropic growing towards sunlight.

Herb a plant which is non-woody or woody at the base only, the above ground stems usually being ephemeral. *adj.* herbaceous.

Herbaceous resembling a herb, having a habit of a herb.

Hermaphrodite bisexual, bearing flowers with both androecium and gynoecium in the same flower. *adj.* hermaphroditic.

Heterocyst a differentiated cyanobacterial cell that carries out nitrogen fixation.

Heterogamous bearing separate male and female flowers, or bisexual and female flowers, or florets in an inflorescence or flower head, e.g. some Asteraceae in which the ray florets may be neuter or unisexual and the disk florets may be bisexual. *cf.* homogamous.

Heteromorphous having two or more distinct forms. *cf.* homomorphous.

Heterophyllous having leaves of different form.

Heterosporous producing spores of two sizes, the larger giving rise to megagametophytes (female), the smaller giving rise to microgametophytes (male). Refer to the ferns and fern allies. *cf.* homosporous.

Heterostyly the condition in which flowers on polymorphous plants have styles of different lengths, thereby facilitating cross-pollination.

Heterostylous having styles of two different lengths or forms.

Hilar of or relating to a hilum.

Hilum The scar on a seed, indicating the point of attachment to the funiculus.

Hirsute bearing long coarse hairs.

Hispid bearing stiff, short, rough hairs or bristles.

Hispidulous minutely hispid.

Histosol soil comprising primarily of organic materials, having 40 cm or more of organic soil material in the upper 80 cm.

Hoary covered with a greyish layer of very short, closely interwoven hairs.

Holdfast an organ or structure of attachment, especially the basal, root-like formation by which certain seaweeds or other algae are attached to a substrate.

Holocarpic having the entire thallus developed into a fruiting body or sporangium.

Homochromous having all the florets of the same colour in the same flower head *cf.* heterochromous.

Homogamous bearing flowers or florets that do not differ sexually *cf.* heterogamous.

Homogenous endosperm endosperm with even surface that lacks invaginations or infoldings of the surrounding tissue.

Homogonium a part of a filament of a cyanobacterium that detaches and grows by cell division into a new filament. *pl.* homogonia.

Homomorphous uniform, with only one form. *cf.* heteromorphous.

Homosporous producing one kind of spores. Refer to the ferns and fern allies. *cf.* heterosporous.

Hurd fibre long pith fibre of the stem.

Hyaline colourless, almost transparent.

Hybrid the first generation progeny of the sexual union of plants belonging to different taxa.

Hybridisation the crossing of individuals from different species or taxa.

Hydathode a type of secretory tissue in leaves, usually of Angiosperms, that secretes water through pores in the epidermis or margin of the leaf.

Hydrophilous water loving; requiring water in order to be fertilized, referring to many aquatic plants.

Hygrochastic applied to plants in which the opening of the fruits is caused by the absorption of water.

Hygrophilous living in water or moist places.

Hymenial cystidia the cells of the hymenium develop into basidia or asci, while in others some cells develop into sterile cells called cystidia.

Hymenium spore-bearing layer of cells in certain fungi containing asci (Ascomycetes) or basidia (Basidiomycetes).

Hypha is a long, branching filamentous cell of a fungus, and also of unrelated Actinobacteria. *pl.* hyphae.

Hypanthium cup-like receptacles of some dicotyledonous flowers formed by the fusion of the calyx, corolla, and androecium that surrounds the ovary which bears the sepals, petals and stamens.

Hypocotyl the portion of the stem below the cotyledons.

Hypodermis the cell layer beneath the epidermis of the pericarp.

Hypogeal below ground as of germination of seed.

Hysteresis refers to systems that may exhibit path dependence.

Imbricate closely packed and overlapping. *cf.* valvate.

Imparipinnate pinnately compound with a single terminal leaflet and hence with an odd number of leaflets. *cf.* paripinnate.

Inceptisols old soils that have no accumulation of clays, iron, aluminium or organic matter.

Incised cut jaggedly with very deep teeth.

Included referring to stamens which do not project beyond the corolla or to valves which do not extend beyond the rim of a capsular fruit. *cf.* exserted.

Incurved curved inwards; curved towards the base or apex.

Indefinite numerous and variable in number.

Indehiscent not opening or splitting to release the contents at maturity as of fruit. *cf.* dehiscent.

Indumentum covering of fine hairs or bristles commonly found on external parts of plants.

Indurate to become hard, often the hardening developed only at maturity.

Indusium an enclosing membrane, covering the sorus of a fern. Also used for the modified style end or pollen-cup of some Goodeniaceae (including Brunoniaceae). *adj.* indusiate.

Inferior said of an ovary or fruit that has sepals, petals and stamens above the ovary. *cf.* superior.

Inflated enlarged and hollow except in the case of a fruit which may contain a seed. *cf.* swollen.

Inflexed Bent or curved inward or downward, as petals or sepals.

Inflorescence a flower cluster or the arrangement of flowers in relation to the axis and to each other on a plant.

Infrafoliar located below the leaves.

Infraspecific referring to any taxon below the species rank.

Infructescence the fruiting stage of an inflorescence.

Inrolled curved inwards.

Integuments two distinct tissue layers that surround the nucellus of the ovule, forming the testa or seed coat when mature.

Intercalary of growth, between the apex and the base; of cells, spores, etc., between two cells.

Interfoliar inter leaf.

Internode portion of the stem, culm, branch, or rhizome between two nodes or points of attachment of the leaves.

Interpetiolar as of stipules positioned between petioles of opposite leaves.

Intrastaminal within the stamens.

Intricate entangled, complex.

Introduced not indigenous; not native to the area in which it now occurs.

Introrse turned inwards or towards the axis or pistil as of anthers. *cf.* extrorse, latrorse.

Involucre a whorl of bracts or leaves that surround one to many flowers or an entire inflorescence.

Involute having the margins rolled inwards, referring to a leaf or other flat organ.

Jugate of a pinnate leaf; having leaflets in pairs.

Juvenile young or immature, used here for leaves formed on a young plant which are different in morphology from those formed on an older plant.

Keel a longitudinal ridge, at the back of the leaf. Also the two lower fused petals of a 'pea' flower in the Papilionaceae, which form a boat-like structure around the stamens and styles. *adj.* keeled. *cf.* standard, wing.

Labellum the modified lowest of the three petals forming the corolla of an orchid, usually larger than the other two petals, and often spurred.

Laciniate fringed; having a fringe of slender, narrow, pointed lobes cut into narrow lobes.

Lamella a gill-shaped structure: fine sheets of material held adjacent to one another.

Lamina the blade of the leaf or frond.

Lanate wooly, covered with long hairs which are loosely curled together like wool.

Lanceolate lance-shaped in outline, tapering from a broad base to the apex.

Landrace plants adapted to the natural environment in which they grow, developing naturally with minimal assistance or guidance from humans and usually possess more diverse phenotypes and genotypes.

Laterite reddish–coloured soils rich in iron oxide, formed by weathering of rocks under oxidizing and leaching conditions, commonly found in tropical and subtropical regions. *adj.* lateritic.

Latex a milky, clear or sometimes coloured sap of diverse composition exuded by some plants.

Latrorse turned sideways, i.e. not towards or away from the axis as of anthers dehiscing longitudinally on the side. *cf.* extrorse, introse.

Lax loose or limp, not densely arranged or crowded.

Leaflet one of the ultimate segments of a compound leaf.

Lectotype a specimen chosen after the original description to be the type.

Lemma the lower of two bracts (scales) of a grass floret, usually enclosing the palea, lodicules, stamens and ovary.

Lenticel is a lens shaped opening that allows gases to be exchanged between air and the inner tissues of a plant, commonly found on young bark, or the surface of the fruit.

Lenticellate dotted with lenticels.

Lenticular shaped like a biconvex lens. *cf.* lentiform.

Lentiform shaped like a biconvex lens, *cf.* lenticular.

Leptomorphic temperate, running bamboo rhizome; usually thinner then the culms they support and the internodes are long and hollow.

Liane a woody climbing or twining plant.

Lignotuber a woody, usually underground, tuberous rootstock often giving rise to numerous aerial stems.

Ligulate small and tongue shaped or with a little tongue shaped appendage or ligule, star shaped as of florets of Asteraceae.

Ligule a strap-shaped corolla in the flowers of Asteraceae; also a thin membranous outgrowth from the inner junction of the grass leaf sheath and blade. *cf.* ligulate.

Limb the expanded portion of the calyx tube or the corolla tube, or the large branch of a tree.

Linear a 2-dimensional shape, narrow with nearly parallel sides.

Linguiform tongue shaped *cf.* ligulate.

Lithosol a kind of shallow soils lacking well-defined horizons and composed of imperfectly weathered fragments of rock.

Littoral of or on a shore, especially seashore.

Loam a type of soil mad up of sand, silt, and clay in relative concentration of 40-40-20% respectively.

Lobed divided but not to the base.

Loculicidal opening into the cells, when a ripe capsule splits along the back.

Loculus cavity or chamber of an ovary. *pl.* loculi.

Lodicules two small structures below the ovary which, at flowering, swell up and force open the enclosing bracts, exposing the stamens and carpel.

Lyrate pinnately lobed, with a large terminal lobe and smaller laterals ones which become progressively smaller towards the base.

Macronutrients chemical elements which are needed in large quantities for growth and development by plants and include nitrogen, phopshorus, potassium, and magnesium.

Maculate spotted.

Mallee a growth habit in which several to many woody stems arise separately from a lignotuber; usually applied to certain low-growing species of *Eucalyptus*.

Mangrove a distinctive vegetation type of trees and shrubs with modified roots, often viviparous, occupying the saline coastal habitats that are subject to periodic tidal inundation.

Marcescent withering or to decay without falling off.

Margin the edge of the leaf blade.

Medulla the pith in the stems or roots of certain plants; or the central portion of a thallus in certain lichens.

Megasporangium the sporangium containing megaspores in fern and fern allies. *cf.* microsporangium.

Megaspore the large spore which may develop into the female gametophyte in heterosporous ferns and fern allies. *cf.* microspore.

Megasporophyll A leaflike structure that bears megasporangia.

Megastrobilus female cone, seed cone, or ovulate cone, contains ovules within which, when fertilized by pollen, become seeds. The female cone structure varies more markedly between the different conifer families.

Meiosis the process of cell division that results in the formation of haploid cells from diploid cells to produce gametes.

Mericarp a one-seeded portion of an initially syncarpous fruit (schizocarp) which splits apart at maturity. *cf.* coccus.

Meristem the region of active cell division in plants, from which permanent tissue is derived. *adj.* meristematic.

-merous used with a number prefix to denote the basic number of the three outer floral whorls, e.g. a 5-merous flower may have 5 sepals, 10 petals and 15 stamens.

Mesic moderately wet.

Mesocarp the middle layer of the fruit wall derived from the middle layer of the carpel wall. *cf.* endocarp, exocarp, pericarp.

Mesophytes terrestrial plants which are adapted to neither a particularly dry nor particularly wet environment.

Micropyle the small opening in a plant ovule through which the pollen tube passes in order to effect fertilisation.

Microsporangium the sporangium containing microspores in pteridophytes. *cf.* megasporangium.

Microspore a small spore which gives rise to the male gametophyte in heterosporous pteridophytes. Also for a pollen grain. *cf.* megaspore.

Midvein the main vascular supply of a simple leaf blade or lamina. Also called mid-rib.

Mitosis is a process of cell division which results in the production of two daughter cells from a single parent cell.

Mollisols soils with deep, high organic matter, nutrient-enriched surface soil (A horizon), typically between 60 and 80 cm thick.

Monadelphous applied to stamens united by their filaments into a single bundle.

Monocarpic refer to plants that flower, set seeds and then die.

Monochasial a cyme having a single flower on each axis.

Monocotyledon angiosperm having one cotyledon.

Monoecious having both male and female unisexual flowers on the same individual plant. *cf.* dioecious.

Monoembryonic seed the seed contains only one embryo, a true sexual (zygotic) embryo. polyembryonic seed.

Monolete a spore that has a simple linear scar.

Monopodial with a main terminal growing point producing many lateral branches progressively. *cf.* sympodial.

Monotypic of a genus with one species or a family with one genus; in general, applied to any taxon with only one immediately subordinate taxon.

Montane refers to highland areas located below the subalpine zone.

Mucilage a soft, moist, viscous, sticky secretion. *adj*. mucilaginous.

Mucous (Botany) slimy.

Mucro a sharp, pointed part or organ, especially a sharp terminal point, as of a leaf.

Mucronate ending with a short, sharp tip or mucro, resembling a spine. cf. cuspidate, muticous.

Mucronulate with a very small mucro; a diminutive of mucronate.

Mulch protective cover of plant (organic) or non-plant material placed over the soil, primarily to modify and improve the effects of the local microclimate and to control weeds.

Multiple fruit a fruit that is formed from a cluster of flowers.

Muricate covered with numerous short hard outgrowths. *cf*. papillose.

Muriculate with numerous minute hard outgrowths; a diminutive of muricate.

Muticous blunt, lacking a sharp point. *cf*. mucronate.

MYB proteins are a superfamily of transcription factors that play regulatory roles in developmental processes and defense responses in plants.

Mycorrhiza the mutualistic symbiosis (non-pathogenic association) between soil-borne fungi with the roots of higher plants.

Mycorrhiza (vesicular arbuscular) endomycorrhiza living in the roots of higher plants producing inter-and intracellular fungal growth in root cortex and forming specific fungal structures, referred to as vesicles and arbuscles. *abbrev.* VAM.

Native a plant indigenous to the locality or region.

Naviculate boat-shaped.

Necrotic applied to dead tissue.

Nectariferous having one or more nectaries.

Nectary a nectar secretory gland; commonly in a flower, sometimes on leaves, fronds or stems.

Nervation venation, a pattern of veins or nerves as of leaf.

Node the joint between segments of a culm, stem, branch, or rhizome; the point of the stem that gives rise to the leaf and bud.

Nodule a small knoblike outgrowth, as those found on the roots of many leguminous, that containing *Rhizobium* bacteria which fixes nitrogen in the soil.

Nomen Illegitimum illegitimate taxon deemed as superfluous at its time of publication either because the taxon to which it was applied already has a name, or because the name has already been applied to another plant. *abbrev*. nom. illeg.

Nomen Nudum the name of a taxon which has never been validated by a description. *abbrev*. nom. nud.

Nomen Dubium an invalid proposed taxonomic name because it is not accompanied by a definition or description of the taxon to which it applies. *abbrev*. nom. dub.

Nucellus central portion of an ovule in which the embryo sac develops.

Nucellar embryony a form of seed reproduction in which the nucellar tissue which surrounds the embryo sac can produce additional embryos (polyembryony) which are genetically identical to the parent plant. This is found in many citrus species and in mango.

Nut a dry indehiscent 1-celled fruit with a hard pericarp.

Nutlet a small. 1-seeded, indehiscent lobe of a divided fruit.

Ob- prefix meaning inversely or opposite to.

Obconic a 3-dimensional shape; inversely conic; cone shaped, conic with the vertex pointing downward.

Obcordate inversely cordate, broad and notched at the tip; heart shaped but attached at the pointed end.

Obdeltate inversely deltate; deltate with the broadest part at the apex.

Oblate having the shape of a spheroid with the equatorial diameter greater than the polar diameter; being flattened at the poles.

Oblanceolate inversely lanceolate, lance-shaped but broadest above the middle and tapering toward the base as of leaf.

Oblong longer than broad with sides nearly parallel to each other.

Obovate inversely ovate, broadest above the middle.

Obpyramidal resembling a 4-sided pyramid attached at the apex with the square base facing away from the attachment.

Obpyriform inversely pyriform, resembling a pear which is attached at the narrower end. *cf.* pyriform.

Obspathulate inversely spathulate; resembling a spoon but attached at the broadest end. *cf.* spathulate.

Obtriangular inversely triangular; triangular but attached at the apex. *cf.* triangular.

Obtrullate inversely trullate; resembling a trowel blade with the broadest axis above the middle. *cf.* trullate.

Obtuse with a blunt or rounded tip, the converging edges separated by an angle greater than 90°.

-oid suffix denoting a 3-dimensional shape, e.g. spheroid.

Ochraceous a dull yellow color.

Ocreate having a tube-like covering around some stems, formed of the united stipules; sheathed.

Oleaginous oily.

Oligotrophic lacking in plant nutrients and having a large amount of dissolved oxygen throughout.

Operculum a lid or cover that becomes detached at maturity by abscission, e.g. in *Eucalyptus*, also a cap or lid covering the bud and formed by fusion or cohesion of sepals and/or petals. *adj.* operculate.

Opposite describing leaves or other organs which are borne at the same level but on opposite sides of the stem. *cf.* alternate.

Orbicular of circular outline, disc-like.

Order a taxonomic rank between class and family used in the classification of organisms, i.e. a group of families believed to be closely related.

Orifice an opening or aperture.

Organosols soils not regularly inundated by marine waters and containing a specific thickness of organic materials within the upper part of the profile.

Ovary the female part of the pistil of a flower which contains the ovules (immature seeds).

Ovate egg-shaped, usually with reference to two dimensions.

Ovoid egg-shaped, usually with reference to three dimensions.

Ovule the young, immature seed in the ovary which becomes a seed after fertilisation. *adj.* ovular.

Ovulode a sterile reduced ovule borne on the placenta, commonly occurring in Myrtaceae.

Oxisols refer to ferralsols.

Pachymorphic describes the short, thick, rhizomes of clumping bamboos with short, thick and solid internode (except the bud-bearing internodes, which are more elongated). *cf.* sympodial.

Palate (Botany) a raised appendage on the lower lip of a corolla which partially or completely closes the throat.

Palea the upper of the two membraneous bracts of a grass floret, usually enclosing the lodicules, stamens and ovary. *pl.* paleae. *adj.* paleal. *cf.* lemma.

Paleate having glumes.

Palmate describing a leaf which is divided into several lobes or leaflets which arise from the same point. *adj.* palmately.

Palm heart refers to soft, tender inner core and growing bud of certain palm trees which are eaten as vegetables. Also called heart of palm, palmito, burglar's thigh, chonta or swamp cabbage.

Palmito see palm heart.

Palustrial paludal, swampy, marshy.

Palustrine marshy, swampy.

Palustrine herb vegetation that is rooted below water but grows above the surface in wetland system.

Panduriform fiddle shaped, usually with reference to two dimensions.

Panicle a compound, indeterminate, racemose inflorescence in which the main axis bears lateral racemes or spikes. *adj.* paniculate.

Pantropical distributed through-out the tropics.

Papilionaceous butterfly-like, said of the pea flower or flowers of Papilionaceae, flowers which are zygomorphic with imbricate petals, one broad upper one, two narrower lateral ones and two narrower lower ones.

Papilla a small, superficial protuberance on the surface of an organ being an outgrowth of one epidermal cell. *pl.* papillae. *adj.* papillose.

Papillate having papillae.

Papillose covered with papillae.

Pappus a tuft (or ring) of hairs, bristles or scales borne above the ovary and outside the corolla as in Asteraceae often persisting as a tuft of hairs on a fruit. *adj.* pappose.

Papyraceous resembling parchment of paper.

Parenchyma undifferentiated plant tissue composed of more or less uniform cells.

Parietal describes the attachment of ovules to the outer walls of the ovaries.

Paripinnate pinnate with an even number of leaflets and without a terminal leaflet. *cf.* imparipinnate.

-partite divided almost to the base into segments, the number of segments written as a prefix.

Patelliform shaped like a limpet shell; cap-shaped and without whorls.

Patent diverging from the axis almost at right angles.

Peat is an accumulation of partially decayed vegetation matter.

Pectin a group of water-soluble colloidal carbohydrates of high molecular weight found in certain ripe fruits.

Pectinate pinnatifid with narrow segments resembling the teeth of a comb.

Pedicel the stalk of the flower or stalk of a spikelet in Poaceae. *adj.* pedicellate.

Pedicellate having pedicel.

Peduncle a stalk supporting an inflorescence. *adj.* pedunculate.

Pellucid allowing the passage of light; transparent or translucent.

Pellucid-dotted copiously dotted with immersed, pellucid, resinous glands.

Peltate with the petiole attached to the lower surface of the leaf blade.

Pendant hanging down.

Pendulous drooping, as of ovules.

Penniveined or penni-nerved pinnately veined.

Pentamerous in five parts.

Perennial a plant that completes it life cycle or lives for more than 2 years. *cf.* annual, biennial.

Perfoliate a leaf with the basal lobes united around– and apparently pierced by – the stem.

Pergamentaceous parchment-like.

Perianth the two outer floral whorls of the Angiosperm flower; commonly used when the calyx and the corolla are not readily distinguishable (as in monocotyledons).

Pericarp (Botany). The wall of a ripened ovary; fruit wall composed of the exocarp, mesocarp and endocarp.

Pericarp the wall of a fruit developed from the ovary wall.

Persistent remaining attached; not falling off. *cf.* caduceus.

Petal free segment of the corolla. *adj.* petaline. *cf.* lobe.

Petiolar relating to the petiole.

Petiole leaf stalk. *adj.* petiolate.

Petiolulate supported by its own petiolule.

Petiolule the stalk of a leaflet in a compound leaf. *adj.* petiolulate.

pH is a measure of the acidity or basicity of a solution. It is defined as the cologarithm of the activity of dissolved hydrogen ions (H+).

Phenology the study of periodic plant life cycle events as influenced by seasonal and interannual variations in climate.

Phyllary a bract of the involucre of a composite plant, term for one of the scale-like bracts beneath the flower-head in Asteraceae.

Phylloclade a flattened, photosynthetic branch or stem that resembles or performs the function of a leaf, with the true leaves represented by scales.

Phyllode a petiole that function as a leaf. *adj.* phyllodineous. *cf.* cladode.

Phyllopodia refer to the reduced, scale-like leaves found on the outermost portion of the corm where they seem to persist longer than typical sporophylls as in the fern Isoetes.

Phytoremediation describes the treatment of environmental problems (bioremediation) through the use of plants which mitigate the environmental problem without the need to excavate the contaminant material and dispose of it elsewhere.

Pileus (Botany) cap of mushroom.

Piliferous (Botany) bearing or producing hairs, as of an organ with the apex having long, hair-like extensions.

Pilose covered with fine soft hairs.

Pinna a primary division of the blade of a compound leaf or frond. *pl.* pinnae.

Pinnate bearing leaflets on each side of a central axis of a compound leaf; divided into pinnae.

Pinnatifid, pinnatilobed a pinnate leaf parted approximately halfway to midrib; when divided to almost to the mid rib described as deeply pinnatifid or pinnatisect.

Pinnatisect lobed or divided almost to the midrib.

Pinnule a leaflet of a bipinnate compound leaf.

Pistil female part of the flower comprising the ovary, style, and stigma.

Pistillate having one or more pistils; having pistils but no stamens.

Placenta the region within the ovary to which ovules are attached. *pl.* placentae.

Placentation the arrangement of the placentae and ovules in the ovary.

Plano- a prefix meaning level or flat.

Pleonanthic refer to palms in which the stem does not die after flowering.

Plicate folded like a fan.

Plumose feather-like, with fine hairs arising laterally from a central axis; feathery.

Pneumatophore modified root which allows gaseous exchange in mud-dwelling shrubs, e.g. mangroves.

Pod a dry one to many-seeded dehiscent fruit, as applied to the fruit of Fabaceae i.e. Caesalpiniaceae, Mimosaceae and Papilionaceae.

Podzol, Podsolic soil any of a group of acidic, zonal soils having a leached, light-coloured, gray and ashy appearance. Also called spodosol.

Pollen cone male cone or microstrobilus or pollen cone is structurally similar across all conifers, extending out from a central axis are microsporophylls (modified leaves). Under each microsporophyll is one or several microsporangia (pollen sacs).

Pollinia the paired, waxy pollen masses of flowers of orchids and milkweeds.

Polyandrous (Botany) having an indefinite number of stamens.

Polyembryonic seed seeds contain many embryos, most of which are asexual (nucellar) in origin and genetically identical to the maternal parent.

Polygamous with unisexual and bisexual flowers on the same or on different individuals of the same species.

Polymorphic with different morphological variants.

Polypetalous (Botany) having a corolla composed of distinct, separable petals.

Pome a fleshy fruit where the succulent tissues are developed from the receptacle.

Pore a tiny opening.

Premorse Abruptly truncated, as though bitten or broken off as of a leaf.

Procumbent trailing or spreading along the ground but not rooting at the nodes, referring to stems. *cf.* ascending, decumbent, erect.

Prophyll a plant structure that resembles a leaf.

Prostrate lying flat on the ground.

Protandous relating to a flower in which the anthers release their pollen before the stigma of the same flower becomes receptive.

Proximal end of any structure closest to the point of attachment. *cf.* distal.

Pruinose having a thick, waxy, powdery coating or bloom.

Pseudocarp a false fruit, largely made up of tissue that is not derived from the ovary but from floral parts such as the receptacle and calyx.

Pteridophyte a vascular plant which reproduces by spores; the ferns and fern allies.

Puberulent covered with minute hairs or very fine down; finely pubescent.

Puberulous covered with a minute down.

Pubescent covered with short, soft hairs.

Pulvinate having a swelling, pulvinus at the base as a leaf stalk.

Pulvinus swelling at the base of leaf stalk.

Pulviniform swelling or bulging.

Punctate marked with translucent dots or glands.

Punctiform marked by or composed of points or dots.

Punctulate marked with minute dots; a diminutive of punctate.

Pusticulate characterized by small pustules.

Pyrene the stone or pit of a drupe, consisting of the hardened endocarp and seed.

Pyriform pear-shaped, a 3-dimensional shape; attached at the broader end. *cf.* obpyriform.

Pyxidium seed capsule having a circular lid (operculum) which falls off to release the seed.

Raceme an indeterminate inflorescence with a simple, elongated axis and pedicellate flowers, youngest at the top. *adj*. racemose.

Rachilla the main axis of a grass spikelet.

Rachis the main axis of the spike or other inflorescence of grasses or a compound leaf.

Radiate arranged around a common centre; as of an inflorescence of Asteraceae with marginal, female or neuter, ligulate ray-florets and central, perfect or functionally male, tubular, disc florets. *cf*. disciform, discoid.

Radical arising from the root or its crown, or the part of a plant embryo that develops into a root.

Ray the marginal portion of the inflorescence of Asteraceae and Apiaceae when distinct from the disc. Also, the spreading branches of a compound umbel.

Receptacle the region at the end of a pedicel or on an axis which bears one or more flowers. *adj*. receptacular.

Recurved curved downwards or backwards.

Reflexed bent or turned downward.

Reniform kidney shaped in outline.

Regosol soil that is young and undeveloped, characterized by medium to fine-textured unconsolidated parent material that maybe alluvial in origin and lacks a significant horizon layer formation.

Repand with slightly undulate margin.

Replicate folded back, as in some corolla lobes.

Resinous producing sticky resin.

Resupinate twisted through 180°.

Reticulate having the appearance of a network.

Retrorse bent or directed downwards or backwards. *cf*. antrorse.

Retuse with a very blunt and slightly notched apex. *cf*. emarginated.

Revolute with the margins inrolled on the lower (abaxial) surface.

Rhizine a root-like filament or hair growing from the stems of mosses or on lichens.

Rhizoid root-like filaments in a moss, fern, fungus, etc. that attach the plant to the substratum.

Rhizome a prostrate or underground stem consisting of a series of nodes and internodes with adventitious roots and which generally grows horizontally.

Rhizophore a stilt-like outgrowth of the stem which branches into roots on contact with the substrate.

Rhombic shaped like a rhombus.

Rhomboid shaped like a rhombus.

Rib a distinct vein or linear marking, often raised as a linear ridge.

Riparian along the river margins, interface between land and a stream.

Rosette a tuft of leaves or other organs arranged spirally like petals in a rose, ranging in form from a hemispherical tuft to a flat whorl. *adj*. rosetted, rosulate.

Rostrate beaked; the apex tapered into a slender, usually obtuse point.

Rostrum a beak-like extension.

Rosulate having a rosette.

Rotate wheel shaped; refers to a corolla with a very short tube and a broad upper part which is flared at right angles to the tube. *cf*. salverform.

Rotundate rounded; especially at the end or ends.

Rugae refers to a series of ridges produced by folding of the wall of an organ.

Rugose deeply wrinkled.

Rugulose finely wrinkled.

Ruminate (Animal) chew repeatedly over an extended period**.**

Ruminate endosperm uneven endosperm surface that is often highly enlarged by ingrowths or infoldings of the surrounding tissue. cf. homogenous endosperm.

Rz value is a numerical reference to the mesh/emulsion equalization on the screen.

Saccate pouched.

Sagittate shaped like an arrow head.

Saline soils soils that contain excessive levels of salts that reduce plant growth and vigor by altering water uptake and causing ion-specific toxicities or imbalances.

Salinity is characterised by high electrical conductivities and low sodium ion concentrations compared to calcium and magnesium

Salverform applies to a gamopetalous corolla having a slender tube and an abruptly expanded limb.

Samara an indehiscent, winged, dry fruit.

Sand a naturally occurring granular material composed of finely divided rock and mineral particles range in diameter from 0.0625 μm to 2 mm. *adj.* sandy

Saponins are plant glycosides with a distinctive foaming characteristic. They are found in many plants, but get their name from the soapwort plant (*Saponaria)*.

Saprophytic living on and deriving nourishment from dead organic matter.

Sapwood outer woody layer of the tree just adjacent to and below the bark.

Sarcotesta outermost fleshy covering of Cycad seeds below which is the sclerotesta.

Scabrid scurfy, covered with surface abrasions, irregular projections or delicate scales.

Scabrous rough to the touch.

Scale dry bract or leaf.

Scandent refer to plants, climbing.

Scape erect flowering stem, usually leafless, rising from the crown or roots of a plant. *adj.* scapose.

Scapigerous with a scape.

Scarious dry, thin and membranous.

Schizocarp a dry fruit which splits into longitudinally multiple parts called mericarps or cocci. *adj.* schizocarpous.

Sclerotesta the innermost fleshy coating of cycad seeds, usually located directly below the sarcotesta.

Scorpoid refers to a cymose inflorescence in which the main axis appears to coil.

Scutellum (Botany) any of various parts shaped like a shield.

Secondary venation arrangement of the lateral veins arising from the midrib in the leaf lamina.

Secund with the flowers all turned in the same direction.

Sedge a plant of the family Apiaceae, Cyperaceae.

Segmented constricted into divisions.

Seminal root or seed root originate from the scutellar node located within the seed embryo and are composed of the radicle and lateral seminal roots.

Senescence refers to the biological changes which take place in plants as they age.

Sepal free segment of the calyx. *adj.* sepaline.

Septum a partition or cross wall. *pl.* septa. *adj.* septate.

Seriate arranged in rows.

Sericeous silky; covered with close-pressed, fine, straight silky hairs.

Serrate toothed like a saw; with regular, asymmetric teeth pointing forward.

Serrated toothed margin.

Serratures serrated margin.

Serrulate with minute teeth on the margin.

Sessile without a stalk.

Seta a bristle or stiff hair. *pl.* setae. *adj.* setose, setaceous.

Setaceous bristle-like.

Setate with bristles.

Setiform bristle shaped.

Setulose with minute bristles.

Sheathing clasping or enveloping the stem.

Shrub a woody plant usually less than 5 m high and many-branched without a distinct main stem except at ground level.

Silicula a broad, dry, usually dehiscent fruit derived from two or more carpels which usually dehisce along two sutures. *cf.* siliqua.

Siliqua a silicula which is at least twice as long as broad.

Silt is soil or rock derived granular material of a grain size between sand and clay, grain particles ranging from 0.004 to 0.06 mm in diameter. *adj.* silty.

Simple refer to a leaf or other structure that is not divided into parts. *cf.* compound.

Sinuate with deep wavy margin.

Sinuous wavy.

Sinus an opening or groove, as occurs between the bases of two petals.

Sodicity is characterised by low electrical conductivities and high sodium ion concentrations compared to calcium and magnesium.

Sodic soils contains high levels of sodium salts that affects soil structure, inhibits water movement and causes poor germination and crop establishment and plant toxicity.

Soil pH is a measure of the acidity or basicity of the soil. See pH.

Solitary usually refer to flowers which are borne singly, and not grouped into an inflorescence or clustered.

Sorocarp fruiting body formed by some cellular slime moulds, has both stalk and spore mass.

Sorophore stalk bearing the sorocarp.

Sorus a discrete aggregate of sporangia in ferns. *pl.* sori.

Spadix fleshy spike-like inflorescence with an unbranched, usually thickened axis and small embedded flowers often surrounded by a spathe. *pl.* spadices.

Spathe a large bract ensheathing an inflorescence or its peduncle. *adj.* spathaceous.

Spatheate like or with a spathe.

Spathulate spatula or spoon shaped; broad at the tip and narrowed towards the base.

Spiculate spikelet-bearing.

Spicate borne in or forming a spike.

Spike an unbranched, indeterminate inflorescence with sessile flowers or spiklets. *adj.* spicate, spiciform.

Spikelet a small or secondary spike characteristics of the grasses and sedges and, generally composed of two glumes and one or more florets. Also applied to the small spike-like inflorescence or inflorescence units commonly found in Apiaceae.

Spine a stiff, sharp, pointed structure, formed by modification of a plant organ. *adj.* spinose.

Spinescent ending in a spine; modified to form a spine

Spinulate covered with small spines.

Spinulose with small spines over the surface.

Spodosol see podsol.

Sporangium a spore bearing structure found in ferns, fern allies and gymnosperms. *pl.* sporangia. *adj.* sporangial.

Sporocarp a stalked specialized fruiting structure formed from modified sporophylls, containing sporangia or spores as found in ferns and fern allies.

Sporophore a spore-bearing structure, especially in fungi.

Sporophyll a leaf or bract which bears or subtends sporangia in the fern allies, ferns and gymnosperms.

Sporophyte the spore-producing phase in the life cycle of a plant that exhibits alternation of generations.

Spreading bending or spreading outwards and horizontally.

Spur a tubular or saclike extension of the corolla or calyx of a flower.

Squama structure shaped like a fish scale. *pl.* squamae.

Squamous covered in scales.

Squarrose having rough or spreading scale-like processes.

Stamen the male part of a flower, consisting typically of a stalk (filament) and a pollen-bearing portion (anther). *adj.* staminal, staminate.

Staminate unisexual flower bearing stamens but no functional pistils.

Staminode a sterile or abortive stamen, often reduced in size and lacking anther. *adj.* staminodial.

Standard refers to the adaxial petal in the flower of Papilionaceae. cf. keel, wing.

Starch a polysaccharide carbohydrate consisting of a large number of glucose units joined together by glycosidic bonds α-1-4 linkages.

Stellate star shaped, applies to hairs.

Stem the main axis of a plant, developed from the plumule of the embryo and typically bearing leaves.

Sterile lacking any functional sexual parts which are capable of fertilisation and seed production.

Stigma the sticky receptive tip of an ovary with or without a style which is receptive to pollen.

Stilt root a supporting root arising from the stem some distance above the ground as in some mangroves, sometimes also known as a prop root.

Stipe a stalk that support some other structure like the frond, ovary or fruit.

Stipel secondary stipule at the base of a leaflet. *pl.* stipellae. *adj.* stipellate.

Stipitate having a stalk or stipe, usually of an ovary or fruit.

Stipulated having stipules.

Stipule small leaf-like, scale-like or bristle-like appendages at the base of the leaf or on the petiole. *adj.* stipulate.

Stolon a horizontal, creeping stem rooting at the nodes and giving rise to another plant at its tip.
Stoloniferous bearing stolon or stolons.
Stoma a pore in the epidermis of the leaf or stem for gaseous exchange. *pl*. stomata.
Stone the hard endocarp of a drupe, containing the seed or seeds.
Stramineous chaffy; straw-liked.
Striae parallel longitudinal lines or ridges. *adj.* striate.
Striate marked with fine longitudinal parallel lines or ridges.
Strigose bearing stiff, straight, closely appressed hair; often the hairs have swollen bases.
Strobilus a cone-like structure formed from sporophylls or sporangiophores. *pl.* strobili
Style the part of the pistil between the stigma and ovary.
Sub- a prefix meaning nearly or almost, as in subglobose or subequal.
Subcarnose nearly fleshy.
Sub-family taxonomic rank between the family and tribe.
Subglobose nearly spherical in shape.
Subretuse faintly notched at the apex.
Subsessile nearly stalkless or sessile.
Subshrub intermediate between a herb and shrub.
Subspecies a taxonomic rank subordinate to species.
Substrate surface on which a plant or organism grows or attached to.
Subtend attached below something.
Subulate narrow and tapering gradually to a fine point, awl-shaped.
Succulent fleshy, juicy, soft in texture and usually thickened.
Sulcate grooved longitudinally with deep furrows.
Sulcus a groove or depression running along the internodes of culms or branches.
Superior refers to the ovary is free and mostly above the level of insertion of the sepals, and petals. *cf.* inferior.
Suture line of dehiscence.
Swidden slash-and-burn or shifting cultivation.
Symbiosis describes close and often long-term mutualistic and beneficial interactions between different organisms.
Sympetalous having petals united.
Sympodial refers to a specialized lateral growth pattern in which the apical meristem. *cf.* monopodial.
Synangium an organ composed of united sporangia, divided internally into cells, each containing spores. *pl.* synangia.
Syncarp an aggregate or multiple fruit formed from two or more united carpels with a single style. *adj*. syncarpous.
Syncarpous carpels fused forming a compound pistil.
Syconium a type of pseudocarp formed from a hollow receptacle with small flowers attached to the inner wall. After fertilization the ovaries of the female flowers develop into one-seeded achenes, e.g. fig.
Tannins group of plant-derived phenolic compounds.
Taxon the taxonomic group of plants of any rank. e.g. a family, genus, species or any infraspecific category. *pl.* taxa.
Tendril a slender, threadlike organ formed from a modified stem, leaf or leaflet which, by coiling around objects, supports a climbing plant.
Tepal a segment of the perianth in a flower in which all the perianth segments are similar in appearance, and are not differentiated into calyx and corolla; a sepal or petal.
Tetrasporangium a sporangium containing four haploid spores as found in some algae.
Terete having a circular shape when cross-sectioned or a cylindrical shape that tapers at each end.
Terminal at the apex or distal end.
Ternate in threes as of leaf with three leaflets.
Testa a seed coat, outer integument of a seed.
Thallus plant body of algae, fungi, and other lower organisms.
Thyrse a dense, panicle-like inflorescence, as of the lilac, in which the lateral branches terminate in cymes.
Tomentose refers to plant hairs that are bent and matted forming a wooly coating.
Tomentellose mildly tomentose.
Torus receptacle of a flower.
Transpiration evaporation of water from the plant through leaf and stem pores.

Tree that has many secondary branches supported clear of the ground on a single main stem or trunk.

Triangular shaped like a triangle, 3-angled and 3-sided.

Tribe a category intermediate in rank between subfamily and genus.

Trichome a hair-like outgrowth of the epidermis.

Trichotomous divided almost equally into three parts or elements.

Tridentate three toothed or three pronged.

Trifid divided or cleft into three parts or lobes.

Trifoliate having three leaves.

Trifoliolate a leaf having three leaflets.

Trifurcate having three forks or branches.

Trigonous obtusely three-angled; triangular in cross-section with plane faces.

Tripartite consisting of three parts.

Tripinnate relating to leaves, pinnately divided three times with pinnate pinnules.

Tripliveined main laterals arising above base of lamina.

Triploid describing a nucleus or cell that has three times (3n) the haploid number (n) of chromosomes.

Triveined main laterals arising at the base of lamina.

Triquetrous Three-edged; acutely 3-angled.

Trullate with the widest axis below the middle and with straight margins; ovate but margins straight and angled below middle, trowel-shaped.

Truncate with an abruptly transverse end as if cut off.

Tuber a stem, usually underground, enlarged as a storage organ and with minute scale-like leaves and buds. *adj*. tuberous.

Tubercle a wart-like protuberance. *adj*. tuberculate.

Tuberculate bearing tubercles; covered with warty lumps.

Tuberization formation of tubers in the soil.

Tuft a densely packed cluster arising from an axis. *adj*. tufted.

Turbinate having the shape of a top; cone-shaped, with the apex downward, inversely conic.

Turgid distended by water or other liquid.

Turion the tender young, scaly shoot such as asparagus, developed from an underground bud without branches or leaves.

Turnery articles made by the process of turning.

Twining winding spirally.

Ultisols mineral soils with no calcareous material, have less than 10% weatherable minerals in the extreme top layer of soil, and with less the 35% base saturation throughout the soil.

Umbel an inflorescence of pedicellate flowers of almost equal length arising from one point on top of the peduncle. *adj*. umbellate.

Umbellet a secondary umbel of a compound umbel. *cf.* umbellule.

Umbellule an, a secondary umbel of a compound umbel. *cf.* umbellet.

Uncinate bent at the end like a hook; unciform.

Undershrub subshrub; a small, usually sparsely branched woody shrub less than 1 m high. *cf.* shrub.

Undulate with an edge/margin or edges wavy in a vertical plane; may vary from weakly to strongly undulate or crisped. *cf.* crisped.

Unifoliolate a compound leaf which has been reduced to a single, usually terminal leaflet.

Uniform with one form, e.g. having stamens of a similar length or having one kind of leaf. *cf.* dimorphic.

Uniseriate arranged in one row or at one level.

Unisexual with one sex only, either bearing the anthers with pollen, or an ovary with ovules, referring to a flower, inflorescence or individual plant. *cf.* bisexual.

Urceolate shaped like a jug, urn or pitcher.

Utricle a small bladdery pericarp.

Valvate meeting without overlapping, as of sepals or petals in bud. *cf.* imbricate.

Valve one of the sections or portions into which a capsule separates when ripe.

Variant any definable individual or group of individuals which may or may not be regarded as representing a formal taxon after examination.

Variegate, variegated diverse in colour or marked with irregular patches of different colours, blotched.

Variety a taxonomic rank below that of subspecies.

Vein (Botany) a strand of vascular bundle tissue.

Velum a flap of tissue covering the sporangium in the fern, Isoetes.

Velutinous having the surface covered with a fine and dense silky pubescence of short fine hairs; velvety. *cf.* sericeous

Venation distribution or arrangement of veins in a leaf.

Veneer thin sheet of wood.

Ventral (Botany) facing the central axis, opposed to dorsal.

Vernation the arrangement of young leaves or fronds in a bud or at a stem apex. *cf.* circinnate

Verrucose warty

Verticil a circular arrangement, as of flowers, leaves, or hairs, growing about a central point; a whorl.

Verticillaster false whorl composed of a pair of opposite cymes as in Lamiaceae.

Verticillate whorled, arranged in one or more whorls.

Vertisol a soil with a high content of expansive montmorillonite clay that forms deep cracks in drier seasons or years.

Vertosols soils that both contain more than 35% clay and possess deep cracks wider than 5 mm during most years.

Vesicle a small bladdery sac or cavity filled with air or fluid. *adj.* vesicular.

Vestigial the remaining trace or remnant of an organ which seemingly lost all or most of its original function in a species through evolution.

Vestiture covering; the type of hairiness, scaliness or other covering commonly found on the external parts of plants. *cf.* indumentums.

Vibratile capable of to and for motion.

Villose covered with long, fine, soft hairs, finer than in pilose.

Villous covered with soft, shaggy unmatted hairs.

Vine a climbing or trailing plant.

Violaxanthin is a natural xanthophyll pigment with an orange color found in a variety of plants like pansies.

Viscid sticky, being of a consistency that resists flow.

Viviparous describes seeds or fruit which sprout before they fall from the parent plant.

Whorl a ring-like arrangement of leaves, sepals, stamens or other organs around an axis.

Winged having a flat, often membranous expansion or flange, e.g. on a seed, stem or one of the two lateral petals of a Papilionaceous flower or one of the petal-like sepals of Polygalaceae. *cf.* keel, standard.

Xanthophylls are yellow, carotenoid pigments found in plants. They are oxidized derivatives of carotenes.

Xeromorphic plant with special modified structure to help the plant to adapt to dry conditions.

Xerophyte a plant which naturally grows in dry regions and is often structurally modified to withstand dry conditions.

Zygomorphic having only one plane of symmetry, usually the vertical plane, referring to a flower, calyx or corolla. *cf.* actinomorphic.

Zygote the fist cell formed by the union of two gametes in sexual reproduction. *adj.* zygotic.

Common Name Index

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