Environmental Footprints and Eco-design of Products and Processes

Subramanian Senthilkannan Muthu
Miguel Angel Gardetti *Editors*

Green Fashion

Volume 2

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Preface

This book is the second volume from us on the subject of green fashion. As stated earlier, sustainable or green fashion (also called "eco fashion") is one of the most "happening" trends in the field of fashion sustainability. The topic comprises a vast and wide subject base consisting of many elements that need to be discussed. We covered many details pertaining to green fashion in our first volume; however, many subjects still remain under the "umbrella" of green fashion; hence, our idea of publishing this second volume. We are sure that these two volumes on green fashion will augment our limited knowledge on the topic. This current volume of *Green Fashion* covers and explains the crux of green fashion through seven important chapters written by prominent researchers working in the field.

The topics of the seven informative chapters in Volume 2 include the following: unexplored vegetable fibre in green fashion; relationship marketing in green fashion (a case study of hessnatur); animal ethics and welfare in the fashion and lifestyle industries; proposal of a responsible fashion council; innovation for a sustainable fashion industry; green flame retardants for textiles; and potent polyphenolic natural colorants derived from plants.

We are confident that the readers of these two volumes of *Green Fashion* will gain much useful information pertaining to green fashion. We sincerely thank each of the authors who contributed the seven chapters in this book for their time and priceless effort expended.

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Unexplored Vegetable Fibre in Green Fashion

Sanjoy Debnath

Abstract Unexplored and unexploited plant fibres are being used in fashion industries along with man-made fibres. Some of these fibres, such as flax, hemp, etc., which are quite popular in fashion industries and standard fashion market, are also available globally. There are quite a number of plant fibres that have huge potential in fashion and are now coming into focus in the field of "green" fashion. This chapter discusses the major unexplored plant fibres that can be used in green fashion commercially. It covers both wearable and nonwearable fashions made from these plant fibres. The chapter also emphasizes the aspects of cultivation and production of the fashion products and present technologies in the development of the green fashion products. Nevertheless, it highlights the future uses of these unexplored fibres in a sustainable fashion.

Keywords Natural fibres · Plant fibres · Unexplored fibres · Green fashion · Product diversification

1 Introduction—History, Importance in Today's Scenario

During the progress of human civilization, the application of natural fibres has been discovered, and these textile materials have been used for protection from different climatic conditions. Little is known about when exactly man switched from wearing tree bark and animal skins to fibre-based clothing in prehistoric times. With the passage of time, the textile fibres were converted into yarns, and subsequently those yarns were used for making fabric. In the latter half of the nineteenth century, synthetic and man-made fibres underwent immense

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development. From the end of nineteenth century to the beginning of twentieth century, human society understood and realized that most man-made fibres are petroleum based and as such the petroleum reserve may be diminished to a large extent over the long run. Apart from having good fibre strength, most man-made fibres are more lustrous and silky in nature. These qualities have affected the natural fibre industry. Recently, efforts have been made to reuse or recycle synthetic fibres as much as possible; at the same time, more emphasis has been placed on the production of the natural fibre as sustainable fibre resource materials. Thus, it is time to give more emphasis to natural fibres, which are renewable in nature and naturally degradable after disposal. Therefore, there is a craze to use and popularize more products and more applications in textiles, especially for development of fashion textiles. As far as plant fibre is concerned, flax, nettle, cotton, etc. are some of the fibres that were used in ancient days. Slowly, the look and appearance of textile material became important, and these qualities were achieved by using natural dye extracted mostly from different plant sources. Basu and Roy (2008) documented blending of various natural fibres, mostly of plant origin, for the development of valued-added products. Fashion textiles are the area of textile applications where textile materials are used to serve different purposes such as appearance, esthetic, fashion, appealing, design, comfort, etc. Mostly these fashion textiles are of two types: wearable fashion (fashion garments, fashion clothing, fashion sport, fashion ornaments, etc.) and nonwearable fashion (fashion items used for decoration of room, wall, floor, home, office, mall, hall, auditorium, etc.). Currently natural fibres are mostly used as luxury textiles and more recently the trend is to design and develop textiles, especially for fashion, from unexplored fibres. “Green” processes and technologies are used so that the overall manufacturing system is eco-friendly and profitable due to value addition.

Recently, more attention has been paid to the use of renewable resources, particularly from plant origin, considering the ecological concerns about the health of our planet. On the other hand, despite abundant availability from the renewable resource of ligno-cellulose materials, few attempts have been made to use them properly. This may be due to the lack of availability of sufficient structure/property data as well as lack of awareness of the users. However, systematic studies may bridge these gaps while leading to value addition for these natural fibrous materials in fashion textiles. History speaks: Several natural fibres were used from ancient times onward, and slowly their use was reduced due to problems with extraction, less remuneration in cultivation, labour intensive, etc.

This chapter provides an elaborate discussion of plant fibres that remain unexplored but which have enormous potential in the manufacture of green fashion products. Although there is a long list of fibres that can be extracted from plant sources, but many of them are not extracted. These ligno-cellulosic fibres, which are as yet unexplored but have a possible commercial market, are given much focus. This present chapter will also discuss in detail the merits and demerits of these unexplored natural fibre and their potential application emphasizing green fashion.

2 Different Unexplored Fibres—Fashion Textiles

Natural fibres can be classified by the source from which they are extracted. Basically, there are two categories: animal sources and plant sources. Wool, silk, etc. are example of animal sources, and cotton, flax, jute, etc. are some examples of plant fibres. If we talk about natural fibres, people in society are aware and customarily think of cotton, silk, and wool as being used in fashion or technical applications. However, in the arena of textiles, there are many unexplored natural fibres out of which technical and fashion textiles are being made. Presented below are some of the important applications of natural fibre-based textiles used for fashion and technical applications.

Fashion textiles can be classified into two categories: wearable textiles and nonwearble textiles. Wearable fashion textiles include trousers, shirts, shawls, jackets, coats, mufflers, neckties, ornaments, etc. Nonwearble textiles include curtains, furnishings (sofa, table, and bed covers), floor coverings/floor mats, doormats, flower vases, fruit baskets, models/idols, door chains, wall hangings, table mats, etc. Different unexplored fibres are used to produce these fashion products.

In terms of unique natural plant fibres, jute is second to cotton in terms of organized production and marketing. India is the largest producer of jute fibre. For a few centuries, jute fibre has been popular for use as packaging and carpet-backing material. Currently substitute synthetic packaging materials are competing with jute in the traditional market. Scientists have tried to find new application for jute in diverse areas. Today jute fibres are being used in diversified fashion applications such as jute-based dolls, idols, models, etc. As for decoration applications, jute is being used in floor mats, doormats, wall hangings, door chains, table mats, etc. There are also applications of jute-based furnishing materials such as curtains, sofa covers, bed covers, etc. Regarding wearable textiles, jute can be used in secondary dress materials. Currently jute-based materials are used for designing and developing warm fashion clothing such as shawls, jackets, blazers, coats, etc.

2.1 Jute

Jute is one of the bast fibres originating in the Mediterranean region (Stewart 1998) and eventually it came to India. Per historical records, jute was known as *patta* in 800 BC. Jute fibre has been popular for more than a century for its industrial applications, such as packaging material, in different sectors, geotextile application, and carpet-backing material (Debnath et al. 2009). However, in the last few decades, jute has been used diversified areas apart from its age-old applications. It has been found from the literature that jute with ornamentation—and using suitable modifications in spinning, weaving, and knitting—can be used to create nonwoven, hand-loom fabrics that have an attractive look of elegance (Anonymous 2006a). Fashion-design aspects have been considered at the fabric-manufacturing stage and

other in the manufacture of clothing using designed fabric (i.e., garment manufacturing). Furthermore, jute-based fashion garments were exhibited in fashion shows at GIFTEX Stationex and Jutex 2005 during August 2005 at Mumbai. The literature also reveals that apart from these conventional products, jute can be used for development of value-added green textiles. Some of these jute-based green textiles are fashionable, and some are of industrial application in nature. Fashionable green products from jute-based materials (Debnath et al. 2009) include fashion garments (Debnath 2013a, 2014b), bulked yarns for sweaters, jute slippers, decorative and utility products from hand-made paper, fashionable bags for school and office, curtain materials, etc.

When comes the question of technical fashion products (nonwearble) from jute apart from its exclusive technical products like improved geotextile and agro textile (Debnath 2014a), decorative composite and moulded products for different domestic and office applications, fancy file boards and file covers from jute pulp, etc. Apart from these fashion products made from jute-based material, particle board made from whole jute plant as well as jute stick also has immense potential in the fashion industry specifically for fashion photo frames, temporary partition walls, decorative false ceilings, table tops, etc. Jute-based particle board has a natural aesthetic look, which is one of the green fashion applications provided that the use of a bioadhesive in the preparation is ensured. Different possibilities of product development of composite and moulded products from jute and allied fibres can open up new avenue of using these natural fibres toward green technologies (Anonymous 2005a). These composite materials made from green plant fibres include chairs and table tops, wash basins, and jute-reinforced plastic tiles in place of porcelain tiles. In this study, the investigator also optimized jute–polypropylene compounding granules and jute-HDPE (high-density polyethylene) of different blends (80:20, 70:30, and 65:35).

2.2 Sunnhemp

Sunnhemp is an important legume crop with multiple uses in textiles (Chaudhury et al. 2015). Researchers developed value-added textiles from sunnhemp fibres (Anonymous 2005b). They found that the fibre procured from Nagpur, India, contained 60 % good spinnable fibre. The raw fibre showed an acceptable level of strength and fineness for subsequent processing. Common wet-processing technology can be adopted for sunnhemp fibre. However, chemical treatment resulted in some loss of strength, but it was sufficient to spin good yarn. After bleaching, substantial whiteness can be achieved, and different colour shades can be applied. Miniature jute spinning, as well as a commercial jute-spinning system, can be adapted to spin sunnhemp yarn, and the physical properties of the resulting spun yarn are comparable with that of conventional jute yarn of similar linear density. Sunnhemp-cotton fabric can be made for diversified application wherein the cotton is used in warp and sunnhemp in weft directions. This compound fabric can

have good colouration with suitable application of reactive dye. The finished sunnhemp-based products have an attractive look and feel (Anonymous 2005b).

2.3 Ramie

Ramie (*Boehmeria nivea*) is a bast fibre extracted from the bast of the ramie plant. China is the pioneer in ramie-fibre production. In China, ramie it is known as "China grass" and is used in different popular fashion products such as women's dress material, shirts, suits, handicraft products, etc. However, ramie-based technologies and fashion products have not spread to a greater extent in other part of the world. The important concern about the ramie is the removal of gum content from the extracted fibres. Gum comprises as much as 30 % of the weight of ramie fibre. An economical process of gum extraction from ramie fibre has been developed; furthermore, extracted natural gum has been used as natural resin for the development of jute particle board. With composite technology, the whole process of ramie-gum utilization for the development of green particle board has been demonstrated (Anonymous 2002a, b). Thakur et al. (1999), reported detailed findings on the chemical composition of ramie fibre. They found that complete removal of gum ramie fibre is similar to that of pure cellulose, thus indicating that ramie contains approximately 94–95 % alpha cellulose. As far as the fibre itself is concerned, ramie is a strong, lustrous, soft, and fine bast fibre obtained from the inner bark of the plant *Boehmeria nivea (L) Gaud*. Research results have shown the processing technology of cotton–ramie blends (Anonymous 2002a, b) on short staple–spinning system (i.e., cotton spinning). Because both fibres are of natural plant origin, it is expected that the products will be environmentally green. *Lisingphee*, fancy ramie-cotton woven towels, fancy designed fabrics, etc. are some of the novel fashion products developed form cotton–ramie blend yarns. The researchers also characterized fibre properties such as bundle tenacity, breaking elongation, fibre fineness in tex, Whiteness Index in Hunter scale, Yellowness Index and Brightness Index at different stages of fibre (decorticated, degummed, and bleached ramie fibre) used for development of cotton-ramie fashion fabrics (Anonymous 2003). Ahmed et al. (2004) found that the reduction of gum content from 20–30 % to 2–3 % using alkali treatment and subsequent bleaching of ramie fibre used in the blended cotton-ramie yarn spun in a cotton-spinning system resulted in deteriorated yarn strength.

2.4 Flax

The earliest example of preserved linen appears to be a needle-netted linen headpiece from Nahal Hemar Cave in Israel from 8500 years ago, and Swiss lake dwellers used native flax to make cloth 5000–6000 years ago. Linen was the

preferred textile of the ancient Egyptians who used it for clothing, bed linen, shrouds for mummies, and ships' sails. The earliest Egyptian linen cloth dates from the period of the Old Kingdom, but flax appears to be have been grown for linen approximately 5000 years ago in the Early Dynastic period. Flax fibre comes under the category of bast fibre and is extracted from the plant of the linseed/flax plant (*Linum usitatissium* L.). This plant is popular for two reasons: One is flax fibre, and the other is linseed oil (used for industrial applications), which is extracted from the seed of the plant (Basu and Dutta 2014). As far as fashion industry is concerned, flax and its blend with other fibres (natural/man-made) is quite popular; hence, an in-depth discussion of flax-based fashion is not provided herein.

2.5 Nettle

In research about the history of spinning, weaving, and knitting machines, English (1969) reported that nettle fibres have been used traditionally for spinning yarn and that apart from industrial applications, those yarns have been further used for apparel fabrics. Dunsmore (2006) and Dunsmore (1998), also explained the importance of nettle-fibre processing and hand spinning of nettle yarn considering different situations in Nepal. She also described the hand weaving of nettle fabric and the different possibilities of creating fashion apparel from sustainable nettle fibre. Guo et al. (2006), applied different spinning systems and techniques for the sustainable spinning of nettle fibers. Their results show that nettle fibers cannot be used for spinning singly because the common length of nettle fibers are short, and the discrete coefficient of length and fineness is varied. However, when nettle is admixed with other fibers, the test-yarn qualities are somewhat acceptable. Their research output can be useful for developing sustainable and fashionable products from wild nettle fibres.

Furthermore, it has been documented that the stem and fibre of stinging nettle are used to prepare traditional handicrafts in several Balkan countries (Dogan et al. 2008). This nettle fibrous material in Bulgaria, known locally as *kop riva*, is used for the sustainable development of cloth, sack, cord, and net manufacturing applications. In Romania, nettle is known as *urzica*, and it is used as a substitute for cotton in fishing-net production and paper-making. It is known as *kop riva* in Serbia, where nettle fibre is considered one of the major textile fibres used in the spinning industry to produce textile products. Overall, a wide range of possible handicraft products can be made from nettle either from fibre yarn or fabric or combination of these. Such products include doormats, flower vases, wall hangings, door chains, carpets, handbags, table mats, beach umbrellas, lamp shades, etc. All of these products have huge profit margin due to the high cost-to-benefit ratio. Most of the handicraft products fall under the category of fashion items. In Nepal, different handicraft products are made out of nettle fibres, and hand-spun yarn has well documented by Dunsmore (2006) and by Deokota and Chhetri (2009).

Bacci et al. (2010) also reported that for sustainable handicraft products can be made from nettle through enzyme retting, which is an example of a green technology. Anonymous (1998a) also described different sustainable fashion items made out of nettle fibre and its blend such as hats, jackets, room decorations, and various handicraft products.

2.6 Pineapple Leaf Fibre

Pineapple leaf fibre is an unexplored natural fibre extracted from the green pineapple plant leaf, which is normally considered agricultural waste (Banik et al. 2011). This fibre has also immense potential of using as fibre source in the arena of green fashion textiles (Debnath 2016). Piña is a fiber made from the leaves of the pineapple plant and is commonly used in the Philippines. It is sometimes combined with silk or polyester to create a textile fabric. Piña's name comes from the Spanish word *piña*, which literally means "pineapple." In the Philippines, pineapple silk is considered the "queen" of Philippine fabrics and is considered the fabric of choice of the Philippine elite. Literature reveals that Ghosh and Sinha (1977) are pioneers in developing textile products from pineapple leaf fibre. They used a special technique to spin pineapple fibre in jute-spinning machinery. In their studies, they found that fine pineapple leaf fibre could be spun into in yarns in 70- to 170-tex linear densities. However, in admixture with jute, 10–15 % pineapple fibre will improve the performance of jute-blended yarn, and fine jute–pineapple blended yarn can be produced. These fine pineapple and pineapple–jute blended yarns have been made into plain and twill cloth developed for fashion-fabric development. These lightweight fashion fabrics are further used to design fashion bags, curtains, and furnishing fabrics. Finally, the investigators concluded that these pineapple leaf or jute–pineapple leaf fibre blended products have huge potential for green fashion. Furthermore, Ghosh et al. (1982) documented the processing pineapple leaf fibre in a cotton-spinning system. Before processing in the cotton-spinning system, they studied and compared the physical and mechanical properties of cotton, jute, and pineapple leaf fibres. They found it is not possible to spin 100 % pineapple leaf fibre into yarn in cotton-spinning machinery. They tried doing so with different proportions of pineapple leaf fibre viz., 50, 33, and 20 %, combined with cotton. However, a 50:50 blend of pineapple fibre and cotton has finally been optimized. Although spinning performance is poor in the cotton-pineapple fibre blend, a huge amount of cotton can be saved and thereby a value-added green product can be made. In the same area of blending of pineapple leaf fibre, there is also evidence to study the performance of blending pineapple leaf with acrylic fibre in a jute-spinning system (Ghosh et al. 1987; Dey et al. 2009). The investigators studied the fibre properties of pineapple leaf and acrylic and compared the similarities and dissimilarities between them. Five different blends of pineapple leaf and acrylic fibre in different ratios have been tried, viz., 87:13; 67:33; 50:50; 33:67, and 13:87. From these blends, fine yarn of 84 tex was spun in a wet-spinning process where the rove

was passed through a temperature bath (80–100 °C) before spinning. They also spun the same yarns through a dry-spinning process. They compared the dry- and wet-spinning process and found that the breaking stress is reduced in wet spinning but the breaking strain was improved by 6 times. The optimum blend composition found from their studies is 67:33 pineapple-acrylic blended yarn. The wet-spinning performance is superior to the dry-spinning method. Finally, they also concluded that there is ample scope for development of green fancy apparel products made out of these pineapple-acrylic blended yarns (Dey et al. 2009, Ghosh and Dey (1988)).

Regarding fancy composite materials, pineapple leaf fibre-natural rubber composites (Lopattananon et al. 2006), soy-based bioplastic as natural resin, and pineapple leaf fibre as natural reinforcement fibre component (Liu et al. 2005; Mishra et al. 2001, 2004) are termed "green" composites. In this regard, natural fibers can replace glass fibers in fiber-reinforced plastics in some application areas (Mohamed et al. 2009) because pineapple leave fibers have high cellulose content (Saha et al. 1993) and are mechanically sound as a reinforcement in polymer composites.

2.7 Coconut Fibre

Coconut fibre, also known as coir fibre, is extracted from the outer fibrous material of coconut fruit. Although coconut palms grow throughout the world's tropical regions, the vast majority of commercially produced coir comes from India and Sri Lanka. White and brown coconut fibres are the two main types of fibres available. White fibres are extracted from the green (tender) coconut, and brown fibres are extracted from matured coconut, which takes 3–6 months of retting in brackish water (Bhattacharya and Basu 2009). There is evidence of processing coconut (coir) fibre (*Cocos nucifera*) in a small-scale jute-spinning system (Anonymous 2002b). The investigator compared the yarn properties obtained from yarns in different spinning systems (manual, semiautomatic, and automatic ratt machines) with a conventional jute-spinning system. They also attempted to blend jute and coir fibre (in ratios of 30:70, 40:60, 60:40, and 70:30, respectively) with the aim of developing value-added products. Experiments on blending coconut with jute fibre (Banerjee et al. 2000, 2001) and at spinning preparatory stage are presently concerning as technical textiles are focused more toward geotextile materials. Anonymous (2006a, b) developed different types of lightweight fancy-design handbags and fashion doormats from jute–coconut fibre blended coarse yarns. Furthermore, Anonymous 2012, revealed that jute (60 %) and coconut (40 %) fibres can be blended for the development of value-added jute–coconut fibre blended yarn. The blended yarn is used for the development of ornamental woven fabric, which can be used to make fashionable ladies slippers, decorative floor mats etc. There has been work to soften coir fibre for better flexibility and there have been attempts to develop dyed jute-coconut fibre blended yarn. Apart from these, sustainable fashion products—such as coconut fibre-based idols, decorative doormats, household decorations, etc.—have a good commercial market.

2.8 Banana Fibre

Banana fibre (*Musa sapientum*) can be a good source for the development of green fashion products. Fibres are extracted from the pseudo-stem of the banana plant. The fibres are bleached and blended with jute fibre aiming for diversified value-added fashionable products (Debnath and Das 2012). Because both jute and banana fibres derive from plant sources, products made of these fibre are environmentally green. Sinha (1974a, b) is a pioneer in blending banana-based fibres for the development of different products. This work elaborates the use of white jute, tossa jute, and kenaf, which were blended separately with 75 and 50 % banana sheath fibre (i.e., extracted from the sheath of banana stem) at the jute-finisher card. Banana reeds (a streak of fibre bundle extracted from the stem), after being softened with an oil-in-water emulsion and piling for 72 h, were stapled in 20 cm lengths to avoid roller lapping at the breaker-card stage. After piling, banana fibres were processed separately in a jute-breaker card followed by jute-finisher cared; finally, blending was accomplished in a jute-drawing machine. Yarns of 345 and 280 tex were spun using a jute-spinning system. Although the yarn quality deteriorated marginally with the increase the in percentage of banana fibre in the blend, the ratio of fibres in the jute–banana fibre blended yarn was judicious, and the yarn could successfully be used as hessian weft and sacking warp. Furthermore, Sinha (1974b) used jute-processing technology for producing coarse yarn and found that plying those individual yarns with the incorporation of suitable twist can lead to preparation of banana rope. Anonymous (2012b), showed that conventional hydrogen peroxide bleaching, which has been used for bleaching the fibre, and further dyeing has been accomplished. Studies have been performed on different blend ratios of jute to banana (100:0; 75:25; 50:50; 25:75; and 0:100) wherein the properties of the different resulting yarns were compared. Due to the coarseness and brittleness of the banana fibre, spinning of 100 % banana fibre showed poor results. Anonymous (2012c), reported that bleached and dyed jute–banana fibre yarns can be used to develop ornamental fibre using a jacquard attachment in handloom. The decorative fabrics are used for the manufacture of fashion jackets. Hence there is immense potential to design and develop green-banana fibre textiles.

2.9 Sisal

Sisal is a plant fibre (*Agave sisalana*) normally extracted from the leaf of the plant. It is very hard and robust, and the lingo-cellulosic fibre is extracted from green sisal leaves using a suitable sisal-fibre extractor. Due to the presence of a waxy coating on the fibre surface, this fibre normally is very slippery, lustrous, and less prone to microbial attack despite its high strength-to-weight ratio. In ancient days, this fibre was used for anchoring ships and boats due to its high resistance to sunlight and water. Sisal fibre was first cultivated in Brazil on a broad scale

and later its use spread to other part of the world. Initially, Brazil cultivated this fibre for rope twine, paper, cloth, wall coverings, dartboards, etc. (Anonymous 2015a). Apart from Brazil, Tanzania, Kenya, Madagascar, China, Mexico, Haiti, Venezuela, Morocco, and South Africa are major producer of sisal fibre products in the world. Basu et al. (2012) tested various Indian varieties of sisal fibres and compared their properties with those of other imported commercial fibres. There is evidence that (Anonymous, 2015b, c) there exist different commercial manufacturers of sisal-based fashion products. Thailand is a manufacturer/exporter/wholesaler of natural handmade handbags based in Bangkok including smart and trendy sisal ladies' handbags, shopping bags, cosmetic bags and cases, gift bags, promotional gifts, shoulder bags, hats, and handmade baskets at attractive prices. In Mexico, jewels are created to highlight the personality of every woman. All pieces are plated with 18k gold and fused with riches of the nature such as wood, sisal, leather, semiprecious stones, and feathers. Tanzania is a specialized exporter of hand-crafted fashion bags and baskets made of natural fibers such as raffia and sisal. These natural fibers originated in Indian Ocean islands. The company presents a wide range of products that are a statement in elegance and style. Kenya produces hand-crafted beaded sandals and flip-flops, beaded bracelets, leather belts, fashion belts, bone/horn jewelry, hand-woven sisal and leather bags/totes, and even home decor such as wood/stone sculptures, mirrors, hand-painted stone pen holders, decor plates, bowls, etc. Unlike found in other textiles, Sinclair (2015) highlighted the different aspects and products of sisal in the area of textiles and fashion. She emphasized its design aspects as well as different technologies for the preparation of sisal fashion products. There is a case study that, in 2012, after serving on big brands in the product development area, the stylist and manager of the fashion industry, Salvia (2012) decided to start his own business and innovated the creation of sisal fashion products. Over time, the service has been improved and now includes private service for customers registered to receive exclusive pieces even outside of the store's regular operating hours. They create a totally personalized service according to the profile and style of each consumer Salvia explained. Thus, the service is performed with every comfort for those people who do not have time to enjoy the warm décor of the stores, which are already in three locations: There are two in São Paulo and one in the Jequiti line in Guaruja, Sao Paulo coast. Sisal Store Mod a works with the women's brands Bobô, Calvin Klein Jeans, Calvin Klein Underwear, Espaço Fashion, Le Lis Blanc, Juicy Couture, Hit, John John Denim, Letage, Mob, Saad, Tigresse, Tryia, Rock Lilly, Chaos and the men's brands Calvin Klein Jeans, Calvin Klein Underwear, Los Dos, Mandi, and Zapala. Apart from these green fashion areas where sisal fibres are used, this fibre is also blended with wool and nylon for the manufacture of fashion carpets and rugs (Anonymous 2015d). One of important fashion as well as utility products made out of sisal is the sisal-based body scrubber. Anonymous (2005c) developed a processing technology using sisal-jute blends for the production of body scrubber that have potential to replace the existing shoddy nylon body scrubber.

2.10 Hemp

Processed hemp fibre can be used to manufacture fabric that is ideal for summer clothing with good ventilation and moisture absorption as well as antibacterial and anti-ultraviolet properties (Paolo and Gianpietro 2004). Hemp fibres are very rigid and rough to handle. Clothing made with the untreated fibres appears wrinkled and feel prickly. As a result of the high levels of friction and tension during the spinning and weaving processes, part of the short hemp fibre stands out from the surface of yarns and fabric, making them appear and feel hairy. Unlike flax fibre, hemp is also popularly known in the fashion industry, and therefore further detailed coverage is not offered herein.

2.11 Other Unpopular Plant Fibre

As far as unpopular fibres are concerned, these are mostly not successful due to present application areas of these fibres, the quantum of cultivation, yield of fibre from the green plant, fibre-collection difficulties etc. Fibres belong to these category include okra/*bhindi* fibre, kapok, khimp, etc. The possible reasons for their lack of popularity are discussed below.

2.11.1 Okra Fibre

The okra plant bark contains fibres, and these fibres can be extracted after proper retting and extraction. However, the okra plant is cultivated for the okra (*bhendi*/ ladies finger), which is popularly consumed as green vegetable. However, for fibre purposes, extraction must be done before formation of okra pods in the plant up to a maximum of the flowering stage. Extraction of fibres at this stage in not economically viable. Moreover, once the fruit develops, the fibres are overly mature, and after extraction the fibre is very coarse and brittle. Hence, this fibre is not popular although it is a potential source of green fibre.

2.11.2 Kapok Fibre

Kapok fibre is mainly seed fibre, and seeds are collected from uncultivated plant. The plant are very large, thus plucking of the fibre ball from the seed is difficult due to the height of the plant and the different growth periods of the fibre ball in each plant. Moreover, the production per volume of plant is quite low. Furthermore, the fibre has poor strength, which overall makes the fibre an unpopular one. Still, in some of the cases, kapok fibres are used in making hand-made quilts, soft toys, etc.

2.11.3 Alfa Fibre

Ghali et al. (2014) extracted alfa fibers from the plant *Stippa tenacissima* or esparto grass (*alfa* is the Arab name for *esparto*), which grows in the dry regions of North Africa. These fibers are used extensively in the production of paper. Given that this plant is very available in Tunisia and in order to make it a successful alternative crop, it must be incorporated into value-added products such as nonwoven materials for domestic textiles. The investigators used this fibre to make nonwoven materials for diverse uses. Bessadok et al. (2007), used alfa fibre and proved that this fibre provides excellent reinforcement for composite materials. However, the main disadvantage of these fibres is their hydrophilic nature; therefore, the ageing of composite materials can be pronounced because of the diffusion of water molecules leading to a swelling effect. Moreover, the adhesion between natural fibres and the polymer matrix is insufficient. Various chemical surface treatments have been performed on alfa (*Stipa tenacissima*) fibre. These different treatments (acetylation, acrylic acid, styrene, and maleic anhydride) are combined with chemicals such as (S), (AA), and (MA). It was found that treatments reduced the overall water uptake of alfa fibres. In particular, styrene treatment significantly increases the moisture resistance of these fibres.

2.11.4 Khimp Fibre

Khimp fibre (*Leptadenia pyrotechnica*) has been studied with a view to exploring its wider uses. Kundu et al. (2005) extracted khimp fibre from the khimp plant and they analysed the fibre properties Jamal et al. (2001) highlighted the importance of khimp fibre for the development of indigenous technologies in the pulp and paper industries. The high alpha-cellulose content and low contents of khimp fibre, along with its favorable length-to-breadth ratio, make it suitable for use in blending with cotton or polyester fibres. We examine the innovation process in selected firms engaged in paper making in India. The present firm-level analysis focuses on incremental innovations as a process to achieve indigenous technological capability (ITC), particularly to use imported technologies more effectively through a process of adaptation and improvement. The study confirms that the "learning by doing" process is one of the indicators for these firms in building the capability to "indigenise" and improve upon the technology. In-house R&D units at the firm level provide strong support for achieving indigenous technological capability.

3 Cultivation to Consumption—Consumption of Natural Resources, Shortcomings in Present Technology Used

Out of different lingo-cellulosic fibres, jute is one of the cheapest fibrous material available in bulk quantities and cultivated for fibre-production purposes. There are two types of jute fibre available: One is tossa jute, and the other is white

jute. Among these two, tossa jute is much more popular due to its high strength and greater productivity. The traditional technology of fibre extraction is a completely manual process wherein the fibres are retted in water for 15–20 days, and the fibres are then separated manually from the jute stick. The jute stick has commercial value, and it is normally used for domestic and farm activities as well as fuel purposes. The conventional retting in water causes environmental pollution, and the employees performing the extraction process often develop dermatomycosis (skin-related fungal disease). Scientists have introduced new technologies of extracting jute fibre wherein retting can be accomplished using less water. In this new technology, the jute ribbons (green bark containing the fibrous material) are separated from the stick, and the ribbons are then retted in water. This required low volume of water can lead to fast retting (6–8 days) with good fibre In some cases, researchers use fungicides to accelerate the retting process under low-water conditions. However, none of these technologies are commercially viable due to the unavailability of a high-production ribboning machine. However, a number of technologies can be employed when using jute to produce different fashion products and utility items (Basu et al. 2006) using green processing technologies (Basu et al. 2009). Although the jute fibre itself is natural, if all of the processes involves to make the end product are environmentally friendly, then the overall process is green. Basu et al. (2009) made an important contribution as far as jute processing is concerned. They used different vegetable oils and compared with commercial jute batching oil as bio-friendly conditioning agents in jute-fibre spinning. Recently, Debnath (2014a, b, c, d) discussed different machinery used for the processing of jute fibres and reported their recent developments in that area.

3.1 Sunnhemp Fibre

Sunnhemp is the fastest-growing species of the genus and is very effective in smothering weeds (Chaudhury et al. 2015). The extraction process for sunnhemp is similar to that for jute and requires a retting process to separate the fibre material from the plant stick. There is must develop an enzymatic/environmentally friendly chemical retting process so the environment remains unpolluted during retting.

3.2 Banana Fibre

In the case of banana fibre, the extraction process is both manual and mechanical. With the manual process, productivity is less, but the quality of the fibre is fine; with machine extraction, the fibres are comparatively coarse (Debnath and Das 2012). Debnath and Das (2012) also documented the different uses of the byproduct (i.e., sap) during the extraction of fibre from banana pseudo-stem.

This extracted sap has good medicinal value apart from its commercial application such as natural dye. All processes from extraction to yarn preparation are green. The investigators also discussed obtaining different fashion and utility products from banana fibre. Debnath (2013a, b, 2015b) demonstrated the process for manufacturing the jute as warm fashion fabrics such as shawls, jackets, blazers etc. Apart from its fashion appeal, banana fibre has good thermal insulation as well as breathability properties.

3.2.1 Flax Fibre

In India, flax fibre is another potential fibre that is extracted through retting for a few days (3–4) followed by drying in the sun and decortication using a decorticator machine. In Europe, the process of due retting is popular (Anonymous (1998b), Basu and Dutta 2014). The process involves an environmentally friendly system, and products manufactured from this fibre use green technology. The fine flax is used for fashion clothing and clothing suitable for extreme summer climates. Apart from its appearance, the material has high moisture-absorbing capacity and can be dyed in appealing color shades.

3.3 Coconut Fibre

Coconut fibre has many industrial as well as fashion applications. Coconut fibre-based ornaments are a luxury fashion item. Apart from its applications in apparel and accessories, coconut fibre has good scope in green fashion products such as doormats, floor mats, carpets, furnishing, and upholstery material when blended with jute (Anonymous 2012a, b, c). The conventional retting process, which creates pollution, can be minimized by controlled chemical retting as well as an enzyme retting process to make the fashion product more green. Recently, Basu et al. (2015), developed an eco-friendly accelerated retting process for coconut fibre that lead to faster productivity apart from the environment friendliness of the fibre itself.

3.4 Sisal Fibre

Sisal fibre is extracted by mechanical means that are environmentally green throughout the process from extraction to product development. Different decorative and fashion products can be made from sisal-based materials (Anonymous, 2015b, c). Fashion bags made of sisal are durable and aesthetically appealing.

3.5 Alfa Fibre

Ghali et al. (2014) reported the extraction process of alfa fibers from the organic matrix, in which three stages were considered. First, the leaves were separated from the stalks by manual cutting. Second, they were immersed in a caustic soda solution (NaOH, 3N) for 2 h at a temperature of 100 °C. The details of the extraction process were described in our previous work. Then they were subjected to bleaching treatment and air dried. After this chemical treatment, it was found that the fibers were not sufficiently separated. For this reason, they were finally separated from the leaves by a mechanical treatment using four passes through a Shirley trash separator. Although this process involves the application of toxic chemicals with the intervention of scientific methods, using green chemicals and enzymes can make the process environmentally friendly.

3.6 Ramie Fibre

Ramie is a very fine textile fibre; the main challenge is removal of gum from the fibre. Removal of the gum through a chemical process is not eco-friendly. Although enzymatic degumming is a green process, it is costly. Apart from this, the technology involved is green, and the products produced, mainly fashion items, can be claimed as green fashion products (Ahmed et al. 2004). Ahmed et al. (2004) used a cotton-spinning system to spin a blended yarn out of degummed ramie and cotton. The whole process from fibre extraction to yarn formation is very lengthy and consumes hazardous chemicals (alkali) for the extraction of gum from the ramie. Sometimes enzymes are also used for degumming, but doing so is costly and time consuming (Saikia et al. 2009). The investigators claimed that the complicated process of blending ramie with cotton is another disadvantage in the present scenario.

Apart from different unexplored fibres, nettle is another fibre from which green fashion products can be made. The extraction to the end product, including its disposal, is environmental friendly as reported in studies by Debnath (2015a). The investigator also described different fashion products such as bags, idols, garments, doormats, table mats, baskets, home decoration items, etc., made from nettle-based products. The overall process is geared toward producing green-fashion textiles.

3.7 Hemp

Hemp falls under the cannabis plant wherein hemp fibre is extracted from the plant stem and used to make rope, strong fabrics, fibre board, and paper (Abdul-Karim et al. 1995 Zhang and Zhang 2010). The extraction process of hemp fibre is a tedious process. Hemp fibre samples were processed by beating and washing and then

made into short fibres by fibre-opening and -carding machines. Special attention was paid to the moisture regain before mechanical handling of the samples. This hemp fibre has also huge potential for the development of green-fashion textiles.

4 Conclusions and Expected Trends for Tomorrow

It is now clear from this chapter that like man-made/synthetic fibres, plant fibres also have huge potential in the fashion industry. Some of the uncommon fibres, such as flax and hemp, no longer fall under the category of "unpopular plant fibre" used in fashion textile products. The main advantage of using natural fibre in the fashion industry is that because fashion changes very quickly, disposal of the products after use is environmental friendly. Many times toxic chemicals are used in different processes during extraction of fibre to produce final fashion textiles. To develop green-fashion textiles, environmentally friendly chemicals and enzymes may be used during extraction and processing of fibres to overcome this problem. Fashion products from these unexplored fibres will open up new avenues of production; hence, the present market of synthetic material may be replaced to some extent if not entirely. Product diversification from conventional to newer fashion areas will bring more income to the people involved in producing and processing these plant fibres for fashion products.

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Relationship Marketing in Green Fashion—A Case Study of hessnatur

Elisa Wagner and Cecilia Mark-Herbert

> *The greatest challenge of the upcoming decades lies in combining the economic and ecological requirements of our modern society. This can only be achieved through persistent and active readiness, by all involved, to be part of a sustainable development.*
>
> Heinz Hess, ca. 1995 (hessnatur 2015c)

Abstract Contemporary marketing strategies offer an understanding of the importance of developing relationships with customers to promote sustainable development. This chapter explores how a relatively small German fashion retailer, 'hessnatur,' creates a relationship platform in their promotion of green fashion through dialogue with consumers. The main communicational platforms in their promotion of green fashion are digital, but importance is also given to engaging employees in personal communication with consumers.

Keywords Communication · Corporate social responsibility (CSR) · Green fashion · Relationship marketing · Small- and medium-sized enterprises (SME)

1 Introduction

The clothing and textile industry is an important part of the global economy employing 26.5 million people worldwide (Jönsson et al. 2013, 59). The industry is characterized by chronic downward price pressure, international sourcing,

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high product variety, high volatility, and low predictability (Perry and Towers 2013, 478).

Customers, shareholders, non-governmental organizations (NGOs), public authorities, trade unions, and international organizations are showing increasing interest in environmental and social challenges related to the fashion industry (Gardetti and Torres 2014). Criticism concerning the treatment of materials, the proliferation of toxins in the workplace and child labor is increasing (Andersen and Skjoett-Larsen 2009, 75; Sevcenko 2013). Despite the critique and an increased awareness of risk in the fashion industry, major disaster still happen, e.g., the collapse of an eight-story garment factory in Rana Plaza in April 2013 in the outskirts of Dhaka, Bangladesh. In this disaster, some 1129 people were killed, and many more were injured (Butler 2013).

In light of the complex problems in fashion-supply chains, an increasing number of companies and designers realize their chance to differentiate by taking responsibility. As designer and founder of an eco-networking site van der Grinten puts it, they "want to change the entire fashion industry, because it's one of the most damaging industries in the world" (van der Grinten, quoted by Sevcenko 2013). Smaller brands as well as many multinational companies, including large chains such as C&A, H&M, and Zara, started selling clothes made of ecological fiber (Oberhuber 2014). Moreover, luxury designers—such as Giorgio Armani, Oscar de la Renta, Stella McCartney, Betsey Johnson, and Todd Oldman—are creating green fashion for runways, boutiques, mass markets, and celebrities (Winge 2008, 511). These examples indicate that an eco-image fashion is gaining acceptance among consumers (Weller 2013, 186). Germany is one example of a country in which the green fashion sector is emerging rapidly.

An increased consumer awareness of sustainable development challenges is reflected in gradual changes in consumption. In 2013, approximately 3.6 million pieces of clothing made from ecological fibers were sold in Germany (Oberhuber 2014). In the last 10 years, revenue from green fashion in Germany increased tenfold to currently 654 million Euro. Green fashion now makes up for approximately 4 % of the German clothing industry (Ibid.).

Consumer awareness is also influenced by cultural, financial, social, and environmental context. Berlin, a city that hosts the internationally renowned Fashion Week twice a year, is a cradle for a growing network of smaller, environmental friendly brands (Sevcenko 2013). Approximately 150 eco-brands are located in Germany, and 15 of them have their headquarters in Berlin (Sevcenko 2013; Schirrmacher n.d.).

As one of the pioneers in the field, the company hessnatur helped shape the idea of green fashion. It was founded in Bad Homburg in 1976 by Heinz Hess with the intention of producing ecological baby clothes. The company initiated the world's first organic cotton-growing project in Sekem (Egypt) in 1991 (hessnatur 2013a, 12; 72). The company has continued to pursue a holistic approach toward its sustainable development commitment, in which relationship marketing plays an important role (hessnatur 2013a, 10).

Challenges to establish a common ground between marketing and sustainability are stated by Tim Gnatek as follows (quoted by Shayon 2015):

> Marketing needs to understand how to speak to and message sustainability — there are nuances and tact that are sometimes lost, risking overselling sustainability aspects and jeopardizing trust, or simply missing big-picture opportunities. Likewise, sustainability professionals can miss opportunities to build a story and engage their audiences more fully throughout their journey of improvement.

These challenges are addressed by hessnatur. In an interview, the head of marketing of hessnatur, Betina Breucha, described what the notion of "marketing" means to her personally (hessnatur 2015d):

> For me, marketing means to take our present as well as future customers seriously. We have to understand what role hessnatur and fashion in general plays in the life of our customers. What relevance does our messages have for them? Does our communication reach our customers correctly or how we intended? Are we meeting at eye level and are we understandable? What can we develop from our history and our products, that is attractive and useful for our customers? Our credo is that humans should feel comfortable with fashion from hessnatur. However, this is a very subjective feeling. I can feel comfortable wearing a soft cardigan and having a feeling of security. I can also feel comfortable through the resonance from other people, this can be a "You look good today!" from someone.

This statement can be seen as an indicator that customers play an important role in the marketing strategies of hessnatur. Because the company pursues the production of ecological clothes with a holistic perspective on sustainable development, it is a suitable basis for trying to understand and analyze how marketing and sustainable development in the green fashion sector can be combined.

Parker et al. (2015, 365) noted that comparatively little research has examined how small- and medium-sized enterprises (SMEs) communicate their corporate social responsibility (CSR) practices using media outlets such as web sites. This chapter aims at contributing to close this gap by presenting a case study of hessnatur's marketing-communication strategies using the communication aspect of relationship marketing. Because hessnatur's culture and approach to manufacturing are focused on producing clothes as sustainably as possible while taking economic, social and environmental aspects into account, hessnatur's communication strategy is intrinsically connected to CSR and therefore lends itself well to this cause.

In this chapter, the notion of relationship marketing will be defined—before communications aspects are described and connections to the stakeholder theory are made—all with a focus on customers. In the following section, a literature overview on theoretical and empirical studies in the field of marketing, CSR, and SMEs will be provided. Empirical results are presented by introducing more details about hessnatur as well as describing examples from hessnatur's communication strategies with its customers. These examples are analyzed with regard to the relationship marketing-communications aspect introduced and are followed by a discussion that connects the findings to the literature presented. Finally, conclusions are drawn, and suggestions for further research are given (sect. 6).

2 A Conceptual Framework for Relationship Marketing

This section introduces several concepts that are crucial for the analysis (sect. 5); starting with relationship marketing, followed by communication aspects and implications. In this section, relationship marketing communication is linked to the stakeholder theory with a particular focus on customers. Finally, the connection of this conceptual framework links academic views of SMEs and CSR communication.

2.1 Definition and Development

Introduced by Neil Borden in his presidential address to the American Marketing Association, the term "marketing mix" refers to the combination of useful components in trying to achieve a certain market response (van Waterschoot and van den Bulte 1992, 84). In this context, many schemata were developed based on McCarthy's (1960) classical "4Ps": product, place, price, and promotion. The latter was split into advertising, personal selling, publicity (in the sense of free advertising), and sales promotion; this has become the most frequently cited and used concept in marketing practice as well as research (van Waterschoot and van den Bulte 1992, 84). Kent (1986, 146) even referred to the 4 Ps as "the holy quadruplet," which implies how much influence the concept has gained in the area of marketing.

In 1983, Leonard L. Berry presented a paper at the American Marketing Association's Services Marketing Conference introducing the term "relationship marketing," a different approach to marketing than the 4Ps (Berry 2002).

Berry introduced the concept in the context of service firms and defined it as follows (Berry 2002, 61):

> Relationship Marketing is attracting, maintaining and – in multi-service organizations – enhancing customer relationships. Servicing and selling existing customers is viewed to be just as important to long-term marketing success as acquiring new customers. Good service is necessary to retain the relationship. Good selling is necessary to enhance it. The marketing mind-set is that the attraction of new customers is merely the first step in the marketing process. Cementing the relationship, transforming indifferent customers into loyal ones, serving customers as clients – this is marketing, too.

Relationship marketing is seen as more than just a set of techniques, tools, and tactics (Palmer 1997). It is a philosophy, a sum of integrated parts that are the drivers of a firm's marketing activities (Berry 2002, 73; Grönroos 1996, 12). According to Berry (2002, 73), to implement excellent relationship marketing strategies, executives must ask "… *how must we fundamentally change what we do and how we do it to create lifetime customers?*" When presenting his paper in 1983, Berry could not imagine a phenomenon such as the Internet, which would tremendously influence the behaviors of customer as well as the marketing

practices and communication of companies. Today, "*customers can communicate, learn from and buy from marketing organizations without a word being spoken*" (Berry 2002, 72).

Trust and commitment are two concepts at the center of relationship marketing with trust defined in this context as "confidence in the exchange partner's reliability and integrity" (Morgan and Hunt 1994, 23) Commitment exists when the relationship is considered important by the parties involved and when they are willing to work at maintaining the relationship (Ibid.).

Moreover, Calonius (1988) argued that the concept of promise is an important element of relationship marketing. A responsibility of marketing activities includes not only giving promises and persuading customers to act in a certain way, but also keeping these promises. This contributes to maintaining and enhancing a relationship with customers. Additionally, Blomqvist et al. (1993) defined three key characteristics of relationship marketing: consideration of every customer as an individual person or unit, concentration of activities on existing customers, and implementation of activities based on interaction and dialogue with customers (Fig. 1).

In a study with Malaysian banks, Ndubisi (2007) identified conflict-handling as another underpinning of relationship marketing. The results of Ndubisi's empirical study implied that four underpinning factors (trust, commitment, communication, and conflict handling) have the greatest influence on customer loyalty: The greater the extent of these underpinnings, the more loyal customers will tend to be towards an organization (Ndubisi 2007, 103).

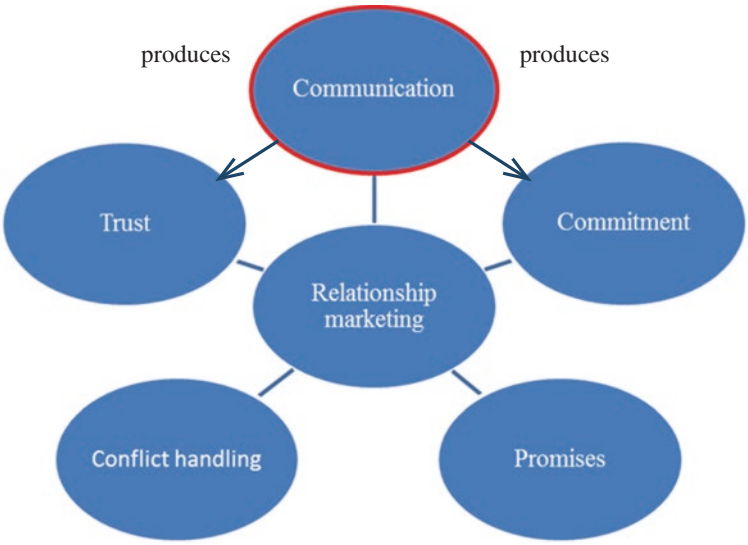

Fig. 1 Illustration of the central aspects of the relationship marketing concept. This section focuses on the aspect of communication

As shown in Fig. 1, trust, commitment, communication, conflict handling, and promises have been identified by various scholars as important parts of the relationship marketing concept. This chapter focuses on the *communication* aspects of relationship marketing (Fig. 1). The argument is that it sets the conditions for the identified cornerstones in relationship marketing.

2.2 Communication

Classical readings, such as Grönroos (1994, 10) emphasize the importance of market communication that entails the creation of a dialogue with customers. However, according to Duncan and Moriarty (1998, 3), relationship marketing research often does not focus on the communication process as a central part in establishing and maintaining relationships. Instead, above-mentioned concepts of trust and commitment, which are products of communication (see Fig. 1), were at the center of relationship-marketing literature in the late 1990s (Duncan and Moriarty 1998, 3).

Duncan and Moriarty (1998, 2) define communication as

> […] the human activity that links people together and creates relationships. It is at the heart of meaning-making activities not only in marketing, but also in a wide range of political, social, economic, and psychological areas. It serves as a way to develop, organize, and disseminate knowledge.

According to Ndubisi (2007, 100), communication in the relationship-marketing context refers "to the ability to provide timely and trustworthy information," maintaining contact with customers, and informing customers proactively in case a problem occurs. If a customer is not satisfied, the company communicates clearly what steps will be taken to solve the problem (Ibid.). Figure 2 illustrates the central position of communication in relationship marketing.

An important aspect of communication is feedback. It refers to the continued dialogue where the sender receives a response from the person to whom the message was sent. Schramm (1973, 48) defines feedback as a "*reversal of the flow, an opportunity for communicators to react quickly to signs resulting from the signs they have put out.*" Without feedback, there is no dialogue. However, this dialogue must be purposeful for both the company as well as customers. If this is not the case, brand messages might be seen as intrusive or implausible (Duncan and Moriarty 1998, 8).

The new technological development described previously has significantly changed the concept of feedback. On websites, including blogs or internet forums, feedback to companies can be given "instantaneously, more far reaching, and in greater quantities" (Duncan and Moriarty 1998, 4). Moreover, in consumer behavior research it is emphasized that consumers decide within a "constellation of consumption activities, situations, social environments, and related products" (Duncan and Moriarty 1998, 5).

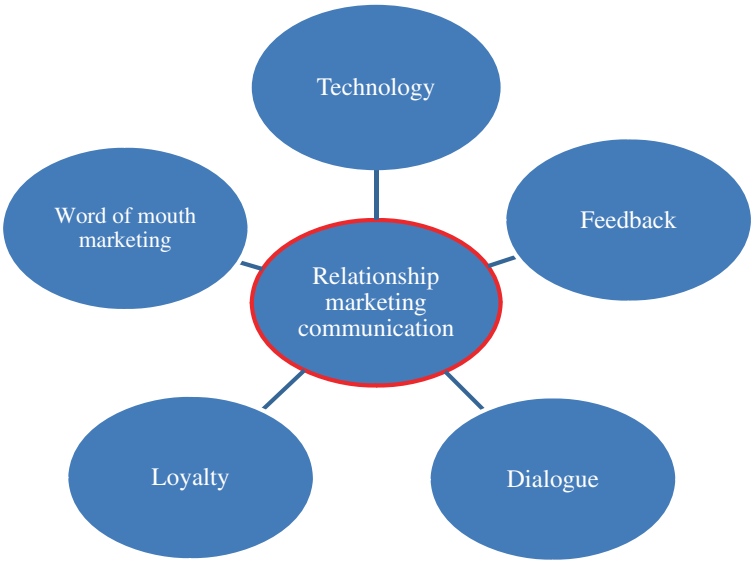

Fig. 2 Illustration of the central aspects of relationship-marketing communication

Factors—including an increasing recognition of relationship marketing's benefits to both firms and customers as well as the aforementioned progress in information technology—have led to an emerging interest in relationship marketing starting in the early 1990s (Berry 2002, 76; Grönroos 1996, 12). Grönroos (1996, 12) interprets this growing interest for relationship marketing as the largest paradigmatic shift in marketing since the introduction of marketing mix in the 1960s.

Due to globalization and intense competition, relationship marketing became of interest for retail consumer markets including small and medium-sized fashion retailers. It is crucial for retailers to create brand loyalty among their customers because loyalty has several benefits both for retailers and customers and makes access for competition difficult (Marzo-Navarro et al. 2004, 425). From a strategic-management perspective, one of the benefits a firm experiences from customer loyalty is an increase of profits per customer. The longer customers stay with a company, the more willing they are to spend more money or recommend the company to other people (e.g., family, friends). Murray (1991, 19) showed that service customers rely more on personal sources of information than impersonal ones such as mass or selective media. This is an indicator for the power of word-of-mouth (WOM) communication through ambassadorship. As research has shown, a satisfied customer will, on average, share that experience with at least three persons. However, negative experiences will spread with the same speed or even faster (Ndubisi 2004, 80f.). Loyal customers as communicators of favorable WOM about organizations can therefore attract new customers. Moreover, loyal customers can serve as valuable sources of new product ideas (Ndubisi 2007, 103; Sheth and Parvatiyar 1995, 264). Therefore, companies seek profitability by building

long-term relationships with customers (Reichheld and Sasser 1990, 106ff). This is especially crucial for small- and medium-sized enterprises with limited marketing departments; they may benefit in many ways from customers' dialogue and positive WOM marketing.

The next section introduces stakeholder theory emphasizing the importance of communication, especially with customers.

2.3 Stakeholder Theory

Stakeholder theory is another concept closely linked to relationship marketing. According to stakeholder theory, a business is "an open and flexible system made up of diverse actors and active in a network of relationships with various other actors" (Maignan and Ferrell 2004, 5). Moreover, although stakeholders show concern for issues that affect them directly (e.g. product safety), they are also interested in issues that have no direct effect on their welfare but concern people in general or the environment (e.g., child labor) (Maignan and Ferrell 2004, 7). Although firms may react to stakeholder pressure and develop CSR strategies and measures to communicate with customers, some organizations have their own norms and may commit to a cause independently of any stakeholder pressure. These norms may even exceed expectations from particular stakeholders (Maignan and Ferrell 2004, 10).

Additionally, Duncan and Moriarty (1998, 7) state that "at the organizational level, a company's or brand's stakeholder relationships involve far more than just customers." They include many more actors such as the financial community, vendors and suppliers, employees, competitors, the media, neighbors and community leaders, special interest groups, and government agencies (Mitchell et al. 1997, 855ff.; Parker et al. 2015, 366ff.). These groups can affect and be affected by a company's marketing (Duncan and Moriarty 1998, 7). This chapter concentrates on the stakeholder group of customers (Fig. 3).

To successfully communicate brand messages with the help of relationship-marketing communication, these messages must be consistent and positively influence brand perception (Duncan and Moriarty 1998, 6ff). Strategic consistency implies that there is a consistency in the presentation of corporate values, the performance of production, and the identification and positioning of the brand. Moreover, brand messages must focus on stakeholders and ensure that brand communications are interactive. Interactivity is created by a mix of one-way (e.g. mass media advertising) and two-way communication (e.g. personal selling, customer service) (Ibid.). Interactivity is crucial in relationship marketing because the relationship between consumers and a company becomes stronger when consumers are actively involved in the decisions of the company. Through this involvement, they become more committed to the relationship and are less likely to switch to a competitor (Sheth and Parvatiyar 1995, 256). Moreover, when a firm uses communication to create an increasing interaction with its stakeholders, identification of stakeholders with the company is likely to be enhanced (Maignan and Ferrell 2004, 15).

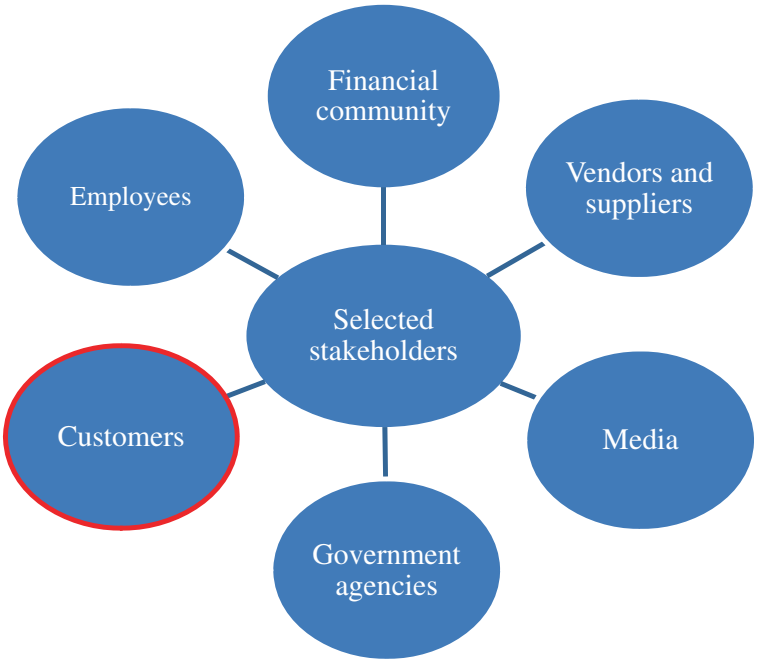

Fig. 3 Illustration of a firm's selected stakeholders. This chapter concentrates on the stakeholder group referred to as "customers."

2.4 Relationship Marketing and SMEs

Several characteristics of SMEs, including advantages such as greater flexibility, innovation, and lower overhead costs, differentiate them from large organizations (McCartan-Quinn and Carson 2003, 202). However, compared with large organizations, SMEs are disadvantaged when it comes to market power as well as accessing financial and managerial resources (Ibid.; Walsh and Lapinski 2009, 571).

Identifying the needs, wants, and aspirations of its target markets are is critical for a firm's success (Walsh and Lapinski 2009, 569). This is one of the aims of marketing that "places the consumer at the center of the firm's activities" (Fuller 1994, 34). The goals of marketing processes are to satisfy customers more effectively and efficiently than competing firms but also to establish long-term profitability (Ibid.). However, relationship marketing seems to be a valuable tool for SMEs, especially due to their smaller size, greater flexibility, and restricted resources. By creating positive, long-term relationships with their customers and using favorable WOM communication, SMEs can invest in marketing and benefit from relationships with their customers as previously described.

Moreover, when it comes to CSR, communication can play an important role in highlighting a message for which both the organization and its stakeholders

care. In this case, CSR can be a "potential bond between the firm and its stakeholders" (Maignan and Ferrell 2004, 15). However, although communication with customers is such an important aspect of relationship marketing and CSR strategies, Maignan and Ferrell (2004, 17) point out that there is still a need for more research in this field. Especially examination of communication strategy and relevant media that can be used for communication of CSR measures within the relationship marketing context is needed. Moreover, Maignan and Ferrell (2004, 17) suggest that businesses cannot benefit from CSR "*unless they intelligently communicate about their initiatives to relevant stakeholders.*"

3 Literature Overview

This section provides a literature overview (late 1990s to current date) on theoretical as well as empirical studies connected to SMEs, relationship marketing, and CSR. The sources will first be summarized in Table 1 and are then described in more detail in the following text.

Barnes (1994) reviewed how the relationship concept has been viewed by different marketing authors. The review points out that there exists a deficiency in the ways in which relationship marketing has been viewed in the past. With insights from social psychology, the author aims at identifying the nature of relationships.

Table 1 Overview on literature in the area of relationship marketing, the development of marketing concepts, and CSR and SMEs

Author (year of publication)	Title	Key findings
Barnes (1994)	Close to the customer: But is it really a relationship?	There are large differences in how relationship marketing is practiced and understood by firms and customers, with some definitions revealing obvious deficiencies
Bejou and Palmer (1998)	Service failure and loyalty: an exploratory empirical study of airline customers	Any given level of service failure resulted in reduction in commitment and trust, which was dependent on the duration to date of their relationship
Blois (1998)	Don't all firms have relationships?	Given its particular circumstances, a firm should determine what types of relationships are appropriate with each of its customers
Chaston (1998)	Evolving "New Marketing" philosophies by merging existing concepts: application of process within small high-technology firms	An entrepreneurial relationship-marketing orientation will enhance overall performance of these firms

(continued)

Table 1 (continued)

Author (year of publication)	Title	Key findings
Parker et al. (2015)	SME stakeholder relationship descriptions in website CSR communications	Reporting of the company's relationships with stakeholders—including society, communities, ecological environment employees, customers and suppliers—is an important aspect of CSR communication
Hwang and Kandampully (2015)	Embracing CSR in pro-social relationship marketing program: understanding driving forces of positive consumer responses	Consumers' CSR-driven cognition (CSR beliefs) and reciprocal emotion (feeling of gratitude) enhance their attitudes towards prosocial loyalty programs and increased participation intentions
O'Malley and Tynan (2000)	Relationship marketing in consumer markets—Rhetoric or reality?	Diversity in operational approaches employed and the lack of accepted definitions had caused boundaries of the concept to become permeable and elastic, making it difficult to identify appropriate contexts for empirical research. It remains unclear whether marketers have internalized the philosophy of relationship marketing
Sen and Bhattacharya (2001)	Does doing good always lead to doing Better? consumer reactions to corporate social responsibility	Findings implicate both company-specific factors (e.g., the CSR issues on which a company chooses to focus as well as product quality) and individual-specific factors (e.g., consumers' personal support for the CSR issues and their general beliefs about CSR) as key moderators of consumers' responses to CSR. The results also highlight the mediating role of consumers' perceptions of congruence between their own characters and that of the company in their reactions to its CSR initiatives. CSR initiatives can, under certain conditions, decrease consumers' intentions to buy a company's products
Webster (1992)	The changing role of marketing in the corporation	A new conception of marketing will focus on maintaining strategic partnerships with customer relationship as the key strategic resource of the business
Yan et al. (2012)	Marketing eco-fashion: the influence of brand name and message explicitness	Respondents formed positive attitudes toward apparel brands when the advertising message contained explicit information about environmentally friendly products. Attitude toward brand, subjective norm, attitude toward advertisement, eco-fashion involvement, and environmental commitment were strong predictors of intention to purchase an environmentally friendly apparel brand

He criticizes that "repeat business" alone does not mean that the customer is loyal. One reason for repeat purchases might be that it is convenient for a customer to buy a certain product, e.g., customers might be locked into a pseudo-relationship that is one-sided without the customers being willing participants (Barnes 1994, 565). Moreover, with a preliminary analysis of more than 40 focus group interviews, the author made a start to understand the relationship from customers' point of view (Ibid.). These interviews showed a range of relationships from the establishment of a positive, long-term relationship to relationships that customers have difficulty describing because they are anonymous or the service provided by the company is automatic.

Similar to Barnes, O'Malley and Tynan (2000) present a critical review of the history of relationship marketing in consumer markets. A number of critical issues that remain unresolved, including the diversity in operational approaches employed and the lack of accepted definitions, are identified in the review. This caused the boundaries of the concept to become permeable and elastic, making it difficult to identify appropriate contexts for empirical research. The authors conclude that the academy has extended the domain of relationship marketing into consumer markets with a lack of conceptual and empirical justification. Moreover, it remains unclear whether or not marketers have internalized the philosophy of relationship marketing.

Connected to Barnes and O'Malley and Tynan (2000), Blois (1998) argued in his paper "Don't all firms have relationships?" that it is impossible for firms not to have relationships. He suggests that firms should determine what types of relationships are appropriate with each of its customers depending on the circumstances of the firm. The depth of relationships might vary including situations where both supplier and customer recognize and accept their mutual interest. However, according to Blois (1998), a firm does not have a choice to decide whether or not it has relationships.

Webster (1992) advocates for strategic management, the conception of marketing as maintaining strategic partnerships, with customer relationship as the key strategic resource of the business. Moreover, he argues that strategic partnerships and networks are replacing simple market-based transactions and traditional bureaucratic hierarchical organizations. Importance is given to personal, targeted, special-purpose communication will be important, and the implementation of market-driven strategy will require skills in designing, developing, managing, and controlling strategic alliances with partners of all kind.

Chaston (1998) carried out a mail survey connected to performance and customer orientation to measure the revenue growth of small high-technology firms. Results of the study suggested that an entrepreneurial relationship-marketing orientation will enhance overall performance of these firms. However, Chaston (1998) points out that the danger of alternative emerging theories lays in researchers rejecting alternative points of view, even though hybrid approaches might be an appropriate solution to certain marketing issues. Moreover, Chaston (1998) emphasizes that the results of the study cannot be seen as prescriptive recommendations about the best style for small high-technology firms to adopt but that it

is important to recognize the company's circumstances as well as the manager's influence.

Sen and Bhattacharya (2001) conducted two studies to understand when, how, and why consumers react to CSR by focusing on both some key moderators of consumers' CSR responses and the mechanisms underlying these responses. Results implicated that both company-specific (i.e., the CSR domain, product quality) and individual-specific (i.e., CSR support, CSR-related beliefs) factors as key moderators of consumers' responses to CSR initiatives and highlight the mediating role played by consumers' perceptions of congruence between their own characters and that of the company.

Connected to Sen and Bhattacharya's (2001) investigation, Yan et al. (2012) conducted a study with ambitions to explore the influence of brand name and message explicitness on attitude toward brand. Their results indicate that respondents showed positive attitudes toward apparel brands when the advertising message contained explicit information. Moreover, attitude toward eco-fashion involvement and environmental commitment were strong predictors of intention to purchase an environmental friendly apparel brand. Implications are that when using more explicit information, marketers might be able to attract college students who are interested in environmentally friendly products but who are not fully committed to the green lifestyle. Moreover, by raising awareness about environmental friendly products, customers might be informed about sustainability issues at large.

Hwang and Kandampully (2015) collected data from 350 US consumers through web-based experiments to find out which factors influence consumers' responses to prosocial loyalty programs (prosocial LPs). These positive marketing programs represent an emerging phenomenon in relationship marketing associated with companies' CSR. Findings suggested that consumers' CSR-driven cognition (CSR beliefs) and reciprocal emotion (feeling of gratitude) enhance their attitudes towards prosocial loyalty programs and increased participation intentions. These results imply that loyalty programs might be a helpful approach to relationship marketing that might benefit companies that engage in CSR and overall.

Parker et al. (2015) carried out a qualitative content analysis of 22 Australian SME websites from the information media and telecommunications sector. Stakeholder theory was used as a basis for analysis. Their findings suggested that the reporting of the company's relationships with stakeholders—including society, communities, ecological environment employees, customers, and suppliers—is an important aspect of CSR communication. Communication examples on websites highlighted the three-way relationship between the firm, its customers, and other stakeholders including the community and the environment. Firms were using CSR as a way to promote to customers or to justify that the firm was worthy of their patronage (Parker et al. 2015).

Bejou and Palmer (1998) investigated a different aspect of relationship marketing: Handling service failure. They conducted interviews with customers to find out what customers perceive as a negative critical incident in their contact with airlines and how this might affect their relationship with the company. The results indicate that there appears to be a critical period in the development of a

relationship between customer and company when tolerance of services failure is very low. Quality of service and its effects on relationship quality are not perceived by customers in a constant manner throughout the duration of a relationship. One of several possible explanations might be that a long-term relationship might lead the customer to emphasize with the problems faced by the provider in trying to deliver high-quality service whereas relative new customers might be alienated through service failures because failures occurred before they had time to develop a relationship with the company (Bejou and Palmer 1998).

The literature review offers academic perspectives on relationship marketing from the time period of the late 1990s to current date. These insights offer a starting point for the continued understanding of how relationship marketing is used in a sustainable development perspective.

4 A Case Study—hessnatur

This section provides an overview of the case that will be analyzed, as well as different communication examples, which reveal how hessnatur uses relationship marketing to communicate with its customers.

4.1 Background Information

Hessnatur was founded in 1976 in Bad Homburg, Germany, by Dorothea and Heinz Hess. The company is a pioneer in the production of ecological clothing and produces clothing free from toxics and made under fair working conditions (hessnatur 2013a, 10). In 2008, hessnatur won the German Sustainability Award ("Deutscher Nachhaltigkeitspreis") in the category "Germany's most sustainable purchasing department" (hessnatur 2013a, 12).

Currently, hessnatur has 343 employees and a turnover of approximately 70 million Euro per year (hessnatur 2013a, p. 28, 35). In 2005, the company joined the "Fair Wear Foundation" as the first German enterprise (hessnatur 2013a, 60). In the financial year 2011–2012, hessnatur worked with 119 suppliers, 75% of these suppliers were from Europe. Out of these 119 suppliers, 83 were in the textile area (hessnatur 2013a, 56ff.).

According to an interview statement by the former chief executive of hessnatur, Wolf Lüdge, the company gains 75% of its new customers through recommendations (Täubner 2012). Moreover, approximately 20–25% of hessnatur's customers can be classified as "dark green," describing customers who are often close to nature and who reject the pursuit of profit (Ibid.)

Hessnatur uses several channels to communicate with its stakeholders including the internet (online shop, blog, Facebook, Twitter, and Pinterest). However,

meetings with customers and the Client Council, to be described in more detail later in the text, are also part of hessnatur's communication strategy (hessnatur 2013a, 23). Table 2 summarizes the most important facts about the company.

In the following text, examples concerning strategies to communicate with customers will be described. Table 3 provides a short overview of these examples, which will then be described in more detail and finally analyzed in sect. 5.

Table 2 Company data (hessnatur 2013a, 10)

Year of foundation	1976
Corporate form	Ltd. (German: GmbH)
Range of goods	Full range of natural textiles, approximately 900–1000 models and approximately 8000 article items per season: – Women's and men's outerwear – Clothes for children and infants – Underwear and stockings – Home textiles – Shoes
Market position	Leading provider of natural textiles in German-speaking countries
Distribution channels	– Shipping (catalog) – Stationary sales (shops) – E-commerce (online shop)
Main sales markets	Germany, Switzerland, Austria
Branches	Shops in Butzbach, Hamburg, and Munich; remainders shop in Butzbach
Daughter company	Hess Natur-Textilien AG, Aarwangen (Schweiz)
Branch office	Austria
Company founder	Heinz Hess (died March 18, 2006)
Executive director	Marc Sommer (chairman)
Employees	343
Trainees	9
Client base	1,000,000
Revenue 2012	70 million €

Table 3 Summary of hessnatur's relationship marketing communication strategies

hessnatur blog	Product tests carried out by hessnatur customers that were reported on hessnatur blog
	Hiking trip with customers including an experiment to test the quality of hessnatur's fabrics
Client council	Meetings and outings of the client council (combined with, e.g., a visit by linen farmers)
hessnatur foundation for applied sustainability	Communication with a wider range of stakeholders, initiation of projects about environmental protection, textile ecology, development cooperation, and social topics

4.2 Online Blog

In 2008, hessnatur started an online blog where the company publishes current news about products, production processes, social projects, and projects with customers (among others). On this blog, readers can leave comments. Hessnatur can read and respond to these comments directly, thereby creating a dialogue with and between customers (hessnatur 2008). The internet platform is an example of a relationship marketing communication tool hessnatur uses to establish relationships through dialogue.

In this section, actions and initiatives published on hessnatur blog will be presented in detail.

In October 2012, customers could test cardigans and share their experiences on the hessnatur blog (hessnatur 2012f, h). The company set tasks for the tester, e.g. hanging the cardigan made out of natural wool in the bathroom next to a cotton shirt while showering (hessnatur 2012b). The goal of this task was to demonstrate that natural wool is more water-repellent than cotton. The testers were also asked, for example, to dirty the cardigan in order to determine the dirt-repellant characteristics of the piece of clothing (hessnatur 2012a). Additional tasks tested the fabric's crease resistance as well as its wear comfort among others (hessnatur 2012a, c).

In the comment section, customers could write comments about their experiences. Moreover, a quiz on hessnatur was used to select a single customer who then got the opportunity to write reports on the blog about her personal experiences (hessnatur 2012d, e, g). Thus, customers could not only comment on hessnatur's tasks but could actually create blog content. While sharing positive experiences about the product, the reporter had the possibility to voice criticism as well, as the following statement form an article written by the customer indicates (hessnatur 2012i):

> Unfortunately, the fitting is not ideal and I have to get used to the shape of the neckline. The cardigan appears very classic. However, I am rather the sporty type and like to wear T-shirts, hoodies and mainly casual clothes including basics without patterns or ruffles. I appear more serious wearing the cardigan, but also more conservative and 3-4 years older. I might have liked a smaller sized cardigan more and it would have fit better as well. If I had ordered the cardigan, I am sure I would have changed it for another […] We will see, maybe I have to get used to the new look.

A similar test was carried out for a hessnatur bath towel. Hessnatur summarized the results of the product tests as follows (hessnatur 2014b):

> 82 % were satisfied with the size of the bath towel
>
> 88 % would buy the hessnatur bath towel
>
> 89 % liked the bath towel's feeling on the skin
>
> 96 % liked the bath towel's finishing.

Additionally, hessnatur summarized positive as well as negative feedback:

> A bigger selection of colors would be nice

> An additional hanger loop on the long side would be great. This makes it easier to hang the towel without letting it drag on the ground. I think the absorbency could be better. Besides that, the towel is perfect and has a great color. Keep it up!

Another example of an initiative that involved customers is a hiking trip with customers that hessnatur organized in October 2013. Goal of this trip was to test hessnatur's functional underwear made out of merino wool, compare it with synthetic long-sleeve shirts from other companies, and demonstrate that the former is better suited for sporting activities. In this case, customers were part of an experiment: Each participant got had a so-called I-button attached to the upper body, which measures the amount of perspiration as well as changes in body temperature (hessnatur 2013b). Subsequently the collected data were analyzed. Results indicated that wool serves as a buffer compensating for fluctuations between skin surface and outside temperature. Ecological merino wool stores moisture and regulates moisture exchange naturally (hessnatur 2014a).

In 2013, hessnatur implemented another strategy to get customers involved with the company: the hessnatur client council.

4.3 Client Council

Hessnatur implemented a client council to represent hessnatur's customers. This council accompanies the company's development and observes whether hessnatur meets its standards and works according to the company's values and principles (hessnatur n.d.).

The client council examines and discusses the work of hessnatur. Moreover, they communicate the results of their discussions and meetings publicly. Their work creates a bridge between the company and its customers. According to hessnatur, impulses given by the client council are important to develop the company both according to its own values and standards as well as to the customers' interests. Suggestions from the client council can lead to strategic and operational decisions (hessnatur n.d.).

In June 2013, the client council was elected for the first time (Fig. 4). All members of the general public were invited to stand as candidates. Originally, the planned 150 members of the parliament were to be selected through a lottery under the supervision of a notary. However, as hessnatur reserved the right to allocate some seats directly, and also due to the large public interest, the client council was eventually extended to 200 seats (hessnatur 2013c, d). The speakers' panel (German: Sprechergremium), comprised of 12 delegates of the council, was then selected during a personal meeting of all council members, and it is responsible for voicing the opinion of the client council to the media and to hessnatur themselves (hessnatur 2013d; hessnatur n.d.). Visiting hessnatur's production sites gives the client council deeper insights into hessnatur's production processes (hessnatur 2015a). These visits are one possibility on which exchange with the company's management takes place. The client council has the possibility to give direct feedback to the management about past and planned future strategic decisions (hessnatur n.d.).

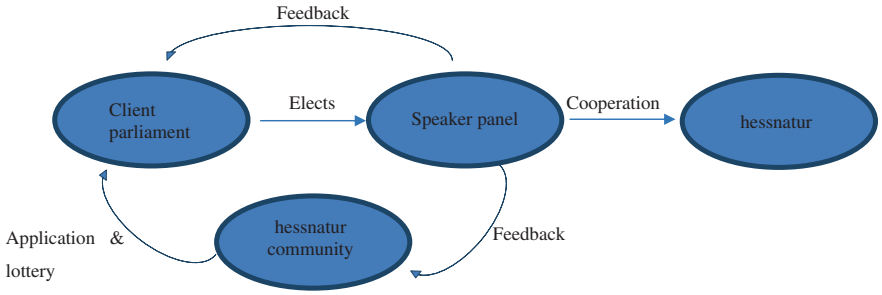

Fig. 4 Structure of the hessnatur client council (based on hessnatur n.d.)

In early 2015, hessnatur established the Foundation for Applied Sustainability, the company's most recent attempt to keep a dialogue going with both its customers and other stakeholders.

4.4 Foundation for Applied Sustainability

In establishing the hessnatur Foundation for Applied Sustainability, an institutional platform was created to inform the public about sustainable businesses. Cooperation with partners, companies, organizations, or scientific institutions is planned to be a central element of the foundation's work in order to communicate about sustainability and encourage awareness of sustainability issues. With the hessnatur foundation, this is possible independent of hessnatur's daily business activities and can be done with greater intensity. The foundation focuses on topics about environmental protection, textile ecology, development cooperation, and social topics. Projects include the support of education institutes and universities and the organization of workshops or projects connected to material development (hessnatur 2015b, c). The next chapter section will analyze the examples introduced in light of the conceptual framework developed in Sect. 2.

5 Analytical Discussion

In the following, the concept of relationship marketing introduced in Sect. 2 will be applied to the German fashion retailer hessnatur (see Sect. 4). It analyzes to what extent the fashion retailer has implemented relationship-marketing strategies based on the examples introduced in Sect. 4 including the online blog, the Client Council and the Foundation for Applied Sustainability.

5.1 Online Blog

The initiatives presented on the blog are examples of relationship-marketing tools that cover the main aspects of relationship-marketing communication. Hessnatur set several objectives over a limited period of time. During this time, the company engaged in a dialogue with its customers and received valuable feedback about their products as well. In addition, hessnatur offered customers the possibility to create blog content themselves. This can be interpreted as another aspect of relationship marketing that is facilitated by the progress of information technologies. Additionally, by letting customers share their views, including critical opinions, this form of customer-created marketing presents a certain credibility (see quote of product testers concerning the cardigan and bath towels in Sect. 4).

In organizing a hiking tour in combination with an experiment, hessnatur created an experience shared between customers and employees of hessnatur. It is likely that customers that went to this hiking trip felt as part of a community, thus making this initiative an example of a bonding experience. Customers who shared such an experience were most likely already customers of hessnatur because participants had to apply for this trip. Therefore, it is likely that people who knew about this trip were involved with the company prior to the hike, although it cannot be excluded that people received information about the experiment without having been customers at hessnatur. However, current customers that were part of the hiking tour are likely to continue purchasing at hessnatur, to become loyal customers, and to share their positive experience with other people including friends or families. By doing so, they are spreading positive word of mouth and attracting new customers. At the same time, hessnatur received valuable feedback and data about their products that they can use in future production and/or marketing activities. These aspects are important for well-functioning relationship-marketing communication.

5.2 Client Council

The Client Council discusses hessnatur's projects and exchanges opinions with hessnatur's executive board and employees (see Sect. 4.3).

By developing a Client Council, hessnatur implemented another relationship-marketing strategy that unites several aspects of relationship-marketing communication including the creation of a dialogue and the reception of feedback from customers. In that sense, it has similar implications to the product-testing initiatives analyzed previously.

However, in case of the Client Council, feedback refers not only to products as in the above-mentioned examples but also to internal decision processes as well. In addition, the hessnatur client council makes customers advisors of the company by entering a dialogue about the company's strategies and planned changes. Moreover,

the council receives confidential information. By doing so, hessnatur shows trust in the representation of its customers and indicates that the company takes their advice seriously. The speakers' panel is an additional element of the council that connects it to the public including a wider range of hessnatur's customers.

In the next section, the hessnatur Foundation of Applied Sustainability is analyzed before closing the paper with pointing to hessnatur's combination of virtual and personal communication channels.

5.3 Foundation for Applied Sustainability

The establishment of a foundation can be seen as another relationship marketing initiative, although it is different from the other initiatives described previously. The hessnatur Foundation for Applied Sustainability does not concentrate solely on the stakeholder group of customers but on other stakeholders as well, including, for example, companies, organizations, or scientific institutions. However, by engaging in different projects and organizing workshops, hessnatur might deepen their relationships with existing customers as well as gain new customers from these environments. The creation of a foundation can be seen as another relationship marketing tool because the focus of the initiative lies on interaction and dialogue with both customers and other stakeholders.

The previous analysis reveals that hessnatur keeps both virtual and personal contact with its customers. By doing so, the company gives customers a platform to communicate and voice their opinions from all over the world. By maintaining personal contact and creating experiences, the company might keep their loyal customers and even attract new ones due to the spread of positive word of mouth. Finally, by combining these measures, hessnatur, as a middle-sized company, established tools for relationship-marketing communication that can help the company retain loyal customers and save expenses in PR and marketing departments.

The following part of this chapter will discuss these results regarding the literature review presented in Sect. 3.

5.4 Discussion and Summary

First, Parker et al. (2015) found communication examples on websites highlighting relationships with society, communities, ecological environment, employees, customers, and suppliers that promote the company to customers and show that the company is worthy of their patronage. These aspects are important parts of CSR communication. This finding is supported by the examples found on hessnatur's blog, which encourage the relationship of hessnatur with customers as described previously.

Moreover, Webster (1992) suggests that personal, targeted, special-purpose communication is important for companies. This is supported by the analysis of

the examples of hessnatur's communication strategies listed previously. Initiatives posted on hessnatur's blog address customers directly and encourage them to participate in product testing or experiments (see Sect. 4). Webster (1992) further argues that the implementation of market-driven strategies will include designing, developing, managing, and controlling strategic alliances with partners of all kinds. The establishment of the hessnatur Foundation for Applied Sustainability, which plans projects and workshops with a wider range of stakeholders besides customers, supports this point of view (see Sect. 4.4).

Concerning the attitudes of customers, Sen and Bhattacharya (2001) identified company and individual-specific factors as key moderators of consumers' responses to CSR initiatives. Moreover, consumers' perceptions of congruence between their own characters and that of the company played an important role when it comes to consumers' responses to CSR. Results of the preliminary previous analysis seem to support this finding. About 20–25% of hessnatur's customer can be classified as "dark green," and initiatives to involve customers in company decisions or product tests created much resonance among hessnatur's customers. Instead of 150 seats as initially planned, the client council was enhanced to 200 seats (see Sect. 4.3) because many customers wanted to be part of the council. Moreover, hessnatur received approximately 47,000 applications for the cardigan product tests, of which 1500 were selected (hessnatur 2012d). These can be seen as indicators that customers of hessnatur are interested in environmental friendly products and do not just react to CSR strategies—which is a key element of hessnatur's corporate culture and the company's communication strategies (see Sect. 4)—but that they view the relationship-marketing strategies implemented by hessnatur positively and want to be actively involved in the company's processes. This in turn encourages meaningful communication between customers and the company in which the customers feel that their opinions are taken seriously and the company receives valuable feedback.

O'Malley and Tynan (2000) argued that the boundaries of the relationship-marketing concept have become permeable and elastic, thus making it difficult to find appropriate contexts for empirical research. However, the examples introduced in Sect. 4 describe communication measures that engage the customer, thereby developing an active relationship between company and relationship. Although O'Malley's and Tynan's (2000) argument is important to keep in mind when doing further research on relationship marketing in retail businesses, the examples in this chapter might be a good demonstration of how far relationship marketing can be taken (e.g., see hessnatur Client Council). Moreover, O'Malley and Tynan (2000) question whether companies really have internalized the philosophy of relationship marketing. Although this is an important question to ask when conducting research in the field of relationship marketing, the examples described in sect. 3 demonstrate that hessnatur indeed has internalized this concept. Not only does the company establish dialogues with its customers, it also makes them its advisors by, e.g., implementing the Client Council.

Barnes (1994) as well as Blois (1998) argued that the depth of relationships between companies and customers varies depending on the context of this relationship.

Moreover, Barnes (1994) criticizes that although a customer repeatedly purchases products from a certain brand, this does not mean he or she does so out of loyalty toward the brand. Buying this brand might be convenient for this customer for another reason, such as that it is the only brand a company has in store; thus, the customer might be in "pseudo-relationships" (Barnes 1994, 565) of which that they are not voluntarily a part. However, this seems not to be true for customers of hessnatur. Considering that hessnatur is one of the pioneers in the retail business of green fashion, that they communicate their values clearly, and that their products are only available through selected channels (see sect. 4), it is unlikely that customers buy clothes from hessnatur solely out of convenience. In addition, the examples demonstrating relationship-marketing initiatives show that the customer chooses to become actively involved with hessnatur by taking part in certain application processes (see sect. 4).

Moreover, Hwang and Kandampully (2015) obtained results from their study indicating that consumers' CSR beliefs, as well as feeling of gratitude, enhance their attitudes toward prosocial loyalty programs and increased participation intention. Although prosocial loyalty programs are not part of this analysis, but rather relationship-marketing initiatives that created a dialogue with and between customers and got them involved in company decisions, the implications of this analysis are similar. Attitudes toward CSR and green fashion of hessnatur customers tend to be positive (see sect. 4). Participation was very high in all the examples previously analyzed. This supports Hwang and Kandampully's (2015) results with regard to relationship-marketing initiatives involving customers.

Additionally, results of the study carried out by Yan et al. (2012) indicated that respondents formed positive attitudes toward apparel brands when the advertising message contained explicit information about environmentally friendly products. Similar to Bhattacharya and Sen's results (2001), attitude toward eco-fashion involvement and commitment were strong predictors of the intention to purchase an environmentally friendly product. In addition, the results indicated that brands can use explicit information about environmental friendly products to educate unaware customers about sustainability issues. These findings support the importance of a brand as shown by Gardetti and Torres (2014) in their studies of sustainable luxury. By using relationship-marketing strategies, hessnatur not only communicates with existing customers but might reach customers who are unaware of environmental problems in the textile industry. This is often the case through WOM marketing as well (see sect. 2.2).

Finally, Bejou and Palmer (1998) point out that there is a critical period in the development of a relationship between customer and company when tolerance of service failure is very low. They suggested that the duration of the relationship might influence the perception of service failure. Although the aforementioned examples do not include service failures, customers have the possibility to voice critical opinions in the comment section on hassnatur's blog. Moreover, the customer reporting the cardigan product test could express their critical thoughts in the articles (see sect. 4.2). This could suggest that customers participating in such initiatives, and who additionally have the possibility to express their opinion, might develop a certain tolerance to service failure. However, this is an aspect that must be examined by further research.

To conclude this discussion, it is crucial to keep in mind what Chaston (1998) pointed out in his study about small high-technology firms: It is important to stay open minded about other views of marketing. Similar to Chaston's (1998) emphasis regarding his results, the analysis provided in this chapter does not suggest that these findings are prescriptive recommendations for all small- and medium-sized fashion retailers. This chapter rather presents one preliminary case study based on selected communication channels of hessnatur. It contributes to the debate about relationship marketing by linking the concept to a green fashion company demonstrating what relationship-communication strategies might be possible for a medium-sized green-fashion retailer. Finally, with regard to the analysis, it is important to keep in mind that "*relationship marketing means different things in different cultures and marketers should be as wary of prescribing universal solutions for exchange bases as they are of developing universal product and promotion for all markets*" (Palmer 1997, 321).

The next section will draw a conclusion and gives suggestions for further research.

6 Conclusion

All initiatives mentioned in this chapter are examples from the field of relationship-marketing communication that incorporate many of the aspects mentioned in sect. 2. Hessnatur manages to not only encourage dialogue between customers and the company but actually integrate customers into product testing and development (see product testing campaign as well as hiking tour described in sect. 4). Moreover, hessnatur takes one step further and makes customers advisors of the company (see hessnatur Client Council described in sect. 4.3). The establishment of the hessnatur foundation might be at the start to develop this kind of dialogue further, thereby informing a wider public about sustainability issues. As discussed in the previous section, this study provided a preliminary single case study demonstrating possibilities of relationship-marketing communication that can support communication strategies with customers in the green-fashion sector.

Further research might include a study analyzing and comparing communication strategies of several retailers in green fashion or retailers that sell parts of their collection as green fashion. Additionally, it is crucial to explore more about the point of view of customers. Further research could explore what effect relationship marketing-communication strategies presented in this chapter have on short- and long-term purchasing behavior of green-fashion customers.

Finally, research can be extended to other stakeholder groups including employees, NGOs, the government or other companies. Questions that must be answered include: How does relationship marketing encourage relationships with these stakeholders? What benefits can small- and medium-sized enterprises gain when cooperating with each other and with other stakeholders when it comes to relationship-marketing communication strategies? How do employees influence

these strategies? What role does word-of-mouth marketing play regarding relationship-marketing communication?

While it might be true that all companies have relationships, as Blois (1998) pointed out, regarding the advance of green-fashion companies in Germany it is crucial to explore these relationships in order to spread awareness about issues in the fashion industry. Customers play a key role in changing the production of fashion and transforming the business into a human and environmentally friendly business in the long run.

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Animal Ethics and Welfare in the Fashion and Lifestyle Industries

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Abstract The purpose of this study is to contribute to the ongoing ethical discussion regarding the use of animals in the fashion and lifestyle industries and to address the attitude and behavioral practices currently being used in the field of animal production and animal welfare. The aim is to investigate, both theoretically and empirically, why it is necessary to apply and implement ethical standards and to address the challenges being faced in how animals are used in these industries. The impact on the environment, a general lack of awareness, and research into ethical consumption will also be explored. By questioning these issues, a better understanding of the contradiction in the ethical production and consumption of animals will emerge. This paper challenges today's decision makers in the fashion and lifestyle industries and argues that despite recent studies in this area, producers, designers, and other decision makers still lack knowledge of what must be addressed to sustain responsible production and consumption practices. The intention is not to write a dissertation on ethics but to attempt to generate interest in the issues that use and take advantage of other living beings, specifically nonhuman animals. The intent is to do this not through negative images, which are otherwise so easily available, but through the prism of impartiality. The goal is to get animal ethics and welfare on the agenda in the fashion and lifestyle industries and to qualify these issues on the same level as human rights and environmental issues. That all decision makers in the future will take responsibility and in turn improve the conditions these animals live in, while supporting the consumption needs of human beings, is the intention and purpose of this chapter.

Keywords Animal rights and ethics · Animal welfare · Non-human animal · Sustainability and flourishing · Decision makers · Answerability · Fashion and lifestyle industries

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1 Introduction

> The more clearly we see the differences between animals and stones or machines or plastic dolls, the less likely it seems that we ought to treat them in the same way. (Midgley 1983).

"Anthropocene" is a popular scientific term designating an epoch that started when humans decisively influenced the planet by igniting the industrial revolution, resulting in a significant global impact on Earth's ecosystems, including the life and welfare of nonhuman animals. It is widely agreed that the Earth is currently in this state.

This paper will empathize the importance that answerability ethics and animal welfare play in the fashion and lifestyle industries of today.

ANSWERABILITY ETHICS (or CRITICAL ETHICS)—Bakhtin's (1990, 1993)
Answerability is understanding the "systemicity" of which one is a part and applying change to stop reproducing unethics. This is working for change, striving for individuality within a social movement, instead of simple individuality (self-absorption).

Over the past 25 years, a slow although radical change has taken place within the fashion world toward more sustainable production. One of the multinational athletic-wear giants, Nike, once accused of paying low wages and having poor working conditions at one of its Indonesian factories, is 25 years later considered to be one of the world's most sustainable companies. Although it must be noted, it is still criticized for its lack of transparency and responsibility in choices of factories and wage issues.[1]

According to Ehrenfeld (1999), *Cultural Structure and the Challenge of Sustainability*, sustainable development is a new paradigm that necessitates a new approach in every action and mindset. This includes basic human rights such as justice, freedom, and dignity.

The focus on sustainability in this sector has, if not factually, then theoretically placed human beings and their environmental challenges on the agenda. This is evidenced in the example from NIKE 25 years ago when child labour and basic human rights were not prioritized. It is only recently that animal ethics and welfare issues have been brought into focus in the fashion and lifestyle industries.

The following example is a general picture of how to describe and process the subject of sustainability within this sector. Animals are not mentioned by name and are therefore not acknowledged as recognizable or worthwhile or as differing

[1] http://www.triplepundit.com/special/sustainable-fashion-2014/brief-history-sustainable-fashion/.

from nature; as a result, they are not given the same value and assimilation as plants and other organisms:

> Within the clothing and textile industry, issues have been raised in several environmental and ethical areas throughout the supply chain. The scope starts from the excessive use of land (3), water and pesticides in growing natural fibres, especially cotton (4); then extends to excessive water and chemicals used and discharged from fabric production, particularly the textile dyeing and finishing process (5). Research has also shown that the clothing usage process, in particular laundering and tumble drying, is more energy intensive than production processes (6). Furthermore, the deflation of garment prices since the 1990s of clothing imported from developing countries (7) has raised the issue of unfair labour sourcing in overseas clothing suppliers and manufacturers (8). This deflation has increased the overall carbon footprint as a result of import logistics (9) and created a cheap and disposable clothing culture that generates more waste, much of which ends up in landfill (10). Such problems have created a growing interest in this subject." (Saicheua et al. 2011)

Those who have been highlighting the issues about animal welfare have been ridiculed as emotional activists and extremists or are simply ignored by an industry that has chosen to turn a blind eye to a subject that is far more complicated to deal with due to traditions, cultures, and a lack of industrial awareness.

> "First they ignore you, then they ridicule you, then they fight you, and then you win." Mahatma Gandhi

It is said that sustainability within the fashion sector is an evident contradiction that raises critical and challenging issues for the clothing industry, for example, how can fast fashion be sustainable when sustainability has to do with a long-lasting perspective in every way (Walker 2006).

This emphasizes the importance of animal ethics and welfare in the fashion and lifestyle industries. How can designers, manufacturers, producers, farmers, and entrepreneurs make use of animals as a natural resource within an industry that always changes and is considered to expand in every way, everywhere, all over the world, always demanding more and something new?

The development within the new paradigm of the sustainable mind-set in the fashion industry makes it inevitable not to counteract ethics and morality. Actually, every choice made in the business of fashion and lifestyle is a matter of ethics, which makes it immensely important to become aware of the consequences of one's actions and choices in every single detail throughout the process.

Involving, including, producing, designing, farming and working with something from another living being demands answerability ethics from the one making this choice. Many people find it incomprehensible and not important to relate to animal suffering when our own race, the human race, is constantly still facing interminable and unsolvable problems and challenges. To these people,

it's an either/or question, whereas to those who relate to the challenges faced by nonhuman animals this does not seem to exclude taking care or showing responsibility their own race. To these people answerability ethics is the only choice.

1.1 To Choose

The fundamental and most elementary choice is to make a conscious choice, whether it resides in a design process or a manufacturer, and to examine this choice for further enlightenment. Therefore, the first decision to take is whether one is convinced that the use of animals as a resource is ethically acceptable.

Afterward one must look at this choice from the perspective of the animals involved. It is necessary to focus on which animals are involved, to decide if another material could be used, asking if there are consequences for the life of the animal chosen, and to consider the costs and environmental impacts and those for the humans involved.

> If we learn to make a product or service more sustainable, all we've probably done is figured out how to make the wrong thing last for a longer time. What we must learn is to make not just anything, but the right thing and make it to last for as long as possible. (Ehrenfeld et al. 2013)

This chapter aims to go through the elements relevant for decision makers to gain an overview and understanding of this issue from a historical perspective, an ethical perspective, and an environmental perspective, and to comprehend how all elements are interconnected. This presentation will be divided into two parts—the theoretical and the practical—which may seem to differ in approach, but this will provide a broader overview and perspective for decision makers within this field.

> We are all interconnected, people, animals, our environment. When nature suffers, we suffer and when nature flourishes, we all flourish. Dr. Jane Goodall

Once upon a time, the human species existed as hunters and gatherers. The general assumption today is that in everything the human species knows and practices today started in this period of man's evolution.

In many ways, the past is used as an indicator of how much humans have evolved today. Over the past 100 years, man has taken the most incredible developmental steps in society, science, and technology.

This development is emphasized in the everyday language used by the ordinary consumer, yet it is expressed in derogatory terms such as 'back then,' stressing that humans no longer live, think, or act in the present.

It seems important to humans to be ahead of development, innovation, and new initiatives. Whether it is in the way people live, think, consume, work, organize, research, or are educated, the tendency is to look ahead. The past is an image of how man acted "*back then*," i.e., not knowing any better, but today man is reaching seemingly new conclusions in the future of development.

> The stone age didn't end because we ran out of stones. The stone age ended because other efficiencies were gained with other raw materials. Jill Dumain Vlahos, Patagonia (Krüger et al. Guideline II, 2012)

However, some things do not seem to change, which is evident in a human's desire for decoration and luxury goods. Since the beginning of time, a range of fundamental needs and instincts has existed that made it possible for man to survive and develop, to decorate, and to communicate through dress, thus expressing the essential basis of understanding of who humans are and where they belong as human beings.

> Dress is a visual form of communication. Before two people are close enough to each other to exchange words, they communicate a world of information (or misinformation) through dress. They may register gender, age, ethnic origin, income, social status, rank, occupation, group membership, sexual availability, personality, opinions, beliefs, tastes, interests, and mood. Some scholars have suggested that because so much information is exchanged through the medium of dress, face-to-face social interaction would be almost impossible without it. There are few places (perhaps none) in the world in which no gender differences in dress exist. Those who participate in a particular culture learn how to distinguish males from females at an early age. (Evenson SL)

In those parts of the world considered to be developed and wealthy, it is possible to find this form of exchange of information and communication flowing everywhere in all levels of society. This is seen through the wearing of high-fashion brands, expensive designer clothing, jewelry crafted from precious and expensive metals or gemstones, and prestige types of fur and hides.

Some of the most luxurious products and materials recognized as the most valued and appealing are being extracted or processed in the most controversial ways. Today diamonds and rubies are extracted from mining by exploited workers. Calfskin and karakul lamb coming from baby or unborn animals are still recognized as the most beautiful, durable, and iconic materials in the world. Fur and jewellery have been the status quo for royalty and celebrities for centuries, creating an undeniable trickle-down effect into the present.[2]

Worldwide those people using and wearing these materials consider this their right, reasoning that human beings have always worn fur and hides. However, this conclusion is debatable because humans actually did not wear garments for an extended period of time.[3]

Although humans consider themselves to be intellectually and technologically superior to their cave-dwelling ancestors, they still decorate their homes, modes of transport, and bodies with the skin of animals of all sorts. Today there are no

[2] http://www.furinsider.com.

[3] http://www.dailymail.co.uk/sciencetech/article-1345109/Man-started-wearing-clothes-170-000-years-ago-according-study-LICE.html.

components in which any animal product cannot be replaced by another material, and due to this fact the industries that are using animals must justify their images of using "natural" resources as being synonymous with functional but mostly aesthetic quality. As technical textiles develop further and synthetic leathers, furs, and fillings improve, industries dealing with living beings will become more compelled to face this challenge of natural versus quality and act accordingly.

> What we need is a deep shift in values that is on a par with the Reformation, the Renaissance, the Enlightenment, or the Industrial revolution. These are "paradigm shifts" (in the words of Thomas Kuhn) changes in the way we think about ourselves, each other and the world around us. (Ehrenfeld et al. 2013)

1.2 Let's Go Back

When did humans actually start to wear animal hides as clothes "*back then*"? This has been a very challenging question for researchers to determine because early clothes would have been constructed from animal hides, which, as organic materials, degraded rapidly and thereby erased all evidence of their existence.

This is why a group of scientists base their data on studies of body hair and on the origin of pubic lice in humans. This research into the DNA of lice has found that man started wearing clothes about 170,000 years ago, 100,000 years before he migrated to colder climates (Toups et al. 2011).

> Because they are so well adapted to clothing, we know that body lice or clothing lice almost certainly didn't exist until clothing came about in humans.

The study also shows that humans started wearing clothes well after they lost body hair, which genetic skin-colouration research pinpoints to be approximately 1 one million years ago. Man therefore spent a considerable amount of time without body hair and without clothing reported Dr. Reed.

> It's interesting to think humans were able to survive in Africa for hundreds of thousands of years without clothing and without body hair, and that it wasn't until they had clothing that modern humans were then moving out of Africa into other parts of the world.[4]

Even though hides are believed to be one of the earliest uses for clothing, animal hides could also be used for other purposes such as providing shelter. The first evidence of tools used to scrape hides appears to be approximately 780,000 years ago (Carbonell et al. 1999), but this does not necessarily mean that these scraping tools existed for the use of clothing. Forty thousand years ago, sewing needles appeared suggesting a complexity in the making of garments, and these studies indicate that the use of clothing may have evolved anywhere from 40,000 years to

[4] http://www.dailymail.co.uk/sciencetech/article-1345109/Man-started-wearing-clothes-170-000-years-ago-according-study-LICE.html.

3 million years ago as evidenced in geological chronology. Given the vastness of this time span, alternative approaches for estimating the origin of clothing use are essential (Reed et al. 2007).

One conclusion is that man dressed himself in hides from animals as his very first garment. As to when humans evolved from animal hides and into textiles, the first fabric is though to have been an early antecedent of felt. From there, based on impressions of baskets and textiles in clay, early humans took up weaving some 27,000 years ago.[5]

The importance in these facts is that for some reason this ancient way of dressing has not evolved. Fashion and lifestyle industries are still using hides and textiles today to dress consumers even though innovation has occurred in almost everything else produced today.

The food industry and the fashion and lifestyle industries have in common the challenge of future production for billions of people worldwide. These industries use a large number of animals in their productions, and the cultivation of soil for growing crops to rear and feed these animals, which provide food, wool, and other products, must be considered.

> Livestock production is the world's largest user of land, either directly through grazing or indirectly through consumption of fodder and feed-grains. Globally, livestock production currently accounts for some 40 % of the gross value of agricultural production. In industrial countries, this share is more than half. In developing countries, where it accounts for one-third, its share is rising quickly; livestock production is increasing rapidly as a result of growth in population and incomes and changes in lifestyles and dietary habits. (Bruinsma 2003)

As in the fashion industry today where using fur and hides from animals for products and materials is considered the norm, eating meat is considered the norm by which man evolved. Studies show that our ancient ancestors were eating meat at least 1.5 million years ago and that eating meat contributed through increased protein intake to the growth of our brains.[6]

> The claim here is just that eating meat to most people in the Western world today is an integrated part of their understanding of what a good life is. Meat is an essential part of most meals and at festive times such as holidays the meal is often centered around certain traditional ways of serving a certain animal: Thanksgiving turkey, Christmas goose, Easter lamb, etc. To problematize meat is thus to problematize not only cultural traditions connecting us to the past, but also problematizing current visions of the good life. It can basically be seen as a threat to realizing what people strive to have. (Gjerris 2014)

These arguments contribute to why people worldwide intensely discuss animal ethics and welfare, and why both industries must take into consideration these arguments when developing future production methods.

From an historical perspective, humans have made numerous objects, had several beliefs, and performed more evil deeds that later on turned out to be

[5] https://en.wikipedia.org/wiki/History_of_clothing_and_textiles.

[6] ScienceDaily.com. 4 October 2012.

wrong. So the question must be asked: Is the historical argument, i.e., that it is right to eat meat and wear furs and hides based merely on the fact that humans have been doing this for thousands of years, still acceptable? If the answer is yes, another question must be answered: How are these productions then going to take place in the future?

Since the advent of industrialized animal production after World War II, the use of animals has been both philosophically and publically debated as seen in Ruth Harrison's Animal Machines (1964). The purpose of humanities and sciences is to create interpretations rather then conclusions or solutions, and that is why there can be no definitive and final results related to this topic.

Even though guidelines on right or wrong would make everything much easier when making decisions, the public often has a personal opinion in relation to culture and traditions. These personal feelings, emotions, experiences, and educations do have an influence on choices made when dealing with the use of animals as products. This is why it is necessary for not only consumers, but also designers and producers, to set the agenda and improve ethics and animal welfare in the future production of fashion and lifestyle products.

Given ethical changes and the awareness of "sustainability," toward the environment as a whole and working conditions for laborers over the past decade, it is essential for the fashion and lifestyle industries to address several aspects concerning the use of animals as a resource and to do so on equal terms with the aforementioned. To work with and use any living being as a resource requires more than simple nourishment but also the possibilities to thrive and flourish. John Ehrenfeld describes this beautifully:

> Flourishing
> Not a word that is in regular use within common discourse, flourishing means not only to grow, but to grow well, to prosper, to thrive, to live to the fullest. It is a dynamic word, representing change and striving.

2 Animal Rights

Legally, at international levels (EU) a series of laws has been passed that puts limits on the use of animals required to meet human needs and desires. One can say that in this way society already recognizes animals as ethical subjects. Animals are no longer to be regarded only as a resource (European Union 10.III.1976).

In 1948, the Universal Declaration of Human Rights was adopted by the UN General Assembly. World leaders decided to guarantee the rights of every individual everywhere.

To write a chapter on animal ethics is actually quite a challenge because this subject is surrounded by a very tense atmosphere. As a result, many people go far in their way of expressing what they believe should be the rights of animals, while others shake their heads in lack of comprehension.

Comparing this subject with any other subject in the entire value chain in the fashion and lifestyle industries—such as pesticides, wastewater pollution, transportation issues, and working and labour issues—it is easy to agree that on one level fair wages, clean industry, and water/energy consumption are all very important issues. Delving into the issue of using animals ethically and sustainably in the fashion and lifestyle industries is often associated with radical movements and organizations, which split people into two camps.

The question is this: Will it ever be possible to find agreement around this subject world wide, as was demonstrated with the issue of human rights, due to the fact that there are different stakeholders, cultures, traditions, history, and beliefs in the way animals are treated?

The kind of respect found amongst people working for "human rights" is not found amongst people working for "animal rights," and this alone makes it very challenging to describe this subject without being labelled as either "fanatical" or "emotional" and thereby not academically correct in relation to scientific fact.

One can say that the term "animal rights" is a label because it is based on the idea that all nonhumans are entitled to their own life and that their basic interests are to be considered on equal terms with the interest of human beings. This means that some people believe that any kind of use of any animals is unethical, that humans have no right at all to use animals alive or dead, and that animals are to be regarded as living species on the same level as human beings or at the very least under the protection of human beings.

In the opinion of some people, animals should not be used as food, clothing, research subjects, or entertainment in any way at all. One of the people advocating for animal rights is Richard D. Ryder (1940-) a British writer and psychologist who became known in the 1970s as a member of the Oxford Group, a group of intellectuals loosely centered on the University at Oxford, who began to speak out against animal use. Ryder is the author of a number of books about animal research, animal rights, and morality in politics, including *Victims of Science* (1975), *Animal Revolution* (1989), and *Painism: A Modern Morality* (2001).[7]

I do not wear, buy, or own fur…. Every designer who kindly lends me clothes for public appearances can tell you that I do not accept … fur pieces, even when they're only a small part of the outfit. **Carla Bruni-Sarkozy**.

The official statement from The White House:
"Mrs. Obama does not wear fur."[8]

[7] http://www.richardryder.com.

[8] http://news.instyle.com/2009/05/11/its-official151michelle-obama-is-fur-free/.

Philosophically, there is also a growing consensus that animals belong to our ethical community, although there is considerable disagreement about why they can be said to be ethically relevant beings and the extent to which they can be compared with humans.

According to Finnish pioneer Leena Vilkka, PhD, animal welfare is based on zoocentrism, a philosophy where issues, concepts, and values of animals are central, which is in contrast to anthropcentrism, which centers on the value of humans. She states that animals have been treated as instruments and models for human illness or as raw materials in the form of meat/fish, science, and fur and wool economies, for the benefit of human needs. The zoocentric approach, from a perspective of humans' well-being, demands being humane and not uncompassionate and brutal to animals (Leena 1997, pp. 37–38).

Basically, manufacturers, designers, and consumers must begin to relate to the fact that a resource in industrial production is alive in the sense that animals are living beings and must be treated differently as opposed to when growing and using plants or other man-made fibres. The first step for any producer, designer, or consumer must be to recognize and acknowledge this fact to act and develop an awareness and sense of responsibility in this area. It is necessary to be open minded and prepared to examine these issues, which can help in accessing and relating to future design processes, production methods, and daily consumption.

The following section describes the three most prominent positions today concerning animal ethics. Utilitarianism is a subject represented by Peter Singer, animal rights ethics by Tom Regan, and virtual ethics by Rosalind Hurst.

3 Animal Welfare and Ethics

Ethics is about responsibility

- Who is responsible?
- Whom do you have responsibility for?
- What is the responsibility about?
- What happens to us when we do not take responsibility?[9]

There appears to be a growing interest in animal welfare worldwide with increasing attention being paid to this subject by the media, government, and especially nongovernmental organizations. The volume of scientific research on animal welfare has also increased significantly, and today, due the Internet and social media, it is easier for anyone to access and gain knowledge (OIE 2013).

As mentioned in the introduction, when discussing the ethical aspects of using animals, whether it is in the meat industry, the pharmaceutical industry, or the fashion and lifestyle industries, various positions, attitudes, and opinions point out

[9]Gjerris M, YouTube, May 18 2015.

basic values about animals, human needs, and the "good life." These are the values toward which ethical theories aim to coherently point (Fraser et al. 1997).

This makes it even more important to gain an ethical overview and become acquainted with the historical facts about the particular product chosen for use or through information in order to set up one's own ethical precautions, develop one's own code of conduct, and not least of all, to be able to communicate these actions and attitudes for one's end users and stakeholders, thus completing the value chain and becoming truly transparent.

This is well emphasized in the following quote by Mickey Gjerris:

> By doing this I obviously run the risk of only saying irrelevant things as these basic experiences might not be recognizable to others. I do, however, hold that it is one of the tasks of philosophy to express interpretations of the thoughts and ideas that lived existence gives rise to. In that sense this can be seen as an example of the kind of phenomenological thinking that the Danish theologian K.E. Løgstrup was an exponent of (e.g. Løgstrup 1997). Ole Jensen, one of Løgstrup's students who later became a doctor of theology himself has later characterized Løgstrup's phenomenological methodology as a 'demonstratio ad oculus', basically meaning: GO AND SEE FOR YOURSELF (Jensen 2001). (Gjerris 2014)

Animal ethics is defined as the proper relationship between humans and animals. Animal welfare is a part of this discussion focusing on how an animal experiences its existence within the limits given by humans.

3.1 Definition of Animal Ethics

> As long as men massacre animals, they will kill each other. Indeed, he who sows the seeds of murder and pain cannot reap joy and love. PYTHAGORUS
> http://www.think-differently-about-sheep.com/Why_Animals_Matter_A%20Religious_Philosophical_Perspective_Philosophy_Quotations.htm

As seen throughout history, the relationship between humans and animals has always been the subject of ethical thinking and argumentation. The ancient Greek philosopher Aristotle concluded that there were three kinds of souls: A plant soul, the essence of which is nutrition; an animal soul, which encompass the basic emotions such as desire, pain, pleasure, and the ability to react and the human soul, which includes reasoning as well as self-awareness and moral sense. Another philosopher, Plato, said the soul will always choose to do good if it recognizes what is good. The philosopher Pythagoras urged respect for animals, believing that human and nonhuman souls were reincarnated from human to animal and vice versa. Against this, Aristotle argued that nonhuman animals had no interests of their own, thus ranking them far below humans. He was the first to create a taxonomy

of animals; he perceived some similarities between humans and other species, but argued for the most part that animals lacked reason (*logos*), reasoning (*logismos*), thought (*dianoia*, *nous*), and belief (*doxa*). (Based on Uconn Health Center 2015). In addition, religious beliefs, descriptions, and regulations for how one should treat animals were and continue to be interpreted and discussed by different parties based on the Bible, the Quran, and Hinduism.

> One is dearest to God who has no enemies among the living beings, who is nonviolent to all creatures. Bhagavad Gita (http://www.serv-online.org/Hinduism-quotations.htm)

In modern times, there are a number of interesting impact points that are worth noting. In 1822, the first actual legislation on animal welfare was adopted by a western country, England. The law prohibited the "unnecessary cruelty against another man's animal." Although part of the legislative objectives was to protect private property rather than animals, the law is still notable because this was the first time a law was made to protect animals through legislation, at least to a limited extent (Sandøe and Christiansen 2009).

Developments in livestock production in the Western world since the Second World War have been characterized by efficiency. The goal has been to produce as much food as possible as cheaply as possible. This has caused the prices of eggs, dairy products and meat to fall considerably through changes in production, better disease control, better feeding strategies, and an intensive breeding program, which—taken together—has developed an extremely effective system. This efficient development is also seen in textile and clothing production, which also includes the different animal breeds used for clothing production. Effectiveness also means that the animals in modern farming are kept under conditions that have been discussed worldwide from an animal welfare and animal ethics point of view (Bousfield and Brown 2010).

The following section will describe the ethical discussion raised by that intensive livestock production whether it is for fashion or food—or both—by elaborating on three key philosophical positions within animal ethics proposed by some of today's thinkers who are working with them: utilitarianism, animal rights, and virtue ethics. To understand the various positions, it is necessary to ask two fundamental questions:

- Is an animal at all ethically significant?
- What is meant when talking about "welfare."

Most human beings have an intuitive sense of how to act ethically toward another human. This includes a sense of what constitutes an ethical community, an ethical government, an ethical business, or an ethical society. This ethical group could be defined as a group of human beings who interact in a way that involves ethical

considerations of what is right and wrong. Also, most human beings have some reasonably clear beliefs about who belongs to this ethical community and who or what is not included. An example of this type of inclusion could be defining things of instrumental value, the value given to a subject where its value lies not in the object but in its use. In this sense, one can act right or wrong toward another human being, but one cannot act right or wrong toward a physical thing like a car or a computer.

> If a being is not capable of suffering, or of experiencing enjoyment or happiness, there is nothing to be taken into account. (Singer 1989)

According to the afore mentioned definition it is very wrong to kill another human being, intentionally or not, but it is not wrong to damage the car or the computer; although of course it could be considered a waste of resources, but the car/computer is not aware of this action and it would not be a wrong action towards the car/computer itself.

An ethical community includes people with dementia, those who are physically disabled, including infants, and those who are severely mentally ill, all of whom can not live up to the demands of rationality and moral sense that are necessary in any community. Based on this fact the philosopher Peter Singer criticizes that not to include animals in the ethical community is unreasonable and discriminatory because it can be argued that animals (also called "nonhuman animals") meet these rationally and morally challenged requirements on equal terms as some beings classified as humans (Singer 1989).

3.2 Definition of Animal Welfare

To set up ethical standards and develop a code of conduct in businesses today, it is necessary to understand animal welfare and the ethics connected to production. This has already been described not only by several thinkers and philosophers but also by governments and other organisations.

There are too many definitions of animal welfare for this next chapter to provide a complete conceptual analysis; therefore, only definitions regarding the use of animals in connection with the fashion and lifestyle industries will be explored. These definitions are drawn from thinkers and organisations often used to provide valuable guidance on animal welfare.

Animal welfare is defined by Hughes (1988), as a state of physical and mental health where an animal is completely in harmony with its environmental surroundings.

A definition of animal welfare, which describes the inter-working conditions the animals perform for the needs of humans, is proposed by Carpenter (1980), as that of one where animals must be allowed to adapt without suffering in an imposed environment set by humans.

Suffering occurs for animals when they experience something difficult or painful that is too prolonged and too severe to cope with as induced by human subjectivity. “Let us not mince words: Animal welfare involves the subjective feelings of animals” (Dawkins 2011).

1. **Saunders Comprehensive Veterinary Dictionary**:
   Animal welfare means the avoidance of abuse and exploitation of animals by humans by maintaining appropriate standards of accommodation, feeding and general care, the prevention and treatment of disease, and the assurance of freedom from harassment, and unnecessary discomfort and pain.
2. **OIE (The World Animal Health Organisation) Definition of Animal Welfare**:
   Animal welfare means how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states such as pain, fear, and distress. Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling and humane slaughter/killing. Animal welfare refers to the state of the animal; the treatment that an animal receives is covered by other terms such as animal care, animal husbandry, and humane treatment.
3. **The Five Freedoms**
   In 1965, the United Kingdom (UK) government commissioned an investigation, led by Professor Roger Brambell, into the welfare of intensively farmed animals, partly in response to concerns raised in Ruth Harrison’s 1964 book, Animal Machines. On the basis of Professor Brambell’s report, the UK government set up the Farm Animal Welfare Advisory Committee in 1967, which became the Farm Animal Welfare Council in 1979. The committee’s first guidelines recommended that animals require the freedoms to “stand up, lie down, turn around, groom themselves and stretch their limbs”. The guidelines have since been elaborated upon to become known as the Five Freedoms: (1) Freedom from thirst and hunger—by ready access to fresh water and a diet to maintain full health and vigour. (2) Freedom from discomfort—by providing an appropriate environment including shelter and a comfortable resting area. (3) Freedom from pain, injury, and disease-by prevention or rapid diagnosis and treatment. (4) Freedom to express normal behavior-by providing sufficient space, proper facilities and company of the animal’s own kind. (5) Freedom from fear and distress—by ensuring conditions and treatment which avoid mental suffering (Bousfield and Brown 2010).

As can be seen from these definitions, animal welfare is an important subject most people can agree upon, but it is much more difficult to reach an agreement on what animal welfare actually is regarding its application in industrial production.

> The welfare of animals in the intensive animal production system is heavily debated. Different notions of what animal welfare actually is, fuels a lot of these debates. In the public sphere, the discussion often takes the shape of a disagreement between producers whose view of animal welfare is often closely linked to parameters also relevant for production rates such as growth, litter size, disease rates and mortality (Te Velde et al. 2002; Bock and van Huik 2007; Vanhonacker et al. 2008) and animal welfare/rights organisations, consumer organisations and citizens to whom parameters as pain perception and ability to perform species specific (natural) behaviour is important (Gjerris et al. 2006; Martelli 2009; Miele 2010). These general views are reflected in the debate within animal welfare science on which welfare paradigm should be used when attempting to evaluate the welfare of animals (Gjerris 2014).

In addition, animal welfare does not only relate to welfare issues in the livestock industry but also ethical issues such as keeping animals caged or killing them regardless of their living conditions.

4 Utilitarianism, Rights Ethics, and Virtue Ethics

Being aware of the various ethical theories helps a decision maker choose wisely, whether as an ordinary consumer, a designer, or manufacturer, and allows him or her create and substantiate transparency in such decisions.

The following descriptions of different theories are based on the interpretations of the Danish philosopher. Jes Lynning Harfeld, PhD, and Mickey Gjerris, PhD and MA Theology, and is intended to serve only as an introduction and inspiration for further research.[10]

Utilitarianism (Bentham 1748–1832): Utilitaranism is the position that on the surface is the critical use of animals, but in practice allows anything as long as welfare is maximized and does not care about the individual but see them as containers for welfare.

Right ethics: Right ethics is the position that rejects all use of animals because it violates their rights not to be used as mere means and rather to have their freedom.

[10] www.harfeld.dk, www.mickeygjerris.dk.

Virtue ethics (eudaimonia): **Virtue ethics is** the position that points out that humans the have responsibility to give animals the opportunity to live a good life and that this can be seen as an expression of the virtues that also help to ensure man a thriving life.

5 Peter Singer

One of the first and most influential works on animal ethics in modern philosophy is *Animal Liberation: A New Ethics for Our Treatment of Animals* from 1975, written by the Australian philosopher Peter Singer (1946–). This book has helped usher in criticism of traditional ethic anthropocentrism and has inspired numerous books on animal ethics from various philosophers and thinkers over the past several decades.

Singer's approach to animal ethics is partly based on the philosophical heritage of the English jurist and social reformer Jeremy Bentham (1748–1832). It is from Bentham that Singer inherited the idea that the ability of animals to experience suffering and enjoyment should be the justification for their inclusion in the community of ethically relevant beings. Thus, Singer quotes Bentham's famous words: *The question is not, Can they reason nor Can they talk? but, Can they suffer?* (Singer 1989).

Singer's approach is incontestably utilitarian. Utilitarianism is defined in various ways including the feeling of pleasure and the lack of suffering. Utilitarianism is an ethics of consequence, a form of right and wrong, which suggests that the "end justifies the means." This means that to assess and judge an action, it is necessary to compare and balance the types of consequences which this action may have including both the "sum-logic" and the weight of an individual's welfare. Singer's argument here is that animals have the ability to experience pain and pleasure, not just react to their environment as elements of nature do. An example of this would be a this: A stone heated by the sun does not actually have interest in or preference for whether it is cold or hot. According to Singer there is nothing that matters to a stone, and therefore welfare does not mean anything to these natural elements. Actually, they cannot experience welfare at all (Singer 1989).

This theory suggests, in principle, that some animals may experience poor welfare if this is sufficiently counterbalanced by others experiencing good welfare.

Sum-logic: To sum up units of pleasure and units of pain or a precise measurement of the overall good or evil tendency of an action is not essential, but it is nonetheless necessary for the utilitarian to make some interpersonal comparisons of the values of the effects of alternative courses of action.

Because animals are obviously not capable of expressing themselves in the same way as human beings, how then is possible to access information on what is experienced as poor welfare for an animal? Singer's answer is to look at what science tells about the similarities between animals and humans at relevant points. The fact is that some animal brains and physiques resemble human brains and physiques and humans are able to experience suffering or pleasure. For instance, when a child falls and gets hurts, the child experiences pain. Thus, according to Singer's suggestions on similarities, it is clear that when a pig or a calf experiences something similar and behaves in a similar ways, it should experience pain as well.

Singer points out that humans have in common with animals, especially mammals and birds, the same parts of the central nervous system that are necessary to experience pain and pleasure. These basic parts of the central nervous system are in an evolutionary sense quite old, and today's animals and humans have them in common from evolutionary ancestors (Singer 1990).

Ethics to Singer is basically how animals can experience suffering and pleasure. Animals can have good or poor welfare. In Singer's point of view, it does not matter what or who is to blame for the good or bad welfare. His only interest is within such aspects as (1) the natural freedom and rights of the animal and (2) if when these are applied whether they contribute to the welfare of the animal's pleasure rather than suffering. Singer's focus stems from the fact that humans use billions of creatures on a global scale and that those creatures can have good welfare but, as is often the case, they have poor welfare.

Because it is difficult for animals to live lives where their interests are respected and in turn would experience good welfare, Singer blames modern animal husbandry practices for not taking care of animals' basic interests. Not experiencing suffering, for example, seems to be almost excluded in modern farming. This does not mean that Singer by principle is opposed to the production of animals for consumption. In Singer's version of utilitarianism, he does not find anything wrong with farms that have a convincing focus on animal welfare. This is described as an environment where (1) the animals live their lives with many positive experiences, which thus (2) allows them to not only get their needs met but also experience a high degree of general welfare and then in the end (3) to be slaughtered without fear and pain, in turn to be replaced by other happy animals.

6 Tom Regan

The American philosopher Tom Regan (1938–) specializes in animal rights and animal theory. Regan is the author of numerous books on the philosophy of animal rights. In 1983, in his book *The Case for Animal Rights* Reagan gave a response to what he saw as a problem regarding parochial focus on welfare as well as a utilitarian fallacy about the basis for the ethical relevance of animals. Regan's criticism of utilitarian welfare thinking is reflected in a background of an ethical focus on individual rights and justices. This is a theory that is mainly inspired by the German deontological ethics (deon = duty) writer Immanuel Kant (1724–1804).

In the utilitarianism position, suffering and pain is the lowest common denominator, but from Regan's point of view the lowest common denominator for ethical relevance within an individual is far more comprehensive. He argues that nonhuman animals, what he calls the "subjects-of-a-life," are just as human and describes them as beings that include more features such as imagination, desire, memory, self-awareness, and individual experienced welfare (Regan 2004, pp. 243). Regan describes utilitarianism as "a *duty* to perform an act that will bring about the best consequences for all those affected by the outcome" (Regan 2001, pp. 14).

Reagan's inspiration and philosophy aligns broadly within the traditions of Kant, pointing to a moral obligation to treat other life subjects "always as ends, never merely as means" (Regan 2001, 17). However, he rejects Kant's idea that respect is due only to rational beings. If one is a life subject, one has, according to Regan, the right not to be used as a means. This entails the right to be treated with respect and includes the right not to be harmed. The intrinsic and absolute value and the aspect of welfare cannot rightfully be undermined by references to the other living beings denied benefits and welfare.

To be natural, or a part of natural wildlife, is not a factor in Reagan's concept of animal ethics. However, it is to be understood that his thoughts about rights are based on an understanding of natural rights, and the idea of intrinsic value is partly therefore the right to liberty where animals have a right to their own self-selected natural life in the wild. Although to be natural is not an explicit criterion for what humans owe animals, morally in theory it is necessary as an aspect when it comes to practice because Regan's conclusion regarding humans is that humans should set animals free. Free to live their own lives, their own natural life in the wild.

> The fundamental wrong is the system that allows us to view animals as our resources, here for us — to be eaten, or surgically manipulated, or exploited for sport or money. Once we accept this view of animals - as our resources - the rest is as predictable as it is regrettable. (Regan 1985, pp. 13–26)

Why is the idea of being the subject-of-a-life important? Because it illuminates our moral sameness, our moral equality.

As subjects-of-a-life, we are all the same because we are all in the world.
As subjects-of-a-life, we are all the same because we are all aware of the world.
As subjects-of-a-life, we are all the same because what happens to us matters to us.
As subjects-of-a-life what happens to us matters to us because it makes a difference to the quality and duration of our life.
As subjects-of-a-life, there is no superior or inferior, no higher or lower.
As subjects-of-a-life, we are all morally the same–all morally equal.

(Regan 2015)[11]

[11] http://tomregan.info/sentiency-and-rights-some-observations/.

7 Rosalind Hursthouse

Rosalind Hursthouse has been a powerful voice within virtue ethics since the 1990s, a voice that has had an impact on animal ethics. Within an overall account of human flourishing, Hursthouse's most significant contribution to modern virtue ethics is her book *On Virtue Ethics*, 1999. Her book is a distinctive action-guiding theory that examines the relationship between virtue, the emotions and moral motivation, and the place of the virtues in animal ethics.

Hursthouse's book *Humans, and other Animals*, 2000, is ideally suited to newcomers exploring philosophy and ethical problems because she carefully introduces the three standard approaches in current ethical theory: utilitarianism, animal rights, and virtue ethics.

The introduction of virtue ethics can be traced as far back as ancient Greece, where especially Aristotle advocated ethics based on good character traits or virtues. Virtue ethics, both in its ancient and the modern conception, is less directly action-prescriptive than utilitarianism and virtue ethics/right ethics; rather it places the main focuses on peoples' ability to possess and express specific characteristics, i.e., virtues.

Hursthouse basically describes a virtue as good or admirable or praiseworthy characteristics (Hursthouse 2000, 147). She does not work with a specific and limited number of virtues, but she provides examples in the language as to how people, and their actions, are relevant to morality. "*We may describe them for instance, as courageous, honest, public-spirited, kind, fair, loyal, responsible… and conversely as cowardly, dishonest, mean, anti-social, cruel, disloyal, feckless and so on.*" (Hursthouse 1987, pp. 219–34).

She emphasizes the Greek term "eudaimonia," which can be roughly translated as "flourishing." The flourishing life for any being is a well-lived life. The link between eudaimonia and virtue is that in order to achieve eudaimonia, it is necessary to be virtuous. This implies the ability and possibility to thrive in order to be able to flourish (Hursthouse 1999). To be able to actively unfold ones own life within virtue ethics in an Aristotelian sense is more than just to act in accordance to ones function.

As seen in the example of welfare within utilitarianism regarding a stone warmed by the sun, in this case a computer example may be used. It may be in good condition and functioning, but a computer cannot develop a good life. The computer is therefore not relevant to ethics. But where is the limit then? Would it be possible to say that both mosquitoes and larvae are able to develop a good life? Hursthouse, as an ethicist, does not give a final answer to those questions, but it can indirectly be found through our language. It would be pointless to claim that one can be dishonest or unpleasant to a computer. It would be equally nonsensical to say that one can be considerate or fair in relation to the computer. It would make sense, on the other hand, to say that one can be friendly or unfriendly towards a pig or a cow (Hursthouse 2011).

This means that the well-lived life for an animal—what we call "welfare"—is in a virtue ethics sense to have the opportunity for a being to develop a full life as the being it is. According to Alasdair Chalmers MacIntyre (1929–), a Scottish philosopher primarily known for his contribution to moral and political philosophy and as one of the modern founders virtue ethics founders a good life for an animal is one in which the animal is allowed the ability to actualize the potentials that are necessary for it to become a "flourish qua member of its particular species" (MacIntyre 1999, p. 64).

Actions toward animals do not have, as in utility ethics, the intention to produce the greatest amount of welfare but instead to give the animals the opportunity to develop and thrive as the kind of beings they are. This implies both positive and negative experiences such as the danger of being killed by another animal for instance. This is why virtue ethics holds the fundamental belief that individual lives are supposed to be lived out within the framework in which they are essentially meant to live.

Whether an animal has a good life according to virtue ethics, including the possibility to flourish, depends on the particular animal, the characteristics of that specific species, and the animal's behaviour combined with the environment in which it lives (Walker 2007, 184).

However, animal welfare in this sense is not only a question about whether the animal functions well as an animal; it is also the fact that the animal needs to experience good to feel well.

"*There are few things more sad than the notice that used to appear on the cages of certain animals in zoos 'Does not breed in captivity'*" (Hursthouse 1999, 200). When a sign in the zoo explains that a certain animal that does not breed in captivity, then the virtue ethics expert will claim that this is an animal welfare issue because the animal is in a situation that is not supportive of its welfare.

8 Environmental Impacts

As explained in the introduction, this section has a much more practical approach than Sect. 2. The purpose of this section is to offer an insight into what species of animals are being used in the fashion and lifestyle industries, the various methods being used in this industry breeding, killing and transforming animals into usable products, and the challenges that may be faced in an environmental and ethical context.

Not only must every decision maker within this industry consider the ethical impact of designs and production methods involving animals, they must collect information on the environmental impact involving animals.

"*We are all interconnected, people, animals and our environment. When nature suffers, we suffer and when nature flourishes, we all flourish.*" Dr. Jane Goodall, famed primatologist, conservationist, founder of the Jane Goodall Institute, and United Nations Messenger of Peace.

As mentioned previously, zoocentrism is a philosophy in which animals are central whereas anthropotrism centers on the value of human beings. To link these two philosophies and create a new approach, a short introduction to biocentrism and ecocentrism is required.

> Biocentrism is an ethical point of view that values all living things. Life is central. This is related to ecocentrism in which the issues, concepts and values of the ecosystem are central. (Leena 1997, pp. 37–38)

From this point of view, animal welfare cannot be understood without getting into the environmental issues and challenges made by the fashion and lifestyle industry, which is considered to be the world's second most polluting industry.[12] Seen from an ethical point of view, the actions of this industry are a threat not only to humanity and the environment itself but also to nonhuman animals nurtured by and living in the environment whose welfare is thus threatened.

> To switch Western culture from its present track to a saving ecopolitical route means finding a new and compelling belief-system to redirect our way-of-living. It must be a vital outgrowth from our science-based culture. It seems to me that the only promising universal belief-system is ecocentrism, defined as a value-shift from Homo sapiens to planet earth. A scientific rationale backs the value-shift. All organisms are evolved from Earth, sustained by Earth. Thus Earth, not organism, is the metaphor for Life. Earth not humanity is the Life-center, the creativity-center. Earth is the whole of which we are subservient parts. Such a fundamental philosophy gives ecological awareness and sensitivity an enfolding, material focus. (Rowe 1994)

Although much evidence has been collected from the animal agriculture sector on all the different stages of environmental impact, somehow the fashion and lifestyle industries have been able to ignore the fact that they are a huge part of this value chain. The negative impacts from livestock production on environmental integrity, community, sustainability, working conditions, and animal welfare found globally in this sector has remained largely underestimated and underappreciated. Many of decision makers and consumers in this industry have convinced themselves, almost as an excuse, that resources such as hides, wool, and feathers are "waste problem," and thereby these decision makers do not consider themselves to be responsible for any negative environmental impacts. Ruminant livestock, including cattle, buffalo, sheep, and goats, are the main agricultural sources of methane (FAO 2013a). It is not a matter of deciding that this industry does not acknowledge these issues; it's more like a mater of the industry choosing to ignore them.

The fact is that since the 1940s, farm animal production has been escalating in large confined operations worldwide increased significantly methane emissions from both animals and their manure (Paustian et al. 2006). In 1965, 10 billion

[12] http://www.businessoffashion.com/community/voices/discussions/can-fashion-industry-become-sustainable.

livestock animals were slaughtered each year; today that number is 55 billion (GRACE Communications Foundation).

> Livestock production is the world's largest user of land, either directly through grazing or indirectly through consumption of fodder and feed-grains. Globally, livestock production currently accounts for some 40 % of the gross value of agricultural production. In industrial countries, this share is more than half. In developing countries, where it accounts for one-third, its share is rising quickly; livestock production is increasing rapidly as a result of growth in population and incomes and changes in lifestyles and dietary habits. (Bruinsma 2003)

This impact on the environment and its effects also seems to be a heated discussion between stakeholders, scientists, and the public in general. Verification and control of the scientific data, which creates such disagreements and uncertainty, must be prioritized in the future. A discussion on how the global contribution of greenhouse gases from animal production can vary to a considerable degree can be found in Bittman (2012): The Food and Agricultural Organisation of the United Nations estimates 18 % (Steinfeld et al. 2006), and the World Watch Institutes estimates 51 % (Goodland and Anhang 2009).

Some of these impacts mentioned in the FAO report from 2006 (Steinfeld et al. 2006) include the extensive use of arable crops to forage production, creating deforestation by providing grazing land to livestock, desertification of meadows, degradation of arable crops due to overgrazing, and decrease of limited water resources. Also mentioned are eutrophication; general pollution of soil, air, and water caused by fertilizers; pesticides used in the production of feed; treatment of livestock with antibiotics; and hormones, which are then excreted in the animals' waste.

The complexity of these LCA results are therefore almost incomprehensible to assess. For example, LCA is mostly used for livestock emissions, but greenhouse gas emissions must be estimated using LCA to cover the "cradle-to-ground gate," which accounts for all direct and embodied greenhouse gas emissions up to the point where the product is ready to leave the farm for following processing. It therefore does not include transportation to the processing plant or any emissions related to processing or transportation of the product to the market (Wheeler 2011).

Data found connected solely to the fashion and lifestyle industry is very hard to find, but as seen from the report by FAO, much of the product data mentioned are linked to this industry.

> In 2010, about 98 percent of the global buffalo meat production was produced in South, East and Southeast Asia with the bulk contributed by India and Pakistan. This is easily explained by the fact that the two countries have 73 percent of the global buffalo population. Besides edible products, ruminants also produce a host of non-edible products such as manure, hides and skin, and natural fibre (wool, cashmere and mohair). (FAO 2013, p. 6; FAO 2013b)

The author of this chapter has no expectations that humanity at any time in the near future will become vegetarians or vegans by sacrificing their own traditions and cultural expectations to "the good life'" and thereby relate to animal welfare problems and contribute to the change of the world's problems. However, it could be argued by some that to quit the consumption of animals, or to stop the use of them, as an unlimited free resource would be the ideal animal rights ethical point of view.

The question is this: Will be possible to live out a more virtue ethical approach in the near future by modifying the expectations humans have toward life and consumption in general to provide animals with greater welfare. If humans can change their diet by eating less meat, it might be possible to eat more locally and in this way ensure better welfare practices, which would benefit both the welfare of animals as well as the environment.

8.1 Faux Fur and Skin

In this section, a short description about the environmental impact on the production of faux fur and skin is introduced because this often seems to be included in the debates on ethics or the use of living nonhuman animals.

Faux skin and fur fibre is produced from petroleum chemicals, which includes in part the practice of substantial integrated chemical-manufacturing production methods. The main annual global production is taking place in Europe, and North America. To transform acrylic fibre into faux skin and fur fabric requires an immense degree of processing.

No systematic quantitative characterisation of the involved processes has been found. Furthermore, the actual production of faux fur fabric is often produced in a different place than the fibre; for example, China is a major producer of faux fur fabric but does not process them (A Comparative Life Cycle Analysis 2012: Natural Fur and Faux Fur Submitted to International Fur Trade Federation Submitted by DSS Management Consultants Inc.).[13]

Serious investments in lifecycle analyzes have been made by Plastics Europe to identify and describe the chemical processes associated with a great diversity of products made from plastics. These data is included are the Ecoinvent database produced by the Swiss Centre for Life Cycle Inventories, but it does not include any specific data representative of faux skin and fur fibre production (Weidema et al. 2009 Code of Practice).

According to *A Comparative Life Cycle Analysis: Natural Fur and Faux Fur Submitted to International Fur Trade Federation Submitted by DSS Management Consultants Inc*., the conclusion is that the environmental benefits of products produced from living animals are better than products made from synthetic materials:

> The life cycle of a natural fur coat tends generally to outperform that of a faux fur coat based on the data and assumptions used in this LCA. Nonetheless, a categorical conclusion cannot be reached that one product is superior environmentally in all respects to the other due to the limitations of the data and LCA method in general. The data and assumptions used in this LCA lead to the conclusion that in general, the life cycle of a faux fur coat results in greater risk of potential impacts associated with ecosystem quality (i.e., 300 % greater), resource consumption (i.e. 169 % greater) and climate change (i.e., 129 % greater). The difference between the two products with respect to the risk of potential

[13] http://www.furinformationcenter.eu/media/3805/lca__final_report.pdf.

> impacts on human health is negligible (i.e., 3 % greater for a faux fur coat). A number of environmental credits (i.e., benefits) are associated with the life cycle of a natural coat. These benefits accrue in particular to natural ecosystems. The life cycle of a faux fur coat does not yield any environmental credits.

Although the report does not mention the impacts incurred from the tanning process, it must be assumed that these are included in the analysis; otherwise, its credibility of data could be questioned.

The report also states that a fur coat can be used for at least 36 years, but it does not take into consideration the impact of human needs such as identity, fashion, and trend. To keep a garment for 36 years actually very rarely takes place because consumers who are able to afford these lifestyle products also have the opportunity to frequently change their wardrobe. It also states that natural furs are actually being recycled. It still remains uncertain how many years natural fur products are stored and cleaned for preservation before being recycled and how all of this impacts the environment.

> A key parameter that affects all aspects of this LCA is the functional unit (i.e., the length of the useful life of a natural fur coat). The peer reviewers identified this parameter in particular as being of key importance. Two variations are analysed. The first is an increase in the useful life of a faux fur coat from six years to eight years. The second change is increase in the useful life of a natural fur coat from 30 years to 36 years. (A Comparative Life Cycle Analysis 2012, p. 12)

Although it is not possible to draw any final conclusions from an ethical point of view in this case, the theory of utilitarianism offers interesting consequences with regard to the production of faux fur. What would be the best outcome for the environment, humans, and nonhuman animals? Assuming that humans cannot live without dressing in hides and furs (bearing in mind that not all consumers will become vegetarians), at what point will animal welfare be maximized, and how can this ever be measured?

9 Tanning

The tanning process for fur and leather production has been on the agenda of environmental challenges for the last few decades. This chemical process is one of the most toxic practiced by industries in the world today.

When incorporating hides, fur, or feathers into a design product, these parts must go through a treatment process before being usable. The tanning process was originally invented to avoid the decomposition of leather and fur. This is achieved by preparing a sort of mummification and stabilization process of the material by scraping the hides clean to make them free of meat, fat, and eventually hair and then applying a lime paste or bleaching or acid treatment.

The difference between a tanned hide and rawhide is based on the hide's reaction to heat and water. Rawhide will become hard and stiff when it is dry; then it will putrefy on contact with water or excessive humidity. Tanned leather, however, remains flexible and soft and will not putrefy when wet.

From an historical perspective, in the 18th and 19th centuries the tanning industry was represented by small- or medium-size family businesses; small-scale cottage industries began shifting to large factories in the mid-19th century.

However, the current leather sector has grown tremendously worldwide, and now leather is one of the most widely traded products in the world. This industry plays a prominent role in the world's economy with an estimated global trade value of approximately US$100 billion per year (UNIDO 2010).

The trend has been for tanneries and manufacturers of leather products (as with any of the other sectors of the fashion and lifestyle industries) to outsource their production to countries where labour is cheapest. These cheap-labour countries have had to import large quantities of hides and skins due to shortages in raw material supply (UNIDO 2010).

To meet the growing demand for leather, new tanneries are being set up in these countries, whereas most tanneries in the United States, Japan, and Europe have closed down their tannery businesses. Unfortunately, it appears there is little or no control of labour or environmental practices within these tanneries. In some parts of the world, it is almost impossible to obtain any reliable data on either tanning processes or the leather goods or clothing markets.

The tanneries that have remained profitable in the developed world, such as Italy and Spain, have built new business models. Some of these have incorporated responsible environmental practices with regard to their own tanning processes and in compliance with European laws.

According to UNIDO (2010), *Future Trends in the Leather and Leather Products Industry and Trade* p. 40, there will be four different types of tanneries in Europe that are likely to survive:

- those able to internationalize via joint ventures and partnerships;
- very large and highly automated facilities primarily for the manufacture of upholstery leather (there is one such enterprise in Austria that processes 100 tonnes of wet salted hides a day);
- enterprises moving towards smaller, creative boutique operations serving local high-end users of leather, and which may also be making use of partnerships with companies in the newer EU member states and/or North Africa;
- niche producers such as manufacturers of chamois and heavy leather for industrial sers.

> The tanning industry is one of the oldest and fastest growing industries in South and South East Asia. There are more than 3000 tanneries located in India with total processing capacity of 700,000 ton of hides and skins per year. The wastewater discharge from these tanneries is about 100,000 cubic per day. More than 90 % tanneries are in small and medium scale sector with processing capacities of less than 2–3 ton of hides/skins per day. (Rajamani et al. 2002)

9.1 Tanning Processes

There are a number of processes whereby the skin of an animal can be formed into a flexible, smooth, and strong material commonly called "leather." The different

stages include preservation, soaking, liming, unhairing, splitting, fleshing, reliming, deliming, bating, degreasing, frizing, bleaching, depickling, and pickling. These tanning methods will depend on what the final product's attributes and uses will be. Described below by Leathernet, Leather Industry Worldwide[14]:

- *Vegetable-tanned leather is tanned using tannin (hence the name "tanning") and other ingredients found in vegetable matter, tree bark, and other such sources. It is supple and brown in colour, with the exact shade depending on the mix of chemicals and the colour of the skin. Vegetable-tanned leather is not stable in water; it tends to discolour, and if left to soak and then dry it will shrink and become less supple and harder. In hot water, it will shrink drastically and partly gelatinize, becoming rigid and eventually brittle. Boiled leather is leather that has been hardened by being immersed in hot water, or in boiled wax or similar substances. Historically leather was used as armour after hardening, and it has also been used for bookbinding. This is the only form of leather suitable for use in leather carving or stamping.*
- *Chrome-tanned leather, invented in 1858, is tanned using chromium sulphate and other salts of chromium. It is more supple and pliable than vegetable-tanned leather, and does not discolour or lose shape as drastically in water as vegetable-tanned. It is also known as wet-blue for its colour derived from the chromium. Colours that are more esoteric are possible using chrome tanning.*
- *Aldehyde-tanned leather is tanned using glutaraldehyde or oxazolidine compounds. This is the leather that most tanners refer to as wet-white leather due to its pale cream or white colour. It is the main type of leather used in chrome-free leather often seen in infant's shoes and in automobiles that prefer chrome-free leather. Formaldehyde tanning (being phased out due to the danger to workers and the sensitivity of many people to formaldehyde) is another method of aldehyde tanning. Brain-tanned leathers fall into this category and are exceptionally water absorbent. Brain tanned leathers are made by a labor-intensive process which uses emulsified oils often those of animal brains. They are known for their exceptional softness and their ability to be washed. Chamois leather also falls into the category of aldehyde tanning and like brain tanning produces a highly water absorbent leather. Chamois leather is made by using oils (traditionally cod oil) which oxidise easily in order to produce the aldehydes that tan the leather.*
- *Synthetic-tanned leather is tanned using aromatic polymers such as the Novolac or Neradol types. This leather is white in colour and was invented when vegetable tannins were in short supply, i.e. during the Second World War. Melamine and other amino-functional resins fall into this category as well and they provide the filling that modern leathers often require. Urea-formaldehyde resins were also used in this tanning method until dissatisfaction about the formation of free formaldehyde was realised.*

[14] http://www.leathernet.com/leather.htm.

- *Alum-tanned leather is tanned using aluminium salts mixed with a variety of binders and protein sources, such as flour, egg yolk, etc. Purists argue that alum-tanned leather is technically "tawed" and not tanned, as the resulting material will rot in water. Very light shades of leather are possible using this process, but the resulting material is not as supple as vegetable-tanned leather.*
- *Rawhide is made by scraping the skin thin, soaking it in lime, and then stretching it while it dries. Like alum-tanning, rawhide is not technically "leather", but is usually lumped in with the other forms. Rawhide is stiffer and more brittle than other forms of leather, and is primarily found in uses such as drumheads where it does not need to flex significantly; it is also cut up into cords for use in lacing or stitching, or for making many varieties of dog chews.*

For nearly 200 years, chrome tanning has been the dominant method of making leather, but efforts are now being made to find alternatives, and thus there has been an increase in the use of vegetable tanning of leather. However, chrome tanning still remains the most efficient way to make leather. Eighty percent of leather produced is chromium tanned. Chromium VI, which is an extremely toxic and environmentally damaging waste product from leather manufacturing, has been found in the food chains and water supplies of both developed and developing countries. This is tantamount to the fact that this industry has to work harder to reduce water and energy consumption and to manage its waste materials, particularly in the case of many developing countries, where industrial development has not included waste-treatment procedures at all. Extremely toxic residues of chromium VI can, with a strict process control, be avoided and exchanged for other easily accessible additives.

According to UNIDO (2010, p. 45), there is an awareness regarding the issues of solid and liquid waste that challenge this industry with a number of evolving areas of concern:

- *common salt (NaCl) and some other water-soluble salts getting into water recipients—rivers, lakes and/or ground water—and making the water unsuitable for drinking and other uses*;
- *the lack of environmentally acceptable and cost-effective solutions for solid waste disposal; landfill for solid wastes in some European countries and the associated trend to increase the cost of landfill via tax or other methods*;
- *growing consumer pressure and associated regulations regarding an increasing number of chemicals now deemed harmful for various reasons*;
- *high levels of water consumption*.

These environmental threats involve the dumping of solid and liquid waste that contains leftover chromium and several toxic and hazardous combinations of compounds. This is common practice in regions without strong environmental protection standards such as China, India, and Bangladesh, the primary regions of leather tanning.

This is why wastewater pollution is one of the biggest problems in this process because small bits of meat, hair, mold, and other animal products are mixed

together and discarded along with large doses of chromium. This does not only damage wildlife in the water, but it also contaminates the whole food chain, including people who drink and bathe in the water, which can then lead to infertility and birth defects among others problems.

> As a rule of thumb, tanning one ton of hide typically results in 20 to 80 cubic meters of wastewater with Chromium concentrations around 250 mg/L and sulfide concentrations at roughly 500 mg/L, not to mention the offal effluence from the preparation phase and the pesticides often added to keep mold growth down during transport to the facility. (Tarantola web blog 2014)

The numbers found in the different reports vary, but the amount of untreated and unusable animal hides that are discarded as solid waste is approximately 50–70 % and are discarded as trash along with hair, fat, meat, and sinew.

Although this chapter's main concern is Animal ethics, it is impossible not to mention the human cost paid. To put it in ethical terms, no flourishing can be found anywhere with practices such as these. Working conditions at the tanneries are extremely dangerous, especially in developing countries. It is commonplace that employees do not have adequate, if any, protection. This includes not only the lack of protective clothing, but working in surroundings where it is possible to slip and fall on improperly drained floors as well as encounter exposure to lime, tanning liquor, acids, bases, solvents, disinfectants, and other noxious chemicals. The handling of chromium is still the most dangerous part of modern tanning.

In dealing with current problems and future challenges, such as the increasing pressures regarding chemicals, water usage, and landfill issues, politicians and decision-makers are urged to ensure a change within this industry.

This industry must align itself with the modern technological improvements achieved elsewhere within textile, faux leather and plastic processes. Today, even in fully modernized and carefully managed facilities, it is still nearly impossible to recycle all of the hazardous waste generated by the tanning process. Consumer awareness and expectations increase year by year; to maintain its position, the leather products industry requires ongoing research at all levels, ethically as well as production-wise.

Considering that humans have been using leather for thousands of years, it must be asked: Why is the leather industry still operating as it did "*back then*." *It* is still using, almost exclusively, only two tanning methods—chrome and vegetable—and with chemists still in disagreement about the mechanisms involved for improvement, it is very clear that this industry must use the necessary resources for research, development, and invention of new or different methods for future opportunities.

Further information on this topic can also be found at The International Union of Leather Technologists and Chemist Societies at IULTS.[15]

[15] http://www.iultcs.org/index.htm.

10 Leather

Leather of an animal is similar to what cotton is to textile fibres, and it is the most common product that consumers own, whose main focus is on design.

Quality leather goods, even with constant use, can last more than 100 years. In fact, the Areni-1 shoe is a shoe made of leather that is 5500 years old; it was found in 2008 in excellent condition. In this context, leather may be called a highly sustainable product.[16]

Leather has been worn forever, but today it seems more popular than ever. Any fashionista, actually any consumer, has wardrobe pieces that include leather: leather belts or accessories such as leather handbags, gloves, shoes, boots, jackets, or pants. Leather is also found in the lifestyle industry in home furnishing and automobile upholstery. The current predictions are that the supply of leather raw material will continue to grow in line with the growth of population (UNIDO 2010).

The FAO report, *World Agriculture: Towards 2015/2030, An FAO Perspective*, highlights the fact that the proportion of animal products in the human diet has increased over the last decades at the expense of grain, corn, and other crops. This emphasizes, from an ethical perspective, that humans who wear leather consume meat without knowledge, awareness, thought, or consideration for the production or life of the animal.

The leather industry and the fur industry are differentiated by the importance of their raw materials. The leather industry claims that the raw materials are byproducts of the meat industry with the meat having higher value than the skin. Because large meat companies have no obligation to release figures, it is very hard to get any statistics, but hides and skins can in some cases actually be more profitable for farmers than the meat. The fur industry only uses raw materials that have a higher value than the meat. Hence the meat being classified as a byproduct might be the reason why the term "fur" is more acceptable, in terms of right or wrong, when it comes to production for the consumer.

Footwear production is one of the largest sectors in the leather industry. By 2007, it had reached 16 billion pairs of shoes, an increase of more then one third since 1995.

> The world leader in leather processing is currently China, producing an estimated 6599.3 million square feet of leather. (ICT 2013) It is reported that the rapid growth in the Chinese leather industry, in particular the footwear industry, is based on the increase of their shoe per capita growth from 1.5 in 2006 to 2.8 in 2011. (Mwinyihija 2014)

Listed are some of the major recent developments by UNIDO (2010), *Future Trends in the World Leather and Leather Products Industry and Trade*:

- *it has taken China only 20 years to move from a poorly organized industry, catering predominantly to its domestic market, to the most dominant player in world footwear by a large margin–a 63.7 % share of global production*;

[16] https://en.wikipedia.org/wiki/Areni-1_shoe.

- *in 2007, more than 84 % of the world's footwear by volume was manufactured in Asia*;
- *Asian production will continue to increase over the next 10 to 15 years, to the further detriment of the "traditional" footwear manufacturing countries*;
- *with their respective shares of the world's production, India (12.3 %), Viet Nam (4.1 %), Indonesia (3.5 %) and Thailand (1.6 %) are the other main contributors to Asia's success*;
- *the leading footwear manufacturing country outside Asia is Brazil, with an estimated 4.9 % of world output*;
- *54 % of global production of genuine leather is used in the footwear industry*;
- *footwear production in the developed world has, in most cases, been downsized to a level that makes this trend irreversible*;
- *it is estimated that 10 million people are employed in shoe manufacturing worldwide*;
- *2.82 billion pairs (more than 18 % of the global output) are classified as sports footwear*.

10.1 Species Used for Leather Production

Today, the most commonly used leather is made from cattle, calf, buffalo, and ox hides, but lamb, sheep, goat, and deer hides are also used in more expensive soft leather apparels. Sheep leather is quite famous for its softness and mostly used in leather garments.

Kangaroo hides are supposedly one of the strongest, lightweight leathers making it well suited for high-performances articles such as premium soccer boots and other heavy-duty sports-like wear. It is favoured by motorcyclists because compared with cowhide it is lighter in weight and has higher resistance to abrasion. The lightweight strength and fine grain of kangaroo hides also makes them desirable for fashion, casual footwear, and apparel (Money 2010).

Hides from exotic and endangered species have, at different times in history, been considered more beautiful and desirable than other hides. For this reason snakes, iguanas, lizards, elephants, and crocodiles have been hunted to near extinction. As of 1987, both snakes and the North American alligator have been removed from the endangered species list and are kept in breeding farms mainly due to their commercial value.[17]

Because of its characteristic "goose bump" look and because the large follicles from which the feathers grow make it one of the finest and most durable hides in the world, ostrich leather is currently used by many major fashion houses and for upholstery, footwear, automotive products, accessories, and clothing.

[17] https://en.wikipedia.org/wiki/Crocodile_farm.

Other species used for this industry are moose or elk, camels, horses, mules, donkeys, pigs, cats, dogs, and birds. Water-dwelling animals—such as frogs, eels, salmons, sharks, walruses, and dolphins—are also used to produce leather.

Complications and challenges regarding the use of any species can be identified and discussed everywhere in this field. However, in this respect it is mostly animal rights activists who point out the current problems. Some of the methods used by animal activists have been viewed as controversial and as a result have led to a loss of credibility on the activists' part, yet their actions have drawn attention to an important issue. With the media shedding light on unethical practices toward animals, the possibility opens up for dialogue and to push farmers, producers, and manufacturers to act in accordance with what consumers believe to be ethical.

One example of activism resulting in change is the accusations made by the animal rights nongovernmental organization PETA against the French luxury group Hermès International for their use of crocodile and alligator farms. The actress Jane Birkin asked Hermès to remove her name from the Birkin Croco bags until Hermès brought its practices in line with international norms. Hermès claimed it was unaware of any practices of cruelty taking place (which is often the case with the fashion and lifestyle business). "Hermès respects and shares her (Birkin's) emotion and are also shocked by the recently published images."[18]

PETA has now become a shareholder in Hermès by buying a single share worth approximately $360 on the Paris stock market. This is enough to give PETA access to shareholder meetings and thereby be able to apply a new pressure tactic that can influence Hermès to stop using exotic animal skins, notably those of crocodiles and alligators, in its iconic products such as the pricey Birkin bags.[19]

Another controversial subject is human hides. In past centuries, human skins have not only been taken as trophies of war but have been made into accessories. Anthropodermic bibliopegy was a practice found in the 18th or 19th centuries involving books, which were likely bound in human skin of executed criminals, although some examples may be centuries older. For an historical list of what human skin is known to have been used for, see Nene Adams.[20]

In 2009, the artist Andrew Krasnow worked with one of the biggest taboos of this century when he made an art piece, a pair of boots he called *Shitkickers,* using the skins of white men who had donated their bodies to medical science.

> "He uses skin to make the point that suffering is universal," Krasnow said. "It is tanned using the same process that you'd use for an animal skin."[21]

The designer and artist Sruli Recht, based in Reykjavik, Iceland, made a similar statement in 2012 by fashioning a ring out of human skin. This action started a

[18] http://america.aljazeera.com/articles/2015/7/29/french-luxury-retailer-to-investigate-crocodile-farms.html.

[19] http://fortune.com/2015/07/30/peta-hermes-crocodile-birkin.

[20] http://listverse.com/2012/12/11/top-10-bizarre-uses-for-human-skin/.

[21] The Apricity: http://www.theapricity.com/forum/showthread.php?4726-American-sculptors-lamps-made-of-human-(white)-skin&s=94ae12061ed914a993ef6e3d1cadf253.

discussion on the actual and ethical differences generated in the wearing of human skin compared with the wearing of animal skin. Furthering the impact and controversy, he video recorded himself having a part of his stomach cut out.[22]

The Museum of Icelandic Sorcery & Witchcraft in Hólmavík, Iceland, has exhibited an object worn in the 17th century called "necropants," a pair of pants made of human skin. The skin used to make these pants was donated by the individual on his death in order for the wearer of the pants, supposedly through witchcraft, to come into possession of money.[23]

The intention in discussing this controversial topic is that in these cases, people have chosen to donate their bodies after a "natural death" for the use of science and for those who can benefit from the deceased's organs, skin, and bones.

Resources such as those being discussed are highly coveted, but they are also loaded with complexity due to the susceptibility of economic and financial corruption they possess. Furthermore, due to the absence of any clear ethical guidelines on how to use human beings as a resource, people are violating perhaps both ethical rules and human rights.[24]

Nonhuman animals cannot be asked if they would care to donate their bodies as beneficial resources for other species. Although the use of nonhuman animals is a legalised business based on a luxury need, not a survival need, there seems to be the same lack of ethical involvement from the fashion and lifestyle industries as is found in the use of human beings as a resource.

Based on the theory of virtue ethics, animals cannot tell us which kind of life they prefer or how they would prefer their body parts to be used after death. It appears that the human species just assumes that to eat and wear body parts from nonhuman animals is an act that is perfectly ethical and correct. This assumption is of great significance to human flourishing.

> Yet a focus on human flourishing alone should not offer the primary virtue ethical resource for care about animals for two reasons. First, the result of such an interpretation is not clear. Dead animals also can be said to contribute greatly to our flourishing (because, among other things, they are tasty to eat, a good source of protein and building on their habitats may give us wonderful homes.)… Secondly, a focus on human flourishing alone obscures a primary benefit of a virtue ethical analysis of how we ought to treat animals, namely that such an analysis offers the theoretical tools for understanding the ethical significance of animals flourishing as such (Walker 2007, pp. 188)

10.2 Surfaces and Finishes on Leather

The leather industry has a full glossary of leather terms regarding the different surfaces and finishes it uses as well as the types of leather used for which kind of

[22] http://srulirecht.com http://srulirecht.com.

[23] http://www.galdrasyning.is.

[24] Skin, bones and tissue for sale: How the dead are being used for grisly trade in human body parts http://www.dailymail.co.uk/news/article-2175006/Skin-bones-tissue-sale-How-dead-used-grisly-trade-human-body-parts.html.

products. Leather Industry Worldwide provides an overview of the different types of leather used in the fashion and lifestyle industries. Further information can also be found at The International Union of Leather Technologists and Chemist Societies, which has a full dictionary and glossary of leather terms that can be found at IULTCS.[25] The following information can be found on LeatherNet.com

Full-Grain leather *or* **Top-Grain leather** is referring to the upper section of a hide that contains the epidermis or skin layer. It refers to hides that have not been sanded, buffed or snuffed (otherwise known as Corrected) in order to remove imperfections on the surface of the hide. Only the hair has been removed from the epidermis. The grain remains in its natural state which will allow the best fibre strength, resulting in greater durability. The natural grain also has natural breathability, resulting in greater comfort for clothing. The natural Full-Grain surface will wear better than other leather. Rather than wearing out, it will develop a natural "Patina" and grow more beautiful over time. The finest leather furniture and footwear are made from Full-Grain leather. For these reasons only the best raw hide are used in order to create Full-Grain or Top-Grain leather. Full grain leathers can mainly be bought as two finish types: aniline and semi-aniline

Corrected-Grain leather is any Top-Grain leather that has had its surfaces sanded, buffed or snuffed in order to remove any imperfection on the surface due to insect bites, healed scars or brands. Top-Grain leather is often wrongly referred to as Corrected-Grain. Although Corrected-Grain leather is made from Top-Grain as soon as the surface is corrected in any way the leather is no longer referred to as Top-Grain leather. The hides used to create corrected leather are hides of inferior quality that do not meet the high standards for use in creating aniline or semi-aniline leather. The imperfections are corrected and an artificial grain applied. Most Correct leather is used to make Pigmented leather as the solid pigment helps hide the corrections or imperfections. Corrected grain leathers can mainly be bought as two finish types: semi-aniline and pigmented.

Split leather is leather that is created from the fiberous part of the hide left once the Top-Grain of the raw hide has been separated from the hide. During the splitting operation the grain and drop split are separated. The drop split can be further split (thickness allowing) into a middle split and a flesh split. In very thick hides the middle split can be separated into multiple layers until the thickness prevents further splitting. Split leather then has an artificial layer applied to the surface of the split and is embossed with a leather grain. Splits are also used to create Suede. The strongest suedes are usually made from grain splits (that have the grain completely removed) or from the flesh split that has been shaved to the correct thickness. Suede is "fuzzy" on both sides. Suede is less durable than top-grain. Suede is cheaper because many pieces of

[25] http://www.iultcs.org/index.htm.

suede can be split from a single thickness of hide, whereas only one piece of top-grain can be made. However, manufacturers use a variety of techniques to make suede appear to be full-grain. For example, in one operation, glue is mixed with one side of the suede, which is then pressed through rollers; these flatten and even out one side of the material, giving it the smooth appearance of full-grain. Latigo is one of the trade names for this product. A reversed suede is a grained leather that has been designed into the leather article with the grain facing away from the visible surface. It is not a true form of suede.

10.3 Surface Treatment

"'Unfinished leather" refers to leather that has been tanned but has had no finish applied. To make leather usable, especially hides of lesser quality, it must undergo an additional treatment. Each treatment applied to the leather makes it less of a natural product. Decision-makers might therefore source or research other processes or materials that can replace these additional treatment processes. Another option would be to find materials using a more ethical approach, thus impacting the environment less.

Treatments added to the surface of the leather include dyeing and polishing of the grain for added smoothness or to create a base for adding artificial grain. The mechanical application of grain and surface treatment using chemicals, such as polyurethane (PU), makes the surface more durable and easier to clean.

- **Aniline leather**: Analine leather has been soaked with a chemical dye called "aniline."
- **Full aniline**: Full-aniline leather is aniline-dyed leather that *does not* have a top pigmented finish coating applied to its surface.
- **Semi-aniline**: Semi-aniline leather is aniline-dyed leather that *does* have a top pigmented finish coating applied to its surface.
- **Corrected grain**: Corrected-grain leather has been smoothed and given a textured grain for a more consistent look, and it is used in the manufacture of boots, clothes, and furniture.
- **Coated leather grain**: Coated–leather grain leather has been coated with various chemical materials, such as a polyurethane mix, and is used mainly for handbags and belts and for upholstering furniture.
- **Split leather**: Split leather is formed during tanning usually before being given a suede or pigment finish and buffed to smooth the surface; for added durability, it is coated with urethane.[26]

[26] http://www.compositionleather.com/glossary.

10.4 Slaughtering Methods

Animals used as leather and raised as livestock, depending on which country they come from, have very different living conditions, e.g., cattle farming versus salmon farming. Generally it can be said that these animals' lives are lived far from a natural and idealized way of life, where they are only offered the most necessary conditions to achieve the right size or weight before slaughter.

A product highlighted today as a sustainable material is, for example, fish skins/hides based on the fact that these are byproducts, but this message can be deceptive and confusing for consumers who in general are not acquainted with the welfare issues found in fish farming.

Intensively farmed fish are exposed to a number of factors that are not in any way taken into account by consumers. These issues are related to welfare issues such as the following stressors: farmed fish experience hunger, sea lice, vaccinations, loading, and transport. Farm salmon are exposed to artificial processes to increase their growth rate rapidly to a marketable size.

This intensive aquaculture creates fish welfare problems in the form of fin erosion, eye cataracts, skeletal deformities, soft-tissue anomalies, increased susceptibility to disease, sea lice infestation, high mortality rates, and, in some countries, often inhumane slaughter methods (WSPA 2007).[27]

With CO_2-stunning systems used for salmon, the water in the stunning tank is saturated with CO_2 gas to pH of approximately 5.0. The salmon are transferred from a holding tank to the stunning tank in bulk using a pivoted riddle. For the first minute in the CO_2-impregnated water, the fish are hyperactive and show escape attempts. The impression is that it is highly stressful for the fish (Robb and Kestin 2002).

> I honestly believe that the harsh reality of salmon farming is that it is inherently unsustainable, damaging to wild fish populations and a threat to the health and wealth of our oceans. Chairman Bruce Sandison Salmon Farm Protest Group[28]

Products made from these nonhuman animals are therefore by no means to be regarded as sustainable because the farming and slaughtering methods do not allow the animals or nature to flourish.

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[27]WSPA, 2007, Stevenson Peter, *Closed Waters: The Welfare of farmed Atlantic Salmon, Rainbow Trout, Atlantic Cod &Atlantic Halibut,* https://www.ciwf.org.uk/media/3818650/closed-waters-welfare-of-farmed-atlantic-salmon.pdf.

[28]Chairman Bruce Sandison Salmon Farm Protest Group (footnote) http://www.salmonfarmmonitor.org/problems.shtml.

Most often animals live one place but are slaughtered elsewhere. Therefore, the transportation of animals can last for hours, sometimes days, before they arrive at the slaughterhouses. These transportation methods have been heavily debated because they do not in any way seem to protect the welfare of the animals, which suffer from thirst, hunger or are crushed and trampled upon by their fellow travelers.

An example can be found India, a country where cattle are considered sacred but also paradoxically are becoming a lucrative export. In India, the cow is a cultural sanctity. A cow is not considered an animal, but a mother, the embodiment of divine virtues such as, compassion, love, tolerance, benevolence, and nonviolence.

Nevertheless, according to APEDA, the Indian government's gatekeeper for exports, India has 115 million buffaloes, more than half the world's population, and produces approximately 1.53 million tons of beef every year.[29] This means India will displace the United States as the world's third largest beef exporter behind Brazil and Australia. Cheap leather products are often acquired from developing countries such as India and have become easily accessible to the fashion and lifestyle industries.

The Council for Leather Exports reports an increased export growth due to aggressive export promotion and market-development activities. By April/March 2015, the export of leather garments was as follows: 9 %, finished leather 21 %, leather goods 23 %, footwear 45 % and saddlery and harness 2 %.[30]

Although laws exist against cow slaughter in some Indian states, they have not been implemented everywhere. However, due to this paradoxical conflict with belief and religion within the cattle industry, cows are being transported from the place where they were farmed to the Indian states where cow slaughter is permitted.

During these transports:

- Cows and buffaloes are forced to travel hundreds of miles without food or water and with little rest.
- Animals are beaten mercilessly and driven forward in the searing Indian heat.
- Their tails are broken deliberately, and tobacco and chili peppers are rubbed into their eyes in order to drive them on or force them to stand up when they collapse.
- Their hooves are often bleeding and worn down to stumps.

[29] http://www.globalmeatnews.com/Industry-Markets/India-s-boneless-buffalo-meat-exports-flourish-BJP-led-government.

[30] http://www.leatherindia.org.

- When transported by truck, cattle suffer unimaginably because of terrible overcrowding. Crammed on top of each other in the trucks, the cows trample one another and are unable to avoid suffocating each other and gouging and blinding each other with their horns.
- When they are unloaded, the cows that can still stand are pulled or forced to jump from the high truck beds often breaking legs and pelvises.
- Those who have collapsed are dragged from the trucks and left lying where other cows are unloaded on top of them. Once inside the slaughterhouse, their legs hacked off or they are skinned while still alive.[31]

Countries differ in the methods of slaughtering, but laws have been determined to ensure minimal suffering. Of course, as seen with the laws concerning human rights, these laws concerning animal suffering are rarely respected due to the lack of insight, awareness, education, or financial oversight stemming from deadline pressures and influences from economic market mechanisms.

In 1958, the first federal Humane Methods of Slaughter Act (P.L. 85–765) was signed into law by President Dwight D. Eisenhower on August 27.
This American Act requires instant stunning by mechanical or electrical means or anesthetization prior to the killing of calves, cattle, horses, mules, sheep, swine, and other livestock except in the case of kosher slaughter.

The first stage of the slaughtering process is usually called stunning. Stunning renders the animal unconscious, and thus not susceptible to pain, but rarely dead. Considered a humane slaughtering method, stunning proves problematic due to the fact that large numbers of animals experience great anxiety, stress, and often pain before stunning and/or death.

In the second stage, the animal is killed, and the methods of killing differ among species and age of the animals. Regardless of methods and precautions made to improve this situation, it will be impossible to improve because of the quantities of animals that are farmed, transported, and killed in giant mass industries. Research in animal welfare addresses the need to change practices in slaughter methods by providing more training and new regulations. There are also differences between conventional and religious practices in methods of slaughter, and these have also been criticized because of inhumane animal welfare conditions.

[31] http://www.occupyforanimals.net/india--cow-slaughter-and-the-illegal-cattle-mafia.html.

10.5 Stunning

Electrical (stunning or slaughtering with electric current known as "electronarcosis")
This method is used for swine, sheep, calves, cattle, and goats. The current is applied either across the brain or the heart to render the animal unconscious before being killed.

Gaseous (carbon dioxide)
This method can be used for sheep, calves, and swine. The animal is asphyxiated by the use of CO_2 gas before being killed.

Gaseous (Inert gas hypoxia)
Various concentrations of argon and nitrogen, often in conjunction with CO_2, have been used to induce unconsciousness.

Mechanical (captive bolt pistol)
This method can be used for sheep, swine, goats, calves, cattle, horses, mules, and other equines. A captive bolt pistol is applied to the head of the animal to quickly render them unconscious before being killed. There are three types of captive bolt pistols: penetrating, nonpenetrating, and free. The use of penetrating captive bolts has largely been discontinued in commercial situations to minimize the risk of transmission of disease when parts of the brain enter the bloodstream.

Mechanical (gunshot/free bullet)
This method can be used for cattle, calves, sheep, swine, goats, horses, mules, and other equines. A conventional firearm is used to fire a bullet into the brain of the animal to render the animal quickly unconscious (and presumably dead). A second method may be used (e.g., drug administration) to ensure the animal is dead.

Exsanguination
The animal either has its throat cut or has a chest stick inserted by cutting close to the heart. In both of these methods, main veins and/or arteries are cut and allowed to bleed.[32]

11 Fur

"Fur" refers to animal pelts that have been processed into leather with the hair still attached. The animals most commonly used for fur clothing and fur accessories include foxes, rabbits, minks, beavers, otters, ermines, sables, seals, coyotes, chinchillas, raccoons, possums, cats, and dogs.

[32] https://en.wikipedia.org/wiki/Animal_slaughter.

When sourcing information on the subject of fur, controversy is not far behind. Either information or images of horror—showing the conditions behind the scenes of the fur industry or the images and information on luxury, glamour, beauty, quality, models, royalty, and celebrities—are presented. It is the latter three of the aforementioned examples who through tradition and culture over the past centuries have convinced human beings that wearing fur signals status and power, i.e., the "good life."[33]

The opposition between the two camps trying to "battle it out" regarding the ethics of fur can leave one who is perhaps already confused even more confused. Web sites from the fur industry or from animal rights organisations promote their own agendas, whether it is clean and proper care for those animals whose fur is being used or portrayal of a brutal and bloody ending.[34] Either way, both can be convincing as well as confusing, which makes the ethical theories and approaches of great and timeless thinkers even more relevant to rely on when making one's own decisions in this matter.

Serious attacks and criminalization from both parties is prevalent when trying to convey their messages. NGOs, in the name of animal welfare and ethics, carry out missions and end up being arrested and charged with terrorizing the fur industry. The poignant following message from the Fur Commission USA does not make any attempt to open a dialogue to improve the situation and can be interpreted as if this is only a financial matter and not a matter of ethics or suffering[35]:

> Their goal is to destroy the livelihoods and reputations of hundreds of family farmers, along with the supporting businesses; but their claims have no basis in fact. In reality, their sensational and unsubstantiated claims are insulting to American mink farmers and misleading to the public.

According to Mick Madsen, Head of Communications at Copenhagen Fur, the ideology from anti-fur NGOs leaves no opportunity for a meaningful dialogue between themselves and animal farmers. The comments from the Fur Commission USA must be read in this light. He claims it is unjust to suggest that fur farmers are not interested in whether the animals suffers or not, in which case the question arises: Why the animals are not being offered better living conditions in accordance with their natural needs?

The environmental aspects within this sector have been described previously in this chapter, although fur farming and production may seem to differ in some areas compared with livestock production. This is especially true when it concerns animals being bred and housed in cages.

European fur producers conduct practices that allow them to use the term "sustainability." Two thirds of the by-products of European fur production are being processed at bio-plants, meaning that 100 % of the animal is used, mainly for fossil-fuel replacement and other energy purposes. The animal fat is being transformed

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[33] http://furglamor.com and http://www.sveketmotminkarna.se/horror-revealed-swedish-fur-farms.

[34] http://www.sagafurs.com/en/fashion_home/fashion and http://www.kopenhagenfur.com.

[35] http://furcommission.com/fur-farming-myth-vs-fact/.

into second-generation biofuel, which contrary to first-generation biofuel has no negative impact on biodiversity and land use.[36]

In this case, the term "sustainability" should perhaps be redefined. This has already been done in various ways, but maybe soon this term should include production and lifestyle ethics and not only take into consideration the means of our natural systems (environment) and ensure that our lifestyle does not harm others (i.e., society and culture).[37]

In the name of sustainability, the fur business argues that their products, compared with products made from an-made fibre, are somehow better in both "cradle to gage" and "cradle to grave" studies.

One may ask if this is like comparing toys made from wood with toys made from plastic. As in this case, the ethical aspects of suffering or flourishing are not included in any way in the definition of "sustainability."

> According to R.S. Blackburn (Biodegradable and Sustainable Fibers, pg xv): 'The main problems with synthetic polymers are that they are non-degradable and non-renewable… Oil and petroleum are non-renewable (non-sustainable) resources and at the current rate of consumption, these fossil fuels are only expected to last for another 50-60 years… An even more important problem with the use of fossil energy is the huge translocation of carbon from the ground into the atmosphere accompanied by emissions of sulphur and nitrogen oxides as well as all kinds of hydrocarbons, and heavy metals. Fossil fuels are also the dominant global source of anthropogenic greenhouse gases (GHG)'[38]

A study made in 2013 for CE Delft, an independent research and consultancy organisation specialising in developing structural and innovative solutions to environmental problems, clearly shows that the environmental impact of natural mink fur coats and trims is greater than the impact of faux fur coats and trims, which then contradicts the claims from the fur industry (Bijleveld 2013).

In theory, the argument regarding sustainability is that it is possible to compost a fur coat when done with it. But due to the tanning processing, this could be questionable, and referring to the example mentioned previously, i.e., the 5500-year-old leather shoe Areni-1 found in 2008, questions concerning composting persist.

This table shows how long some common items will take to break down if left in the environment, which can then be part of the argument regarding degradability. To clarify, a natural product such as glass can take 1 million years to decompose and a nylon t-shirt can take 40 years.[39]

Vegetables	5 days–1 month
Paper	2–5 months
Cotton T-shirt	6 months
Orange peels	6 months

[36]European Fur Information Center http://www.fureurope.eu.

[37]Land Learn, What is sustainability http://www.landlearnnsw.org.au/sustainability/what-is-sustainability.

[38]Fur Council of Canada http://www.furisgreen.com/earth-friendly.aspx.

[39]http://sciencelearn.org.nz/Contexts/Enviro-imprints/Looking-Closer/Measuring-biodegradability.

Tree leaves	1 year
Wool socks	1–5 years
Plastic-coated paper milk cartons	5 years
Leather shoes	25–40 years
Nylon fabric	30–40 years
Tin cans	50–100 years
Aluminum cans	80–100 years
Glass bottles	1 million years
Styrofoam cup	500 years to forever
Plastic bags	500 years to forever

Renowned ethical fashion expert Joshua Katcher argues: "Factory farming is factory farming. When you place a concentrated number of wild animals in an area that hasn't evolved to deal with that concentration of waste environmental disaster is inevitable."[40] This statement does not address all farms. In the Nordic countries they claim to have full control of their waste management through the entire value chain. These proclamations can be interpreted in a broader context, which could have the potential to change the fur industry landscape. But the increasing Asian market, through its lack of regulatory environmental, and ethical transparency oversights, continues the use of cruel cages, terrible transport methods, and painful slaughter methods, and thus the landscape is still unchanged.

The question for debate is how the lives and deaths of these animals can be interpreted when stressing the word "sustainability." According to Ehrenfeld (2013), this could mean that the production methods are sustainable and that fur products do last for a longer time, but does it make the involved animals flourish? Again, the argument is that understanding the ethical significance of nonhuman animals flourishing cannot be differentiated from the flourishing of human beings.

The challenges may be of even greater concern. Varied aspects in a much higher context seem to create a huge gap between humans beings and nonhuman beings. This subject of fur now more than ever fuels the debate about ethics, social interactions, traditions, and culture.

Somehow, in the fashion and lifestyle business, fur is preferable, and yet it is a loathsome subject. This might be due to the fact that furry animals look cuter than other livestock animals.

Mark J. Estren, Phd. in psychology from the University at Buffalo, claims that cute animals get more public attention and scientific study due to having physical characteristics that would be considered neotenous. Estren says that humans should be mindful of favouring of cute animals such that animals not considered cute are also valued (Estren 2012).

[40]LinkedIn Profile of Joshua Katcher https://www.linkedin.com/profile/view?id=4796397&authType=NAME_SEARCH&authToken=sg-h&locale=en_US&trk=tyah&trkInfo=clickedVertical%3Amynetwork%2CclickedEntityId%3A4796397%2CauthType%3ANAME_SEARCH%2Cidx%3A1-1-1%2CtarId%3A1439274443075%2Ctas%3Ajoshua%20katcher.

Due to the intensive debates that have been based on this particular subject, the fur sector in developed countries has had to spend time, resources, and efforts to analyze and document their businesses and professions to be able to justify and clarify the reason and need for fur to the majority of the public. To sustain and survive in this part of the business, developed countries have cleverly predicted the future trends by their ability and resources to involve scientists and collaborate with designers, economists and politicians, which allows them to document their process in a rhetorical and politically correct way seen in the light of today's sustainability agenda.

Nevertheless, legislation and transparency is still missing for the most part in the fur industry.

There is no legislation regarding labeling at the moment. Consumers have the right to know what kind of animal they are buying. They cannot tell whether the fur on their garment is faux or actual animal fur. Fur should require labeling of all types of animals including, at the very least, the country of origin and how animals were bred so that people know what they are buying.[41]

The law, known as The Truth in Fur Labeling Act, passed the House of Representatives in July 2010 and was signed by President Obama later that same year. The act "will bring much-needed accuracy and disclosure to fur products," as long as those committed to animal rights in terms of Corporate Social Responsibility ensure that it is upheld.[42]

H.R. 2480 (111th): Truth in Fur Labeling Act of 2010
Introduced:
May 19, 2009
111th Congress, 2009–2010
Status:
Enacted—Signed by the President on Dec 18, 2010
This bill was enacted after being signed by the President on December 18, 2010.[43]

> It may be objected that comparisons of the sufferings of different species are impossible to make, and that for this reason when the interests of animals and humans clash the principle of equality gives no guidance. It is probably true that comparisons of suffering between members of different species cannot be made precisely. Nor, for that matter, can comparisons of suffering between different be made precisely. Precision is not essential. As we shall see shortly, even if we were to prevent the infliction of suffering on animals only when the interests of humans will not be affected to anything like the extent that animals are affected, we would be forced to make radical changes in our treatment of animals that would involve our diet, the farming methods we use, experimental procedures in many fields of science, our approach to wildlife and to hunting, trapping and the wearing of furs, and areas of entertainment like circuses, rodeos, and zoos. As a result, a vast amount of suffering would be avoided. (Singer 1979)

[41]The humane Society of the United States http://www.humanesociety.org/news/press_releases/2010/12/senate_passes_fur_labeling_bill_120810.html.

[42]Quote: https://fashionwithaheart.wordpress.com/2012/05/06/friend-foe-or-frock-animal-rights-in-fashion/.

[43]https://www.govtrack.us/congress/bills/111/hr2480.

11.1 Wild Fur and Farmed Fur

The following section will discuss the division between wild fur, also known as free-range fur, and farmed fur and will compare their use in developed versus underdeveloped countries.

Slaughter and breeding methods from an ethical point of view differ in different countries. These differences stem from varied cultural and traditional methods practiced in each individual country and relate to how animals are bred and slaughtered. This set of differences involves ethical choices faced by decision makers when working with nonhuman animal products.

> I have concentrated on the use of animals as food and in research, since these are examples of large-scale, systematic speciesism. They are not, of course, the only areas in which the principle of equal consideration of interests, extended beyond the human species, has practical implications. There are many other areas, which raise similar issues, including the fur trade, hunting in all its different forms, circuses, rodeos, zoos and the pet business. Since the philosophical questions raised by these issues are not very different from those raised by the use of animals as food and in research, I shall leave it to the reader to apply the appropriate ethical principles to them. (Singer 1979)

11.2 Farmed Fur

Fur farming is the practice of breeding or raising certain types of animals for their fur. Fifty-eight percent of all farmed fur comes from Europe. China, Russia, and North America also engage in intensive fur farming.

According to WeAreFur.com, a Web site from the International Fur Federation and the worldwide fur trade, fur farming includes everything from the most humane slaughter methods for each type of animal to specifications that ensure the general well-being of the animals.

> Fur farming is well regulated throughout the world and operates within the highest standards of care. Although laws differ slightly from country to country, there are international regulations that govern all fur farming, prohibiting animal cruelty and determining cage size and enrichment.[44]

WeAreFur.com defines the word "enrichment" for animals being used in fur farming and the regulations surrounding them as that which can adhere to the principles of virtue ethics and right ethics including a *flourishing* environment for wildlife to live in. It would seem that fur-farming practices in some countries do not conform with this definition.

> According to Fur Commission USA, mink raised on fur 'ranches' are treated 'humanely,' meaning with compassion, kindness, and mercy. In fact, they are 'the best cared-for livestock' in the world, a statement that, tragically, just might be true. Compared with veal calves, hogs, and chickens raised in confinement, those lucky mink who spend their waking hours pacing back and forth, jumping up the sides of cages, and rotating their heads, are leading a country club existence. May God forgive us. (Regan Empty Cages, p. 110).

[44] http://www.wearefur.com/welfare/farming-regulations.

11.3 Slaughtering Methods

Carbon monoxide is the most used technique for killing mink, but electrocution is also permitted. Scientific evidence show that the use of exhaust gases to induce unconsciousness in mink provokes excitation and convulsions. Electrocution requires considerable restraint and the use of electrodes inserted into orifices. New York State banned the electrocution of foxes; this method was also banned in the UK before fox farming was prohibited there altogether.[45]

The following facts on fur farmed animals are from Furinformationcenter.eu[46] and will help create an image of the number of animals used alone in Europe per year.

Production figures by country:

Belgium: 200,000 mink, 100 chinchilla
Bosnia: 6000 chinchilla
Czech Republic: 2200 chinchilla
Denmark: 15,000,000 mink, 7000 fox, 24,000 chinchilla
Estonia: 4600 chinchilla
Finland: 1,700,000 mink, 1,800,000 fox, 130,000 Finn raccoon
France: 150,000 mink
Germany: 350,000 mink
Greece: 550,000 mink
Holland: 4750.000 mink
Hungary: 14,000 chinchilla
Iceland: 160,000 mink
Ireland: 200,000 mink
Italy: 160,000 mink
Latvia: 350,000 mink, 9100 fox
Lithuania: 550,000 mink, 1200 fox
Norway: 595,000 mink, 150,000 fox
Romania: 17,000 chinchilla
Serbia: 10,000 chinchilla
Spain: 600,000 mink
Sweden: 1,100,000 mink
Poland: 6,000,000 mink

To estimate how many animals are used for a single fur coat depends on the style and size of the garment, but this is a guide to the number of animals used.

Mink 30–70
Rabbit 30–40
Fox 10–20

[45] http://www.hsi.org/world/europe/work/fur/facts/fur_farming_eu.html.

[46] http://www.furinformationcenter.eu/facts/facts-fur-farmed-animals.aspx.

Chinchilla 30–200
Seal 6–10
Lynx 8–12
Badger 10–12
Otter 10–16
Dog 15–20
Bobcat 16–22
Coypu (nutria) 26–34
Raccoon 30–40
Marten 50–60
Sable 60–70
Squirrel 200–400

It takes 25 PET one-litre plastic bottles to make a sweater.[47] Comparing, as was previously done with the fur industry and faux fur, the amount of oil it takes to make a faux fur can be found in the report made for CE Delft, *Natural mink fur and faux fur products, an environmental comparison* (Bijleveld 2013). However, data found about the recycling of PET bottles made of polyethylene terephthalate (which can be recycled into fashion garments and thereby reduce the amount of waste going into landfills) should be taken into consideration.

Seen from a position of utilitarianism and sum logic, the amount of suffering endured by millions of animals might not counterbalance the consumer's desires. The harm done to the environment by farmed fur might not counterbalance the environmental impacts from wearing faux fur.

11.4 Wild Fur

Wild fur or free-range fur completes the circle of animals being used in the fashion and lifestyle industries. These animals include everything classified as endangered species (a full list can be found on the WWF site[48]) to animals being hunted as wildlife in order to address such issues as overpopulation, disease, and starvation. Jaguars, ocelots, cheetahs, margays, tigers, leopard, snow tiger, red wolves, vicuna, bears, raccoons, foxes, beavers, seals and cougars are among the animals the are hunted for their fur.

This issue of wild fur or free-range fur being used today can also fuel the debate surrounding fur fashion. Hunting has been practiced since "back then" and is considered as a natural and far better method than any other when it comes to killing and using animals because it is suggested that the animals have lived natural and free lives.

[47] http://www.plastics.ca/_files/file.php?fileid=itempSTiDvmuEn&filename=file_Fact_Sheet_on_PET_Feb_09.pdf.

[48] https://www.worldwildlife.org/species/directory?direction=desc&sort=extinction_status.

According to the right-ethics theory, a free-range animal has lived a free, optimal life unaffected by starvation and disease. The fact remains that people today have gradually taken over most animal habitats. So the question must be asked: Is the monitoring of animals needed to protect human habitat, crops, and lifestyles or is it done because the animals are too many compared to the amount of space allocated to them by humans?

> The ethics of hunting are complicated. Even ardent supporters of hunting disagree among themselves, for example, over the appropriateness of hunting methods that maximize the possibility of a clean kill (to minimize suffering) and the appropriateness of methods that emphasize fair chase. A more basic ethical concern is under what conditions is hunting appropriate? That question rests, in turn, on an even more basic question; what counts as an adequate reason to kill a sentient creature? Some thoughtful people believe that hunting is generally wrong for the same reasons eating meat is wrong. Other thoughtful people believe that hunting is morally acceptable, even virtuous, for anyone who can reasonably conclude that eating meat is morally acceptable. These perspectives offer a sense of the issues concerning the ethics of hunting such species as deer and elk when the hunter, her family, and her friends will eat the animal being hunted.
>
> (Vucetich and Nelson 2014)

11.5 Trapping and Hunting

Figures on how many animals are being killed every year varies from approximately 10 million to more than 100 million wild animals that are trapped and killed.

11.6 Leg Hold Traps

Although the steel-jaw trap has been deemed “inhumane” by 90 countries around the world and the American Veterinary Medical Association and has been banned because of the torture it inflicts on the animal. Still, it is the most preferred form of trapping throughout Canada, the USA, and Russia.

The steel-jaw trap clamps down on the animal’s leg, leaving the animal in pain for hours or days without food, water, or protection. When the animal is collected, it will be killed in a way that ensures that the animal pelt is not damaged. This is debatable because in the eyes of animal rights petitioners it is considered painful and inhumane. Hunters, for the most part, have the opposite opinion.

11.7 Drowning Sets

Drowning sets are designed by trappers to drown and kill particular aquatic animals such as beavers and muskrats. The traps are designed to drown the ensnared animals from the weight of the leg-hold trap.

11.8 Conibear Traps

Frank Conibear is a long-time trapper and inventor of the humane trap for fur-bearing animals. His first model was handmade in 1929, but is was not until 1958 that this vertical trap became accepted. It was designed as an "instant-kill" device that breaks the neck of its intended victim. The problem is that the trap will only function on the animal it is designed for and thus causes slow painful suffering to those animals of inappropriate size who enter the trap.

11.9 Risks

Some animals do not die instantly in a hunting situation, and many animals suffer because they are seriously injured and they must often wait until the hunter finds them or they finally die of their own accord. Bow hunting can exacerbate the problem because there is no way to ensure an animal will die instantly with a bow.[49]

The risks involved with trapping include that an animal will try to free itself by amputating a limb to survive or will knock out its teeth as it bites on the steel trap. Some hunting groups recommend shooting animals in the face or in the gut, which can be a painful way to die if the strike is not precise. This action relies on coincidence or luck that the animal does not move in those nanoseconds it takes the bullet or the bow to reach the animal.

> Many sources indicate between one and ten "non-target" animals are caught in traps for every single target animal. Non-target animals include golden eagles, antelope, domestic livestock, birds, rabbits, deer, porcupines, domestic dogs and cats, and even humans. These animals are considered "trash" by the merciless fur trappers and discarded.[50]

11.10 Wildlife Crop Control

Every year hunters and wildlife managers make an estimation of the percentage of wild animals that can be "harvested." Carnivores, such as wolves, cougars, and bears, were the natural ecosystem managers before the influence of man. Today, hunters and wildlife managers assess that it is necessary to have control over ecosystems and the animals deemed harvestable. One example of nature balancing itself is the reintroduction of wolves to Yellowstone National Park (YNP). This action caused a ripple effect throughout the ecosystem, increasing biodiversity, including a higher occurrence of birds, more beavers, and plant species and natural habitats.[51]

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[49] http://animalrightscoalition.com/doc/bowhunting_report.pdf.

[50] http://www.lcanimal.org/index.php/campaigns/fur/fur-trade-facts.

[51] http://www.yellowstonenationalpark.com/wolves.htm.

11.11 Natives and Aboriginals

Seal fur is the one subject within wild range fur being debated the most as mink is within the category of farmed fur. This issue involves vulnerable ethnic minorities, culture, traditions, and craft and is one example of a threatened ecosystem in need of management.

According to WWF, the EU does not do much to inform the general public about the Inuit situation. This is due in part due to an ongoing dispute between Canada and the EU at the world trade Organisation (WTO) regarding the EU import ban on seal products. The Directorate-General for the Environment at the EU Commission must be extremely careful in communicating about the trade in seal products (WWF 2013).

It is possible to find abundant information on this debate dealing with traditions, history, environmental facts, ethical facts, laws, and regulations. To put it simply, the discussions entail discrepancies between emotions and understanding for either the welfare of nature and animals or the welfare of humans.

Inuits have been living in the Arctic for more than 5000 years. Their main sources of food have been the animals of the Arctic. The Inuit cannot depend on plants for food because the climate of the c is not suited for agriculture and lacks forageable plant matter for much of the year. This is why the traditional Inuit diet still is based mainly on the meat of wild animals, which is lower in carbohydrates and higher in fat and animal protein compared with the global average. Depending on the season, the Inuit hunt for different types of seal such as harp seal, bearded seal, and harbour seal.

It is in this respect, questions arise about what should be done with the leftover hides and skins. Are they resources as is suggested from the hide by-products found in the food industry? Is it possible these skins could be used in other products without immediately exploiting commercial overconsumption and unethical mass killings?

Those who make money on seal fur are retailers and designers, whereas hunters live a financially precarious existence. Hunters need help to build a solid future for themselves and their families, and this is not enhanced by overexploitation from companies that do not act responsibly.

According to quota numbers in the Daily Mail, the regulation in seal hunting population in 2015 was as follows: 400,000 harp seals, 60,000 grey seals, and 8,200 hooded seals for a total of more than 468,000 animals[52] According to Kopenhagen Fur, these data is incorrect because they reflect only the quota, not the actual culling.

Nowadays the Inuit do not hunt with kayaks and dog teams but with motor boats, skidoos, and four wheelers, which brings up the issue and discussion about

[52]http://www.dailymail.co.uk/news/article-3014363/Canada-s-killing-fields-Government-gives-green-light-HALF-MILLION-seals-killed-fur-annual-cull-vast-majority-pups.html#ixzz3imZ3tCWP.

eco-management and industrialization. The majority of seal hunting is now commercial, whether it is taking place in Norway, Greenland, or Canada.

Today the Inuit live in heated buildings and have high expenses for heating and imported goods. Approximately 60–70 % of the northern population of Canada are unemployed and unable to sustain themselves by hunting alone live and are dependent on welfare systems and aid.[53]

> At the time, **Greenpeace** argued that their protest was not directed against the Inuit, "but when they supplied to an international market they could no longer call this 'traditional seal hunting'. Anybody who enters international trade and uses its mechanics must necessarily also bear the risk of the ever-changing market situation, which may be caused by the currents of fashion or an increased environmental consciousness in the buyer countries. In truth, the Inuit are the victims of the irresponsible actions of the seal fur industry. (Greenpeace 1996)

It must be noted that Greenpeace has published a statement in full support of the Inuit hunt in 2015. Joanna Kerr, executive director of Greenpeace Canada, said in a recent statement that the Inuit "*take only what they need, and no more. They honour the animals, the land and the ocean*."[54]

> One might as well argue that because Canada used to hang convicted murderers by the neck until they were dead the tradition should not be allowed to disappear. Sealing in Canada is not a tradition; it is just an unenlightened, outdated practice.
> Nobel-prize laureate John Maxwell "J.M." Cape Town, South Africa.[55]

> The Inuit have been hard-hit when the European Union banned the import of seal hides in 1983. Environmentalist organizations like Greenpeace, the World Wildlife Fund and other associations for the protection of animals had been protesting, for perfectly valid reasons, against the slaughter of baby seals by Canadian and Norwegian hunters, and demanded protective action. The seal hide market crashed. The Inuit, who in order to preserve the stock had never hunted baby seals, could suddenly no longer earn their living by hunting the grown-up animals. They also had to refrain from whaling. An important part of their cultural integrity and their social system vanished without any replacement.
>
> A similar threat looms in the import ban on hides of wild animals, as proposed by the European Union. This would concern the Inuit and the other native population of Canada. In 1995, about 35,000 of them had a license to hunt with traps. Usually they have no other income, especially those living in the remote northern settlements. Inuit organizations protested, not least, against the way in which this ban was to be imposed: in bad, colonial manner, without talking to those concerned.
>
> (Rathgeber 2005)

[53] http://www.bambusspiele.de/spiele/nanuuk/e_nunavut.htm.

[54] http://www.theglobeandmail.com/news/national/greenpeace-inuit-come-together-to-fight-arctic-seismic-testing-for-oil-and-gas/article19718153/.

[55] http://www.humanesociety.org/news/interview/2008/03/JM_Coetzee_interview_031408.html.

Nobel-prize laureate John Maxwell about slaughter:
In the first place, baby seals are highly photogenic. In the second place, they are entirely helpless and haven't the faintest idea of what is about to happen to them. In the third place, even the hardest-hearted among us has private reservations about killing creatures that have barely tasted the sweetness of life. In the fourth place, the people who do the killing are very unappealing, very unphotogenic.

The Humane Society of the United States claims that seals are killed primarily for their fur, which is used to produce fashion garments and other items. There is only a small market for seal oil (both for industrial purposes and for human consumption), and seal penises have been sold in Asian markets as an aphrodisiac. There is almost no market for the meat, so seal carcasses are normally left to rot on the ice. Senior Canadian government representatives define the seal slaughter as "primarily a fur hunt."[56] This must mean that authorization is given to kill far more animals than can be consumed either for economic reasons or for ecosystem management, which in both cases are man-made needs. The campaigns against fur have had the effect that tens of thousands of seal furs are piling up in warehouses in Greenland and the hunters have been throwing them away because they have not been able to sell them. Comparing this to the leather industry, it makes no sense. It is neither sustainable nor understandable given that the animals would at least have had a better life instead of a more painful death.

> Reasons for being vegetarian or vegan are varied. Moreover, a person might conclude that eating meat is appropriate in some circumstances but not others. For example, a person might think eating meat is wrong in general but acceptable for Native Alaskan Inuits, whose welfare would seem to depend on eating animal flesh. While that kind of complexity is important, it does not obviate the central point, which is a demand to confront the question, What counts as an adequate reason to kill a sentient creature? The hunting community has long recognized the value of this question for understanding the conditions under which various kinds of hunting is appropriate.
>
> (Vucetich and Nelson 2014)[57]

The Humane Society of the United States also claims that independent, international teams of veterinarians observed a hunt and examined the corpses of skinned seals. They found evidence that up to 40 % of the dead seals had skull injuries that were not sufficient to have caused death.

> On the Canadian seal hunt…
> Despite official assurances to the contrary, many seals are skinned while still alive. It would be a relief to learn that this happens rarely, although of course it should not happen at all. The bad news is, it happens a lot. An independent scientific study, conducted in 2001 by a team of veterinarians, concluded that 42 percent of the seals were skinned alive. That works out to approximately 130,000. (Tom Regan Empty Cages, p. 115)

[56] http://www.humanesociety.org/issues/seal_hunt/2013_hunt/about.html.

[57] Vucetich and Nelson (2014).

This unresolved debate has had a high price for both animals and humans due to industrial development and economics. The debate does not seem to be settling. Resolution requires a change in human consciousness, a 360° view, and innovative thought. Research and a new mind-set based on anything but pure survival and economic will not be able to solve these overwhelming problems.

Decision-makers in this field must take responsibility for the choices made and be thorough in approaching these problems in order to become enlightened as to what exactly is being supported and why.

Mick Madsen, head of communications at Kopenhagen Fur, makes a final statement in this chapter underscoring the lack of understanding and dialogue going on within this field especially regarding welfare of human beings versus animals. The reader and decision-maker is therefore invited once more to decide what will be the right thing to do and choose in making an ethical approach in production and consumption for a future on earth and everybody living on it:

> As already stated the references to animal rights advocate Tom Regan inevitably leads to a polarised debate over human use of animals as his ideology leaves no room for compromise. The same thing can be said about Humane Society International. Though communicating with utilitarian arguments, it is not difficult to figure out that the ultimate end-goal of HIS (and mother organisation HSUS) is a vegan society. The references to committed animal liberation ideologues appear to bias the report in favour of idea not shared by society at large. Mick Madsen, Kopenhagen Fur, 2015.

United federation of teachers offers a very interesting program of teaching for students who would like to work with endangered animals and the fur trade. This can be found at their Web site.[58]

12 Wool

In the beginning was wool, but not the kind of wool known and used today. "Back then," when man was hunting sheep, it was not for the wool but for the meat. The hair on sheep was more like deer hair is today: thick and short fibers and not as long and curly as is found today.

The story of wool begins approximately 10,000 years ago in Asia Minor during the Stone Age. At a certain time, homo sapiens began to make clothes instead of only wearing furs and skins. One of the hides used was from sheep, and the wool was not very useful because it was too thick and brittle. However, noticing that wool from the stomach and underside of the sheep was softer and more usable, a development took place. Humans started to cross-breed sheep that had the best hair. It took thousands of years and many generations of sheep, but in

[58] http://www.uft.org/endangered-animals-and-fur-trade.

approximately 5000 BC, man could spin wool fibers for clothing. During antiquity in Central Asia's cold winters, wool was a favorite material thus prompting this region to become the main center of wool production. Scythian shepherding nomads made wool into boots, felt blankets, and yurts. In approximately 500 BC, some Indo-Europeans were still living in Central Asia and were known as Scythians and Sogdians. Turks and Mongols wove wool into clothing and created knotted wool carpets for their homes.

There are many types of wool, but the most common type of wool is made from the fleece of a sheep. In scientific terms, wool is a protein called "keratin." Its length ranges from 3.8 to 38 cm (1.5–15 in.) depending on the breed of sheep. Wool fiber is measured in microns: The smaller the micron, the finer and softer the wool. Each piece is made up of three essential components: the medulla, the cuticle, and the cortex.

Wool is collected from the animal in a process known as "shearing," which is when the wool is shaved from the animal and then washed and processed into yarn. During the washing process, a substance called "lanolin" is removed from the wool. Lanolin is very moisturizing and can be used in soaps. The wool is then cranked through rollers, dried, and brushed. After the cleaning process, it is formed into different types of yarn by a process known as "spinning." It can then be woven or knitted into fabric and clothing.

Modern technology has not been able match wool fiber. No other material, natural or man-made, has all of its qualities. It is a fiber that absorbs moisture (such as sweat) and keeps the body dry and warm. Wool also has a natural waxy coating that makes it durable and water resistant. However, it is possible to refine and improve wool, and this has been done through selective breeding of sheep throughout the centuries.

12.1 Which Animals Have Wool to Shear

Camels

Camels, from North Africa, the Middle East and Central Asia, are less known for their wool than other species of wool animals. Camel hair is used most commonly in Inner Mongolia and other regions in China. Camel hair is most often obtained from the two-humped Bactrian camel (*Camelus bactrianus*). The hair is not usually gathered by shearing or plucking; it is most often collected as the animal sheds its coat once a year. Both the outer coat and the undercoat are shed at the same time, and combing, frequently by machine, separates the desirable down from the coarse outer hairs. A camel grows approximately 7 kg of fiber annually. The wool from camels is mainly used for high-grade overcoat materials and is also made into knitting yarn, knitwear, carpets, and rugs. The coarse outer fibers are strong and used in industrial fabrics such as machine belts.[59]

[59]FAO, CORPORATE DOCUMENT RESPOSITORY http://www.fao.org/docrep/v9384e/v9384e05.htm.

Australia has the world's largest population of wild camels, an estimated 1.2 million which is considered to be a growing environmental problem. The Australian government has proposed that killing these wild camels be officially registered as a means of reducing greenhouse gas emissions. According to the government, camels compete with sheep and cattle for food, trample vegetation, and invade remote settlements in search of water.[60]

The Australian association for the camel industry is called Camels Australia Export. The registered business name is the Central Australian Camel Industry Association Inc (CACIA). This association is made up of members from the pastoral industry, meat industry, aboriginal communities, tourism operators, transport operators, contractors, and governmental agencies.

The role of CACIA is to promote the sustainable development of the camel industry through the use, knowledge, and well-being of camels in Australia.[61] CACIA provides guidance in compliance with animal welfare regulations and advises how to handle the camels in complicity with human needs:

> Camels must be used to being handled. This is so that they can be handled at the abattoir by a yardman not familiar with camels. Also once camels become stressed they are more difficult to handle.

The Animal Welfare Working Group (AWWG) has within the Primary Industries Ministerial Council (PIMC) committee system prepared *The Australian Model Code of Pratice for Welfare of Animals, The Camel*, where again information can be found on how to handle the camel in the context of industrial production of the meat, hides, and wool. However, no actual bioethical and philosophical analysis concerning ethical questions about the production of camels for human consumption is addressed.[62]

IN addition, a pre-feasibility study 2009 on camels in Queensland, titled *Commercial Opportunities for Diversification*, by Lauren Brisbane criticizes the lack of available husbandry information and the serious impacts on the appropriate use of camels. Because camels are a herbivores, there are distinct differences in their management compared with other stock animals, e.g., cattle and sheep.[63]

> Anthropomorphism is the projection of human personality and mannerisms to animals and the criticism would be relevant for example, if someone said: "The camel is a haughty animal as it looks down its nose at you", whereas it is not anthropomorphic to diagnose pain or suffering in an animal by bringing in one's own experience of pain in a comparable situation."
> Neville G. Gregory, Royal veterinary College, UK, 2007

[60] http://www.huffingtonpost.com/2011/06/09/australia-camels-slaughter-carbon-credits_n_873768.html.

[61] http://www.camelsaust.com.au.

[62] http://www.camelsaust.com.au/code-of-practice-for-camels-in-australia.

[63] http://australiancamelindustry.com.au/cjamel/images/pdfs/camelgrazing/Camels.in.Queensland.Pre-feasibility.Study.2009.pdf.

Llamas

The llama family originally derives from South America and consists of llamas, alpacas, vicuñas, and guanacos. The most used in fashion is alpaca because alpaca does not contain stiff guard hairs and therefore can be used to spin finer yarns.

Llamas have coarse guard hairs typically used in the inner wool for rope and blankets. They are usually sheared once a year.

Little attention has been paid to any potential animal welfare problem related to the capture, fencing in, or translocation of these wild animals. Vicuñas have a very hard time coping with their native cold environment once they have been sheared and no longer have the isolation once provided by their fleece, especially when not provided with any form of shelter.

The lack of welfare in the breeding methods of the vicuñas has had a negative effect. It has resulted in more substantial mortality rates and new diseases that affect the entire population thus creating an unstable market and economic liability of farming and producing these luxury products (Gordon 2009, p. 49). Currently there are estimated to be more than a quarter of a million vicuñas in the Andes.[64]

Because wool fleece from the llama family is regarded as a luxury product servicing a niche market, it is essential that the decision makers in this industry help to safeguard and protect its international image by promoting and demanding high standards of animal welfare and to do so to minimize ecological impacts on the natural environment.

> The vicuñas case study shows how local communities articulate to the global market via a sustainable use project. The complex and challenging nature of this asymmetric relationship needs to be recognized and appreciated in order to address poverty alleviation and conservation and arrive to a win-win scenario. Dr. Gabriela Lichtenstein

Musk Oxen

Ovibos moschatus is Latin for sheep cow. In fact, the musk ox is more closely related to goats and sheep than cattle and can be considered as a "giant sheep." The musk ox's soft inner wool is called "qiviut." The musk ox lives in far northern climates such as Canada, Greenland, and Alaska.

Musk ox was brought from Greenland to The Nuniuak Island National Wildlife Refuge in Alaska in 1930. Archaeological and ethnographic evidence is consistent with the hypothesis that once the musk ox was hunted as a critical resource before the arrival of Europeans in the Canadian Arctic (Wilkinson 1974).

Breeding programs for production of qiviut have been taking place since the late 1960s, but the scientific implications of musk ox domestication will, according

[64]Lichtenstein G. *Vicuna conservation and poverty alleviation: trying to link the two ends of the social scale*. Instituto Nacional de Antropología y Pensamiento Latinoamericano (INAPL)/CONICET. 3 de Febrero 1378, (1426) Buenos Aires, Argentina. Email: glichtenstein@fibertel.com.ar. https://dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/6007/Lichtenstein_128501.pdf?sequence=1.

to Poul F. Wilkinson,[65] not become apparent until many more generations of domesticated musk oxen are available for study. However, it is suggested that it will be an economical advantage to reduce the average size of domesticated musk oxen relative to their wild counterparts because smaller animals produce more wool relative to food intake than larger ones. Also factors controlling the patterns of shedding are important to those musk ox farmers who are seeking a rapidly shedding, highly productive anima (Wilkinson 1974). Every spring, the musk ox sheds its undercoat by rubbing against something (Wilkinson 2008).

Qiviut, musk ox wool, is one of the most exclusive and rare wools available and is said to be softer than cashmere and warmer than wool from sheep, which makes it suitable for fine textiles and clothing. Qiviut does not shed and will not shrink in water at any temperature unlike sheep wool. Furthermore, it is very warm even when it is wet. Finally, musk ox wool is easy to maintain, and a sweater made of musk wool can last years with the right care.

Musk ox wool is much warmer because the oxen must withstand temperatures down to −60 °C. No other cloven-hoofed animal lives as far north as the musk ox. The reason why it can cope in the cold and harsh conditions of the arctic tundra is because of its 60-cm-long hair and woolly undercoat, which can ward off frost and provide insulation.

An adult musk ox can produce 0.8–1.5 kg of wool per year. The wool is either collected during molting season, or hides are purchased from hunters during the hunting season. The long outer coat of the musk ox is not shed in springtime because it provides protection against the sun and insects in summer.

If the outer coat is sheared, this will endanger the welfare of the musk ox in summer and will not significantly improve the quality of the annual qiviut yield. If the thick outer coat is retained, shearing will be impossible, but plucking qiviut is possible although time consuming (Wilkinson 1974, p. 139). Qiviut is collected from intensive husbandry by enclosing the musk oxen in a small stall or crush and using long-toothed combs to remove the fibre that is already loose. If attempts are made to remove tightly held qiviut, this will make the animal extremely agitated causing stress (Drew et al. 1989, p. 392). Wool used for larger productions is most often bought directly from the hunters because the fashion industry has not included the time aspect needed for molting seasons and the time it takes to collect the wool in the tundra.[66]

Decision-makers in the fashion and the lifestyle industry should be very conscious about and research thoroughly before choosing fiber like this in a production. Paying attention to seasons, animal welfare, and productions methods is also suggested.

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[66]http://atasteofgreenland.com/material/qiviut-musk-ox-wool/ (Accessed August 28, 2015).

Goats

Angora goats grow a long, shaggy coat of fur called "mohair," which can be sheared twice a year and yields approximately 2.5 kg of wool fleece. Mohair is known for its shine and is often used in clothing and luxury accessories.

Cashmere is considered a luxury fiber, and a cashmere goat yields less than 2 kg of wool. It takes a full year of growth from approximately four goats to produce enough fiber for one sweater.

Cashmere is the second largest hard currency-earning export of Mongolia, which makes the emerging Asian nation the world's second largest producer, after China, of the coveted cashmere goat's wool. Human costs are very high to the goat herders in Inner Mongolia, according to Dr. Carol Kerven, because the compensation they receive for the cashmere fibre is very low by current world standards. Its value will only increase to the extreme by the time it reaches the international market, and unfortunately this compensation does not reach the goat herders. It is common for cashmere to be mixed with yaki hair, synthetic fiber, or worse in order to meet the requirements of fast fashion (Kerven 2003).

Annually Mongolia produces 6700 tons of raw cashmere accounting for approximately 28 % of the total world supply. The number of cashmere goats in the country increased almost 300 % between 1990 and 2009. During the same period, the amount of raw cashmere produced increased by 450 %. Other major cashmere-producing countries are New Zealand, Nepal, Iran, Afghanistan, Australia, and the United States.

Desertification is the largest environmental threat to the cashmere industry in Mongolia, and over-grazing, along with global warming, intensifies the problem. The increased population of cashmere goats destroys other Mongolian animals such as sheep, cattle, horses, or camels. Because of the way they graze, cashmere goats destroy the roots of the plants and damage topsoil and grass root systems with their stiletto-like hoofs. This is why the cashmere supply cannot keep up with demand in a sustainable way.[67]

> There is no certification label that guarantees a cashmere product is ethical, says Dani Baker, of the Ethical Fashion Forum. Customers should ask retailers where they source from, if the farming method is sustainable and what conditions the animals are kept in.[68]

Sheep

The ordinary consumer, when considering "wool," thinks of sheep. Wool is traditionally considered a sustainable lifestyle choice for fashion and lifestyle products, which is a misunderstood assumption. Wool from sheep affects the environment

[67] http://mongolia-briefing.com/news/2012/02/mongolias-cashmere-industry.html#sthash.XRM6sxP7.dpuf.

[68] http://www.theguardian.com/environment/2011/jan/16/does-cashmere-get-your-goat.

like everything else produced and used, and as in all other cases mentioned in this chapter, the use of wool is also a nonhuman animal welfare-based topic.

Today, wool is a global industry, and there are nearly 1 thousand million sheep in the world. Annual wool production is approximately 2.1 million tonnes. In 2010, wool amounted just 2 % of the world's total fiber consumption (FAO/ICAC World Apparel Fibre Consumption Survey 2013). Australia produces 25 % of the world's wool.[69] The main producing countries besides Australia are China, New Zealand, United Kingdom, Iran, Russia, and Uruguay.[70]

Sheep can adapt to the environment in a variety of ways such as those that deal with climate, soil, herbage, and terrain. Some of the more famous sheep breeds are accountable for the significance of sheep, especially in the large pasture countries in the southern hemisphere.

Sheep are the most used animals in wool production, and their wool can be categorized into three types: fine, medium, and coarse. Fine wool from the Merino sheep is the most widely used in the garment industry and comes from breeds called Debouillet and Rambouillet. The amount of wool that a sheep produces depends upon its breed, genetics, nutrition, and shearing interval. A Merino sheep grows up to 18 kg of greasy wool a year. Lambs produce less wool than mature animals. Medium and coarse wool fleece is mainly used for the production of wool yarn for hand knitters.

The International Wool Textile Organization (IWTO) has in 2013 closely aligned with GOTS in adopting a new organic wool standard, *Guideline for Sheep Welfare*. According IWTO, "Eco wool" must meet the standards set by the EU Ecolabel.[71] The International Wool Textile Organisation (IWTO) has been the recognized global authority for standards in the wool textile industry since 1930. According to IWTO, the fashion and lifestyle industry has slowly started to understand the importance of posing questions about the provenance, origin, and sustainability of wool. Animal welfare and care for the earth are increasingly important elements in the areas of corporate social responsibility, which are addressed in this guideline.

In addition, animal rights groups have made the textile industry aware of the various problems regarding animal welfare in the production of wool over the past decade. A standard of unethical treatment of animals has led several large firms to take a stand about what kind of production they want to support. This has resulted in an increased production of both organic and ethically generated wool, although it accounts for only a very small part of the total global production of wool.

Each country has its own standards on organic wool, such as that in Australia, which has no resemblance to or agreement with the USA organic standards. The term "eco wool" is also used by many companies, which means the wool is

[69] Australian Bureau of Statistics, "Year Book Australia, 2009–10," 6 Apr. 2010.

[70] http://www.naturalfibres2009.org/en/fibres/wool.html.

[71] http://www.iwto.org/uploaded/publications/WEB_IWTO_Sheep_Welfare_Guidelines_Web.pdf.

sheared from free-roaming sheep that have not been exposed to toxic flea dipping, but it does not mean that the fleece has not been treated with dyes, chemicals, and bleaches.

Domesticated Sheep

The most discussed issue within wool production has been "mulesing" (see following text), whereby Merino sheep are selectively bred to overproduce thick, heavy coats. The most commonly raised sheep in Australia is the Merino sheep, which accounts for approximately 30 % of all wool used worldwide. Merino sheep have been bred to have more skin than their actual body size to produce more wool. Their coats are so thick that they can die of heat exhaustion during hot months, and, unlike wild sheep, Merino sheep cannot shed their fleece by themselves and are totally dependant on human beings.

Mulesing

"Mulesing" was developed approximately 80 years ago because Merino sheep not are able to keep themselves naturally clean because of the many folds in their skin. The tail and the breech area become moist with urine and contaminated with feces, and the blowfly is attracted to this humid area where it lay eggs. The eggs hatch and maggots eat away at the flesh of the living animal, which is very painful to the animals. This is called "fly strike."

Mulesing is the cutting of flaps of skin from the breech and tail of the lamb with a scalping to create an area of bare and stretched skin. Because the scarred skin has no folds or wrinkles the area is less attractive to blowflies. This makes mulesed Merino sheep less sensitive to fly strike.

However, because mulesing is carried out without anesthesia, it is a very painful and anxiety-producing procedure for the animal. Other procedures performed without anesthesia include punching a hole in lambs' ears, docking lambs' tails, and castrating male sheep. This is carried out in a way where a rubber ring cuts off the blood supply on male lambs' testes and tails.

Alternatives to these issues are to change the genetic traits of sheep, which is the point this industry has reached today. Several initiatives and research are being carried out in this area, and it can therefore be concluded that the issues of animal welfare are being recognized and accepted as a problem that must be solved.

The RSPCA, an independent NGO, in 2011 published a research report, *Prevention and control of blowfly strike in sheep*.[72] This report includes a long list of references on every aspect of on welfare issues, including blowfly management, and new emerging technologies for further study.

Shearing

During the shearing process, many of the animals are injured. Human beings can only perform this, and the sheep are handled very roughly and brutally because of

[72] http://kb.rspca.org.au/What-is-mulesing-and-what-are-the-alternatives_113.html Research report - Prevention and control of flystrike August 2011.pdf.

the heavy workload. The hard work leaves no room for taking into account that sheep are living beings capable of feeling pain.

Transportation

When sheep cannot produce the amount of wool required, they are sold for slaughter. Millions of animals are exported each year where the sheep are transported for long distances in very crowded feedlots and are then loaded on ships. Many animals die during this treatment, experiencing everything from stress and anxiety to lack of space, harsh treatment, and lack of food or water. Usually the animals are transported to countries with minimal or no slaughter regulations and where the sheep often will be deliberately dismembered without compassion.

Rabbits

The Angora rabbit is recognized throughout the world as both a pet and as an animal used in commercial farming. They are available in different breeds: the English Angora, French Angora, German Angora, Giant Angora (which is an English Angora bred to produce more wool), Satin Angora, and a new breed, the Dwarf Angora. Angora rabbits are believed to have originated from Turkey.

The fur from the Angora rabbit, both undercoat and guard hairs, is very long (Meredith 2000).

These qualities make them in particular at risk of suffering such conditions as matting, fly strike, and gastrointestinal obstructions caused by an autosomal recessive gene that is responsible for the characteristic and abnormal long fur of the Angora rabbit's coat (De Rochambeau and Thebault 1990).

The long fur of Angora rabbits mats easily. This can be very uncomfortable for the animal and causes irritation as well as sore and infected skin and predisposes the rabbit to life-threatening conditions. These conditions not only cause significant pain, distress, and suffering, but they can affect the ability of the rabbit to eat and move around (Deeb 2000; Harcourt-Brown 2007; Cousquer 2006).

Its long and fluffy coat makes it impossible for the Angora rabbit to groom and care for itself, which, if not cared for, leads to matting and fly strike. Merino sheep flies are attracted to moist hair and skin that is soiled by urine and feces. They lay their eggs in the Angora rabbit's coat, and the larvae eat the living body tissues causing significant pain (Cousquer 2006).

From an ethical point of view, the effects of such a dense coat might also cause the rabbit much thermal discomfort especially if it is bred in a hot environment. This may be difficult to measure because rabbits show very few obvious signs of pain. Their suffering may therefore be underestimated, and problems may be undetected until they are in severe pain.[73] Based on these facts, opinions as to whether it is ethically acceptable to breed Angora rabbits at all may differ, but the Angora rabbit's welfare is at particular risk because of the abnormality in its genes.

[73] http://www.rspca.org.uk/adviceandwelfare/pets/rabbits/health.

Caring

Angora rabbits, if they are to be free of disease and discomfort, are very dependent on time-consuming care and impeccable husbandry. This includes daily contact and care that consists of regular grooming and general shearing as well as inspections to check for perineal soiling, especially in warmer weather or in warmer climates. Angora rabbits require a high-fiber, high-protein diet to support their constant wool production.

Furthermore, rabbits in general often find it very uncomfortable and stressful to be sheared and groomed. Rabbit skin is very thin making it easy to cut into the skin, especially if the rabbit is feeling anxious. Some are so distressed they require sedation or anaesthesia before shearing (RWF 2007).[74]

Rabbits naturally move a lot and therefore need daily exercise. This also goes for Angora rabbits. Housing of rabbits in small wire cages with no possibility of being able to move is a result of the heavy demand from the fashion and textile industries, which have deprived the rabbits from developing naturally. According the American Rabbit Breeders Association (ARBA), the minimum space requirements for one rabbit based its weight is about 1 square foot per 3 pounds of rabbit. This size cage does not allow for much exercise.

The European Commission (2007) recommendations on the housing of animals used in research states that solid floors with bedding or perforated floors are preferable to grid or wire mesh floors for rabbits and that wire floors should not be used unless a resting area is provided large enough to hold all rabbits at any one time (European Commission 2007).[75]

Rabbits naturally also must dig and chew on branches for entertainment and to keep their teeth from growing too long, which can cause serious health problems requiring veterinary care. Consequently, if none of the rabbit's natural needs are handled, the successful production of Angora wool will not occur.

A case in point is that of Angora rabbits used in production, which are farmed intensively in underdeveloped countries. Because raising Angora rabbits requires more skilled workers, which results in a higher production cost, success is not always achieved. According to FAO, the Food and Agriculture Organization, it has spent 10 years supporting the concept of backyard rabbitries as examples of sustainable development with extensive programs in 10 countries in Africa, South America, and the Caribbean, without much success due to the many challenges in raising and maintaining Angora rabbits.[76]

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[74]RWF (2007). The long and the short of it. Caring for long-haired pet rabbits. Owner information leaflet. Horsham, UK: RWF http://www.rabbitwelfare.co.uk/resources/content/leaflet_pdfs/longhairNov07.pdf.

[75]http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007H0526.

[76]http://www.fao.org/docrep/t1690e/t1690e03.htm.

12.2 Harvesting Wool Fiber

The harvesting of wool and slaughtering methods have been discussed worldwide because several animal right activists have documented these methods on social media.[77] This attention made several fashion brands stop using Angora wool in their future collections realising that quality of the product and luxury feeling did not measure up with the production methods and the living conditions these animals underwent.[78]

Most Angoras will naturally shed their coats –three to four times a year (Within this area every 90 days). However, some breeds do not molt their wool, so shearing the rabbits is necessary. Other Angora breeds can have the wool pulled or plucked by hand when the rabbit starts to molt. The hair should pull easily and not require force to be removed. If this hurts the rabbit, the rabbit is not ready for wool removal, and pulling or plucking should be stopped immediately and retried later.

Milk Fiber

Casein plastics and milk casein fiber were introduced and used in clothing in American and Europe during the 1930s and 1940s. They were substitutes for wool, fell out of use after WWII, but have grown in popularity as a so-called "eco-friendly fiber" (Gridley et al. 2005).

Casein, the protein in milk, was used by the ancient Egyptians as a fixative for pigments in wall paintings and has historically also been used as a constituent in various glues.

Casein was also used in plastic until the end of the 19th century and in imitation tortoiseshell and horn for use in buttons for fashion products.

Milk fiber is a blend of casein protein and the chemical acrylonitrile. Acrylonitrile is a key ingredient used to make acrylic fiber.

> Acrylonitrile is used to produce plastics that are impermeable to gases and are ideal for shatter-proof bottles that hold chemicals and cosmetics, clear "blister packs" that keep meats fresh and medical supplies sterile, and packaging for many other products. It is also a component in plastic resins, paints, adhesives, and coatings.[79]

It takes approximately 100 pounds of skim milk to make 3 pounds of milk fiber,[80] and combined with the knowledge that dairy farming has a large negative impact on the environment given the inhumane way in which dairy animals are treated at mass-production farms, this fiber can never be considered "eco-friendly" in any way.

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[77] http://www.chai-online.org/en/compassion/clothes_fur.htm#rabbits.

[78] The names of these companies can be accessed through PETA. (http://www.peta.org.uk/blog/things-stand-Angora/).

[79] Thesohio Acrylonitrile Process, Bp Chemicals Inc. Warrensville Heights, Ohio, September 13, 1996.

[80] http://www.ecouterre.com/milkofil-it-does-a-bodice-good/.

The dairy cow is the hardest working of all livestock. In order for cows to produce the amount of milk required by the industry, cows are artificially inseminated two to three months after giving birth. Soon after calves are born they are removed from their mothers, deprived from all natural needs, such as connection to their mother and natural milk, while other cows are required to nurture a growing calf inside of their bodies to produce milk for humans.

As a result, today the dairy industries overproduce milk, much of which is discarded. With the intention of saving resources, the textile industry has rediscovered and industrialized the possibility to change milk fibers into textiles.

Feathers

Feathers have had a wide range of uses for thousands of years. Archaeological evidence suggests that people dating back to Neanderthal populations have used or extracted materials from animals that can not be linked to food or utilitarian purposes but are possible indicators of a symbolic behavior value. This includes the use of feathers and the long bones of large-sized birds such as vultures, eagles, and swans (Peresania et al. 2011).

Throughout the centuries, pillows have been filled with feathers, and in a number of cultures feathers have been deemed to have a great symbolic association with spirituality. However, in the context of this chapter, the greatest relevance for feathers is their use in personal adornment across time and culture. All kinds of birds have been used for decoration. Ostrich, peacocks, birds of paradise, and herons have been enormously popular, but ordinary garden fowls, such as doves, geese, and turkeys, have also been used in quantity. Robin W. Doughty, in *Feather Fashions and Bird Preservation*, presents a highly detailed chart of feather fashions recorded in Doughty (1975).

13 Feather Farms

From the 1880s until the First World War, exotic ornamentation was at its peak, which created a great trading of feathers, such as ostrich feathers. These were coveted for their flamboyant and lavish expression as interpreted by fashionable women (Stein 2008). This demand resulted in farms where the birds were plucked alive. An ostrich, for example, was plucked once a year from its first year of life, which could be turned into many harvested feathers in a single ostrich's lifetime. By the 1900s, the North American millinery industry employed 8300 people, which included the exploitation of children in preparing the feathers for sale (Stein 2008). In addition, the business of killing birds for the millinery trade was practiced on a large scale, involving the deaths of hundreds of thousands of birds in many parts of the world, which in turn endangered some species.

Thus, as people became more enlightened, the first animal-protection groups were formed in response to actions that were described as a "murderous fashion trade." In England, clubs and associations such as RSPB (Royal Society for

Protection of Birds) and the Audubon Society (which was established in America and initiated by women), were against the use of feathers in costumes (Haynes 1983). The RSPB attempted to persuade women not to wear feathers by lobbying for protective legislation and working to change what was considered fashionable.

And as is always seen within fashion, the truth was being downplayed and distorted for commercial reasons, which even at the time of RSPB's efforts could be read in a comment from Harpers Bazaar November 1899 presenting a completely different angle on the use of feathers as decoration:

> The tender-hearted women who have refused to wear egrets on their hats and bonnets, on account of the poor mother-birds, will be glad to learn that they are not killed for the purpose of obtaining these lovely ornaments. As a matter of fact, the hunters, without powder or shot, go around (in South America or India) during the right season to the breeding or roosting grounds and collect the plumes, which are cast by the male birds every year.
>
> In Venezuela the natives are beginning to farm the birds, as they are easily domesticated; as the egrets grow again each year, the enterprise should be very profitable.
>
> It has long been considered a very cruel thing to wear an egret, as it was supposed that a mother-bird was killed to obtain it. We have heard harrowing descriptions of nests of young birds left unprotected while the mother-birds lay mangled on the ground-all for the adornment of heathen woman-kind. But now the most tenderhearted lady (provided she can afford the luxury) may wear this beautiful ornament with a clear conscience.
>
> "The Week", Harper's Bazaar, 1899[81]

13.1 Fashion Repeats Itself

Today a percentage of the world's supply of down and feathers are still plucked from live birds (Hanson 2011), a practice that today is also condemned as cruel by animal welfare groups. Live-plucking is illegal in Europe and the United States, but it is known to occur in European countries (Poland and Hungary) and in China (Villalobos 2011).

Down is the soft layer of feathers closest to birds' skin, primarily in the chest region. These feathers are highly valued by manufacturers of down clothing and comforters because they do not have quills. Plucking of geese and ducks is very painful and causes great suffering. Birds are lifted by their necks or wings and their legs are held back or tied so their feathers quickly can be ripped straight out of their skin. Plucking can begin when the animals are only 10 weeks old and is repeated in 6-week intervals. Due to the pain, the birds struggle even more from the brutal handling, which ensures that their skin is made prone to being ripped open, and workers sew the wounds without anaesthesia using dirty needles and thread.

[81] "The Week," *Harper's Bazaar,* 18 November 1899, 974.

As seen with all other kinds of animals used in the fashion and lifestyle industries, feathers and down are used as a commodity and many types of down are from many synthetic materials, thus making it difficult to determine exactly what percentage of down is actually harvested from live animals (Villalobos 2011).

From an ethical perspective, one action in this context is really no better than the other because not all down and feathers are harvested from live animals. Some down is harvested from animals that have been slaughtered before being plucked with most not having been bred or raised in a way that can be regarded as ethical in any way. The poultry industry produces a large amount of birds raised for meat and foie gras, and the feathers have been used as by-products in a number of industrial applications such as fashion and lifestyle products. Some exotic feathers from endangered species used in fashion decorations and home decor are illegal to trade; however, poaching and black-market trade continue to be profitable.

Strict laws have been made to protect more than 1000 species of migratory birds, and these laws are available to decision-makers who need information before purchasing a product that contains feathers.

Labeling

Regulations on the labeling of feathers are found in several countries. The purpose of these guidelines is to clarify the requirements for the labelling of down and feather fillings in consumer textile articles. Manufacturers must label the percentage of feathers and down used in a product, as well as the species of bird, but there are no requirements to describe what type of farm the animals come from or if the feathers are plucked from living or dead birds. This could be considered incomprehensible because it does not give the consumer the opportunity to gain insight and thus have a say in his or her in choice of products.[82]

14 Insects

This part of the paper discusses insects, animals which humans tend to ignore, mainly because insects are experienced as a nuisance or perceived as pests. Insects have traditionally been dealt with by spraying pesticides to stave off crop infestation or simply by slapping them out of disgust or annoyance. Insects represent 75 % of all animal species, and there exist approximately 200 million insects for each human being (Lockwood 1988).

Archaeological records show that humans had to feed themselves as hunters gatherers in order to obtain enough proper nutrition to ensure their survival. This nutrition, among other things, could be found in insects (Gjerris et al. 2015).

As has been mentioned, man not only dresses to protect the body from the elements but to embellish and decorate his or her dress as an important part of

[82]http://www.competitionbureau.gc.ca/eic/site/cb-bc.nsf/eng/01237.html, http://www.competitionbureau.gc.ca/eic/site/cb-bc.nsf/vwapj/down-e.pdf/$FILE/down-e.pdf.

communication. Throughout time, part of this decoration has consisted of use of the insects. The most well-known insects used in apparel throughout time are beetles, caterpillars, and spiders.

The scarab or dung beetle's striking looks have lead to it being associated with the sun as well as the concept of the eternal renewal of life. Beetles have been used as decoration, dead or alive, and have appeared from an historical perspective in many places around the world including the Amazon, the highlands of New Guinea, Northern Thailand, Australia, Mexico, Central European Americans, the Caribbean, and, of course, ancient Egypt.[83]

The most recognized and well-known luxury fiber produced by insects and known as the "queen of fiber" is the silkworm. Actually, the silkworm is a domesticated insect that in nature goes through the same stages of metamorphosis, i.e., egg, larval, pupal, and adult, that all moths do (Gardetti and Muthu 2015).

Animals with indirect development, such as insects, amphibians, or cnidarians, typically have a larval phase of their life cycle. The caterpillar's appearance is very different from its adult form (for example, larvae versus butterflies). Silk is the fiber that silkworms weave to make cocoons. The production of silk originates from China in the Neolithic, Yangshao culture, 4th millennium BC. The silkworm, *Bombyx mori*, has been domesticated for so long that it probably no longer survives in the wild because it can no longer fly.

Silk production today is a mix of old techniques and modern innovations. Silk is produced by hatching silkworm eggs that are free of disease. Larvae are then fed with chopped mulberry leaves, and, when ready, spin their silk cocoons. Pupae within the cocoons are killed by steam or fumigation to keep them from breaking through the cocoons. Approximately 3000 silkworms must die to make one pound of silk.

Ahimsa silk, is known as peace silk, is processed from cocoons without killing the larvae inside. "Ahimsa" means "nonviolence" and is a part of Buddhist philosophy stating that humans should refrain from inflicting suffering on others, including nonhuman beings. Vegetarians and some vegans are convinced that it allows them a way to use silk without sacrificing animal life. But this is more complicated than it appears.

There are two kinds of Ahimsa silkworms—*Samia ricini* and Eri silk moths—and the various Tussah/Tasar moths (such as the Indian Tasar moth [*Antheraea pernyi*], the Chinese Tussah moth [*A. mylitta*], and the Muga moth [*A. assamensis*]).

An Eri moth is bred with multivoltine *Bombyx* strains: They breed and lay eggs, which will hatch, but the larvae will die from dehydration or starvation if not fed; however, because of the amount of eggs layed, it is not possible to feed them all. It may be a question of whether it is intentional or unintentional if these moth die through neglect or die from specific efforts made; however, it cannot be substantially different than killing them by choice.[84]

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[83]Victoria Z. Rivers, *Beetles in Textiles* http://www.insects.org/ced2/beetles_tex.html.

[84]http://www.wormspit.com/peacesilk.htm.

Unlike silkworms, which are easy to raise in captivity, spider silk is extremely hard to mass produce because spiders have a habit of biting off each others heads when housed together.

Spider silk is well known for its extraordinary mechanical properties. Spiders can produce several types of silk, and the strongest of these—dragline silk—is one of the toughest materials known to man. It is of great interest to military defense industries and structural material industries due to its combination of high strength, elasticity, ductility, and light weight. Scientists worldwide are studying this silk's properties to mass produce it, but no one so far has succeeded in replicating 100 % of the properties of natural spider silk. Approximately 1400 spiders are needed to spin 1 oz of silk, so farming spiders has not been a successful venture; it has required unimaginable amounts of test animals in order to gain insight into this subject.

A group of researchers has managed to build a replica of a spider machine invented by the French missionary Jacob Paul Camboue in 1890. In this replica, spiders accept imprisonment with resignation and lay perfectly quiet while the silken thread issuing from their bodies is rapidly wound onto a reel by means of a cleverly devised machine that is worked by hand.[85]

These insects, among others, have been used by designers and known luxury brands, in fast fashion and for décor, to create spectacular artistic expressions for human beings. However, unlike the other animals mentioned here, insects have not received much attention in the area of sustainability, although much research has been focused on insect by-products to be incorporated into discussions of the ethical treatment of animals.

Questions about developing ethical standards for insects must be addressed given the possibility of insects' suffering, especially because more evidence is not available. The impact humans have on insects and bugs, e.g., through the application of insecticides, must also be considered. Given the early argument of Jeremy Bentham that pain is intrinsically evil (Bentham 1789) and the contemporary philosophical arguments regarding the moral relevance of pain in animals (Singer 1975, 1977; Regan 1983), it must be appropriate to discuss ethical behavior when it comes to insects.

The insect physiologist, Wigglesworth (1980), argued that insects experience visceral pain as well as pain caused by heat and electrical shock; however, cuticular damage apparently causes no pain (Lockwood 1988).

> In any case, abundant evidence indicates that all invertebrates with a brain can experience pain. Like vertebrates, numerous invertebrates produce natural opiates and substance P. These animals include crustaceans (e.g., crabs, lobsters, and shrimps), insects (e.g., fruit flies locusts, and cockroaches), and mollusks (e.g., octopuses, squids, and snails)… Also, crustaceans, insects, and mollusks show less reaction to a noxious stimulus when they receive morphine. For example, morphine reduces the reaction of mantis shrimps to electric shock, praying mantises to electric shock, and land snails to a hot surface. (Dunayer 2004)

[85]Hadley Leggett, "1 Million Spiders Make Golden Silk for Rare Cloth," *Wired* 23 Sept. 2009. http://www.wired.com/2009/09/spider-silk/.

Lauritz S. Sømme concludes in a report to the Norwegian Scientific Committee for Food Safety, 2005, on "Sentience and Pain in Invertebrates" with this statement about insect sentience:

> The nervous system and senses of insects appear to be better developed than in crustaceans since an active life on land may be more demanding. With the great diversity of insects, there are great differences in the organization of the central nervous system and senses. In general, insects are equipped with numerous sense organs. The brain is particularly well developed in social insects, and the size of certain neural centers can be correlated with learning capacity. Learning is also known from many solitary species of insects. Insects do not react to damage of their bodies, but may show strong reflexes to constraint. With our present knowledge, it is usually concluded that insects cannot feel pain. Still, doubts have been raised. Among invertebrates, social insects represent a high level of cognition, and their welfare should be considered during handling.[86]

> To Nicholas Strausfeld, a tiny brain is a beautiful thing. Over his 35-year career, the neurobiologist at the University of Arizona at Tucson has probed the minute brain structures of cockroaches, water bugs, velvet worms, brine shrimp, and dozens of other invertebrates. Using microscopes, tweezers, and hand-built electronics, he and his graduate students tease apart—ever so gently—the cell-by-cell workings of brain structures the size of several grains of salt. From this tedious analysis Strausfeld concludes that insects possess "the most sophisticated brains on this planet.[87]

The fact is that insects, although they have the smallest brains containing thousands of neurons, can learn and exhibit memory (Alloway 1972) has led researchers and great thinkers to theoretical considerations regarding the consciousness of insects.

> … Strangely, I believe that cockroaches are conscious…… I believe that many quite simple animals are conscious, including more attractive beasts like bees and butterflies…….. I can't prove that they are, but I think in principle it will be provable one day and there's a lot to be gained about thinking about the worlds of these relatively simple creatures, both intellectually—and even poetically. I don't mean that they are conscious in even remotely the same way as humans are; if that we were true the world would be a boring place. Rather the world is full of many overlapping alien consciousnesses Alun Anderson, Editor-in-Chief, New Scientist.[88]

[86] http://www.vkm.no/dav/413af9502e.pdf.

[87] http://discovermagazine.com/2007/jan/cockroach-consciousness-neuron-similarity.

[88] http://edge.org/q2005/q05_4.html#andersona.

15 Conclusion

The soul is the same in all living creatures, although the body of each is different.

Hippocrates (460 BC–377 BC)

Sentience encompasses awareness and consciousness as well as intelligence (the ability to solve problems) and intuition (to reason) emotion based. Sentience encompasses and recognizes a universe of positive and negative emotional experiences including those of suffering. A sentient being is aware of his or her surroundings and is aware of heat, cold, hunger, and thirst as well as the feelings related to these sensations. In short, a sentient being is a conscious, thinking, feeling being.

In concluding this chapter, the author would like to state that animals fulfill these sentient criteria in the same way as do humans, but this may differ in some aspects. Animals in all forms experience pleasure, joy, and pain. They have their own form of sentience, and because humans lack consciousness on the same level, humans are unable to perceive the communication forms of animals. There could one day come a time when animals challenge human beings on this reality. Maybe one day man will be able to decode communication and awareness levels held by animals. In doing, so man might begin to equate himself with humans living in the past to a time when clothes were not even worn.

This presentation on ethics and animal welfare in the fashion and lifestyle industries has attempted to present and clarify relevant issues faced by today's decision maker. The possibility to explore the subject of ethics and animal welfare and how to justify one's choice has never been so readily at hand. Today's, the productions of which rely on the use of animals, must clarify the question of why man needs to relate to animal ethics and welfare.

This must be clarified not only to quell the mounting pressure from consumers who themselves are beginning to ask this question, but because it is vital to recognize that the ethical treatment and welfare maintenance of nonhuman beings and humans beings are perhaps one in the same.

We are used to regarding the oppression of blacks and women as among the most important moral and political issues facing the world today. These are serious matters, worthy of the time and energy of any concerned person. But animals? Surely the welfare of animals is in a different category altogether, a matter for old ladies in tennis shoes to worry about. How can anyone waste their time on equality for animals when so many humans are denied real equality? (Singer 1979)

Scientific studies on animals, including rats, pigs, goats, and bees, all show the same optimistic/pessimistic response. It seems that the life of an animal can be good or bad and that the inner state of an animal at any given moment has an influence on the short-term feeling it experiences. Their lives matter to them just as humans' lives matter to man. An animal's desire for rewards is part of its sentient makeup, namely, the capacity to feel as do human beings.[89]

Recognizing the ethical dilemma humans are finding themselves in regarding the welfare of animals is in itself relevant. How can humans do good while they are seduced into a sense of luxury and quality that is dependent on materials that come from animals? To abandon all use of animals can be compared with the practices of monks and nuns, who forsake much of the world's goods in favor of something seen as higher than themselves, something not possible to measure or prove. Answering such a question calls for a sacrifice for some and a conscious position for others to take.

In the future, producers, manufactures, fashion brands, and designers will undoubtedly encounter problems of consequence and reliability in their decisions when working with animals whether it involves fur, skin, wool, or feathers. The question then will be this: Is it more fruitful to take action regarding these issues by becoming more knowledgeable and insightful or by taking traditional defensive role.

Knowing and showing will be the way to transparency. To demonstrate and explain choices toward an ethical approach and to be honest and transparent: These are the next steps. Labeling will must be improved in order to tell the true and full story of what kind of animals are used, where were they bred, and what kind of slaughter methods were used.

The potential for collaboration across disciplinary boundaries should not be ignored in this industry. Ethical thinkers, NGO, farmers, manufacturers, and designers should all collaborate together for future production and possibilities.

All matter, energy, and life are an interconnected unit; all are inseparable including human and nonhuman beings. That humans are an integral part of nature is something everyone should cherish, revere, and preserve in all its magnificent beauty and diversity.

As never before researchers are questioning nonhuman animals' inner lives, and the capabilities for probing these issues are growing more and more sophisticated. This notion gives this author an optimism that the neglectful and abusive expressions seen today within the human–animal relationship will evolve through a better understanding, through compassion by recognizing the inherent value of all life, and through striving to treat all living beings with respect through a direct understanding of this concept.

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[89] http://www.livescience.com/49093-animals-have-feelings.html.

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Time for a Responsible Fashion Council?

Xenya Cherny-Scanlon and Kristin Agnes

Abstract Fashion is one of the least regulated and most unsustainable global industries. It has recently come into the spotlight due to its social and environmental performance, which brought into sharp focus both the lack of adequate international regulations in the fashion sector and lack of compliance with existing ones. Despite the proliferation of voluntary initiatives, there is no single body that sets global rules in the fashion industry today, thus leading to lack of coordination and common standards around the world on anything from advertising to environmental performance. The chapter analyzes the current regulatory landscape in the fashion sector at the international level, including the existing standards and certification schemes as well as key initiatives in this sector. It explores the feasibility and possible mandate of a future global fashion council and its role in promoting sustainability across the industry.

Keywords Responsible fashion council · Fashion · Apparel · Sustainability · Regulations · Legal compliance · Standards · Certification schemes · Multi-stakeholder initiatives · Governance · Mandate

1 Introduction

Fashion is one of the least regulated global industries, especially compared with highly regulated sectors such as air transport, mining, or energy. Moreover, trade liberalization in recent years led to dramatic changes in the industry's sourcing and

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business strategies resulting in an increasingly globalized, fast-paced, and largely unsustainable business model. Meanwhile, the fashion industry has recently come into the spotlight due to its social and environmental performance, in particular following the 2013 Rana Plaza garment factory collapse in Bangladesh. The Rana Plaza tragedy brought into sharp focus both the lack of adequate international regulations in the fashion sector and lack of compliance with existing ones (e.g., labor standards). Despite the proliferation of voluntary initiatives, there is no single body that sets global rules in the fashion industry today, thus leading to lack of coordination and common standards around the world on anything from advertising to environmental performance.

This chapter analyzes the current regulatory landscape in the fashion sector at the international level as well as key initiatives led by the United Nations, governments, industry, and civil society. It explores the feasibility and possible mandate of a future global fashion council and its role in promoting sustainability across the industry. The chapter content is based on literature review and expert interviews complemented by the authors' own insights and reflections.

2 Fashion and Sustainability—An Overview

The fashion industry is an enormous and enormously influential industry that is worth more than $3 trillion a year and employs 60 million people, predominantly women, worldwide (Ditty 2015; International Labour Office 2014). In some countries, e.g., Bangladesh, up to 90 % of garment-sector workers are women (Begum 2001).

The fashion industry is an increasingly important economic sector in many countries. For example, the UK fashion industry directly contributes £26 billion to the UK's gross domestic product and supports 797,000 jobs (British Fashion Council 2014).

Moreover, trade liberalization in recent years resulted in an increasingly globalized, fast-paced, and largely unsustainable business model. In 2005, the United States Association of Importers of Textiles & Apparel (USA-ITA) was instrumental in eliminating the global apparel quota system, and since then the industry has globalized leading to dramatic changes in the industry's sourcing and business strategies (Lu 2014).

Since trade liberalization, the total value of textiles and clothing exports increased from 480 to 709 billion between 2005 and 2012, representing 4 % of total merchandise export worldwide; CLOTHING accounted for USD$423 billion and textiles for USD$286 billion. Despite trade liberalization and the large number of producer countries, the world's textiles and clothing industries are concentrated in few countries (WTO 2005, 2013).

Today, most fashion companies operate a complex supply chain, which often spans several countries or even continents, involves a multitude of actors from suppliers to subcontractors, and consumes significant resources before reaching the end consumer who will further add to the environmental footprint. For example, Levi

Strauss & Co.'s sourcing for three global brands includes approximately 700 suppliers across 42 countries for 110 destination markets (Levi Strauss & Co. 2012).

Meanwhile, the emergence of so-called "fast fashion" has been widely criticized as disposable, cheap fashion delivered from the runway to the consumer as quickly as possible, often at high social and environmental costs (Siegle 2011).

Fashion is one of the most polluting industries in the world, second only to oil in terms of its environmental impact. For instance, one quarter of chemicals produced worldwide are used for textiles, and the industry is often noted as the number two polluter of clean water after agriculture (Fibre2Fashion 2012). It is estimated that one tenth of Europe's environmental impact can be attributed to the consumption of clothing (Wills 2014).

A number of initiatives in recent years have sought to account for the often "invisible" social and environmental costs of the fashion industry. For example, the 2014 study by Trucost estimated that the apparel sector's total natural capital cost to be more than USD$40 billion per year, equivalent to more than 6 % of the sector's revenue (Trucost 2014).

The fashion industry has recently come into the spotlight due to its social and environmental performance, in particular following the 2013 Rana Plaza garment factory tragedy in Bangladesh, in which more than 1100 people lost their lives. Meanwhile, Greenpeace's Detox Fashion campaign exposed several luxury fashion companies (e.g. Prada, Dior, Versace) for their role in causing toxic pollution in China (Greenpeace 2014).

In response to these concerns, as well as pressure from environmental and labor groups, increasingly more companies in the apparel sector are developing sustainability strategies and programs. These include commitments to a "living wage" for workers and elimination of child labor on the social side as well as "zero discharge" of toxic chemicals and various carbon-, water-, and waste-reduction targets on the environmental side.

Industry-wide cooperation is also on the rise as exemplified by initiatives such as Sustainable Apparel Coalition, which represents one third of the global market share for clothing production or the UK-based Sustainable Clothing Action Plan (SCAP), which brings together 12 key retailers with a combined 30 % share of the country's clothing retail market (SCAP and MADE-BY 2015).

Furthermore, the past decade has seen a growth in the number of fashion brands that have ethical and environmental concerns at the core of their corporate "DNA." Increasingly more consumers care about where their products come from, and sustainability is a crucial factor in deciding which brands they will buy. Several initiatives, for example, MADE-BY, Fashion Footprint, and Positive Luxury, seek to highlight companies and brands that "do good." However "ethical fashion" still accounts for a marginal market share overall (Ethical Fashion Forum 2015).

In April 2014, the fashion industry came together for the Copenhagen Fashion Summit held under the patronage of HRH Crown Princess Mary of Denmark, and it stands as the largest sustainability event in the industry to date (Danish Fashion Institute 2014). However, the summit did not yield any new industry-wide commitments to sustainability.

3 Current State of Regulations in the Fashion Industry Vis-à-Vis Sustainability

Fashion is one of the least regulated global industries, especially compared with highly regulated sectors such as air transport or energy. To start with, there is no single legal framework or apex body for the fashion industry that would set global rules for the sector.[1]

Unlike the International Air Transport Association (IATA) for aviation or the International Energy Agency (IEA) for energy, fashion does not have a global industry- or government-led forum for developing new and enforcing existing laws, setting standards and managing associated certification schemes, coordinating the increasingly complex interactions within the industry, and resolving eventual disputes.

Indeed, some industry insiders, notably the Business of Fashion's Colin McDowell, have been calling for the establishment of a global fashion authority with a broad regulatory and advisory mandate to help with all matters of common concern from coordinating increasingly unruly fashion calendars to addressing the industry's "human cost" (McDowell 2015).

As McDowell argues, "… the concept of a single international organization that moderates and coordinates an industry provides a useful metaphor for the international fashion industry."

At the moment, fashion companies are grappling with the need to comply with existing legal obligations at national, regional, and international levels, meet international standards set by the International Standardization Organization (ISO), develop self-regulation policies, and continuously exceed consumer expectations.

Among legal instruments at the international level of direct relevance to the fashion industry in the areas of human rights and environment, one may mention ILO Convention 182 on the Worst Forms of Child Labour and ILO Convention 138 on the Minimum Age for Employment, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973), and the Stockholm Convention on Persistent Organic Pollutants (2001).

In addition to international legal instruments, laws and regulations vary greatly from country to country and from category to category. In some countries, e.g., the United Kingdom, trade restrictions currently include certain textiles originating in Belarus, North Korea, and Uzbekistan due to their human rights record (UK Trade & Investment 2013).

Furthermore, according to McDowell, "The industry's lack of international coordination is just as troubling on other issues. France, Spain, Italy, Israel and Denmark have all set up their own regulations trying to check the use of excessively thin runway models. The result is an uneven mix of legal and non-legal guidelines, overseen by a menagerie of organizations, from governments to local

[1]Although there is a World Fashion Council registered in Washington D.C., it does not seem to have a credible fashion industry membership nor a visible influence on industry affairs.

fashion industry bodies, such as the Danish Fashion Institute. What's more, such well-intentioned but uncoordinated efforts are often thwarted by the fact that designers—not to mention art directors and photographers—continue to use very thin girls in campaigns and editorials, despite the fact that they may be seen by consumers worldwide, even in those countries with strict laws on the kinds of models used in local shows."

One example cited above is the controversial French law passed in April 2015 making it a criminal offence to employ dangerously skinny women on the catwalk. Under the new law, anyone running an agency found employing undernourished models below an as-yet undefined BODY MASS INDEX, or BMI, risks a maximum 6-month prison term and a €75,000 fine. Magazines will also have to systematically indicate when a photograph of a model has been digitally "touched up" to make her look skinnier or bulkier on pain of a €37,500 fine or up to 30 % of the sums spent on advertising (Samuel 2015).

This latest legislative move follows a nearly decade-long campaign against the so-called "size zero" models. After the public outcry over the death of Brazilian model Louisel Ramos from anorexia in 2006, Italian fashion labels Prada, Versace, and Armani have agreed to ban size-zero models from their catwalks. The Italian Chamber of Fashion did not, however, go through with a general ban, instead opting for a self-regulation code drawn up in Italy by the government and designers. In line with these commitments, larger sizes 14 and 16 would be introduced into shows, and all models younger than 16 years would also be banned.

Ironically, however, even clothing sizes tend to vary from country to country and even from store to store. There are no laws or regulations retailers must follow at the international level, but there are three European standards of clothes sizing which aim to establish a common sizing system.

At the regional level, the European Commission works on initiatives to strengthen the competiveness of the fashion and high-end industries including measures to protect intellectual property rights, to fight fake goods, and to help fashion small- and medium-sized enterprises (SMEs) access finance and stimulate creativity and innovation.

Furthermore, the EU recently passed Directive 2014/95/EU on the disclosure of nonfinancial and diversity information by certain large undertakings and groups. It requires the companies concerned to disclose in their management report information on policies, risks, and outcomes regarding environmental matters, social and employee aspects, respect for human rights, anticorruption and bribery issues, and diversity in their board of directors. With 5 million people directly employed in the fashion value chain across the EU and the sector's important contribution to the EU economy, this new directive is likely to have significant implications for the European fashion industry (European Commission 2015).

In April 2015, the Arab Fashion Council was launched as a nonprofit, international fashion organization for the Arab world with the United Arab Emirates as its hub. The Arab Fashion Council represents all 22 Arab countries, and its main objectives is to place the Arab world on the international fashion map and support designers from the region through educational initiatives. The Council's honorary

president is Mario Boselli, president of the National Chamber of Italian Fashion (Camera Nazionale della Moda Italiana or CNMI), who oversaw the adoption of CNMI's Sustainability Manifesto in 2012.

Internationally, however, there seems to be little appetite within the industry for greater coordination and self-regulation. Some attribute it to the inherent "creative spirit" of fashion, which some perceive to be constrained through greater regulation, i.e., "putting fashion in a straightjacket." Indeed, some experts point out that the fashion industry is so versatile and encounters so many sustainability issues that are different for geographic and economic situations that it might be difficult for one single body to manage those specific contexts effectively.

Others argue that there are many—indeed, too many for some—legal provisions in place already and that it is only a question of ensuring compliance with existing laws and regulations. Due to the industry's globalized supply chain, legal frameworks are of considerable complexity and involve national, regional, and international regulations and standards.

However, as other experts point out, "Ironically, legal compliance is hardly ever at the forefront of the sustainability discussion within the fashion industry" (Ravasio 2012). For example, at the international level, lack of compliance with the ILO Conventions on child labor does not prevent Uzbekistan from exporting its cotton—and companies from buying it through anonymous commodity traders. The 2015 Behind the Barcode report found that 91 % of fashion brands in Australia still do not know where their cotton comes from, and 75 % do not know the source of all their fabrics and inputs (Baptist World Aid 2015).

Furthermore, the 2013 Rana Plaza tragedy exposed the shortcomings of the current legal system, which leaves significant loopholes for unscrupulous companies, generates lack of accountability along the supply chain, and provides little or no legal recourse for the victims. Even if Bangladeshi laws were fully enforced, and even if the victims filed suits in European courts, major international companies would largely elude responsibility because they did not own the doomed factory.

Admittedly, in the 6 months since Rana Plaza, many of the brands and retailers sourcing from Bangladesh took some first steps toward a safer industry by forming the Accord on Fire and Building Safety in Bangladesh, a legally binding agreement that has been signed by more than 150 corporations from 20 countries, global and local trade unions, NGOs, and workers' rights groups. However, in May 2015 the United Nations Working Group on business and human rights reported that "the lessons of the Rana Plaza disaster have still not been learned" (UN Human Rights 2015). It is noteworthy that 79 % of American retailers who responded to the 2014 US Fashion Industry Benchmarking study continue to source from Bangladesh (Lu 2014).

By contrast, voluntary standards are a key component and integral part of current efforts by the fashion industry. However, despite the proliferation of various voluntary initiatives during the past decade, the overall level of performance on social and environmental issues in the fashion industry is still extremely poor.

4 Existing Standards and Certifications in the Fashion Industry

What sustainable fashion means and how it can be measured is still an open question. There is no single, universally accepted standard for sustainability in the fashion industry, and terms such as "eco-," "ethical," "green," "slow," and "responsible" fashion are all being used interchangeably.

There are close to 100 different labels addressing environmental or social sustainability, or consumers' health, in the textile and clothing industry. Those labels have been developed by either public institutions (national or supra-national), private certification agencies, NGOs, industry federations, or retailers themselves.

These include Global Organic Textile Standard (GOTS), Cradle to Cradle product certification, Wildlife Friendly certification scheme, and WRAP certification scheme, among others. In addition, there are numerous tools to help companies and consumers navigate this maze and gain a better understanding of sustainability in the fashion industry. Some examples are cited below.

Cradle to Cradle (C2C) Certified rewards achievement in five categories (material health, material reutilization, renewable energy and carbon management, water stewardship, and social fairness) and at five levels (basic, bronze, silver, gold, and platinum). Products certified at the basic level have achieved a minimum set of requirements that show a commitment to future assessment and optimization, whereas the platinum represents a product ideally designed and produced in accordance with C2C principles.

The GOTS is recognised as the world's leading processing standard for textiles made from organic fibres. It defines high-level environmental criteria along the entire organic textiles supply chain and requires compliance with social criteria as well.

The Wildlife Friendly Enterprise Network (WFEN) and its Certified Wildlife Friendly® label represent grassroots producers, farmers and ranchers, indigenous communities, artisans, and conservation experts. Products may be certified by Wildlife Friendly® if they contribute directly to in situ conservation of key species, production has a positive impact on the local economy, individuals or communities living with wildlife participate in the production, harvest, processing or manufacture of the product, and include a clear enforcement mechanism such that failure to follow through with required conservation actions results in immediate consequences including forfeiture of any economic reward.

WRAP Certification Programme is the largest independent facility certification program in the world mainly focused on the apparel, footwear, and sewn-products sectors. WRAP issues three levels of certification that are valid from 6 months to 2 years based on a facility's compliance with WRAP's 12 principles. These principles are based on the rule of law within each individual country and include the spirit or language of the relevant ILO conventions.

Furthermore, several initiatives aim at setting benchmarks for sustainability in the fashion industry. The most noteworthy development is the Higg Index, a

voluntary self-assessment tool that is not yet linked to any third-party certification or standard, developed by the Sustainable Apparel Coalition. The Higg Index is the most likely basis for the development of a future unified standard for the fashion industry.

5 Major Players in Fashion and Sustainability

The first decade of the twenty-first century saw a dramatic growth in the number of initiatives that seek to address sustainability issues in the fashion industry. These range from United Nations—backed initiatives to multi-stakeholder platforms and from industry-led coalitions to campaigns led by major NGOs. They also vary greatly in size, and geographic coverage.

Although it is impossible to list each and every initiative, the analysis focused on selection of key ongoing initiatives tackling various issues related to sustainability in fashion. Detailed descriptions of these initiatives are included in Annex 1. Table 1 summarizes these initiatives including their sustainability efforts, participants, geographic scope, mandate and current status, as well as whether or not fashion is their sole focus.

As Table 1 shows, there is currently no single initiative on fashion that "ticks all the boxes" in terms of participation, geographic scope, and sustainability focus, nor is there an established body at the international level that oversees the fashion industry and brings together the key players from government, private sector, and civil society.

Among UN-backed initiatives, the UN Global Compact comes closest as the global forum bringing together governments, companies, and non-business participants. However, apart from producing the first-ever sectoral guidance together with the Danish Fashion Institute, the UN Global Compact does not have a major focus on the fashion industry. Another interesting finding is that, at the moment, the only clearly government-led fashion sustainability initiative that the authors have knowledge of is Defra's Sustainable Clothing Roadmap. Nonetheless, there is considerable public-sector involvement and support for the Nordic Initiative Clean and Ethical (NICE) led by the Nordic Fashion Association.

Recent years have seen a great number of multi-stakeholder and NGO-led initiatives dealing with various sustainability issues in fashion with frequent overlaps in their overall objectives, membership, and activities. The initiative with the broadest mandate and membership thus far, as well as significant research capacity, is the UK-based Ethical Fashion Forum. However, being an NGO-led initiative focused on supporting ethical fashion brands, it appears to lack necessary government backing and mainstream industry buy-in in order to spearhead the establishment of a possible international regulatory body for the fashion industry.

Indeed, the global fashion industry could benefit from a new powerful alliance addressing the economic, social, ethical, and environmental aspects of fashion, which could help catalyze a global transition toward a more sustainable model

Table 1 Analysis of key initiatives on sustainability in fashion

	Sustainability issues			Participants			Geographic scope			Fashion focus		Mandate		Completion		
	Environmental	Social	Economic	Government	Business	Consumer	International	National	Regional	Yes	No	Voluntary	Regulatory	Already completed	In process	Not started
Un-backed																
UN Ethical Fashion Initiative	X	X	X	X	X		X		X	X		X			X	
UN Global Compact	X	X	X	X	X		X		X		X	X			X	
10YFP SCP	X	X	X	X	X		X	X			X	X			X	
Government-led																
Defra	X	X	X	X	X			X		X		X		X	X	
Industry-driven																
British Fashion Council	X	X	X		X			X		X		X			X	
Danish Fashion Institute/ NICE	X	X	X		X	X		X	X	X		X			X	
Italian Chamber of Fashion			X		X			X		X		X			X	
United States Fashion Industry Association			X	X	X			X		X		X			X	

(continued)

Table 1 (continued)

	Sustainability issues			Participants			Geographic scope			Fashion focus		Mandate		Completion		
	Environmental	Social	Economic	Government	Business	Consumer	International	National	Regional	Yes	No	Voluntary	Regulatory	Already completed	In process	Not started
Multi-stakeholder																
Better Cotton Initiative	X	X	X		X		X			X		X			X	
Ethical Fashion Forum	X	X	X	X	X	X	X			X		X			X	
Natural Capital Coalition	X		X	X	X		X			X		X			X	
Sustainable Apparel Coalition	X	X			X		X			X		X			X	
WBCSD	X	X	X	X	X		X				X	X			X	
World Economic Forum	X	X	X	X	X		X				X	X			X	

of production and consumption. It could also benefit from having a united voice in international government-led negotiations and forums, thus ensuring that the industry's interested are clearly articulated and addressed.

What is more, most—if not all—existing initiatives would be able to find a new "home" under the proposed umbrella of the fashion industry body. In addition, the new global body would bring together national and regional fashion industry associations, thus ensuring relevance and implementation at the country level similar to the UN Global Compact's Local Networks.

One possible example from which to draw inspiration is the Responsible Jewelry Council (RJC), which was set up in 2005 as a not-for-profit standards-setting and certification organization. Today, it has more than 600 member companies that span the jewelry supply chain from mine to retail.

RJC Members commit to and are independently audited against the RJC Code of Practices, an international standard on responsible business practices for diamonds, gold, and platinum-group metals. The code of practices addresses human rights, labor rights, environmental impact, mining practices, product disclosure, and many more important topics in the jewelry supply chain. RJC also works with multi-stakeholder initiatives on responsible sourcing and supply-chain due diligence. The RJC's Chain-of-Custody Certification for precious metals supports these initiatives and can be used as a tool for members and stakeholders.

One key factor behind RJC's success was solid backing by the major players in the luxury industry from the outset, which ensured broad membership from across the jewelry value chain and generated "peer pressure" to obtain RJC certification. Another important aspect was the deep engagement between RJC members and major stakeholders throughout the 18 month-long multi-stakeholder review process of the RJC Code of Practices, which ensured that its shortcomings were addressed in a transparent and inclusive manner. Although RJC has been criticized by NGOs and experts for not raising the bar high enough (Doyle and Bendell 2011), it has nonetheless generated a previously nonexistent groundswell of action across the industry, which previously had not been engaged in the sustainability agenda.

6 Toward a Responsible Fashion Council

So what would a possible future Responsible Fashion Council look like?

For this new fashion industry body to be successful, it must have a broad regulatory and advisory mandate, a transparent and clear governance structure, a critical mass of participants from across the fashion industry, and a stable and adequate funding base.

Mission: The mission of the future Responsible Fashion Council must be ambitious, far-reaching, and focused at the same time. Building on the mission and vision statements of various existing industry-led initiatives in fashion and beyond, such as the Ethical Fashion Forum, the Sustainable Apparel Coalition, and the

RJC, the possible mission of the future Responsible Fashion Council would be to act as a catalyst for sustainable performance improvement in the fashion industry from field to retail.

Mandate: The mandate of the possible Responsible Fashion Council will include issues related to:

- Representing the fashion industry in major international forums including the United Nations and the World Trade Organization (WTO);
- The development, harmonization, and enforcement of laws and regulations that affect the fashion industry in collaboration with relevant national, regional and international bodies (e.g., EU, OECD, WTO);
- Setting standards and managing associated certification schemes based on existing ones in collaboration with relevant organizations (e.g., ISO, ISEAL);
- Coordinating activities of the regional and national-level Fashion Councils with a view to bringing greater coherence among various events and initiatives (e.g., Fashion Weeks);
- Promoting cooperation among members on matters of common concern (e.g., zero discharge of hazardous chemicals, etc.);
- Implementing broad-ranging programs to improve performance standards across the industry (e.g., Higg Index) and to stimulate creativity and innovation;
- Promoting dialogue with major industry stakeholders (e.g., through regular Fashion Summits); and
- Resolving eventual disputes among members and ensuring compliance with the council's decisions.

Membership: Members should represent the entire fashion value chain from producers of raw materials to traditional and online retailers as well as major industry stakeholders such as fashion media, consumer associations, academic institutions, and national/regional industry and regulatory bodies. It would be essential to provide for equitable representation to ensure its universal appeal and relevance.

All members will sign the Code of Principles, which could be based on the existing NICE Code of Conduct and Manual, developed using the Ten Principles of the UN Global Compact. By signing the code, they will also make a time-bound commitment to achieve compliance with the code or else have their membership rescinded.

Governance: Drawing on the best practices in the area of governance, the new Responsible Fashion Council members would elect the Board, which is entrusted with the ultimate responsibility for managing the council. The Board will then appoint the Chief Executive Officer (the "CEO"), and determines the CEO's powers, duties, and responsibilities. The Board may also establish various committees (e.g., Executive, Finance, Membership) to assist it in the discharge of its duties. Members will meet at regular intervals, e.g., during a biannual General Assembly, which will also serve as a preeminent industry forum and trade show.

Funding: Each member shall pay annual dues, which will be set based on the member's annual turnover. Additional funding will be leveraged through proceeds from advertising/sponsorship at council-organized events, certification/accreditation fees, and voluntary contributions by individual members.

Platform: The next obvious question is how to make this happen, in other words, identify existing platforms that can take the lead in creating the future Responsible Fashion Council.

At the moment, at least four international bodies have the necessary clout and membership base to kick-start the process. These are the UN Global Compact, the World Business Council on Sustainable Development (WBCSD), Business for Social Responsibility (BSR), and the World Economic Forum.

As the United Nations body specifically set up to address the concerns of the private sector, the UN Global Compact would be a natural place for an international, broad-based, and legitimate initiative on fashion. Among its global membership, the UN Global Compact has more than 8000 companies and more than 4000 non-business participants including approximately 100 representing the fashion industry. In addition, it has already collaborated with the Danish Fashion Institute on the voluntary Code of Conduct for the fashion sector.

The second body, WBCSD, is a CEO-led coalition uniting companies with strong commitment to sustainability. WBCSD counts several apparel and fashion companies as members, although its membership is much more restricted compared to the UN Global Compact. Having spearheaded the development of the Greenhouse Gas Emissions Protocol, which is the most widely used carbon emissions-assessment tool for business, WBCSD is currently engaged in the development of the Natural Capital Protocol for Apparel Sector and could therefore serve as a forum for ambitious fashion industry action.

With a wide membership from across the fashion industry, BSR has touched upon fashion-related issues through its Consumer Products Industry Focus as well as its Sustainable Luxury Working Group. It would be well placed to convene fashion industry representatives around corporate responsibility issues.

Last, but not least, the World Economic Forum, best known for its annual meetings in Davos, Switzerland, is arguably the most prestigious and influential global gathering of political, business, and civil society leaders. Through its Global Agenda Councils, the forum promotes innovative thinking on critical global issues, regions, and industries as well as incubates projects, campaigns, and events for the public good. The WEF would present a credible high-level opportunity for bringing together the industry and major stakeholders as well as a platform to launch an eventual council.

At the time of writing, none of these organizations are to the authors' knowledge directly involved in an initiative focusing on the establishment of a global fashion industry body. Thus, it would seem that the opportunity is ripe for picking if the fashion industry were so inclined.

Annex 1: Mapping of Major Players in Fashion and Sustainability

UN-Led Initiatives

Ethical Fashion Initiative is a program developed by the International Trade Centre (ITC), which is an organization mandated by the United Nations Conference on Trade and Development (UNCTAD) and the WTO. The collaboration between these two international intergovernmental bodies permits ITC to effectively focus on global economic sustainability with strong guidance from its parent organizations. The goal of ITC is to improve trade capabilities of developing countries by providing assistance, guidance, and connections to the global economy and advancing international competitiveness of SMEs. ITC fosters an international and impartial perspective while strategically engaging a wide range of stakeholders and organizations on a global level, thereby sustainably developing the global value chain. Clients of ITC include policymakers, trade-support institutions, and the business community.

ITC developed the Ethical Fashion Initiative as a part of their Poor Communities Trade Programme (PCTP) with an aim to meet PCTP's intentions of reducing poverty and improving global economic competitiveness. To do so, Ethical Fashion Initiative incorporates micro-entrepreneurs from developing regions in international trade. Ethical Fashion Initiative focuses on empowering marginalized individuals and communities in Africa and Haiti with market-led career growth opportunities within the global fashion industry. The inclusive model of Ethical Fashion Initiative helps establish partnerships between artisans in Africa and Haiti with global fashion designers, brands, and companies to develop mutually beneficial business opportunities and long-term trade partnerships. The talented and renowned fashion designers in the initiative include Stella McCartney, Vivienne Westwood, and Marni, among others, as well as established brand partners such as United Arrows, Macy's, Manor Switzerland, and Myer Australia/Hands That Shape Humanity.

To accomplish the economic and social goals of the program, Ethical Fashion Initiative trains local artisans through varying stages of production while simultaneously encouraging participants to gain economic independence by adopting entrepreneur business models. The program follows precise protocols in the three key areas of Performance Enhancement, Fair Labor Compliance Monitoring, and Feedback Protocol and Social Impact Evaluation, and then implements an Impact Assessment to evaluate the effectiveness of the program's actions. Although the Ethical Fashion Initiative does not intentionally focus on a specific gender, the initiative is comprised of 90 % female teams, which work to promote long-term economic growth for women and families in regional communities. The initiative also increases gender equality in regions where such equality is often limited.

Aside from constructing social and economic advancements in the fashion sector by involving micro-entrepreneurs, Ethical Fashion Initiative also ensures that sustainable environmental needs are met by using mostly recycled and local materials with their trained artisans and but remaining carbon neutral throughout the training and production processes. Their Web site is http://www.intracen.org/itc/projects/ethical-fashion/.

UN Global Compact is a UN initiative dedicated to developing a sustainable global economy by supporting businesses in their efforts to address corporate sustainability. The UN Global Compact offers companies and organizations an ethical framework that is founded on universal principles in which to encourage innovation and collaboration among stakeholders, governments, and society. The initiative is open to a wide range of organizations and businesses with the goal of ensuring that each participating organization commits to addressing, defining, measuring, and communicating their organization's sustainable strategy. The UN Global Compact does not act as a performance or assessment tool, but rather participation is based on voluntary initiatives by a company's CEO; the company is responsible for implementing the sustainable framework and principles.

The policy framework consists of the UN Global Compact's Ten Principles, which are categorized by human rights, labor, the environment, and anti-corruption. For companies to effectively adopt the Ten Principles, the UN Global Compact developed guidelines consisting of five essential elements that, when adopted, can ensure a high level of commitment to sustainable practices and add value to business activity.

Because the UN initiates the Global Compact, the organization is able to act as a standing entity between the UN body and businesses worldwide. Thus, the UN Global Compact initiative works at both the global and local levels and connects its 85+ Local Networks to the global platform. The UN Global Compact developed the Local Networks in an effort to progress the initiative of the Ten Principles from an international perspective to a regional practice. The Local Networks also allow for businesses to develop connections and further their actions towards sustainability. The Local Networks are independent entities, yet they work closely with the UN Global Compact Headquarters.

The UN Global Compact also hosts annual events and meetings, such as the Annual Local Networks Forum, for the 85+ country networks to assemble and discuss governance of the Local Networks, as well as the triennial UN Global Compact Leaders Summit, which gathers the senior executives of company participants and stakeholders in an effort to develop strategic guidance for the continuance of the Global Compact. The Web site for the UN Global Compact is https://www.unglobalcompact.org.

10-Year Framework of Programmes for Sustainable Consumption and Production (10YFP on SCP) is a leading sustainable policy support initiative. The aim of 10YFP, operating from 2012 to 2022, is to enhance international cooperation and action of sustainable consumption and production patterns to improve

the natural resources in both developed and developing countries. The initiative was generated in response to the Marrakech Process (2003–2012) and was delivered in 2012 by the United Nations Environment Programme (UNEP) at the UN's sustainable development conference, Rio+20. The 10YFP aims to decouple economic growth from natural resource degradation, thereby advancing social equity and economic opportunity. The long-term goal of 10YFP is to mainstream sustainable consumption and production policies and strategies. The 10YFP is built on the concept of common, yet differentiated, responsibility that is to be conducted on a global level with developed countries taking the lead in the initiative.

10YFP serves as a platform for international collaboration, cooperation, innovation, and action between interested participants from all countries including governments, businesses, researchers, and financial institutions. It is the intention of 10YFP that the international cross-sector collaboration will create a unified perspective of sustainability for each regional participant.

The strategy of 10YFP is based on the foundational principle of taking only what is necessary from our natural resources. By increasing resource efficiency and promoting sustainable lifestyles, participants of the initiative can work to safeguard the needs of future generations. The key tools of this initiative are collaboration of knowledge and experiences between partnerships and providing resources for developing countries. 10YFP provides financial and technical aid to developing countries to further promote implementation of sustainable consumption and production practices.

The programs developed for the 10YFP combine policy, regulation, and voluntary instruments with clear objectives for successful performance. The initial six programs of the 10YFP include:

1. Consumer Information
2. Sustainable Lifestyle and Education
3. Sustainable Public Procurement
4. Sustainable Building and Construction
5. Sustainable Tourism Including Ecotourism
6. Sustainable Food Systems (in October 2015).

The programs are strategically guided by the five-step model of stocktaking and consultations, developing program proposals by key partners, submission of template for online final comments, validation by the Secretariat, and confirmation by the Board and launching and implementation practices. The Web site for 10YFP is http://www.unep.org/10yfp/.

Government-Led Initiatives

Defra's Sustainable Clothing Roadmap was launched in 2007 as an initiative to research the components of sustainable fashion and to create action plans toward improving the environmental and social impacts of the UK fashion industry.

Defra, the UK's governmental Department for Environmental Food and Rural Affairs, works collaboratively with fashion stakeholders, government personnel, and industry workers throughout the clothing road-mapping process to identify gaps within a product's life cycle. By identifying the gaps, Defra then creates voluntary-implementation action plans to improve the sustainable life cycle of the clothing product. Defra developed a strategic, four-part plan for conducting research and developing actions plans, which consists of the following:

- a thorough evidence review to highlight the problematic gaps in the current product lifestyle;
- the engagement of stakeholders from across the product lifecycle who have the capability of initiating change;
- collaboration with stakeholders to develop an action plan from the evidence review, which is then implemented with the intention to improve sustainability of the product; and
- the monitoring and evaluation of the action plan to assess the plan's delivery and effectiveness.

Since 2007, Defra's Clothing Roadmap initiatives have included the following:

- 2007—Mapping of Evidence of Sustainable Development Impacts That Occur in Life Cycles of Clothing
- 2008—Use: Public Understanding of Sustainable Clothing
- 2009—Use: Reducing the Environmental Impact of Clothes Cleaning
- 2009—End of Life: Maximizing Reuse and Recycling of UK Clothing and Textiles
- 2010—Sustainable Design: Promoting Sustainable Indian Textiles
- 2010—Sustainable Manufacture: Eco-efficiency of Indian Dyehouses
- 2010—Sustainable Manufacture: The Role and Business Case for Existing and Emerging Fibres in Sustainable Clothing.

The goal of each Clothing Roadmap initiative targets one of the following action areas: improving environmental performance, creating ethical traceability across the supply chain, developing market drivers, and changing consumption trends and behaviors or providing education and awareness to consumers through media and networks. The action plans were previously monitored by a steering group; however, as of April 2011, the Waste & Resources Action Programme (WRAP) formally took the lead to further direct the development and monitoring of the roadmap and actions plans. The Web site is https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69299/pb13461-clothing-actionplan-110518.pdf.

Industry-Led Initiatives

British Fashion Council (BFC) is a London-based progressive nonprofit organization devoted to advancing the British fashion economy by providing collective knowledge, experience, and fashion industry resources to British designers and the

BFC network. With creative influence, strategic development plans, and international connections, BFC leads the British fashion economy as it repositions British fashion in the global fashion economy both in the media and with buyers. BFC compartmentalizes their efforts into five strategic pillars: business, education, innovation and digital, investment, and reputation. Each pillar has an appointed strategic president to help progress the pillar.

BFC stands as an economic propeller and voice of the fashion industry by hosting key events throughout the year—such as London Fashion Week, London Collections: Men, the British Fashion Awards, and Vodafone London Fashion Weekend—as well as annual fashion forums compiled with carefully curated British fashion influencers to brainstorm the development of the British fashion industry. Aside from events, BFC also advances the economic activity of the British fashion industry by hosting fashion charities, providing supportive initiatives for designers to progress their businesses, and publishing research reports.

In terms of sustainability, BFC has made strides toward developing this sector of the fashion industry. Estethica is BFC's sustainable designer-support initiative focusing on the growth of sustainable fashion and simultaneously exposing the sustainable challenges currently faced by the fashion industry. Established in 2006, Estethica selects fashion designers to join their initiative due to a designer's sustainable dedication and innovative designs. In order to qualify, Estethica designers must adhere to one of three sustainable principles: (1) fair trade and ethical practice in production process, (2) inclusion of organic fibers, and/or (3) use of up-cycled and recycled fabrics and materials. Estethica designers are given the opportunity to showcase their work in London Fashion Week's Estethica showroom, thereby promoting their work and their name. In 2009, Estethica introduced a new one-on-one mentoring program between eco-fashion businesses and commercially successful designer companies. Also in 2009, Estethica collaborated with Defra to promote the Clothing Sustainability Roadmap at London Fashion Week. Furthermore, Estethica has produced their own publication, the Estethica Review, which promotes sustainable fashion by including editorials on sustainability issues, interviews, and fashion shoots featuring Estethica designers. Finally, Estethica developed the Estethica Veolia Re-Source competition with Central Saint Martins (CSM) University. This competition, in collaboration with Veolia Environmental Services, honors a graduate fashion student from CSM with the opportunity to compete, develop, and create sustainable opportunities in the fashion industry. The winner of this competition receives resources, mentorship and the opportunity to showcase in a London Fashion Week. The Estethica Web site is at http://www.britishfashioncouncil.com.

Danish Fashion Institute (DAFI) is a member-based organization established in 2005 by and for the Danish fashion industry to provide effective networking, development, and promotion of the Danish fashion market in the global fashion economy. DAFI established various initiatives to further the overall Danish fashion industry as well as projects to directly benefit DAFI member organizations. To enhance the Danish fashion industry, DAFI developed Copenhagen Fashion Week, an international biannual fashion show; Fashionforum.dk, an online forum

that launched in 2010 and consists of industry news and career information; Modezonen, a 3-year political initiative (2008–2011) in collaboration with academies and institutions that examines economic and responsible growth in the fashion industry; and NICE, the Nordic Initiative Clean & Ethical program initiated in 2008.

NICE is a DAFI project in collaboration with DAFI's sister organization, Nordic Fashion Association, with the goal of motivating and assisting fashion companies in their effort to implement sustainable business practices. As a pan-Nordic initiative, NICE takes precedence as the first approach of Nordic fashion industries to work collaboratively on a common project with a global perspective.

DAFI developed various programs under the NICE initiative to advance sustainable practices. NICE programs include the following:

- **The Fabric Source**: A sustainable fashion fabric and textile platform, this initiative works in collaboration with C.L.A.S.S., Source4Style, Better Cotton Initiative, and Sustainable Apparel Coalition with the intention to promote products and production practices with limited impact on the environment.
- **Copenhagen Fashion Summit**: This summit serves as the world's largest biennial sustainable fashion conference with participants consisting of international industry professionals, politicians, sustainable experts, and NGOs.
- **New Nordic Fashion**: The Nordic platform gathers transformational and sustainable initiatives taking place in the global fashion industry.
- **The NICE Consumer**: Because consumers are key to progressing fashion sustainability, NICE developed this program to increase awareness of responsible and sustainable business models in the industry.
- **Textile Waste as a Resource**: Through the collaboration of the National Institute for Consumer Research, stakeholders, and partners, this program is an ongoing research project intended to discover the value of textile waste. The program questions reverse life-cycle approaches, designers' contribution to recycling, and political authority over the matter to gain insight on the value of waste.
- **NICE 10-Year Plan**: This plan is a 10-year collaborative effort between the five Nordic countries to create and promote a sustainable and ethical Nordic fashion industry. The collaborative effort aligns the intentions of the Nordic countries, thereby generating a common vision and common actions toward sustainable practices. The initial plan examines five critical areas in need of advancement: labor and ethics, water, chemicals and dyes, carbon dioxide emissions, and waste.

DAFI developed a NICE Code of Conduct and Manual, which is used as a guide for effective implementation of their various programs. The Code of Conduct and Manual is built on the UN Global Compact's Ten Principles.

To further spread awareness and dialogue of sustainable fashion, NICE also developed Nicefashion.org, an online forum for consumers, designers, and textile companies to share resources and information. The aim of Nicefashion.org is to transform the supply chain by inspiring industry professionals to design and

supply ethically while simultaneously informing consumers on the proper care of garments and the benefit of prolonged-use of items.

The NICE Web site is at http://danishfashioninstitute.dk/en/node/757 and http://nordicfashionassociation.com/nice.

Italian Chamber of Fashion (Camera Nazionale della Moda Italiana or CNMI) is a not-for-profit organization established in 1958 and located in Milan with the intention of protecting, coordinating, and economically promoting the Italian fashion industry in the global fashion economy. To do so, the organization developed various events, including Milan Fashion Week, as well as promotional programs for young Italian designers to gain visibility within the organization's network. Members of the Italian Chamber of Fashion are allotted exclusive services and international visibility through promotional news and events.

In 2012, the Chamber released the Manifesto for the Sustainability of Italian Fashion, which has been supported by the 150 members of CNMI and by the 1500 textile and clothing companies of the industry. The manifesto states that the future of Made-in-Italy is unimaginable without considering environmental and social factors and underscores the industry's responsibility to map out a way for Italian sustainable fashion.

The manifesto contains 10 points ranging from the value chain to horizontal principles:

1. Design: design quality products that can last and minimize the impacts on ecosystems;
2. The choice of raw materials: use raw materials, materials and textiles having a high environmental and social value;
3. Procession of raw materials and production: reduce the environmental and social impacts of the activity and acknowledge everyone's contribution to the product value;
4. Distribution, marketing, and sales: include sustainability criteria at every stage of the journey of your product toward the customer;
5. Management systems: be committed to the ongoing improvement of the business performance;
6. Fashion and national production system: support the community as well as Made-in-Italy products;
7. Business ethics: integrate universal values into your brand;
8. Transparency: communicate to stakeholders your commitment to sustainability in a transparent way;
9. Education: foster ethics and sustainability with consumers and all the other stakeholders;
10. Make the manifesto live: the manifesto emphasizes CNMI's commitment to publicize it and increase the number of its supporters as well as to identify mechanisms to recognize good practices and extend partnerships with institutions.

The manifesto can be found at this Web site: http://www.cameramoda.it/en/.

United States Fashion Industry Association (USFIA) is a government-supported, industry-led fashion association comprised of US government partners, textile brands, apparel brands, retailers, importers, and wholesalers that conduct business domestically and globally. USFIA acts as a representative body and respectful voice before the US government, international governments, and stakeholders. Formally known as the United States Association of Importers of Textiles and Apparel Products (USA-ITA), the organization was initially formed in 1989 with the intention of eliminating the global apparel quota system and has since evolved the organization's objective to correspond with the needs of the fashion industry.

Currently, USFIA aims its initiatives toward eliminating tariff and nontariff barriers in place that obstruct free trade and progressive economic opportunities. USFIA collaborates with members to understand the needs of the fashion industry while simultaneously communicating with government partners to develop creative solutions for the industry. USFIA encourages collaboration between their member organizations as well as provides their members with resources, events, and conferences to enable members with competitive business approaches in the fashion industry. USFIA also ensures members are informed of current and future regulatory challenges facing the industry. Some sustainable initiatives the organization has provided include a discussion led by sustainable speaker Brian Whitters of Global Sustainability Services at the 2012 USA-ITA West Coast Seminar, information regarding social compliance and sustainability programs in a 2013 newsletter, a Cotton LEADS webinar in 2014 regarding responsible cotton production, and access to a labor compliance webinar in early 2015 showcasing a discussion led by Avedis Seferian of Worldwide Responsible Accredited Production (WRAP). The USIFA Web site is here: http://www.usfashionindustry.com.

Zero Discharge of Hazardous Chemicals (ZDHC): In 2011, a group of major apparel and footwear brands and retailers made a shared commitment to help lead the industry toward the zero discharge of hazardous chemicals by 2020. As a part of the commitment and first steps toward ZDHC, the group of brands published a Joint Roadmap in November 2011. The document demonstrates the group's collaborative efforts in leading the apparel and footwear industry towards ZDHC for all products across all pathways by 2020. The ZDCH Web site is http://www.roadmaptozero.com/.

Multi-stakeholder Platforms

Better Cotton Initiative (BCI) is a voluntary, member-based, nonprofit organization headquartered in Geneva that has revised global standards of cotton production with the intention of reducing negative environmental impacts associated with cotton production and safeguard the livelihoods of cotton farmers. Consisting of global stakeholders, organizations, and individuals across the cotton supply chain, BCI intends to improve and transform cotton production on a global scale

by focusing on social and environmental initiatives with the goal of establishing Better Cotton as a mainstream product. To do so, BCI developed the Better Cotton Standard System, which covers the three pillars of sustainability: economic, environmental, and social pillars. There are six components to the implementation of the Better Cotton Standard System:

1. **Production Principles Criteria**: BCI created the universal definition of Better Cotton through specific criteria to include farmers who minimize the harmful impact created by crop-protection practices, incorporate water efficiency, care for soil health, conserve the natural environment, preserve the quality of fiber, and encourage decent work.
2. **Capacity Building**: BCI works with trained and endorsed Implementation Partners who directly assist farmers in creating change at the farm level. Implementation Partners are monitored regularly and provide BCI with a high level of efficacy.
3. **Assurance Programme**: To ensure advancement in the farming industry, BCI farmers are expected to continue learning and growing. Initially BCI farmers must reach the BCI minimum requirements to receive the BCI license to grow Better Cotton. After a farmer reaches a specified amount of Better Cotton growth, the farmer must continue to meet improvement requirements to remain a Better Cotton producer.
4. **Chain of Custody**: This stage develops BCI's authenticity by requiring documentation for a change in cotton capital ownership. BCI's Better Cotton traceability tools are available online for members to easily access.
5. **Claims Framework**: Aside from guidance on Better Cotton production, members also benefit from BCI by association with the initiative. BCI allows members to make credible claims regarding their production of Better Cotton and the activities involved. Claims can be applied at the corporate, brand, or in-store levels.
6. **Results and Impact**: BCI created the Results Indicator, a quantitative tool used to measure differences between Better Cotton farms and conventional farms. This information is used for the Assurance Programme. BCI also uses case studies to reference against the Results Indicator.

Currently, BCI is partnering with academic institutions to research and better comprehend the environmental and social impacts of Better Cotton implementation. The BCI Web site is http://bettercotton.org.

BSR is a global nonprofit organization that works with its network of more than 250 member companies to build a just and sustainable world. From its offices in Asia, Europe, and North America, BSR develops sustainable business strategies and solutions through consulting, research, and cross-sector collaboration. Through its Consumer Products Industry Focus, BSR has conducted an analysis of Bangladesh's ready-to-made garment sector. Through its Sustainable Luxury Working Group, BSR provides a forum for dialogue among luxury sector actors and stakeholders to pre-emptively identify, understand, and prioritize emerging sustainability issues in luxury-industry value chains. It acts as an incubator

for co-creating broad-based sustainable solutions via collaboration including with relevant stakeholders and complementary initiatives. It coordinates common approaches for implementing solutions to avoid duplication, maximize economies of scale, and ensure applicability and usefulness for business. The BSR Web site is http://www.bsr.org.

Ethical Fashion Forum (EFF) is the industry body for sustainable fashion representing more than 6000 members in more than 100 countries. EFF is a not-for-profit organization focused on poverty reduction, education, and the environment in relation to the fashion industry. It is run by a representative board.

The Ethical Fashion Forum aims to develop a collaborative movement that will transform social and environmental standards in the fashion industry within a decade. In line with its vision, the EFF goals are as follows:

- The eradication of exploitation, hardship, and environmental damage from supply chains to the fashion industry and the practices of fashion businesses.
- The creation of a movement led by the fashion industry, for the fashion industry, which upholds and practices more than doing no harm; it is actively striving to add value for people and the environment across the entire industry sector.
- Industry training and resources made available that ensure that every single UK fashion business is aware of how they can become more sustainable, why it is important, and where to find the tools to do so.
- The raising of consumer awareness in relation to sustainable fashion.
- The creation of a clear and consistent system for communication of ethical standards by fashion businesses.
- A system of standards and regulations ruling out exploitative practices in the fashion industry.
- Broad and fundamental change toward better practices in the fashion industry within the next 10 years.
- The creation of a model and precedent for industry change that can be drawn from and built upon by other industries.

To facilitate sustainability in the fashion sector, the EFF has developed the SOURCE: The Global Platform for Sustainable Fashion. Including a sourcing and business database, online network, business intelligence platform, and global programme of events, the SOURCE offers a sustainability tool kit for the fashion sector. The EFF Web site is http://www.ethicalfashionforum.com/.

Natural Capital Coalition (NCC) has a mission of amalgamating the various approaches of natural capital preservation into one universal vision. The coalition is comprised of stakeholders in the government, financial and reporting industries. NCC's focus is on research development and stakeholder engagement in order to establish standardized methods of accountability and valuation in business practices. Overall, NCC understands the value of preserving natural capital recognizing that natural capital is the foundation of all economic productivity and is thus necessary for sustaining operable businesses.

In an effort to develop a standardized approach of natural capital preservation, NCC developed the Natural Capital Protocol and Sector Guides, including

the Apparel Sector Guide, which work to generate acceptable principles of natural capital accounting. The combined protocol and sector guide provide a compelling case for implementing natural capital valuation into an organization's strategic planning process. The Protocol and Sector Guides are available globally and across various business levels including the organization/corporate level, the project/site level, and the product/process level.

The World Business Council for Sustainable Development created NCC's protocol along with a selected Technical Group consisting of various international businesses, NGOs, and academic institutions. The protocol provides companies with natural capital accounting counsel including a step-by-step guide to qualitative, quantitative and monetary valuation. The protocol measures the direct and indirect impacts that an organization may have on natural capital, the organization's dependency level of natural capital, and methodology suggestions to help alleviate negative outcomes from natural capital overuse.

The Sector Guides develop the case for specific industries, such as the Apparel Sector, with compelling information that displays the relevance of natural capital to that industry as well as the benefits of developing strategic business approaches of measuring, evaluating, and valuing natural capital to further an operable industry. The guide also provides counsel for adapting NCC's protocol to a specified industry. The Apparel Sector Guide is one of the first NCC sector guides to be produced due to the intricate and immense impacts from the fashion industry. The Apparel Sector Guide was developed by TruCost, with a team of experts to review the guides.

NCC's efforts for sustainability—including the production of a high-level guide for senior management teams to review and adopt, which will provide leaders with a clear understanding of the relevance of including natural capital preservation in their business strategy—are still in progress. NCC's Web site is http://www.naturalcapitalcoalition.org/projects/the-natural-capital-protocol.html.

Sustainable Apparel Coalition (SAC) is a San Francisco-based coalition founded by sustainability leaders with the goal of directing the apparel, footwear, and home textile industries toward those that do not negatively impact the environment or the people and communities associated with such production. SAC addresses specifically targeted environmental issues including water use and quality, energy and emissions, chemical and toxicity, waste, and social and labor sectors. The coalition's membership is comprised of nearly one third of the global market share for clothing production and is a self-initiated organization. SAC's intention is to create an industry-wide shared vision of sustainability by developing a common language in the industry that can serve to alleviate negative environmental and social impacts through a common evaluative approach of product sustainability performance.

SAC developed a qualitative analysis index called the Higg Index, which is a publicly available self-assessment tool used by textile producers to measure the environmental and social performance of apparel products and to identify ways to improve products and production processes. SAC's theory is that with effective self-assessment and modifications to the production process, an organization can

strengthen their company value with innovative, sustainable practices. Since the emergence of the Higg Index 1.0 in 2012, SAC has enhanced the Higg Index's measuring effectiveness and introduced the Higg Index 2.0 in 2013, which expanded the scope from measuring solely environmental concerns to a scope that includes social concerns and footwear production as well. Overall, the Higg Index is designed with three assessment tools, called "modules," which evaluate the impacts of three textile-supply sectors: facility, brand, and product.

- **Facility Tools**: These ready-to-use tools are appropriate for facilities, vendors, or manufacturers in both environmental and social modules to assess the performance of material, packaging, and manufacturing facilities.
- **Brand Tools**: The brand tools assess product-specific environmental and social practices at the brand level.
- **Product Tools**: The product tools assess product-specific impacts. The two product tools include the Rapid Design Module (RDM) and the Materials Sustainability Index (MSI) Data Explorer. RDM is used as a prototype to help guide an organization toward sustainable product design with accurate information and the use of the decision-support framework. MSI is an online platform that expands on the RDM methodology allowing users to understand the data collected from RDM and the scoring of the quality of materials.

The modules allow for increased efficiency and transparency in sustainable practices throughout the supply chain due to rapid understanding of an organization's practices and environmental hot spots for improvement. SAC also provides companies with a platform for engagement with the coalition's stakeholders to create decisive and innovative measures toward alleviating current environmental and social instability. To date, the Higg Index 2.0 does not include an assessment of retail activity; however, such consideration may be included in future versions of the Higg Index. The SAC Web site is http://apparelcoalition.org.

World Business Council for Sustainable Development (WBCSD) is a CEO-led organization uniting progressive companies with a mission to develop sustainable solutions for various global challenges. Headquartered in Geneva, the Council consists of CEOs and board executives of more than 200 participating companies. The overall goal of WBCSD is to lead businesses to valuable sustainable solutions and recognize businesses for implementing such efforts. Council members work across a range of industry sectors, geographies, and value chains, thereby activating diverse discussions and perspectives on sustainability issues and experiences.

WBCSD is one of the most respected and leading voices for sustainability due to its multilateral collaboration with considerable involvement from the UN, World Bank, and UNFCCC. The involvement of such organizations allows the conversations generated from WBCSD to reach influential global platforms such as the UN Climate Summit and COP negotiations. WBCSD Global Network includes more than 65 participating companies and partner organizations with two thirds of the participants representing developing economies.

The two programs developed by WBCSD, Vision 2050 and Action2020, work together to promote the long-term sustainable goals of the organization.

The Vision 2050 report is a sustainable report compiled by 29 leading global companies across 14 varying industries and includes dialogue from more than 200 companies and stakeholders representing approximately 20 countries. From the Vision 2050 report, WBCSD generated the long-term sustainable goal of developing a pathway for a livable world for 9 million people and within our planet's resources by 2050.

To strategically meet the Vision 2050 goal, WBCSD and Action2020 member companies developed Nine Priority Areas with specific goals, known as the societal "must-haves" that can be attained by adopting specific business solutions. The Nine Priority Areas are Climate Change; Release of Nutrient Elements; Ecosystems; Exposure to Harmful Substances; Water; Basic Needs and Rights; Skills and Employment; Sustainable Lifestyles; and Food, Feed, Fibre, and Biofuels. The WBCSD Web site is http://www.wbcsd.org.

World Economic Forum is an independent and impartial not-for-profit organization operating as an officially recognized foundation for public and private sectors to cooperate on global sustainable solutions. Headquartered in Geneva, the World Economic Forum provides an integrated platform for international politicians, businesses, academia, and other society leaders to engage in discussion regarding challenges and solutions to the world's most critical issues.

The forum fosters collaboration through integrated meetings, research networks, and digital discourse focusing on the 10 categorized projects—Agriculture and Food Security; Employment, Skills and Human Capital; Future of the Global Financial System; Global Gender Parity; Long-Term Investing, Infrastructure and Economic Development; Economic Growth with Social Inclusion; Environment and Resource Security; Future of the Internet; International Trade and Investment—as well as other forum projects.

World Economic Forum also developed the World Economic Forum Academy. The online platform and collaborative peer-to-peer community of innovators, experts, and practitioners provides a holistic view on the topics of sustainable intelligence and strategic foresight. The subscription-based academy also acts as a navigational guide for applying and taking action on sustainability. The World Economic Forum Web site is at http://www.weforum.org.

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Innovation for a Sustainable Fashion Industry: A Design Focused Approach Toward the Development of New Business Models

Anika Kozlowski, Cory Searcy and Michal Bardecki

Abstract This chapter proposes a normative sustainable business model composed of the elements in which a fashion brand would engage. These elements include product sustainability, sustainable supply-chain management, design practice, business innovation, and consumer engagement. The model adopts a systems thinking approach in identifying elements within the fashion system and their organization. Typically within the field of sustainable fashion, the effort has been on technological modifications within the supply chain. Although these efforts can significantly reduce environmental impacts, the outsourced manufacturers are in control, thus limiting the influence of a fashion brand. The emphasis in the model is on those elements within the direct control of the business, particularly design practice. The holistic approach looks at how the design practice can evolve to increase sustainability within the supply chain, the product, innovative business models, and consumer consumption. By shifting focus to the design process, products can be designed to influence consumer behaviour, induce sustainable consumption, and reduce impact from use. Looking beyond the supply chain to include consumer behaviour, the development of sustainability-driven business models can be fostered in support of sustainable production and consumption. This research contributes an analysis of how the design process can support the development of new and competitive business models for a sustainable fashion industry.

Keywords Sustainable fashion · Innovation · New business models

1 Introduction

Sustainability is one of the key issues facing the fashion industry today. This is due to the complex nature of the negative environmental and social impacts associated with fashion apparel throughout its life cycle from production to consumption

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(acquisition, use, and disposal). The industry is composed of many actors forming one of the longest and most complicated industrial chains involving agriculture, chemical fibre production, textile and apparel manufacturing, retail and service sectors, second-hand markets, and waste management (Fletcher 2008; DEFRA 2011). There has been a dramatic reorganization in the industry, especially in supply-chain management, during the last 30 years since its shift to offshore production. Developments within the supply chain have typically focused on technological production efficiencies and cost in order to maintain low-priced products. This has left the current fashion production system to be based on traditional practices and commercial technologies that are not sustainable (Tseng et al. 2013).

What was once a linear system with clear delineation between supplier and customer has developed into a virtual, global, and fragmented system where suppliers have multiple functions (Abernathy et al. 1999; Armstrong and LeHew 2011; Fletcher and Groese 2012). Globalization and the delocalization of production to nations with developing economies, particularly Asia, have eliminated supply-chain transparency and encouraged polluting behaviours (Abernathy et al. 1999; Christmann and Taylor 2001; Welters 2008; Steinberger et al. 2009; Fletcher 2008). The rapid industrialization of Asia has led to exploitation of the environment and labour forces while causing significant pollution problems to air, land, and water due to weak environmental regulation.

Although awareness of the environmental and social impacts and research into sustainable fashion have increased over the last decade, questions remain as to how the concept of sustainability fits within current fashion business, design practices, and consumer consumption. Research has primarily focused on improving supply-chain sustainability through the development of cleaner production technologies (Thorpe 2010).

Addressing sustainability issues in the fashion industry is extremely challenging due to the production–consumption relationship. The globalization of apparel supply chains aided the development of the "fast fashion" business model, which enables consumers to buy fashion apparel in never-before-seen quantities (Gwilt and Rissanen 2011; Siegle 2011; Fletcher and Groese 2012). Fast fashion is characterized by a quick response system or just-in-time manufacturing that allows for short production and distribution lead times enabling a close match of supply with uncertain demand. This supports the retailing of low-cost highly fashionable apparel products that mimic high fashion luxury runway collections (Cachon and Swinney 2011; Fletcher and Groese 2012; Joy et al. 2012). This economic accessibility, although extremely profitable, neglects both the quality of materials used and construction, subsequently increasing the disposability of fashion products (Gwilt and Rissanen 2011; Siegle 2011). Global brands have wielded their economic power and economies of scale to prioritize low price points and create mass availability and volume purchasing while forcing out of business those small producers who cannot compete (Fletcher and Groese 2012). Consumerism is now based on rapid product acquisition and obsolescence and a continually increasing throughput of resources (Fletcher 2010; Fletcher and Groese 2012), and it is exclusively structured around the traditional capitalistic business model. Costs to

society at large from mass production are experienced through increased pollution, resource depletion, and climate change (Esslinger 2011; Fletcher and Groese 2012).

Awareness by key stakeholders of the negative environmental and social impacts of the fashion industry has steadily increased during the last decade. In particular, governments, media, and activists are quite adept at targeting companies to become responsible and accountable for the social consequences of their activities (Porter and Kramer 2006). This increased awareness and concern of key stakeholders has led to a gradual response by the fashion industry to improve the environmental and social impacts of the manufacturing processes (Wong and Taylor 2000; Chen and Burns 2006; Dickson and Eckman 2006; Birtwistle and Moore 2007; Goworek 2011). The response has resulted in corporate social responsibility (CSR) and the principles of sustainability being increasingly implemented into the business strategies of fashion apparel brands to maintain healthy relationships with their stakeholders (Dickson et al. 2009). For the purpose of this chapter, CSR is the application of strategies by a fashion brand to develop sustainability within their brand.

However, management often develops most of its societal engagement in relation to the economic goals of a company because companies are founded and run for economic purposes (Parnell 2008), with social and environmental considerations being secondary (Freeman and Gilbert 1992), and reiterate the crucial importance of corporate sustainability strategies (Schaltegger et al. 2011). The challenge of CSR and sustainability strategies is to recognize the equal importance of financial sustainability as well as social and environmental sustainability (Parnell 2008). This integration is the target and purpose of the business case for sustainability (Schaltegger et al. 2011; Gwilt and Rissanen 2011).

The supply chain, the production processes, and the fashion apparel products are the elements that have predominated strategies in achieving sustainability within the fashion industry. However, the role of design and business practices, along with consumer behaviours and consumption, must be equally acknowledged. Systematic change of the fashion industry toward a more sustainable future requires a holistic approach (Fletcher and Groese 2012) encompassing all facets and stakeholders. To achieve global sustainability, there must be a fundamental shift in how we produce and consume (Perrels 2008; Pettersen and Boks 2008; Hoffmann 2012). Companies bear a great deal of responsibility for existing production/consumption patterns and can contribute to the change of these patterns through innovations to their products and services (Hoffmann 2012).

Within the industry, there is a growing consensus that sustainability is only possible through a radical transformation of the fashion system as a whole (Kemp 2008; Fletcher and Groese 2012) and that sustainability initiatives must move beyond the supply chain to other areas such as business and product innovation and consumer engagement. This chapter therefore proposes a normative sustainable business model (SBM) composed of the elements in which a fashion apparel brand would engage as they develop sustainability within a fashion brand. These elements include product sustainability, sustainable supply-chain management,

design practice, business innovation, and consumer engagement. The model adopts a systems approach where all elements within the system must be engaged in the shift toward sustainability. The emphasis of this model is on the elements within the direct control of the business, such as design practice, product sustainability, and business innovation, as the fashion apparel brand is the link between production and consumption.

Current sustainability strategies employed by business are deficient in three ways: There is a lack of focus on the consumer; they do not acknowledge the threats of global over-consumption; and they do not take a holistic approach (Sheth et al. 2011). By shifting the focus to the design process, products can be designed to influence consumer behaviour, induce sustainable consumption, and reduce impact from use. Consumer behaviour can have a significant influence on the environmental and social impact of clothing (Fletcher 2008; WBCSD 2008). By focusing on consumer behaviour, the development of innovative sustainability-driven business models can be fostered in support of sustainable production and consumption. One of the most important tools to gain a sustainable competitive advantage is innovation and an innovation-management approach (Teece 2010). This chapter therefore suggests a focus on design practice to translate the principles of sustainability in shaping the development of innovative sustainability-driven business models and inducing sustainable consumption.

2 The Need for a Sustainable Business Model in the Fashion Industry

Teece (2010) defines a business model as the articulation of the logic while providing data and other evidence to demonstrate how a business creates and delivers value to customers. The dominant business model today is based on the neoclassical economic theory, which values the maximization of profits as a primary obligation to shareholders (Stormer 2003; Stubbs and Cocklin 2008). This development of the industrial era functions under a supply side–driven logic that is no longer viable in today's social climate (Teece 2010). The development of sustainability within fashion requires a systematic and holistic approach that considers all stakeholders within the fashion system (Kozlowski et al. 2012), therefore highlighting the need for a business model that has considerations beyond shareholder obligations.

The dominant business model in the apparel industry for the past two decades has been reliant on the perpetual production and consumption of vast amounts of apparel. This business model benefits from large economies of scale that maximize profits with significant negative environmental and social impacts creating an unsustainable apparel system (Fletcher and Grose 2012). Current business models,

from a strategic management perspective, primarily focus on customer value creation (Wirtz 2011) and shareholder obligations (Stormer 2003; Stubbs and Cocklin 2008).

A company looking to develop sustainability and increase sustainability performance would have to transform traditional business models (Schaltegger et al. 2011). Business model modifications for both new and existing models must accommodate the growing relevance of environmental and social issues in business strategies (Schaltegger et al. 2011), thereby driving innovation. However, the shift in the business mandate to sustainability and CSR has yet to occur. Sustainability and CSR continue to be justified through the lens of the neoclassical economic theory (Freeman and Gilbert 1992).

Many companies are beginning to integrate the principles of sustainability into their business strategies (Gobble 2012). Research shows the integration and development of sustainability within business produces organizational and technological innovations that yield both top- and bottom-line returns (Nidumolu et al. 2009). Innovations are deliberate interventions designed to initiate and establish future developments concerning technology, economics, and social practices. Smart, top-performing companies are using sustainability as a frontier driver for innovation (Nidumolu et al. 2009) and as a source for opportunity and long-term competitive advantage (Verganti 2009; Gobble 2012). Therefore, business models can be the strategic leadership asset to drive and integrate sustainability and innovation within an organization (Chesbrough 2010; Schaltegger et al. 2011). Mitchell and Coles (2003) analyzed 100 outperforming public companies and found one common feature:

> … it was clear that perennial top performers were frequently making fundamental improvements in several dimensions… of their business models at once for serving their customers, end users and other important stakeholders (such as employees, partners, suppliers, distributors, lenders, shareholders, and the communities the company serves). The most effective companies were making these multidimensional business model shifts every two to four years. (Mitchell and Coles 2003, p. 16)

Innovation will therefore play a key role in delivering solutions that are both sustainable and competitive (WBCSD 2010; Gobble 2012). This reinforces the notion that a transformation to sustainable business models is key for a sustainable fashion industry and that they must continue to evolve. This is necessary for fashion businesses to maintain competitive advantage and remain viable in this changing global market as they struggle to deal effectively with increasing social and environmental impacts and deliver consumer value through innovation. CSR and the principles of sustainability can form the core of business models because only companies that make sustainability a goal achieve a competitive advantage. That means rethinking business models as well as products, technologies, and processes (Nidumolu et al. 2009).

3 A Sustainable Business Model for the Fashion Industry

This chapter proposes a normative theoretical framework composed of the elements in which a fashion brand could engage into to develop sustainability within their business. The model (Fig. 1) is based on a systems approach. Meadows (2008) describes a system as an interconnected set of elements that are coherently organized in a manner that achieves something and creates its own pattern of behavior over time. Application of Meadows' definition to the apparel industry is logical because the apparel industry is a functioning system with interconnected elements and its own set of distinct behavioural patterns. Meadows explains that once the structure of a system is identified and understood, the relationship between structure and behaviour can be explored. Understanding the relationship between structure and behavior allows for an understanding of how the system works, what makes the system produce poor results, and how to alter the system for better behaviour patterns (Meadows 2008)

The model (Fig. 1) is intended to promote the development of sustainable business models (SBM) in support of a sustainable fashion system. The key driver of this proposed SBM is the implementation of innovative socially relevant design (ISRD) within the fashion apparel design practice, which looks to redefine the role of design and designer. ISRD is a holistic multidimensional, cross-disciplinary collaborative approach to fashion design that at its core has a socially relevant purpose. The context of the term "socially relevant" allows for the inclusion of a diverse set of factors beyond the three dimensions of sustainability to be considered with the design practice such as factors such as stylistic and/or technological

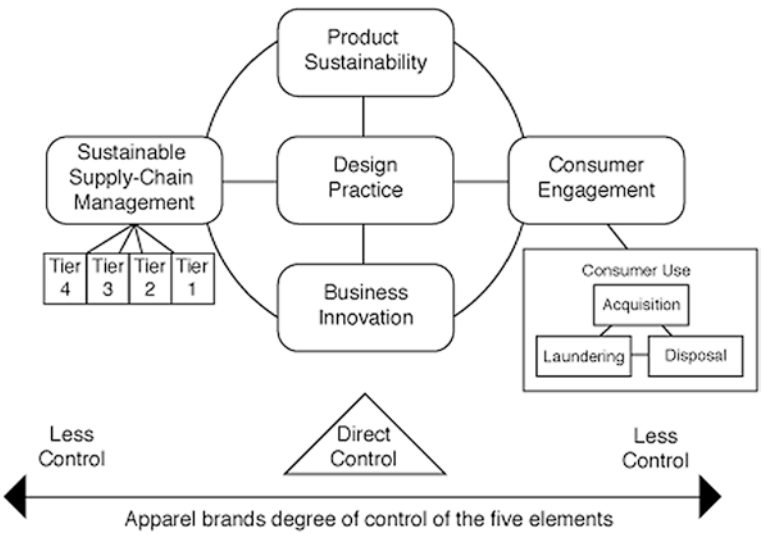

Fig. 1 Innovative design-driven sustainable business model

innovation and cultural and global trends in developing sustainability within a fashion apparel brand. The idea of social relevance to sustainability is based on the rationale that value is a fundamental aspect of sustainability (Laszlo 2008) and sustainable design (Chapman 2005; Tseng and Ho 2013). Innovation arises from good design, and innovation can drive sustainability. What is considered to be "good design" remains a subjective notion, but it can be attributed to how relevant and valuable design is within society, to a fashion brand, and/or to consumers. Value in turn is created through socially relevant factors such as quality, aesthetics, taste, novelty, trends, culture, style, ethics, emotional durability, symbolism, and technological performance.

The model is organized by the degree of control that a fashion brand has over the various elements. Elements such as design practice, business innovation, and product sustainability are directly controlled by an apparel brand. Brands have varying degrees of influence and control over supply-chain sustainability and consumer engagement. The supply chain consists of phases from raw-material acquisition to the retail environment. Apparel brands typically subcontract manufacturing of fashion products to suppliers who are usually located in developing nations (Jones 2006; Fletcher 2008; Sherman 2009). The supply chain can be further segmented into tiers as illustrated in Fig. 1. Apparel brands typically organize suppliers into tiers for organizational purposes. Tier 1 (manufacturing) is where apparel brands will typically have a moderate to high influence. In tier 2 (outsourced processes), tier 3 (textile and fibre processing/mills), and tier 4 (raw materials), the lack of control increases and transparency decreases (Jones 2006; Fletcher 2008; Lim and Phillips 2008). The difficulty in exerting influence over tier-2 through -4 suppliers is that apparel brands do not deal directly with them, a disadvantage of a fragmented supply chain. Moving toward the other end of the value chain, once a product is sold to the consumer, the apparel brand virtually loses all control over the rest of the product life cycle. This lack of influence and control over apparel products end-of-life creates challenges in implementing sustainability initiatives and actions.

Although the apparel systems model is holistic in its approach, it is imperative to have a complete understanding of the five elements. Addressing problems within the individual elements, while recognizing its interconnections in the system, a new system can begin to be developed. Addressing the problems within a single element will not significantly alter the system. If a product is sustainable, but the system itself is not sustainable, the full potential of the product is underutilized. For example, a biodegradable t-shirt cannot simply be discarded but must be composted under ideal conditions (Fletcher and Grose 2012). Benefits arising from improvements to the sustainability of apparel products are subject to restrictions by the production system, the business models that market and sell apparel products, and the behaviours of consumers who purchase these apparel products. Therefore, all elements within the apparel system require transformation to achieve whole-system transformation.

The approach of this sustainable business model has foundations in a systems-level description. Stubbs and Cocklin (2008) note SBMs can be conceptualized

in various ways. Just as there is no consensual definition as to what sustainable fashion is, there are no sufficient answers as to what a sustainable business model might be (Stubbs and Cocklin 2008). What this does offer is the flexibility and freedom to develop sustainability within a fashion brand by fostering design-driven innovation. Therefore, the model emphasizes the need for fashion brands and designers to challenge the bounds of traditional design practice.

3.1 Design Practice

Modifications in the design phase and product development processes are key phases: Decisions made at this stage determine more than 70 % of the product development costs and manufacturing and significantly impact end-of-life management (Waage 2007). These processes present many opportunities for designers to introduce and integrate the dimensions of sustainability (Dickson et al. 2009; Armstrong and LeHew 2011). However, sustainable approaches to design and product development are still relatively new (Walker 2006). Technological efficiencies within the supply chain remain the dominant output of environmentally responsible considerations made during design and product development.

The Centre for Sustainable Fashion (2008) found that although designers are becoming more aware of and rethinking their role in creating sustainable fashion, they are finding it difficult to work within a sustainable framework. This could be due to the fact that research shows characteristics such as colour, style, price, and fit, as opposed to social or environmental considerations, are the strongest predictors for apparel acquisition by consumers (Dickson and Littrell 1996; Kim and Damhorst 1998, 1999; Shaw and Tomolillo 2004; Joergens 2006). Predefined product types whose reliance for differentiation and value rests solely on either technological or stylistic indicators limits the user's emotional experience. The moment a newer model is released ensures perceived product obsolescence and loss of meaning (Chapman 2005).

A challenge for designers will be to approach design with a systems view where the relationships between producers and consumers are better understood. It is not only important for designers to consider consumer behaviours and patterns but to also explore options in engaging the consumer to develop greater meaning and value to both product and process. Papanek (1971) advocated that the most important aspect about design was how it related to people. By repositioning and engaging consumers within a collaborative action role, they can participate in an open-ended design process and an open-source design system. Consumers evolve to active subjects within the process, becoming co-designers or co-producers, thereby changing the power relationship between consumers and fashion creators (Fletcher and Grose 2012; Meroni 2012). This allows for the nurturing of new relationships and trust and for the consumer to have more control over the institutions and technologies that affect their lives (Fletcher and Grose 2012).

The use of a concept such as ISRD can aid designers to evolve and integrate a holistic multidimensional, cross-disciplinary collaborative approach to sustainable fashion apparel as a system. ISRD looks at all socially relevant issues such as environmental responsibility, labour impacts, consumer engagement and consumption, technological innovations, social movements and trends, co-creation, social media, stakeholders, and economical aspects. The idea is to not limit the designer to "aesthetic" design inspiration but to explore socially relevant issues and developments beyond the fashion industry. "The way designers conceive of the nature and purpose of design will affect their practice" (Galle 2011: 81). There is no "right way" to design, especially within a creative field such as fashion. There is a common set of elements or stages a designer will employ; however, these are adaptable and unique to individual designers (Stone 2012). Papanek (1971) states, "design has become the most powerful tool with which man shapes his tools and environments and, by extension, society and himself" (p. ix). Design in essence can become a tool to drive innovation in sustainable business, product, and consumption while challenging the boundaries of the design practice. Although concepts such as designing for "slow fashion" promotes the purchase of fashion apparel that is of high quality, durable, and generally made locally in small production runs, it does not address the issue of over-consumption.

Media platforms such as Instagram, Twitter, and Facebook allow for new ways to engage with consumers, collect data, and develop brand loyalty. Information collected along with the higher level of consumer engagement offers opportunities to develop sustainable business models through innovation and design. A better understanding of consumer behaviour with fashion apparel and a higher level of engagement can drive fashion design in a new direction, one built on the principles of developing a sustainable fashion system. The key challenge for designers will be to design fashion apparel that can alter consumer behaviours in favor of sustainability while fulfilling the desire of fashion participation. Technological advancements, such as 3D or 4D printing, could play a fundamental role in developing sustainable business models, new services and products. The ISRD approach promotes cross-disciplinary product development where fashion designers are encouraged to work with non-designers, such as textile chemists, scientists, artists, and/or biomechanical engineers, to create innovative sustainable products, SBM, and new services.

3.2 Product Sustainability

Product sustainability is the easiest aspect to alter for an apparel brand because this is where a company has the most and direct control through design and product development (Armstrong and LeHew 2011; Fletcher and Grose 2012). Transforming product sustainability may be achieved via various aspects such as fibre/textile selection, processing methods, use behaviours, and reuse/recycle strategies. Fibre/textile selection is often the first step that designers and product

developers can take in reducing the environmental impact of a garment because it is quick and can be on the sales floor within months. Within the field of sustainable product design, the focus has been strongly on the supply side. This includes solutions to lower impacts through design-for-disassembly, recyclability, use of environmentally conscious materials, and dematerialization (Wever et al. 2008). Environmentally preferred fibres/textiles can significantly reduce the environmental impact and increase the resourcefulness of an apparel product throughout the garment's life-cycle without change to design practice or product development processes (Graedel and Allenby 1995; Ljungberg 2007; Fletcher and Grose 2012). Costs are lowered through the development of environmentally friendly products due to decreased inputs. This process yields better products and enables new business opportunities (Nidumolu et al. 2009).

Alternative fibre/material selection can be limited by the supply chain and the business system to which the fibres/materials belong. Offering consumers an alternative choice is not dealing with the deeper issues such as increasing consumption rates, patterns, and behaviours (Fletcher and Grose 2012). Verganti (2009) highlights an interesting aspect concerning products: People do not buy products, they buy meanings. Verganti suggests that firms look beyond the performance and aesthetic functions of a product to better understand the meaning users attribute to products. A better understanding of attributed meanings can drive innovation in creating sustainable products, value, and new business opportunities. Champan (2009) also advocates that by creating an emotional attachment through value and meaning can lead to greater product durability and longevity or a more sustainable product. A product can be perceived to be irreplaceable due to meaning, value, and emotional attachment (Chapman 2005). Meaning and emotional attachment can be created through strategies such as customization or co-creation with the user (Chapman 2009), which alternatively can create new business opportunities for firms.

Product sustainability is quite variable because it can range from a simple shift to an environmentally preferred material to altering product characteristics such as how a consumer may use the product and product end-of-life strategies. However, the underlying goal is the need to move beyond life extension to resolve issues concerning use and disposal.

3.3 Consumer Engagement

Engaging with stakeholders such as consumers can help in establishing a vision for social responsibility (Dickson et al. 2009). This process is fundamental for improving social responsibility and, in turn, sustainable development. Achieving sustainability requires all participants in the apparel system to recognize that extrapolating on the current system will not work because the current system and the relationship between consumers, apparel brands, and apparel products is the very antithesis of sustainability (Fletcher and Grose 2012).

It is not just behaviours that have changed but also how consumers have defined value. Stylistic innovation, a core output of the fashion industry, has high symbolic value leading to and encouraging conspicuous consumption (Tran 2010). Consumers have learned to value quantity and attribute little value to the resources needed to produce their goods. Altering value, informing and creating awareness, consumers can learn how to make more sustainable choices in the purchase, use, care of, and disposal of apparel items.

Hethorn and Ulasewicz (2008) mention that the role of apparel brands within the market, and ultimately the consumer, must be viewed differently to progress toward sustainability. Hethorn and Ulasewicz specifically promote a holistic approach to defining consumer preferences and how successful sustainable fashion requires that the consumer be placed as a focal point in the design process. Gaining insight into environmentally friendly apparel-consumption behaviours (acquisition, use, and disposal) will aid apparel brands in developing strategies that promote these behaviours (Connell 2010).

Hethorn and Ulasewicz (2008) argue that fashion is an excellent platform by which to create awareness for sustainability because it is ubiquitous and is embedded in a system of communication. With the rising popularity of social media, today's consumers can significantly influence the design and product development process along with marketing strategies. For example, a growing trend of authenticity and a return to value of traditional craftsmanship can be seen at the core of the DIY movement. There is an opportunity for designers and fashion brands to strategically utilize these growing social trends to their advantage. The rise of co-creation not only involves the consumer in the process but allows for greater access to consumer needs, behaviours, and wants, subsequently leading to the creation of greater-valued products. A better understanding of the consumer and consumer engagement through co-creation processes is a driver for innovative sustainable products and services. As Yoo et al. (2009) point out, consumers can interact, collaborate, coordinate, and co-create with fashion brands because digital technology has radically reduced the cost of communication. Integrating the principles of sustainability into the design process becomes a manageable task with the evolution of these new communication media, which allow for a better understanding of consumer behaviours, needs, and wants. Ideas such as Jonathan Chapman's (2009) design for emotional durability, where attempts to associate value and meaning to consumer products by creating an emotional connection, is clearly more feasible in a co-creative process.

3.4 Sustainable Supply-Chain Management

Despite sustainable supply-chain management gaining prominence in CSR strategies, there are still many questions as to what a sustainable supply-chain is and what are its defining characteristics. Key characteristics mentioned in the literature are transparency, development of codes of conduct, auditing, and capacity

building (Wong and Taylor 2000; Allwood et al. 2006; Carter and Rogers 2008; Fletcher 2008; Bhaduri and Ha-Brookshire 2011; GRI 2011). Transparency is a significant factor in developing a sustainable supply chain. It allows consumers to see how and where the products that they purchase are produced (NICE 2012). Transparency engages stakeholders as to the business practices of an apparel brand and allows for accountability.

Gobble (2012) states, changes to the supply chain, such as reducing waste and streamlining process for energy efficiency, do not transform the system; they simply reshape it. True innovation requires a disruption in the current system to achieve sustainability. Changes to develop a sustainable supply chain will stem from the creation of innovative sustainable products, design practice, and business models. Innovation within these elements will dictate product development and manufacturing. At this point fashion brands can re-evaluate current supply-chain practices and look to develop sustainable production methods that better suit sustainable product innovation. Designers may also work in tandem with manufacturers, which could alternatively drive innovation in sustainable product development. Engaging stakeholders within the supply chain offers opportunities to co-create new process, value, and products that further the sustainability agenda.

3.5 Business Innovation

Although financial responsibility is a vital element of any business, this particular aspect does not require transformation. The responsibility to remain profitable is a core business operation. Within sustainability, financial responsibility is viewed as being equally important as environmental and social responsibility. Therefore, innovation in developing alternative business models and strategies to diversify revenue streams is as vital as innovative sustainable product development. Porter and Kramer (2006) state:

> Strategic CSR moves beyond good corporate citizenship and mitigating harmful value chain impacts to mount a small number of initiatives whose social and business benefits are large and distinctive. Strategic CSR involves both inside-out and outside-in dimensions working in tandem. It is here that the opportunities for shared value truly lie. Many opportunities to pioneer innovations to benefit both society and a company's own competitiveness can arise in the product offering and the value chain (p. 88).

For example, Nike has been quite successful in creating new business practices by developing innovative products through the co-creation of value and sustainability initiatives (Ramaswamy 2008, 2009; Rodrigues et al. 2011; Gobble 2012). Innovation is not only a strategic long-term competitive advantage (Verganti 2009); it is at the core of creating a sustainable society (Schaltegger et al. 2011; Gobble 2012; Seebode et al. 2012). The model presented in Fig. 2 seeks to examine and redefine the role of design on business from an innovation perspective in developing sustainable practices within a fashion brand.

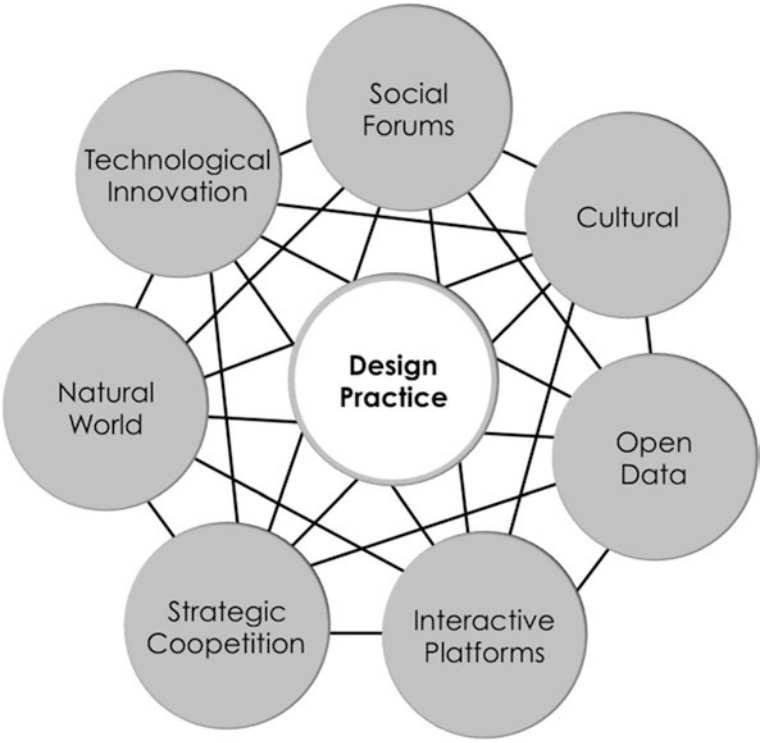

Fig. 2 Application of ISRD using trends in relevant areas to inform design practice

4 An Example on ISRD

A model of how ISRD may be applied to design practice is presented in Fig. 2. This model relates to Fig. 1 by focusing on the design-practice element, an area where a fashion brand exerts a great level of control. The emphasis on design is based on the assumption that those interested in formulating sustainable practices should begin in areas where they wield a higher degree of control.

The model in Fig. 2 advocates the observation and interpretation of trends and societal developments (which are culturally and socially significant to a fashion brand and their consumer market) to inform and transform current design practices. The idea is to identify trends and developments that may be relevant to the various elements within the sustainable fashion system (i.e., consumer engagement, sustainable supply-chain management, business innovation, and product sustainability) and how they interact or may influence one another. It is an iterative process drawing on Baudrillard's (2007) notion to observe, interpret, and transform.

The seven areas highlighted in the Fig. 2 (technological innovation, social forums, cultural trends, open data, interactive platforms, strategic coopetition, and the natural world) have been chosen due to their relevance in today's global market place, design industries, and society at large. They are broad in scope to ensure encapsulation of macro (global) and micro (local) trends that would be socially significant to a fashion brand and their consumer market. This model applies the same holistic view and systems thinking theoretical framework as the model in Fig. 1. These areas are not isolated nor do they function in isolation within society or an individual's personal microcosm. For example, the success and use of open data works in tandem with interactive platforms and social forums. The rise and use of open data is also a recent cultural trend and is present in many different forms and industries. Applying a holistic view to trends within these seven areas and determining how they could function within the fashion system can be the driver for innovation and the development of new sustainable products, services, and business strategies.

To demonstrate the application of the model, consider its application in the context of fast fashion. The fast-fashion consumer primarily engages in the rapid consumption of low-cost, trend-driven fashion and enjoys the continuous replenishment of new fashion products. Fast fashion has been demonized as being highly unsustainable due to its low-quality, low-price disposable nature. It can be argued, however, that certain features of this model are sustainable due to its ability to reproduce on-trend items in weeks as opposed to preplanning months in advance (Armstrong and LeHew 2011). The longer the time frame between conception and the retail floor, the higher the risk a fast-fashion product may not sell. Fast fashion is increasingly responding to consumer desires while dramatically reducing the time-to-market and on-hand inventory aspects. However, it is unclear whether the ability to respond to consumer desires is measured by the retailer's capacity to offer the latest trends within weeks to days of the original inception and whether this reduces the amount of styles that do not sell (Armstrong and LeHew 2011). This is a problem plagued by all commercial products because there is no clear method to accurately predict what a consumer will buy.

When looking at how recent trends in **technological innovations** may inform and transform fast fashion design practices, one may look to 3D printing. The use of 3D printing is rapidly expanding, and one day 3D printers may be a ubiquitous home product such as the paper printer. The use of 3D printers moves the mode of production from the fashion brand into the hands of the consumer. This may correspondingly satisfy the growing cultural trend of DIY (do-it-yourself) consumers that has propagated through social forums such as Facebook, Instagram, and fashion blogs. When looking at social forums and cultural trends such as DIY, designs are available for consumers to download free of charge to be printed with various 3D printers.

Cultural trends, such as DIY, co-creation, artisanal and traditional craftsmanship and hacketivism (which is rooted with classic DIY) (von Busch and Palmas 2006), are increasing in popularity as consumers look to engage and participate in fashion in a more meaningful manner. These trends may have arisen as a backlash to the oversaturated offshore mass production of fashion. A common theme is the

flexibility to individualize and/or customize apparel while allowing consumers to reconnect and engage in practices that were once a ubiquitous practice and form of knowledge. **Social forums** include communication mechanisms, such as blogs, Facebook or Instagram, or other common technological tools where consumers can share information on a variety of subjects and issues in many different forms (i.e., written text, images, or photographs). These tools have popularized individual fashion styling, naturally proliferating and popularizing the DIY movement and a return to traditional craftsmanship techniques to further personalize one's style.

A fashion brand may look to create its own **open-data** platform by engaging with consumers through an **interactive platform** tool that is either created by the brand (e.g. Nike+) or currently exists (e.g., Instagram). The Nike+ website is an interactive platform that engages consumers through an innovative service creating an online community where runners voluntarily share information, thus creating an open-data forum. Privacy levels for sharing within the community are set by the consumer, and Nike collects all of the data provided through the Nike+ service platform. A company cannot improve what it cannot measure, and open data allows for consumer activity to be measured.

The development of Nike+ website, service, and the *Nike+ iPod Sports Kit* adds value to the brand image through the implementation of a **strategic coopetition** with Apple. Coopetition can be defined as the simultaneous cooperation and competition between companies to achieve mutual gains and competitive advantages (Brandenburger and Nabeluff 1996). There is an implication of knowledge sharing for the use of competitive advantage, and any knowledge gained or released from the union may be used to compete (Levy et al. 2003). The strategic coopetition between Nike and Apple created the joint communication of brand image, reputation, and credibility by capitalizing on the homogenous and convergent lifestyles of consumers in the global marketplace (Rodrigues et al. 2011). As observations of relevant social trends, such as the increasing urban running trend in the case of Nike, enter the design process, a fashion brand can investigate how they might interpret and transform these trends into a sustainable business strategy, new services, and/or product.

A fashion brand could also look to develop personalized designs with consumers through a collaborative approach using a social **interactive platform**. The consumer would no longer be purchasing a product but a design, such as a fashion shoe, that is downloaded and printed by the consumer. The fashion brand may even enter into a membership relationship where a biopolymer, inspired by the **natural world**, that could be continuously recycled is sold to the consumer at a frequency of their choice. The membership terms may be that the biopolymer for printing is sent every week to satisfy the fashion craving of a fast-fashion consumer where the consumer can print as many shoes as they chose and return those no longer wanted to be recycled, thus closing the production-consumption loop. The fashion brand has eliminated the need to produce the product themselves, focusing on raw materials only and has now developed a new business service that binds the consumer for a length of time to the particular service offered.

This example highlights the mutual benefits to be gained by both the consumer and fashion brand. The needs of the fast-fashion consumer are satisfied through the offering of a new service while they are simultaneously engaged in the design and product-development process. The offering of a service by the fashion brand allows the consumer to directly participate in the production process and allows the fashion brand to pursue innovation within design and business strategies. By engaging with the consumer, the fashion brand is able to gain information that can be translated to data in support of innovation and sustainability. ISRD provides the framework to guide the design practice in developing innovative and sustainability driven business strategies and products that ultimately provide a means for sustainable consumption that is financially viable.

5 Conclusion

Sustainability in the fashion industry has become recognized as an important issue due to increasing awareness of the negative environmental and social impacts of fashion. Recent literature suggests the need for systemic change in the sustainable development of the fashion industry where initiatives must move beyond the supply chain to other areas such as business innovation, sustainable consumption, and consumer engagement. This chapter highlights the need for systemic change within the fashion industry in support of sustainability. To translate the principles of sustainability, there is a focus on design practice with the aim to develop innovative sustainability-driven business models that induce sustainable consumption. This research contributes an analysis of how the design process can support the development of new and competitive business models for a sustainable fashion industry. This chapter proposes a model based on a theoretical systems-thinking framework to guide the design practice.

Currently the ISRD model is a theoretical construct that is broad in scope and limited in its ability to provide a detailed process for its application. ISRD does, however, provide flexibility in its application to any area within the fashion industry. The theoretical foundation would benefit from further research on consumer engagement and adaptability within organizational cultures in the fashion industry. Ultimately, ISRD aims to achieve sustainability within the fashion system through a systems-thinking approach of a design practice that supports innovation.

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Green Flame Retardants for Textiles

Asimananda Khandual

Abstract Application of flame retardants plays a crucial protective function to reduce overall fire risk by suppressing the spread of fires or by delaying the time of flashover, thus enabling people or resources to have sufficient time to escape or rescue from the fire hazards, respectively. Among them, only few have gained commercial importance, are halogenated and phosphorus-based flame retardants those proved to be persistent are carcinogenic, bioaccumulative, and toxic for animals and humans. There has been an ever-growing demand for new flame retardant product options recognizing not only to ensure a favourable ecological profile but also to have a durable and cost-effective product. The sustainability concerns of various hazardous textile chemicals have been intensively researched. This chapter discusses fire science concepts, histrotical development in fire retardants their types, applications and some potential alternative products that have recently been reported—such as natural extracts of casein, spinach, and banana—along with currently reported technology such as DNA, nano materials, plasma, etc.

Keywords Flame retardants · Eco-friendly · LOI · Plasma · Nanotechnology · DNA · Casein

1 Introduction

Our daily life is associated with using highly combustible raw materials in products such as textiles, clothing, composites, plastics, electronic appliances, etc. These are now undergoing intense scrutiny for the safety of our life and resources. Today, we are seeing developments of high-rise buildings, shopping malls, yard goods, modes

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of transport, carpeting, furnishings, appliances, storage, and consumption of oil and gas, etc., resulting in increased fire risk. In fact, modern infrastructure design for rescue, fire-fighting techniques, sand equipment to reduce of fire risk have already been created, but even the best of these cannot assure to control devastating fire. New technologies, processes and applications introduce new fire hazards such as new ignition sources, welding sparks, and short circuits. The statistics have shown that textile sources contribute to the largest percentage of deaths in residential fires. Although fire-safety measures initially evolved for hostile environments, their application is now becoming indispensible not only for the military but also for civilians. Application of flame retardants plays a crucial protective function to reduce overall fire risk by suppressing the spread of fires or delaying the time of flashover, thus enabling people or resources to have sufficient time to escape or time to be rescued from fire hazards, respectively. The phenomenon evolved by a combination of many factors including ignitability, ease of extinction, flammability of the volatile products generated, rate of heat released, flame spread, smoke obstruction and smoke toxicity, etc. It is estimated that escape times can be up to 15 times longer when flame retardants are present.

Flame retardants are applied to textiles to make them noninflammable or self-extinguishing. The most common classes of flame retardants are brominated, phosphorus, nitrogen, chlorinated, and inorganic. Most of the successful halogenated and phosphorus-based flame retardants proved to be persistent, carcinogenic, bioaccumulative, and toxic for animals and humans; only few have gained commercial importance as of today. Recently, there has been an ever-growing demand for new flame-retardant product options that not only ensure a favourable ecological profile but also a durable and cost-effective product. The search continues for efficient and economic flame-retardant products that use natural plant extracts and environmentally friendly application techniques.

A recent survey conducted in 2015 by National Fire Protection Association (NFPA) in 2013 states that there were 1,240,000 fires reported in the United States causing 3240 civilian deaths, 15,925 civilian injuries, and $11.5 billion in property damage. A fire department responded to a fire accident every 25 s and reported the following fire demographics: 1 structure fire every 65 s, 1 home-structure fire every 85 s, 1 civilian fire injury every 33 min, 1 civilian fire death every 2 h and 42 min, 1 outside fire in every 56 s, and 1 vehicle fire every 167 s (http://www.nfpa.org/research/reports-and-statistics/fires-in-the-us) (Fig. 1).

Looking at the recent statistics regarding causes of residential building fires resulting in injuries in 2013, it is evident that how the flame-retardant textiles could prevent such damages (http://www.usfa.fema.gov/data/statistics/).

In this chapter, we initially lucidly explained the previous arts and concepts in briefs and then discussed various types of flame retardants and their merits and demerits as well as some potential alternative natural products that have recently been reported—such as extracts of spinach, and banana—along with currently reported technology such as DNA, casein, hydrophobins, nano materials, plasma, etc.

Fig. 1 Causes of residential building fire injuries

2 Fire Science

Fire is closely associated with our day-to-day life and their causes are numerous: cooking, smoking, industrial furnaces, welding, thermal combustion in power stations, even our vehicles with internal combustion engines, which require electricity in order to drive them. Past discoveries has shown that much pain and effort were combined to generate fire for typical applications, and today's modern era of rapid civilization and industrialization faces a challenging issue to control these applications to ensure minimal fire hazards (Adivarekar and Dasarwar 2010; Weil et al. 1975; Shirley Institute 1982; Jackson 1998; Horrocks et al. 1989; Stan 1986; Jeffries 1988; Smith 1989; Bajaj and Sengupta 1992; Ajgaonkar 1994; Smith 1994). The self-sustaining nature of fire, if uncontrolled, makes it extremely dangerous and devastating. Fire has been described as a "*living entity consuming both oxygen and matter in order to survive*" (Adams 2004). Beyer in (Beyer 2005) reported that apart from fire deaths, the direct property loss caused by fire hazards was approximately 0.2 % of the gross domestic product and the total cost of fires preventive majors approximately 1 % of the gross domestic product. Archaeology studies state that some 790,000 years ago ancestors of modern humans, such as Homo erectus, seemed to use controlled fire. A million years ago, the Cradle of Humankind site located 50 km northwest of Johannesburg, South Africa, evidenced controlled fire. Gradually the scientific community came to know how to understand fire science and its control.

Let us consider an example of fire hazard that starts within a room that contains flammable materials. Initially the fire will generate heat and then gradually proceeds in three stages: the growth period, fully developed fire, and the decay period (Fig. 2). The rate of fire progression increases, generating increasingly more heat with a progressive increase in the room temperature. The radiant heat and temperature can increase to such an extent that all materials in the room are ignited very easily, resulting in an extremely high rate of fire spread. This point in time is called

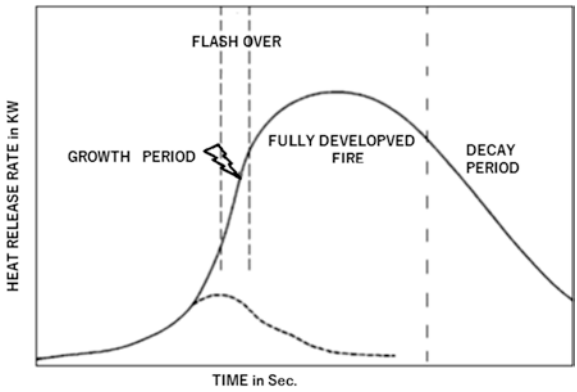


Fig. 2 The course of a well-ventilated compartment fire

"flashover" (Fig. 3b) resulting in a fully developed fire. Flashover generally occurs at approximately 500 °C, and the incident heat flux at floor level is approximately 20 kW m^{-2}. At this point, escaping from the room will be virtually impossible, and the spread of the fire to other rooms is highly likely. As soon as the fire reaches flashover, every polymer will release approximately 20 % of its weight as carbon monoxide producing excessive toxic smoke. Consequently, it only can excuse a very few left alive, immediately causing unconsciousness; approximately 90 % of fire deaths are a result of the release of too much toxic smoke, which is lethal. A fully developed fire can burn everything in the room within just a few seconds to minutes.

The mechanism of fire was previously based upon the "fire triangle," but further fire research found that a fourth element, a "chain reaction" that is a necessary component of fire development. The concepts of fire triangle and fire tetrahedron depicted in Fig. 4 are simple but important to discuss. The fire triangle is comprised of three pillars on the fire stands: heat, fuel, and oxygen. The triangle will collapse when any or many of these pillars, which are necessary to create a fire, are manifested. Fire is a chemical process that involves oxidation: Oxygen

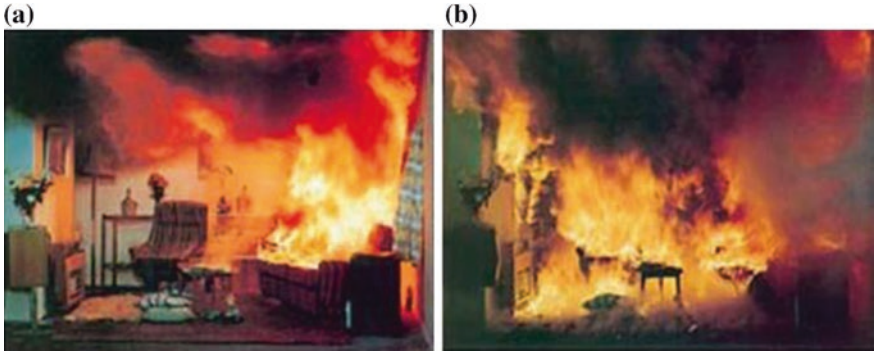


Fig. 3 Flashover in a domestic room. **a** Before and **b** after, images from www.azobuild.com

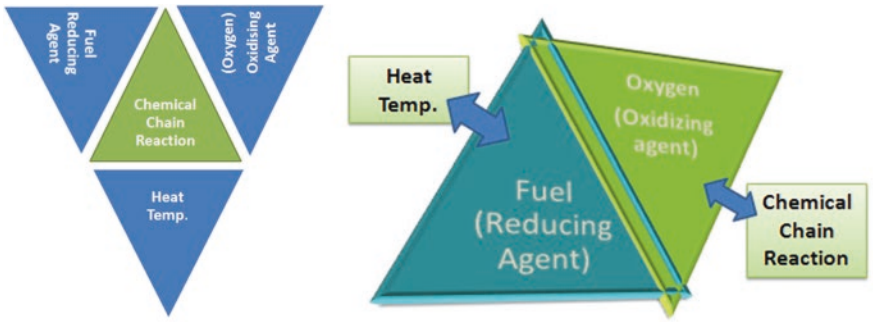
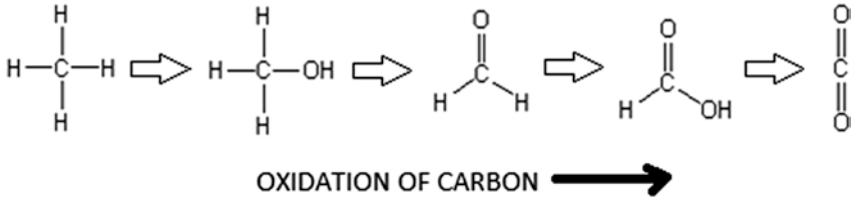


Fig. 4 Fire tetrahedron

combines with hydrogen and carbon, which is then rearranged to form water and carbon dioxide. This energy causes heat generation, i.e., an exothermic reaction where carbon burns to CO_2; however, if it reduces partially back to CO, the reaction is endothermic. The same process takes place when metal rusts, but the apparent lack of heat is due to the much lengthier time required for the rusting process to take place.



In the case of most gasifiers, the actual gasification process is preceded by pyrolysis whereby the biomass or coal turns into char releasing methane (CH_4) and tar rich in polycyclic aromatic hydrocarbons (PAH). Other gasifiers are fed by previously pyrolysed char. Wood gas is flammable because of the carbon monoxide, hydrogen, and methane content. Multiple properties of a material relate to its flammability, out of which the material is easily ignited and the rate; the amount of heat released as a consequence is the matter of concern. The way in which the flame spreads and the amount and level of toxicity generated in smoke release are critical (Price et al. 2001).

3 Basis of Combustion Process

There exist plenty of definitions of combustion, but not all of them have the same fundamental explanation: A heat-producing chemical reaction occurs in which a fuel combines with oxygen. As stated previously, a fire triangle represents the key

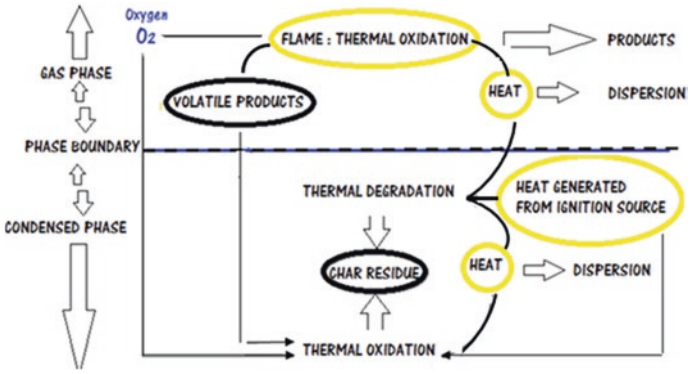


Fig. 5 Thermal degradation process

components of combustion, but it does not contain adequate information of the physical and chemical processes of combustion. Combustion requires fuel, oxygen and adequate heat in the correct proportion for catalyzing the process. However, when dealing with a compartment fire, the fuel is commonly a solid fuel such as wood, paper, or plastic. When wood is first heated, water vapor is driven off as the wood dries. Subsequently heating continues; the wood begins to pyrolyse; and the wood decomposes into its volatile components plus carbon. Pyrolysis evolves at a considerably lower temperature (below 400 °F/204.5 °C) than that required for the ignition of volatile pyrolysis products (1000–1300 °F/538 to 704 °C). Figure 5 depicts the outline of the thermal-degradation process, and Table 1 outlines the effects of pyrolysis within different temperature zones (Browne Pitts, Johnsson, and Bryner). The ignition temperature of carbon and common volatile components evolved from the pyrolysis of wood.

The burning criteria of cotton have been elucidated well by Granzow (1978), Barker and Drews (1978), where the key reactions were pyrolysis and combustion. Pyrolysis is synonymous with the thermochemical decomposition of organic material at specific higher temperatures (>350 °C). Here flammable gaseous fuel is generated, which is the potential precursor of a subsequent combustion process. Successful combustion requires three basic elements: heat, oxygen, and fuel. The gaseous fuel has to be in a steady concentration that is higher than the lower explosion limit of the fuel–oxidant mixture. Once ignition occurs, it can continue if the energy feedback from the flame is unceasingly provided to the polymer surface. During combustion, sufficient heat is released, which is then provided to the pyrolysis as an input again and hence the chain reaction of burning proceeds (Fig. 6).

The heat released, denoted as heat flux (heat-release rate), depends on the temperature of the polymer flame, which in turn is determined by the concentration of the atmospheric oxygen.

The pyrolysis process is the thermal degradation causing the polymer decomposition into lower molecular-weight components. This thermal degradation process gets heat from a fire source and is endothermic. Cotton, a natural cellulose, is

Table 1 Pyrolysis effects within different temperature zone

Pyrolysis zones	Ignition temperatures (Lewin and Weil 2001)
Zone A: Up to 392 °F (200 °C) Wood is dried and small amounts of decomposition take place **Zone B: 392–536 °F (200–280 °C)** A large number of complex chemical compounds are generated through decomposition, and charring begins **Zone C: 536–932 °F (280–500 °C)** Rapid pyrolysis takes place releasing and/or generating a wide range of complex chemical compounds. Secondary reactions between these products can take place, and charcoal is formed **Zone D: >932 °F (500 °C)** The surface temperature of charcoal is sufficient to induce secondary reactions such as combination of free carbon and carbon dioxide (simple asphixiant) to the production of large amounts of carbon monoxide (toxic and flammable)	Fixed carbon: 765–1094 °F (407–590 °C) Hydrogen: 1076–1094 °F (580–590 °C) Methane: 1202–1382 °F (650–750 °C) Ethylene: 1008–1018 °F (542–548 °C) Ethane: 968–1166 °F (520–630 °C) Benzene: 1097−1364 °F (740 °C) Carbon monoxide: 1191−1216 °F (644–658 °C) Listed ignition temperatures are based on the range of temperatures (low to high) listed in multiple reference sources. The ignition temperature is also influenced by the oxygen concentration in the atmosphere Pyrolysis of wood results in the production of a far greater number of complex chemical compounds. The materials listed are simply a representative sample of the more common of these substances

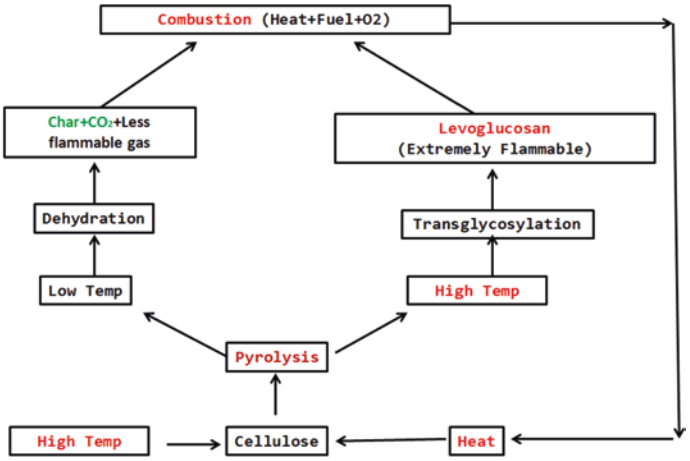


Fig. 6 Burning behaviour of cotton

composed of β-glucopyranose monomeric units linked together by 1,4-glycosidic bonds. The pyrolysis of cellulose causes cleavage of the C–O bond prior to the C–C bond because of its polarity; dehydration occurs at lower pyrolysis temperatures by scission of the within-ring (pyranose ring) bonds, thus causing in complete breakdown of the molecular structure with carbon dioxide, carbon monoxide, water, and carbonaceous char as the principal products (Fig. 7).

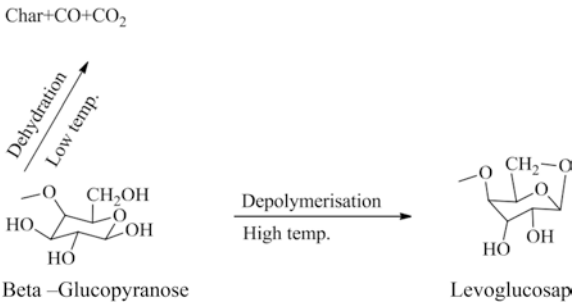


Fig. 7 Dehydration and depolymerisation pathways of cotton at lower and higher temperatures

However, at higher pyrolysis temperatures, the glycosidic linkage is disrupted (transglycosylation). The heterolytic reaction leads to the formation of levoglucosan (1,6-anhydro-β-D-glucopyranose) and further decomposes to volatile combustible fragments such as alcohols, aldehydes, ketones, and hydrocarbons (Hirschler 2001; Little 1947; Basch and Lewin 1973; Hendrix et al. 1970).

To confer information on fire size, fire flourish rate, available escaping time and suppression system, the heat-release rate (HRR) is the primary factor. Heat release determines the rate at which a burning item releases chemical energy and is probably the most important quantity used to predict flammability hazard shown by a given material (Horrocks 2001). The generation of most other undesirable fire products tends to increase the flammability hazard with increasing HRR. This after effect involves not only the increased release of smoke and toxic gases but also further intensification of HRR. As a result, a high HRR endangers life and resources. Not every fire-hazard variable threatens life i.e., a product shows easy ignitability or flame-spread rates; however, this does not necessarily mean that the product catches fire, which is expected to be dangerous. Such behavior may merely suggest a predisposition to hinder fire progression. However, a high HRR is intrinsically dangerous. This is because the speed with which the fire develops causes high temperatures, high heat release rates, and high heat flux environments, which may be deadly to life and the duration of burning is dependent on both the characteristic of the fuel involved and the ventilation profile as illustrated in Fig. 8.

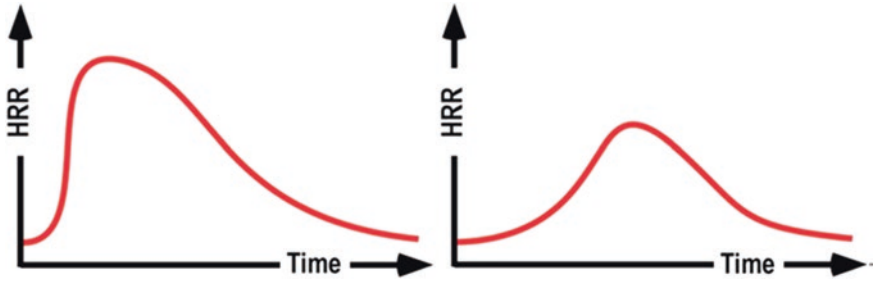


Fig. 8 Heat release rate varies with fuel characteristics and vent profile (Hartin 2015)

Secondary fire effects are also crucial factors that promote the rate of flame spread by emissions of smoke and toxic gases. The greatest danger to people happens when the combination of radiant heat release with lack of oxygen occurs. The HRR of burning material is the product of mass-loss rate per unit of exposed surface area and its actual heat of combustion. Hence, heat release rate is not just one of many variables used to describe a fire, but it is the single most important variable in describing fire hazards.

3.1 Thermal Behavior of Fibers

Ignition occurs when the temperature of the fabric is high enough for thermal decomposition and the generation of flammable volatiles. The fire hazard of apparel fabrics depends to a large extent on the ease of ignition and the rate of spread of flame of the particular fabric. A high incident flux, low thermal inertia and weak chemical bonds will result in faster time of ignition and a greater flammability hazard. The fiber content, structure, and finishing treatments of the fabric influence its ignitibility. Cellulosic fabric, such as cotton, viscose and linen ignite easily and burn quite fast. They can also continue to smoulder (afterglow), thus causing fires to restart or propagate[1]. A rapid spread of flame can occur over the surface of cellulosic fabric with pile such as fleece, flannel, or terry. Thick, tight, and smooth cellulosic fabrics will not ignite so easily. Generally, fabrics made of animal fibers, such as wool or silk, will not ignite easily. Man-made fibers, such as polyester and polyamide, melt away from the flame as the flame touches them and they often extinguish themselves, whereas synthetic fibers are not prone to catch fire easily and they melt away from a heat source. However, this means that they provide no fire protection for enclosed materials, such as foams in furniture, so that a small flame can develop into a horrible house fire. Synthetic textiles will burn strongly if they cannot melt away from the flame, and the molten fibers can cause severe burns (see Footnote 1).

The demand for the degree of heat and flame protection vary includes clothing for situations in which the wearer may be subjected to occasional exposure to a moderate level of radiant heat as part of his or her normal working day and clothing for prolonged protection where the wearer is subjected to severe radiant and convective heat or to direct flame, e.g., firefighters (Table 2).

3.2 Factors Affecting the Flammability

Ease of ignition, rate of burning and heat release rate are the important textile properties that govern the extent of fire hazard. Other factors that influence the

[1] http://www.ceficefra.com/Objects/2/FilesMaking%20textiles%20safer%20against%20fire.pdf. Accessed on 23 August 2015.

Table 2 Flame properties of fibres (Vinatage resources 2009)

Material/fabric name	Flame properties	Smoke properties	Ash/residue	Smell and misc
Naturals	Generally they ignite easily with a steady glowing flame	Most produce minimal smoke	Usually leaves a soft ash, if any, that can be blown or wiped away	Paper, wood, or leaf odor
Cotton	Ignites easy, continues to burn when removed from flame; usually a sputtering flame	Little white to grey smoke	Soft white or grey ash that blows away; the weave in the ash can still be seen on personal tests	Odor of burning paper or wood; cotton burns rather slow and has a glow after flame is out
Hemp	Very similar to cotton	White to grey smoke	Grey to white ash	Odor of burning paper or wood
Linen	Very similar to cotton; a little harder to ignite with a slower burn	Same as cotton	Same as cotton, but may be more brittle at the base of the ash on the fabric edge	Appearance will differ from that of cotton but same odor
Silk	Ignites quickly, burns easy and slower the thicker it is curls as	Very minimal to light smoke	Leaves a beaded or gritty dark grey or black ash	Burning-hair odor but sometime too faint to detect; harder to extinguish than
Rayon	Burns slower than cotton; steady flame, minimal dark grey to black smoke	Tends to have a darker smoke than cotton but can vary	Soft ash that can be blown away; ash is slightly more brittle than cotton ash and may be gritty	Paper- or wood-like odor; tends to have more ash left and is not as clean of a burn as cotton Has a bright glow before flame burns out
Synthetics	Tend to retreat from flames and melts	Usually dark and thick smoke	Hard, brittle, lumpy ashes or melted beads	Harsh acidic odors or little to no odor; usually blended making hard to identify
Acetate	Melts and burns with flame; Will retreat from flame; burns quickly	Sometimes dark grey to black smoke	Hard dark brittle bead; can drip while burning	Vinegary or treated-wood odor
Acrylic	Retreats from flame; burns rapidly and melts; will burn if flame is on it long enough Sputtering flame	Varies	Hard, brittle, irregular ash/beading	Harsh acidic odor

(continued)

Table 2 (continued)

Material/fabric name	Flame properties	Smoke properties	Ash/residue	Smell and misc
Nylon	Melts then burns; will retreat from flame burns slowly	White smoke	Hard grey, smoky, or brown bead	Vegetable- or plant-like odor; if ash is burned, it smells like plastic
Polyester	Melts and burns at the same time; retreats from flame.	Black smoke	Hard brittle cream or brown bead; can turn black if burned excessively	Sweet or acidic odor; drips while burning; drippings are sometimes on fire
Spandex	Melts; does not retreat from flame		Black or dark ash	An acidic or rubber odor like a hot pencil eraser

thermal protection level include melting, shrinking characteristics of synthetic-fiber fabrics, emission of smoke and toxic gases during burning. While selecting and designing the flame protective clothing, the following points should kept in mind:

- Burning behavior of textile fibres
- Influence of fabric structure and garment shape on the burning behavior
- Selection of non-toxic, smoke free flame-retardant additive
- Intensity of the ignition source
- Oxygen supply

Heat applied to textile material causes both physical and chemical changes (Adivarekar and Dasarwar 2010; Bajaj and Sengupta 1992; Lewin 1984; Van Krevelen 1977). For thermoplastic fibres, physical changes occur at the second-order transition (T_g) and melting temperature (T_m), whereas chemical changes occurs at the pyrolysis temperatures (T_p) at which thermal degradation occurs. The complex textile combustion process involves heating, decomposition leading to gasification (fuel generation), ignition, and flame propagation. A fuel source and a means of gasifying the fuel are essentially needed for a self-sustaining flame. When a fibre is subjected to heat, it pyrolyses at T_p, and thus combustible volatile liquids and gases are produced, which act as the fuels for further combustion. In pyrolysis, if the temperature is equal to or greater than the combustion temperature T_c, the flammable volatile liquids burn in the presence of oxygen to produce carbon dioxide and water. When a textile is ignited, the rate of increase in temperature depends on the following:

- The specific heat of the fibre
- The fibre's thermal conductivity (Ross 1977)
- The latent heat of fusion (for melting fibres)
- The heat of pyrolysis

The burning propensity and profile of textiles is complex. Different textiles, whether natural or synthetics, or even their construction state (yarn, fabric, garment) react in different ways when exposed to heat. Most natural fibres, such as cotton and silk, burn relatively easily in comparison with synthetic fibres because they have greater ability to resist ignition (Menezes and Paranjape 2004). Synthetic fibres, such as polyester, polypropylene, and polyamides, shrink away when exposed to a flame. However, this action does not mean that the fabric is flame retardant. The melted droplets from these types of fabric can result in severe burns and injuries (Smith 1989). Additionally, although the fiber shrinks away from the ignition source, a secondary ignition may occur. Hence these concerns clearly underscore the need for flame retardants that can be applied to synthetic fabrics. The FRs suited for synthetics often acted upon increasing the tendency of the fabric to melt and shrink away from the flame source. Second, they promote the extinction of flaming droplets (Horrocks 2001). The physical construction of textile, yarn geometry, blend percentages, etc., also affect the burning behaviour of these fabrics. For example, a tighter spun yarn can resist ignition more than a loosely spun yarn, and this can be the same for fabric made of these fibres

Table 3 Lists of glass transition, melting, pyrolysis temperatures combustion temperature, heat of combustion and LOI% (Bajaj and Sengupta 1992)

Fibre	T_g (°C) Glass transition	T_m (°C) Melting	T_p (°C) Pyrolysis	T_c (°C) Combustion	H[a] kJ/g	LOI[b] (%)
Wool	–	–	245	600	27	25.0
Cotton	–	–	350	350	19	18.4
Viscose	–	–	350	420	19	18.9
Triacetate	172	290	305	540	–	18.4
Nylon 6	50	215	431	450	39	20.0–21.5
Nylon 6.6	50	265	403	530	32	20–21
Polyester	80–90	255	420–477	480	24	20–21.5
Acrylic	100	>220	290	>250	32	18.2
Polypropylene	−20	165	469	550	44	18.6
Modacrylic	<80	>240	273	690	–	29–30
PVC	<80	>180	>180	450	21	37–39
PVDC	−17	180–210	>220	532	11	60.0
PTFE	126	>327	400	560	4	95.0
Oxidised acrylic	>640	–	55	–	–	–
Nomex	275	375	310	500	30	28.5–30
Kevlar	340	560	590	>550	–	29
PBI	>400	–	>500	>500	–	40–42

[a]Heat of combustion—kcal/g
[b]*LOI* Limited of Index (%)

(Menezes and Paranjape 2004). The density and structure of a fabric are also critical; a dense fabric composed of several layers or with high GSM is less likely to burn than a low-density fabric with an open structure (Horrocks et al. 1989). The limiting oxygen index (LOI) is often used to indicate the burning tendency of a material. Any fiber with a LOI value of 21 % or lower will effortlessly ignite and burn in the presence of air. LOI values of 26–28 % are indicative of fibers that are flame retardant. Heat of combustion (HC) is an important factor that indicates how quickly a fire will spread (Table 3; Figs. 9 and 10).

3.3 Burning Behaviour of Textile Fibers

Burning behaviour of textile fibers are summarised in Fig. 11.

3.4 Heat-Protective Textiles (Hartin 2015; Scott 2000)

There exists a significant difference between civilian and military fire events. The majority of civilian fires are accidental events, whereas the majority of military

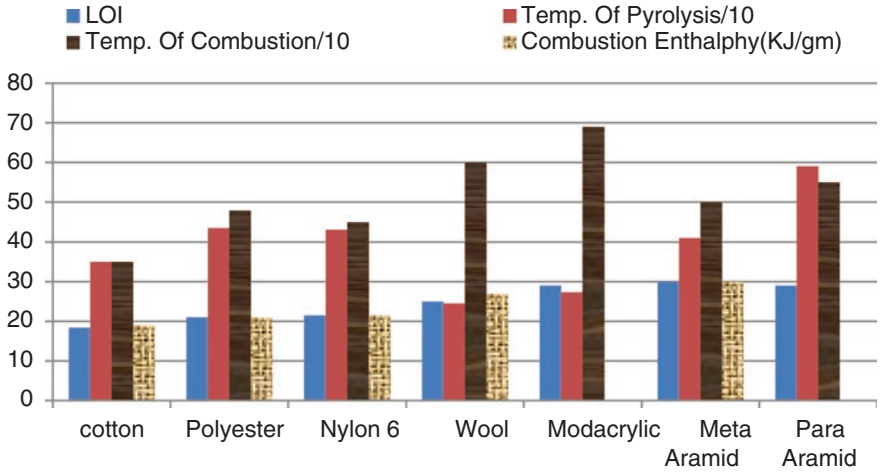


Fig. 9 LOI, pyrolysis temperature combustion temp, and enthalpy of typical fibres

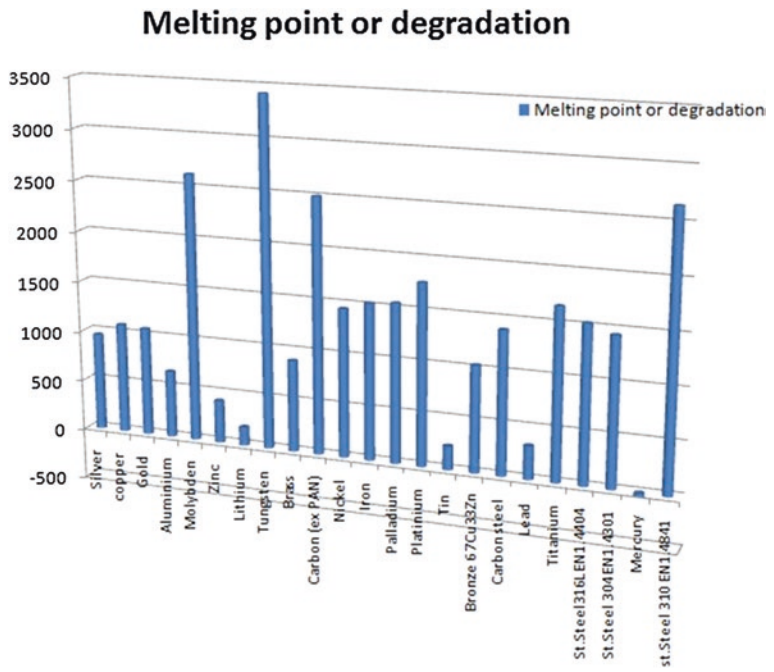


Fig. 10 Melting-point comparative chart for nontextiles (http://www.tibtech.com/melting_point.php. Accessed on 23 Aug 2015)

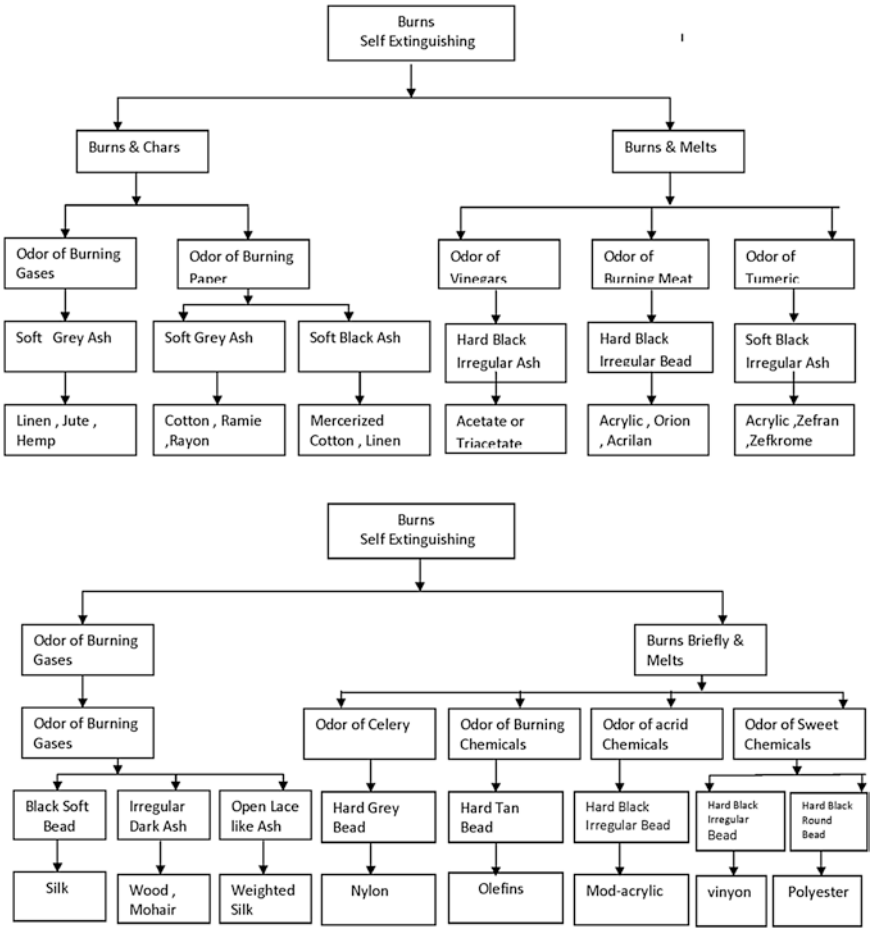


Fig. 11 Burning behavior of textile fibers

fires are deliberately planned, professionally executed and specifically intended to destroy equipment and installations to maim and kill people. Military textile materials are often the first materials to ignite, and they propagate small fires that may rapidly lead to large conflagrations. The use of flame-retardant textiles for many defence applications can specifically include the following:

- Protective clothing for fire-fighters, bomb-disposal (explosive ordnance disposal, EOD) crews, nuclear, biological and chemical (NBC) protection, AFV tank crews, naval forces aboard ships and submarines, aircrew, and special forces such as SAS (Special Air Service), SBS (Special Boat Service), and US navy seals.
- Equipment such as tents, shelters, vehicle covers, and bedding.

Table 4 Melting points of some thermoplastic textile fibers (Scott 2000)

Fibre type	Trade names	Melting point (T_m °C)
Polyester	Terylene, Dacron, Trevira, Thermastat, Coolmax, Patagonia	255
Polypropylene	Meraklon, Leolene, Ulstron	150
Polyamide	Nylon 6, Nylon 6–6, Tactel	250
Polyvinylidene chloride	Damart Thermolactyl, Rhovyl	Shrinks 95
Modacrylic	SEF, Velicren, Teklan,	175
Spandex (elastic fibres)	Lycra, Vyrene	250

The threats to humans and equipment can be sorted as follows:

1. Open flames from burning textiles, wood, vegetation, furnishings, and fuels
2. Radiant weapon flash whether conventional or nuclear weapons
3. Exploding penetrating munitions, especially incendiary devices
4. Conducted or convected heat including contact with hot objects
5. Toxic fumes generated in confined spaces
6. Smoke that hinders escape in confined spaces and can damage other equipment
7. Molten, dripping polymers, which can injure clothed humans and spread fires in furnishings and interior fittings

It is noteworthy to mention the thermoplastic melt hazard (Scott 2000). In many situations, armed forces can experience the detrimental effects of molten fibre polymer sticking to their skin, which may cause severe injuries. Table 4 shows that thermoplastic fibres have melting points as low as 105 °C, and if used in underwear, can shrink onto the skin before melting. Commonly used synthetic fibres, such as polyester (T_m = 255 °C) and nylon (T_m = 250 °C), are often used in blends with cotton or other fibres. A melting burn event that may occur in hostile environment could have multiple implications as follows.

1. There may be little or no "pain alarm time" allowing an individual to instantly register pain and move away from the heat source.
2. Latent heat, which is re-released on resolidification, thus causing more heat to be pumped into a localized area of skin.
3. The residues of molten polymer shrink and stick to the skin causing treatment complexity for medical providers.
4. Degraded polymer products may rush to broken skin causing wounds and circulate in the bloodstream.

More often, polyester/cotton fabrics containing no more than 35 % polyester are suggested because polyester can cause skin burns.

The melt-hazard issue is still a cause for much debate, especially regarding its implications for infantry and marines operating in cold climates. Some nations ignore this potential problem, whilst others, including the UK, observe the risk

in certain special situations for all aircrew-, tank crew-, and naval action clothing. The UK has recently relaxed the restrictions on the use of thermoplastic textiles in certain cold-weather operations (Scott 2000). Thus, the fiber inherent characteristic as well as the structure and finishing treatments of the fabric, influence the ignitibility and burning propensity. The demand for the degree of heat and flame protection varies (Hirschler 2001; Little 1947; Basch and Lewin 1973; Hendrix et al. 1970) widely ranging from clothing for normal situations to various hostile environments where the wearer may be subjected to high risk of fire hazards. Design of suitable fire- and heat-protection clothing can save lives and resources. Further research work on flame-protective textiles should focus on developing new fibres and finishes with improved performances having reasonable handle and comfort properties. New-generation developments are also have improved biodegradability and eco-friendly processing routes. It is estimated that escape times can be up to 15 times longer when flame-retardant textiles are present, thus providing increased chances of survival (Vytenis et al. 1988). Figures 12 and 13 depict how flame retardants help save the lives of military personnel.

A number of FRs are available that serve a vital purpose in protection against textile-related fires, and they are used throughout the world in various applications such as textiles, plastics, and building materials. The other major applications of flame retardants apart from textiles are outlined in Table 5.

Fig. 12 Credit of FRs to save all 309 passengers (Jackson 1998)

Fig. 13 Non-FR and FR (Horrocks et al. 1989)

Table 5 Major applications of flame retardants other than textiles

Industry sector	Applications
Electrical engineering and electronics	Wire and cable Consumer electronics and back plates Office electronics housings and back plates Printed circuits boards Appliances
Transportations	Applications
Motor vehicles	Wire and cable Seats
Rail vehicles	Compartment linings and coverings Insulation Compartment interior Seats
Aircrafts	Panels Carpets, flooring
Buildings	Thermal insulation for roofs, facades, walls Sheeting for roofs Floor coverings Ducting and conduit Panels, linings, coverings

4 Flame Retardancy Theory and Mechanisms

FRs are applied to material to make them nonflammable or self-extinguishing. In fact, different kinds of FRs are applied to many materials that we come into contact with every day such as building supplies, furniture, plastic molding materials, clothing, mattresses, bedding, etc. The principle of FRs is to decrease an item's propensity to burn when subjected to a heat source or open flame. As a consequence, deciding the suitable FR treatment for textiles is typically a complex process that largely depends on the quality of fabric demanded for the end use and the FR's impact on the basic essential and desireable properties of textiles. Some good flame retardants associated with good fabric quality can end up having undesirable effect during FR finishing of fabrics, during which some of the most important textile properties may be sacrificed. They may cause detrimental effects on aesthetic properties such as luster, stiffness, smoothness, handle, and drape; processing properties such as bulkiness, warp stability, wash ability, soiling, soil release, static electricity accumulation; tensile properties such as modulus, tensile strength, elasticity, and pilling propensity; and physiological properties such as comfort, odor, water absorption, heat of water absorption, leaching, and health hazards (Jeffries 1988).

4.1 Mode of Action of Flame Retardancy

In the 1970s, the use of flame-retardant materials gained momentum, and they were applied to flammable materials, which led to breaking the combustion cycle

by affecting chemical or physical process occurring in one or both of the gas and condensed phases.[2] The function of flame retardants are to interrupt the combustion cycle by chemical and/or physical means during the solid, liquid, or gas phases of burning (The Consumer Council 2015; Bourbigot and Duquesne 2007). Flame retardants should inhibit or suppress the combustion process during particular stages of the fire process e.g., heating, decomposition, ignition, or flame propagation (The Consumer Council 2015).

4.1.1 The Physical Action

Formation of a Protective Layer

The chemicals should preferably block the heat transfer from the heat source and prevent oxygen flow to the flammable material. They should also prevent the supply of pyrolysis gases to the material surface. This mechanism can be observed in phosphorus compounds, silicon, and boron compounds, basic base additives, and inorganic borates (Bajaj and Sengupta 1992; Ajgaonkar 1994).

Cooling Effect

Such FRs trigger the endothermic process, which cools down the substrate to a temperature so that ignition temperature is not reached. Alumina trihydrate (ATH) acts this way (The Consumer Council 2015; Bourbigot and Duquesne 2007).

Dilution Effect

These FRs create nonflammable decomposition gases and dilute the fuel in gas and solid phases so that the flammable gases concentration falls under the ignition limit and thus the textile cannot ignite (The Consumer Council 2015; Bourbigot and Duquesne 2007). The most important chemical reactions that flame retardant have in combustion process take place in the solid and gas phases (The Consumer Council 2015).

4.1.2 Chemical Action

Chemical action is the most relevant action to suppress the combustion cycle in the solid and gas phases.

[2]INCHEM, http:// www.inchem.org/documents/ehc. Accessed 23rd August 2015.

Reaction in Gas (Vapour) Phase

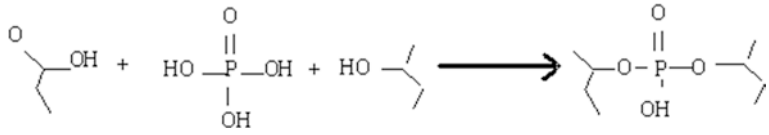
The free-radical mechanism of the combustion process, which takes place in the gas phase, is interrupted by flame retardants. The exothermic process is thus stopped, the system cools down, the supply of flammable gases is reduced and eventually completely suppressed. Polymers under pyrolysis can react with air resulting in chain branching reactions, which advance the combustion. Halogenated flame retardants interfere with this chain reaction by preventing hydroxide and hydrogen free radicals from reacting with oxygen and carbon monoxide. Radicals are captured, therefore disturbing the exothermic oxidative flame chemical processes resulting in the hindrance of combustion (Lewin 1984; Lewin and Weil 2001).

The reactions in the vapor-phase mechanisms are as follows:

- $H\cdot + HX = H_2 + X\cdot$
- $HO\cdot + HX = H_2O + X\cdot$
- $RH + X\cdot = R\cdot + HX$

Reaction in Solid Phase

Flame-retardant chemicals in the condensed phase cause a reduction in the amount of gaseous combustibles produced by altering the pyrolytic path. Instead, carbonaceous char, water and carbon dioxide are often produced (Lewin 1984; Lewin and Weil 2001). The inert insulating material (e.g., char) serves to reduce the gases. The char forms a heat- and mass-flow barrier, which serves to protect the fibre. Carbon is stabilized and prevented from turning into combustible gases. Dehydration and cross-linking are two significant processes that play a role in flame retardants, which act by way of the condensed-phase mechanism. Most of these phenomena occur in the case of phosphorous-based FR compounds. These are both recognized to occur in cellulosic and synthetic fibres. These flame retardants can cause a layer of carbon to form on the polymer surface. This can occur, for example, through the dehydrating action of the flame retardant generating double bonds in the polymer. Theses form the carbonaceous layer by cycling and cross-linking. The chemical reaction mechanism can be explained as follows.



Preventive protection from flame, including the use of flame retardants, has been practiced since ancient times. Some examples of early historical developments in flame retardants are shown in Table 6 showing that the FRs can act in the gas phase in order to interfere with combustion reactions in the flame.

Table 6 Early historical developments is fire-retardant treatments (Hindersinn 1990)

Development	Date
The Egyptians used alum to reduce the flammability of wood	Approximately 450 BC
The Romans used a mixture of alum and vinegar on wood	Approximately 200 BC
A mixture of clay and gypsum is used to reduce the flammability of theatre curtains	1638
In Britain, Wyld uses a mixture of alum, ferrous sulfate, and borax used on wood and textiles	1735
Alum is used to reduce flammability of balloons	1783
Gay-Lussac reported a mixture of $(NH_4)_3PO_4$ NH_4Cl and borax to be effective on linen and hemp	1821
Perkin described a flame-retardant treatment for cotton using a mixture of sodium stannate and ammonium sulphate. His earlier systematic studies reported obtaining nonflammable cotton at various add-on levels of metal oxides, minerals, and salts	1912

4.2 Early Historical Fire-Retardant Developments

The early synthetic polymers earlier early in this century was of special concern because the water-soluble inorganic salts used up until that time exhibited little or no consumption in these largely hydrophobic materials. Therefore, the development of polymer-compatible flame retardants was essential. By the start of the Second World War, flame-proof canvas for outdoor use by the military were produced with a treatment of chlorinated paraffin and an insoluble metal oxide, mostly antimony oxide as a glow resistor, together with a binder resin (Wolf and Kaul 1992). After the war, noncellulosic thermoplastic polymers became increasingly important as the basic fibres used for flame-retardant applications. An archaistic example of the superiority of noncellulosic compounds is provided by the diminished use of cotton fiber in children's sleepwear since the inception of new standards. In 1971, cotton supplied 78 % of the fibers used to produce children's sleepwear, whereas in 1973 it supplied less than 10 % in the USA (US EPA 1976).

4.2.1 Types of Flame Retardants

Broadly, FR compounds can be classified as organic or inorganic based; then they can be further subclassified as phosphorous- and nonphosphorous-based and so on depending on the halogen groups present in the FRs. According to KemI 1996 (The Flame Retardants Project, Swedish National Chemicals Inspectorate (KemI) Report 5/9), flame-retardant chemical types are classified as described in Fig. 14.

Flame retardants are also classified based on their durability. For textiles, depending on their fastness to laundering, flame retardants can be classified as nondurable, semi durable, and durable. A distinction is made between reactive and additive flame retardants. Reactive flame retardants have reactive components chemically built into a polymer molecule. Additive flame retardants are incorporated into the polymer

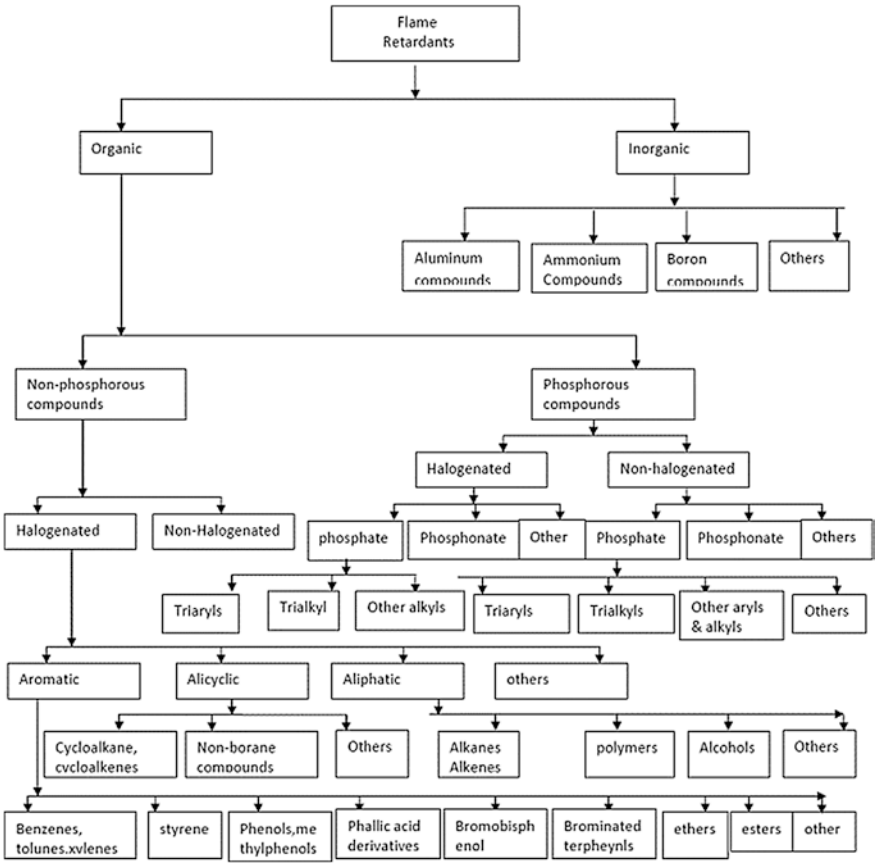


Fig. 14 Flame retardants, chemical types, KemI (1996)

either before, during, or (most frequently) after polymerisation. It has also been reported that most FRs come from three main families of flame-retardant chemicals (Jiang and Wang 2010; She and Huang 2009; Healey et al. 1994).

Inorganic Flame Retardants

The main function of inorganic flame retardants is to trigger the endothermic process; examples include aluminum trihydroxide, magnesium hydroxide, ammonium polyphosphate and red phosphorus. This group represents approximately 50 % (by volume) of the worldwide flame-retardant production due to its high stability and low cost. Antimony trioxide is the most important chemical used as a flame-retardant synergist (OECD 1994).

The effectiveness of these FR types arises due to its superiority and effective quality, which helps to achieve necessary improvements in flame retardancy. Metal hydroxides

form the largest class of all flame retardants used commercially today by common people and are employed alone or in combination with other flame retardants to ensure desired results in terms of safety level. Antimony compounds are used as synergistic co-additives in combination with halogen compounds, thus facilitating the reduction in overall flame retardant levels needed to achieve a desired level of flame retardancy. These compounds may be used alone, but they are most commonly used with antimony trioxide to enhance other characteristics, for example, smoke reduction or afterglow extinguishing. Inorganic phosphorus compounds are primarily used in polyamides and phenolic resins or as components in intumescent formulations. Ionic compounds have a very long history as flame retardants for wool- or cellulose-based products.

Metal Hydroxides

Metal hydroxides function in both the condensed and gas phases of fire by absorbing heat and shrinking to release their water from hydration. This process cools both the polymer and the flame and dilutes the flammable gas mixture. The very high concentrations (50–80 %) required to impart flame retardancy often adversely affect the mechanical properties of the polymer into which they are incorporated. Aluminum hydroxide, also known as alumina trihydrate (ATH), is one of the the largest-volume flame retardants in use today. It decomposes when exposed to temperatures greater than 200 °C, which limits the polymers into which it can be incorporated. Magnesium hydroxide is stable to temperatures greater than 300 °C and can be processed into several polymers.

Antimony Compounds

Originally, antimony trioxide is not a flame retardant, but it is used as a synergist. It is not only used in plastics, rubbers, textiles, paper, and paints but also 2–10 % by weight mixed with organochlorine and organobromine compounds used to diminish the flammability of a wide range of plastics and textiles (IARC 1990). This is usually accomplished by the release of halogen acids at fire temperatures, which then react with the antimony-containing materials to form antimony trihalide and/or antimony halide oxide. These materials act both in the substrate (condensed phase) and in the flame to suppress flame promulgation. In the condensed phase, they promote char conformation, which acts as a physical barrier to flame and resists the volatilization of flammable materials. In the flame, antimony halides and halide oxides, generated in sufficient capacity, provide an inert gas blanket over the substrate, thus helping to avoid oxygen and preventing flame spread. These compounds commute the chemical reactions occurring at fire temperatures in the flame, thus reducing the ease with which oxygen can combine with other reactants available. It has also been proposed that antimony oxychloride or trichloride reduces the rate at which the halogen leaves the flame zone, thus increasing the probability of reaction with the reactive species. Antimony trichloride probably creates heavy vapours, which form a layer over the condensed phase, stop oxygen attack, and thus block the flame. It is also assumed

that liquid and solid antimony trichloride particles contained in the gas phase reduce the energy content of the flames by wall or surface effects (Troitzsch 1990).

Boron Compounds

Following the classification of boron compounds, boric acid (H_3BO_3) and sodium borate (borax)($Na_2B_4O_7{\cdot}10H_2O$) are the two flame retardants that are primarily being used for cellulosic material, e.g., cotton and paper. However, these products are not preferred in the case of cellulosic materials when durable flame retardancy is required because both are water-soluble. Zinc borate, however, is water-insoluble and is widely used in plastics and rubber products. It is used either as a complete or partial substitution for antimony oxide in PVC, nylon, polyolefin, epoxy, EPDM, etc. Zinc borate can function as a flame retardant, smoke suppressant, and anti-arcing agent in the condensed phase. Recently zinc borate has also been used in halogen-free, fire-retardant polymers.

Other Metal Compounds

Molybdenum compounds have been used as flame retardants in cellulosic materials for many years and, more recently, with other polymers mainly as smoke suppressants (see Sect. 3.4, Troitzsch 1990). They appear to function as condensed-phase flame retardants (Touval 1993; Avento and Touval 1980). Titanium and zirconium compounds are used for textiles, especially wool (Calamari and Harper 1993). Zinc compounds, such as zinc stannate and zinc hydroxy-stannate, are also used as synergists and as partial replacements for antimony trioxide.

Phosphorus Compounds

Red phosphorus and ammonium polyphosphate (APP) are used in various plastics. Red phosphorus was first investigated in polyurethane foams and was found to be an effective flame retardant. It is now used particularly for polyamides and phenolic applications. The flame-retarding effect is due, in all probability, to the oxidation of elemental phosphorus during the combustion process to phosphoric acid or phosphorus pentoxide. The latter acts by the formation of a carbonaceous layer in the condensed phase. The formation of fragments, which act by interrupting the radical chain mechanism, is also likely. Ammonium polyphosphate is mainly applied in intumescent coatings and paints. Intumescent systems puff up to produce foams. Because of this characteristic, they are used to protect materials, such as wood and plastics, that are combustible and those (e.g., steel) that lose their strength when exposed to high temperatures. Intumescent agents have been available commercially for many years and are used mainly as fire-protective coatings. They are now used as flame-retardant systems for plastics by incorporating the intumescent components in the polymer matrix, which are mainly polyolefins, in particular polypropylene (Troitzsch 1990).

Other Inorganic Flame Retardants

Other inorganic flame retardants, including ammonium sulfamate (NH_4SONH_2) and ammonium bromide (NH_4Br), are used primarily with cellulose-based products and in fighting forest fires (Weil 1993).

Halogenated Organic Flame Retardants

Most of the members of this flame-retardant family are based on chlorine and bromine. This group represents approximately 25 % (by volume) of the worldwide production (OECD 1994). Halogenated flame retardants can be divided into three classes: aromatic, aliphatic, and cycloaliphatic. The effectiveness of halogen-containing flame retardants increases in the order of F < CI < Br < I. Bromine and chlorine compounds are the only halogen compounds having commercial significance as flame-retardant chemicals. Fluorine compounds are not used in practice because they do not interfere in the combustion process, and they are also expensive and, except in special cases, ineffective because the C–F bond is too strong. Iodine compounds, although effective, are expensive and have a too-loose bond to carbon (Cullis 1987; Pettigrew 1993). Brominated flame retardants are much more effective than chlorinated types because they release HCL over a wider temperature range (Cullis 1987).

With respect to processability, halogenated flame retardants vary in their thermal stability. In general, aromatic brominated flame retardants are more thermally stable than chlorinated aliphatics, which are more thermally stable than brominated aliphatic. Brominated aromatic compounds can be used in thermoplastics at fairly high temperatures without the use of stabilizers and at very high temperatures with stabilizers. The thermal stability of chlorinated and brominated aliphatic is such that, with few exceptions, they must be used with thermal stabilizers for e.g. a tin compound. Halogenated flame retardants are either added to or reacted with the base polymer. Additive flame retardants do not react in the application designated. A few compounds can be used as additives in one application and reactive in another; tetra-bromo bis-phenol A is the most notable example. Reactive flame retardants become a part of the polymer either by becoming a part of the backbone or by grafting onto the backbone. The choice of a reactive flame retardant is more complex than the choice of an additive type. The development of systems based on reactive flame retardants is more expensive for the manufacturer, who in effect must develop novel copolymers with the desired chemical, physical and mechanical properties as well as the appropriate degree of flame retardancy (OECD 1994; Weil 1993; Cullis 1987; Pettigrew 1993; IARC 1990; Calamari and Harper 1993; Avento and Touval 1980). Synergists, such as antimony oxides, are frequently used with halogenated flame retardants.

Brominated Flame Retardants

These FRs have the highest market share because of their good technical and performance properties. FRs can be subdivided into several classes based on the types of chemical structure listed in Table 7. Bromine-based flame retardants are highly brominated organic compounds with a relative molecular mass ranging from 200 to that of large molecule polymers. They usually contain 50–85 % (by weight) of bromine (OECD 1994). The highest-volume brominated flame retardant in use today is tetrabromobisphenol A (TBBPA) (IPCS 1995) followed by decabromodiphenyl ether (DeBDE) (IPCS 1994). Both of these flame retardants are aromatic compounds. The primary use of TBBPA is as a reactive intermediate in the production of flame-retarded epoxy resins used in printed circuit boards (IPCS 1995). A secondary use for TBBPA is as an additive flame retardant in ABS systems. DeBDE is the second largest-volume brominated flame retardant and is the largest-volume brominated flame retardant used solely as an additive. The greatest use (by volume) of DeBDE is in high-impact polystyrene, which is primarily used to produce television cabinets. Secondary uses include ABS, engineering thermoplastics, polyolefins, thermosets, PVC, and elastomers. DeBDE is also widely used in textile applications as the flame retardant in latex-based back coatings (OECD 1994). Hexa-bromo cyclo-dodecane (HBCD), a major brominated cycloaliphatic flame retardant, is primarily used in polystyrene foam. It is also used to flame-retard textiles. Some examples are listed in Table 7.

Chlorinated Flame Retardants

Chlorine-containing flame retardants belong to three chemical groups: aliphatic, cycloaliphatic, and aromatic compounds. Chlorinated paraffins are by far the most widely used aliphatic chlorine-containing flame retardants. They have applications in plastics, fabrics, paints, and coatings (Segev et al. 2009). Bis(hexachlorocyclop entadieno) cyclo-octane is a flame retardant having unusually good thermal stability for a chlorinated cycloaliphatic. In fact, this compound is comparable in thermal stability with brominated aromatics in some applications. It is used in several

Table 7 Typical FR examples with chemical constituency

Type of chemical structure	Example
Several benzene rings	Polybrominated diphenyl ethers Decabromobiphenyl 1,2-bis-(pentabromophenyl)
Tetrabromobisphenol acid	Tetrabromophthalate diols and poyethers
Tetrabromobisphenol A (TBBPA)	TBBPA-derivatives
Oligomeric and polymeric compounds	TBBPA-carbonate oligomer TBBPA-based epoxy resin Poly-di and tribromostyrene

polymers, especially polyamides and polyolefins, for wire and cable applications. Its principal drawback is that higher quantities are needed for achieving require flame retardancy compared with brominated flame retardants (OECD 1994).

Organo-Phosphorus Flame Retardants

They are primarily phosphate esters and represent approximately (20 % by volume) of the worldwide production. Products containing phosphorus, chlorine and/or bromine are also important. In addition, nitrogen-based flame retardants are used for a limited number of polymers. One of the principal classes of flame retardants used in plastics and textiles is that of phosphorus, phosphorus–nitrogen, and phosphorus–halogen compounds. Phosphate esters, with or without halogen, are the predominant phosphorus-based flame retardants currently in use. For textiles, phosphorus-containing materials are by far the most important class of compounds used to impart durable flame resistance to cellulose. These textiles with flame-retardant finishes usually also contain nitrogen, halogen, or sometimes both (OECD 1994; Weil 1993; International Agency for Research on Cancer 1990; Hartmann et al. 2004).

Non-halogenated Compounds

Although many phosphorus derivatives have flame-retardant properties, the number of those with commercial importance is limited. Some are additive and some are reactive. The major groups of additive organophosphorus compounds are phosphate esters, polyols, phosphonium derivatives and phosphonates. The phosphate esters include trialkyl derivatives such as triethyl or trioctyl phosphate, triaryl derivatives such as triphenyl phosphate and aryl–alkyl derivatives such as 2-ethylhexyl-diphenyl phosphate. The flame retardancy of cellulosic products can be improved through the application of phosphonium salts. The flame-retardant treatments attained by phosphorylation of cellulose in the presence of a nitrogen compound are also of importance (Rosenthal et al. 1979).

Halogenated Phosphates

In addition to the above-mentioned types of flame retardants, those containing both chlorine/phosphorus or bromine/phosphorus are used widely. Halogenated phosphorus flame retardants combine the flame-retardant properties of both the halogen and phosphorus groups. In addition, halogens reduce the vapour pressure and water solubility of the flame retardant, thereby contributing to the retention of the flame retardant in the polymer. One of the largest selling members of this group, tris(1-chloro-2-propyl) phosphate (TCPP), is used in polyurethane foam. Tris(2-chloroethyl) phosphate is used in the manufacture of polyester resins, polyacrylates,

polyurethanes, and cellulose derivatives. The most widely used bromine- and phosphorus-containing flame retardant used to be tris(2,3-dibromopropyl)phosphate, but it was banned in many countries due to carcinogenic properties in animals (Green 1992; Liepins and Pearce 1976).

Nitrogen-Based Flame Retardants

Nitrogen-based compounds can be employed in flame-retardant systems or form part of intumescent flame-retardant formulations. Nitrogen-based flame retardants are used primarily in nitrogen-containing polymers such as polyurethanes and polyamides. They are also used in PVC and polyolefins and in the formulation of intumescent paint systems (Grabner 1993). Melamine, melamine cyanurate, other melamine salts, and guanidine compounds are currently the most used group of nitrogen-containing flame retardants. Melamine is used as a flame-retardant additive for polypropylene and polyethylene. Melamine cyanurate is employed commercially as a flame retardant for polyamides and terephthalates (PET/PBT) and is being developed for use in epoxy and polyurethane resins. Melamine phosphate is also used as a flame retardant for terephthalates (PET/PBT) and is currently being developed for use in epoxy and polyurethane flame-retardant formulations. Also in the developmental stages for use as flame-retardant additives are melamine salts and melamine formaldehyde for their application in thermoset resins (Grabner 1993).

Summary of important FR systems and their performance: The flame-retardants formulation and application for textiles has seen a significant evolution from nondurable mineral salt finish to durable halogen and or phosphorous- and-nitrogen-based, high performing and commercially successful FR systems before this earlier century. The action of a phosphorus-based flame retardant can be summarised as follows. When exposed to an ignition source, formation of phosphorus pentoxide and phosphoric acid occurs leading to the dehydration of cellulose; gradually this dehydration reduces the temperature of decomposition (275–325 °C compared with 375 °C for untreated cotton), thus it inhibits the evolution of levoglucosan. Along with these, the flammable tars and gases are reduced, the char is increased, and formation of a protective layer of char occurs. Synergistic effect with nitrogen pair has became a proven concept because nitrogen catalyses the cellulose phosphorylation, and the retention of phosphorus in the char may be aided by nitrogen. The release of nitrogen gas, which dilutes flammable gases, reduces flaming and thus higher levels of nitrogen, may allow lower levels of phosphorus in the flame retardant (Figs. 15 and 16).

A simplified summary of flame retardants for cellulose is shown in Table 8 (Horrocks 1996).

Application techniques polymeric tetrakis(hydroxymethylol) phosphonium salt condensates (compound no. 3) was sophisticated because an ammoniation chamber is required along with stringent process control measures. On the other hand, the *N*-methylol functional phosphorus (compound no. 4) exhibits less durability with an easy pad–dry–cure finishing sequence. Most of them are based on the use

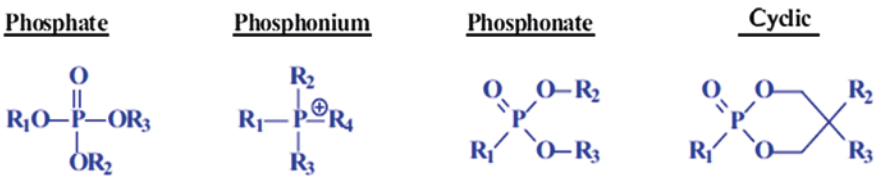
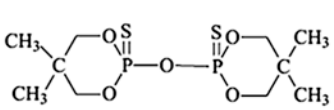
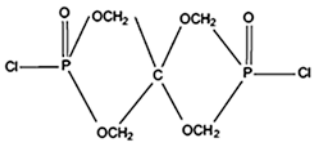


Fig. 15 Phosphorous-based FRs



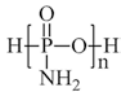
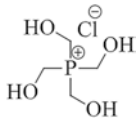
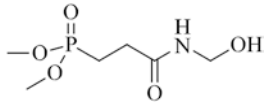
Cyclic phosphorus based additive for viscose



Spirocyclic pentaerythritol di(Phosphate acid monochloride additive for Polyester)

Fig. 16 FRs additives during fibre spinning

Table 8 Summary of flame retardants for cellulose

Type of flame retardant	Durability	Structure/formula
Salts		
(1) Ammonium Polyphosphate **1**	Non- or semi-durable	
(2) Diammonium Phosphate **2**	Non-durable	
Organophosphorus		
(3) Polymeric tetrakis (hydroxymethylol) phosphonium salt condensates **3**	Durable	
(4) Cellulose-reactive methylolated phosphonamides **4**	Durable	
Back coating		
(5) Chlorinated paraffin waxes **5**	Semi-durable	$C_nH_{(2n-m+2)}Cl_m$ **5**
(6) Antimony-halogen **6**	Semi-to-fully durable	Sb_2O_3 (or Sb_2O_5) Decabromodiphenyl oxide

of *N*-methylol dimethyl phosphonopropionamide (MDPA), commercially known as Pyrovatex CP (marketed by Ciba-Geigy), in combination with melamine formaldehyde resin. If durability is the sole criteria, these two compounds can meet

the up-to-date demand for flame retardancy for cotton. However, both of them potentiality release a significant amount of formaldehyde during application as well as lifetime (Pepperman and Vail 1975; Beninate et al. 1981; Mehta 1976). This formaldehyde was classified as a carcinogen by World Health Organization (Liteplo et al. 2002). Hence, a formaldehyde-free durable flame retardant for cellulose is of the utmost necessity (Figs. 17 and 18).

Regarding the development of a formaldehyde-free FR for cellulose, several attempts have been made during last few decades. A hydroxyl-functionalized organophosphorus oligomer (HFPO) was used by Wu and Yang (2009) for cross-linking by 1, 2, 3, 4-butanetetracarboxylic acid (BTCA) as cross-linker having four carboxylic acid groups. This forms ester linkage with cotton cellulose in the presence of sodium hypophosphite as catalyst (Fig. 19).

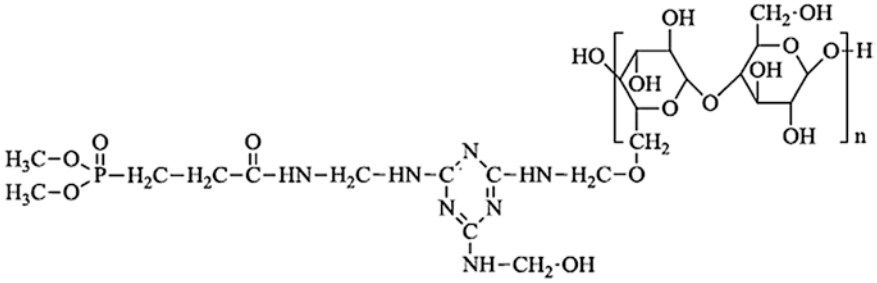


Fig. 17 Chemistry of Pyrovatex CP bonded with cellulose

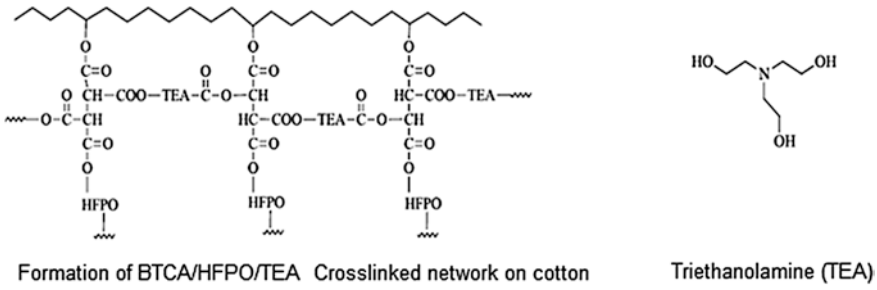


Fig. 18 BTCA/HFPO/TEA cross-linking with cellulose

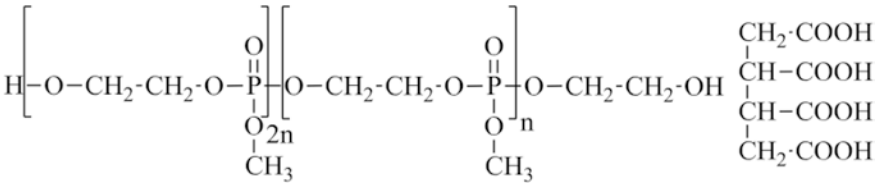


Fig. 19 Hydroxyl-functionalized organophosphorus oligomer (HFPO) and BTCA

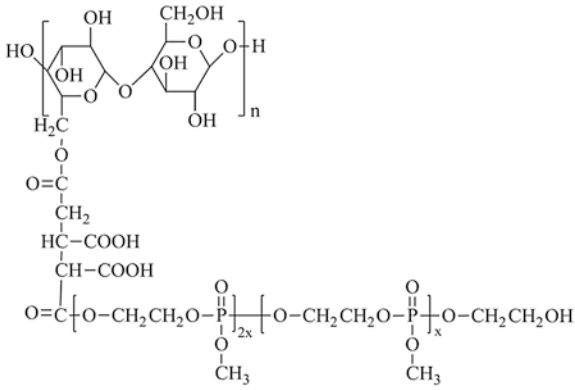


Fig. 20 HFPO cross-linked to cotton by BTCA

A moderate level of flame retardancy was achieved with 10 times pill-test washing (for carpet) of the fabric (Blanchard and Graves 2002) (Fig. 20).

The possibility of exchange between the hydrogen ion of a free carboxylic acid group and calcium ions during washing in hard water causes hydrolysis of the BTCA-cellulose ester link with poor durability. However, addition of triethanolamine (TEA) was able to reduce calcium ion pick-up during esterification.

To render durability, a combination of BTCA, HFPO, and TEA was applied to different types of textiles, such as cotton fleece (Wu and Yang 2009) and a blend of 35 %/65 % cotton/Nomex, to achieve acceptable levels of durability which passed the vertical strip test (ASTM D6413-99) after 30 home launderings (Fig. 21).

Yang and Yang (2007) applied a combination of FR, DMDHEU, and TMM to a 50/50 cotton/nylon fabric; approximately 40 % of the FR exhausted to the nylon fabrics by a FR/TMM cross-linked polymeric network (Fig. 22) and was durable to multiple launderings.

It is obvious that in this case durability was achieved up to an appreciable level, but the problem of formaldehyde release remained. Another work from ICL

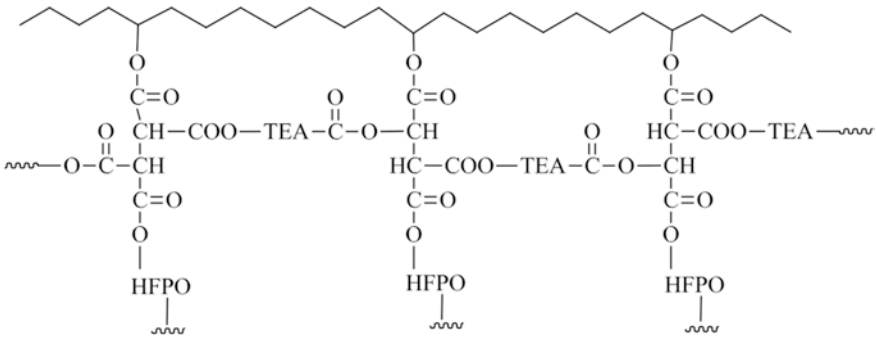


Fig. 21 Formation of BTCA/HFPO/TEA cross-linked network on cotton

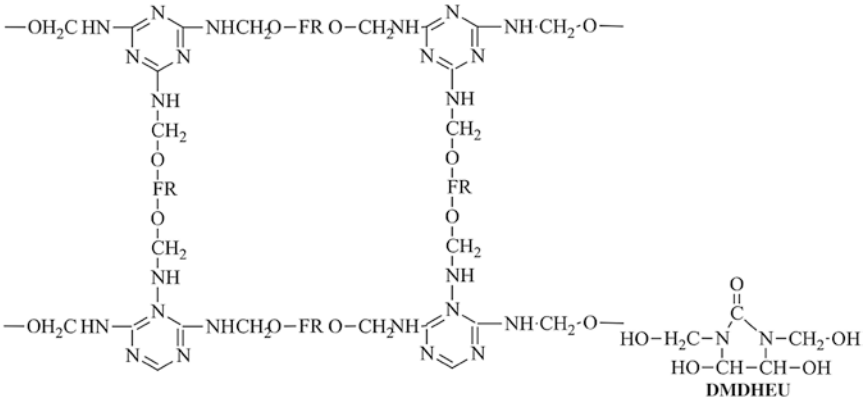


Fig. 22 The FR/TMM polymeric network

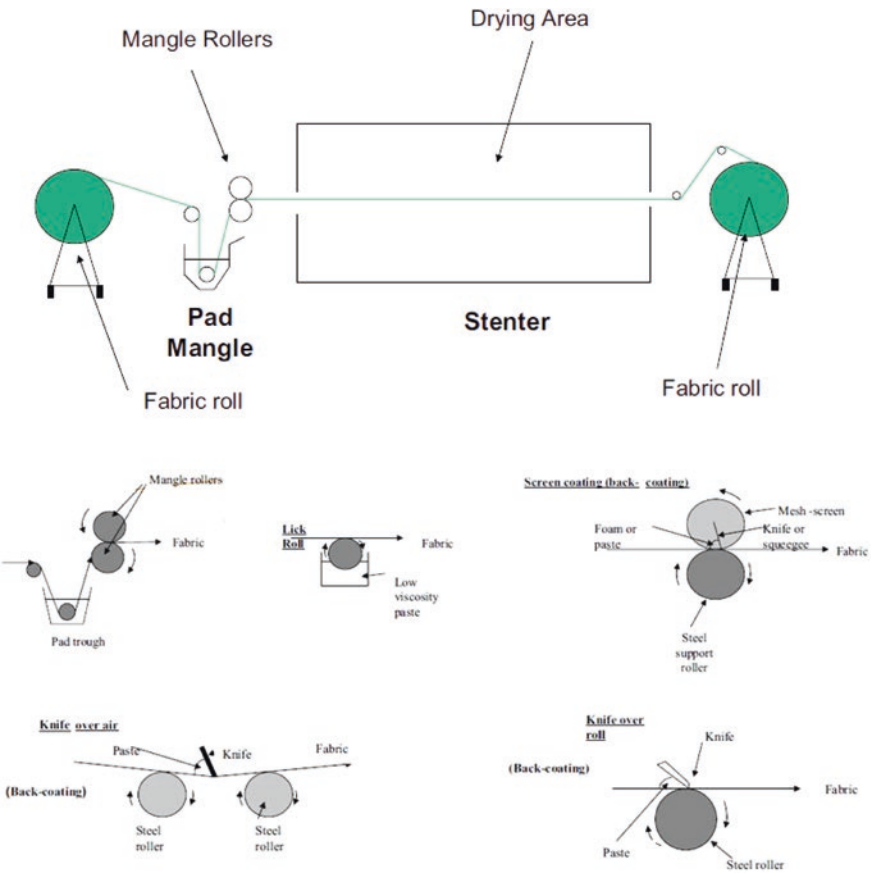


Fig. 23 Various application techniques

Table 9 Man-made fibres with inherently FR currently in use

Fibres	Comonomers/additives	Remarks
Polyester	Bifunctional phosphinic acid/ester	Most established inherent FR, Trevira CS®, 1970
Polypropylene	Halogen-organic synergist (ATO, a tin derivative)	Harmful, only single halogen-organics used
Viscose rayon	Cyclodithio phoric anhydre additive	Developed in 1970 and now available as Exolit 5060 PK (Clariant/Achroma) Lenzing FR®
Modacrylic	15–65 % vinylidene chloride	Developed in 1950 and still produced in Japan (Kanecaron)

(formerly Akzo Nobel) described Fyroltex HP with phosphate phosphonate oligomer, which showed encouraging durability in multiple laundering. However, the use of methylolated resin species, such as di-methylol di-hydroxy ethylene urea (DMDHEU) or methylated formaldehyde-urea, was a matter of concern for the same problem of formaldehyde release (Yang and Wu 2003; Wu and Yang 2004).

Thus, totally formaldehyde-free FRs do not possess unconditional durability to laundering. On the other hand, better durability could be imparted, but formaldehyde release still requires a solution. Thus, a reasonably novel organophosphorus compound with improved durability is needed, i.e., synthesize and develop an aldehyde or aldehyde equivalent containing organophosphorus molecules, which would have the capacity to react and cross-link to cellulose by way of acetal linkage to enhance durability in washing (Fig. 23; Table 9).

5 Search for Durable Eco-friendly Flame Reatardants

A good flame retardant should ideally have following properties:

- Prevent ignition
- Delay the spread of fires
- Delay the time of flashover to allow people time to escape
- Longer durability
- Prevent loss of physico-mechanical properties of the substrate
- The cross-linker and or binder copolymer should also eco-friendly
- Ease of application
- Prevention of immediate local pollution to air and water
- Prevention of lesser-known long-term environmental effects
- Cost-effectiveness

A market study in 2012 by Townsend reported approximately that 2 million tons of flame retardants are consumed worldwide, and this number is expected to increase at a rate of approximately 4–5 % a year with the North America being the largest consumer (Fig. 24).

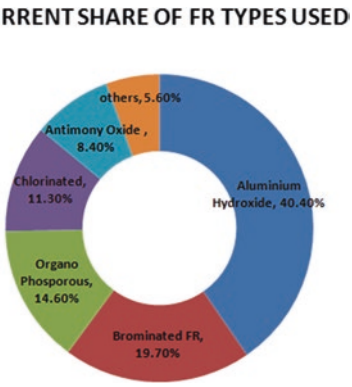


Fig. 24 Current market share of various types of FR (Alakkad 2015)

Phosphorus flame retardants have the upper hand over halogen-containing flame retardants because they have a more environmentally friendly performance (specifically organo-phosphrous based) with better flame retardancy (Yang and Yang 2005; Zhou and Lu 2012; Tang et al. 1996; Peng et al. 2008; Chen et al. 2005; Hoang et al. 2008; Xia et al. 2006; Wang et al. 2007; Wu and Yang 2006). However, FRs containing only phosphate requires a high phosphorus content to achieve good fire retardancy (Li and Liu 2012). The design of an FR system based on nitrogen and phosphate is a proven concept because of the phosphorus–nitrogen (P–N) synergistic effect (Laoutid et al. 2009; Horrocks 2011; Zhou 2012; Zhan et al. 2009; Tang et al. 2010; Ke et al. 2010).

However, the FRs resulting in perceived environmental problems, such as the release of toxic gas and free formaldehyde, have been either banned or restricted to only limited potential commercial use depending on societal eco-norms. Last decade, we saw increasing global awareness of environment issues and sustainable eco-friendly green textile chemicals, auxiliaries, and textile products. The detrimental effects (Bourbigot et al. 1999; Ma et al. 2007; Darnerud 2003; Liu et al. 2010; Reddy and Ashok 2004; Charles and Wu 2003; Chen and Wang 2005; Zhu and Sui 2004) of some well-known FR systems could be summarized as follows:

- Formaldehyde released during the curing process is hazardous and treated as an environmental pollutant.
- Halogenated compounds are toxic; products and byproducts can produce toxic dioxins and furanes.
- Many heavy metals are regarded as pollutants.
- Phosphorous, halogenated compounds, zirconium, and antimony compounds increase the BOD/COD load and toxicity of the wastewater and environment.
- A majority of the flame retardants reduce fabrics' physico-mechanical properties. Many of them are the causes of decreased tensile, tear strengths with increased stiffness, harsh feel, bad odour and color. Although industries are mostly using softener and easy-care chemicals to mitigate such shortcomings in fabrics, they increase the number of processing steps and cost due to the additional requirements of chemical and process in addition to effluent generation.

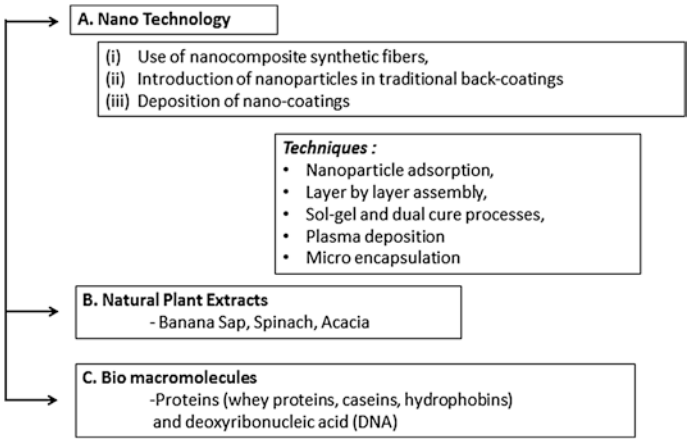


Fig. 25 Recent technology for flame-retardancy applications

The recent technology for flame retardancy applications are outlined in Fig. 25.

5.1 Nano Technology

In last few decades, research and development of new functionality of textile materials by nano-engineering gained a noticeable breakthrough with improved mechanical performance, antimicrobial protection, conductivity enhancement, dirt- and water-repellent properties, UV protection, resistance to wear, etc. Nanoparticles, nano oxides, allied cross-linkers and additives are being increasingly used and expected to be more frequently used in textiles (Khandual et al. 2015). Nano-systems are being explored for developing potentially novel FRs (Alongi et al. 2014).

5.1.1 Nanoparticle Adsorption

This is one of the easiest way of surface modification with nano-particles just by simply immersing the fabric into an aqueous suspension to enhanced the flame-retardancy properties of both cellulosics, polyester fibres and their blends as well as the possibility of application to other fibres. The mechanism developed is an inorganic shield that protects underlying polymer from heat, oxygen, and flames because these nano-coatings can act as thermal insulators. This type of coating can entrap volatile species produced by the substrate, thus reducing the fuel for further combustion; rather the substrate tends to pyrolyse instead of burn. An example is the use of hydrotalcite, titania, silica, (Tata et al. 2012) and cloisite, (Carosio et al. 2011) which can make polyester flame retardant; the efficacy depends on the length of immersion time, the pH of the nanoparticle dispersions, and the

Table 10 Nanoparticles for FR

Sodium cloisite	$Mx[Al_{4-x}Mg_x](Si)_8O_20(OH)_4$
Carbonate hydrotalcite	$Mg_6Al_2(CO_3)(OH_{16})\$4(H_2O)$carbonate salt
Sulphonate bohemite	AlO(OH) p-toluenesulphonate salt
Titania (anatase form)	TiO_2
Silica	SiO_2
Octapropylammonium POSS®	$R(SiO_x)$
CNT, Graphene oxide	
Alumina-coated silica	

surface pretreatment by cold oxygen plasma. It should be noted that the plasma pre-treatment enhances better adsorption and thus improves flame-retardancy performance. A hydrotalcite and silica system was also found to impart good flame retardancy for cotton fabrics as well (Alongi et al. 2011). In fact, a surface cold oxygen plasma pretreatment (200 W, 5 min, flux 20 cm^3/min) resulted in better nanoparticle adsorption by simple immersion (Table 10).

5.1.2 Coatings from Layer-by-Layer (LbL) Assembly

LbL made its debut in 1966 (Iler 1966) and was rediscovered and adapted later (Decher and Schlenoff 2002; Kuang et al. 2010). In simple terms, LbL is a multi-adsorption process done step-by-step to build a nano-film coating based on electrostatic interactions. It gradually gained evolution exploiting different interactions such as covalent and hydrogen bonds in addition to the electrostatic one, which simply requires alternate immersion of the substrate into an oppositely charged polyelectrolyte, commonly a water-based solution/dispersion. In other words, an assembly of positively and negatively charged layers piled up on the substrate surface by total surface-charge reversal after each immersion step (Bernt et al. 1992). Very recently, the LbL technique proved to be greatly advantageous when it was explored for incorporating flame retardancy into foams, (Laufer et al. 2012; Kim et al. 2011) textiles, (Carosio et al. 2012) and thin films (Apaydin et al. 2013; Laachachi et al. 2011; Carosio et al. 2013) Srikulkit and coworkers, in 2006, probably made the pioneer attempt to apply the LbL process to deposit a polyelectrolyte multilayer consisting of chitosan and polyphosphoric acid on silk (Srikulkit et al. 2006). Recent works on inorganic LbL coatings deposited by dipping, hybrid organic–inorganic/intumescent LbL coatings deposited by dipping, char-former/enhancer coatings by deposited by dipping and inorganic LbL coatings deposited by spray techniques have been lucidly summarised by Alongi et al. (2014) (Table 11 was reprinted with kind permission of the author and Publisher).

Table 11 Collected results on inorganic LbL coatings deposited by dipping and spray

Positive counterpart	Negative counterpart	Results	Reference
LbL inorganic coatings deposited by dipping Polyethylenimine	Laponite	Afterglow of 10BL-coated cotton fabrics occurred 10 s earlier with respect to untreated fabrics	Li et al. (2009)
Polyethylenimine	Sodium montmorillonite	Final residue of 10BL-coated cotton fabrics after vertical-flame spread tests is consistent	Li et al. (2010)
Alumina-coated silica	Silica	10BL-coated fabrics exhibit a 20 % pkHRR reduction as assessed by cone calorimetry	Laufer et al. (2011)
Octa-3-ammoniumpropyl chloride POSS®	Octakis(tetramethylammonium) pentacyclo[9.5.1.13.9,15,15.17,13] octasiloxane 1,3,5,7,9,11,13,15-octakis (cyloxide)hydrate POSS®	Afterglow time is reduced, and fabric texture is preserved	Li et al. (2011)
LbL inorganic coatings deposited by spray Alumina-coated	Silica	Applying horizontal spray, 40 % increase of TTI and 30 and 20 % reduction of pkHRR and TSR, respectively, were assessed by cone calorimetry (35 kW m^{-2}heat flux)	Alongi et al. (2013)
Chitosan	Ammonium polyphosphate	20BLs reduced cotton-rich (70 %) blend THR (−22 %) and pkHRR (−25 %) as assessed by cone calorimetry (35 kW m^{-2} heat flux)	Carosio et al. 2012
Alumina-coated silica nanoparticles	Ammonium polyphosphate	10BLs increased cotton-rich (70 %) blend TTI (+40 %) and reduced THR (−15 %), as assessed by cone calorimetry (35 kW m^{-2} heat flux)	Carosia et al. 2012
Poly(allylamine)	Poly(sodium phosphate)	10BLs reduced cotton THR and pkHRR (−80 and −60 %, respectively), as assessed by PCFC	Li et al. (2011)

(continued)

Table 11 (continued)

Positive counterpart	Negative counterpart	Results	Reference
Chitosan	Phytic acid	30BLs blocked the flame propagation on cotton and reduced pkHRR (−50 %), as assessed by PCFC	Laufer et al.(2012)
An aminoderivative of poly(acrylicacid)	Sodiummontmorillonite	20BLs increased cotton TTI (40 %) and reduce THR and pkHRR (−50 and −18 %, respectively) as assessed by combustion calorimetry (35 kW m^{-2}) heat flux	Huang et al. (2012)
A derivative of polyacrylamide	Graphene oxide	20BLs increased cotton TTI (56 %) and reduced pkHRR (−50 %), as assessed by combustion calorimetry W m^{-2} heat flux	Huang et al. (2012)
Chitosan	Poly(sodium phosphate)	17 BLs made cotton consistently passed vertical-flame testing, Reduced pkHRR and THR (−73 and −81 %, respectively) as assessed by PCFC	Guin et al. (2014)
Branched poly(ethylene imine)	Poly(sodium phosphate)	Layer by Layer is proposed in alternative approach as "One-pot" for imparting flame retardancy to cotton, thus mimicking nanoparticle adsorption	Cain et al. (2014)
Branched poly(ethylene imine)–urea-diammonium phosphate Kaolin	Kaolin	Only case in which a semi-industrial roll-to-roll plant is employed for depositing LbL assemblies to enhance cotton flame retardancy. The final add-ons as well as the combustion results by PCFC (significant reductions of pkHRR and THR) turned out to be functions of the cotton texture (namely, print cloth, mercerized print cloth, and twill cotton fabrics)	Chang et al. (2014)

5.1.3 Sol-Gel Process

The concept and application of sol-gel technique was developed in the 1950s and gradually gained importance for obtaining a high degree of homogeneity at the molecular level with excellent engineering of physical and chemical features with morphological conformity (Sakka 2003), although needed extra care for variables and process control for a two-step reaction, i.e., hydrolysis and condensation. This process has already established its popularity in textile application in various fields such as antimicrobial, biomolecular immobilization, UV protection, photocatalytic properties, dye fastness, anti-wrinkle finishing, super-hydrophobicity, and sensor characteristics (Sakka 2003; Mahltig et al. 2004, 2005a, b; Abidi et al. 2007; Xing and Ding 2007; Xing et al. 2007; Mahltig and Textor 2006; Cireli and Onar 2008; Huang et al. 2006; Mahltig and Böttcher 2003; Yu et al. 2007; Xue et al. 2008; Li et al. 2007; Moafi et al. 2011; Colleoni et al. 2012; Caldara et al. 2012; Van der Schueren et al. 2012). However, has just recently been explored for flame retardancy. Silica combined with various sol-gel precursors—such as tetramethylorthosilicate (TMOS: 4Methoxy), tetraethylortho silicate (TEOS: 4Ethoxy), tetrabuthylorthosilicate (TBOS), and alkoxysilane—has shown flame retardancy in cotton. In addition, the following have also been reported to be useful: titania, zirconia, and alumina + silica; titania, zirconia, and alumina + tetraethylorthotitanate; and tetraethylorthozirconate + and aluminium isopropylate precursor. Among all of these, the silica-based treatment has shown the slowest burning rate with highest residue in vertical flame-spread tests, the highest TTI, and the lowest pkHRR, THR, and TSR in cone calorimetry tests (35 kW m^{-2} heat flux) as studied by Alongi et al. (Notations of cone calorimetry test results TTI, pkHRR, THR and TSR can be refered in details here).

Possible advantages of these coatings are that its application can be indifferent to natural and synthetic fabrics as well as to their blends with water as a solvent. In most of cases, LbL assembly is extremely diluted (0.2–1 wt%) and because it has a nano-coating size, there is less of a chance to alter common fabric aesthetic features such as colour, comfort, and hand; in addition, it can be multifunctional by assembling other components of interest. The simpler application technique, such as impregnation/exhaustion by padding, is adventitious. However, durability and industrial scale-up processes are the larger challenges to overcome in the future because most of them are nondurable flame-retardant systems; only a few are semidurable.

5.2 Natural Plant Extracts

A consumer survey on willingness to pay extra for an environmentally friendly garment/garments that are produced by environmental friendly process was conducted by Levinson Elsa of Stockholm University in 2010. The investigator reported that 89 % of the respondents expressed their willingness to pay extra

money for an assurance that the garment is eco-friendly. In fact, the median amount they are willing to spend is approximately 65 SEK (Swiss currency) extra (Levinson 2010; Jena et al. 2015).

Currently switching over to natural herbal products derived from plants is appealing because they represent a greener approach and are environmental friendly, abundant, biocompatible and they are being explored all around the world to be used for textiles (Joshi et al. 2009; Samanta and Agarwal 2009) to enhance many functional properties. In last decade, some of these applications to textiles, made in the last decade are worth mentioning here: flame retardancy, (Huang et al. 2001) deodorizing properties/pleasant aroma, (Specos et al. 2010) insect-repellent properties, (Sricharussin et al. 2009) antimicrobial properties, (Joshi et al. 2009; Shahid et al. 2012) and UV protection (Grifoni et al. 2011; Sun and Tang 2011). The potential market opportunities for plant-derived natural products for textile applications is huge, compared with their synthetic counterparts, in terms of significant cost reduction and increased environmental friendliness (Islam et al. 2013).

In fact, Huang et al. (2001) reported that cyclodextrin has been widely used in flame-retardant textiles (Huang et al. 2001). Anti-blaze RD 1 is a commercial flame retardant has shown superior FR properties when applied with cyclodextrin (Huang et al. 2001) (Fig. 26).

These natural polymers act as a physical barrier to limit heat, fuel, and oxygen transfer between the flame and the textile substrate in an eco-friendly manner. Cyclodextrin applications were first published in 1891 and patented in 1953, and since 2009, the total number of cyclodextrin related publications amounted to 42,000 (average of 7 publications/day) in 2009 (http://www.cyclolab.hu/services4.html) clearly indicating its wider applicability and basis of research (Usha et al. 2011) (Fig. 27).

Cyclodextrins, being natural products, are not expensive, water-soluble, nontoxic, can easily functionalized and made commercially available. They are becoming the most important and promising macrocyclic hosts (Zhou and Ritter 2010). Cyclodextrins (CDs) are being used extensively in different industrial applications such as textiles, cosmetics, pharmacology, filtration of pesticide formulations, etc. Industrially produced CDs are in one of three classes: α-, β-, and γ-CD. However, another kind of cyclic oligo-saccharide is being produced, but limited applications are reported due to its prohibitive cost (Vögtle 1991). Cyclic oligomers of a-D-glucopyranose are produced with the transformation of starch by certain bacterias such as Bacillus macerans (Astray et al. 2009; Jeang et al. 2005) (Table 12).

The uses of α-CDs have shown promising opportunities to obtain innovative products through an eco-friendly chemical finishing route for functionalization of

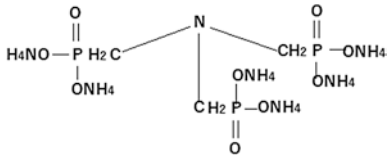


Fig. 26 Anti-blaze RD 1

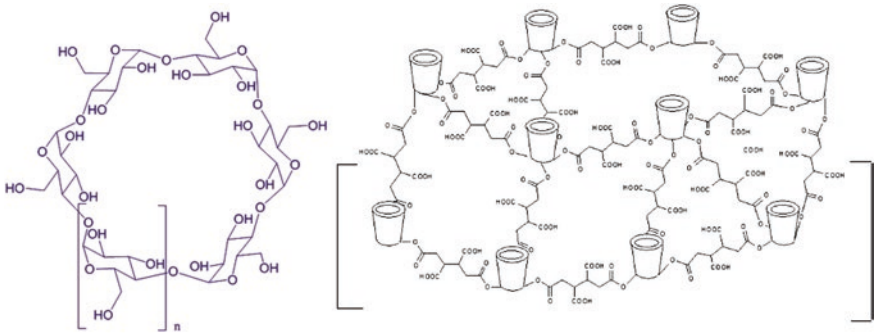


Fig. 27 Cyclodextrin and nano-assembly of β-CD cross-linked with BTCA on textile surface

Table 12 Feasible interactions between α-CD and some textile fibres (Andreaus et al. 2010)

Parameter	Cotton	Wool	PES	PA	PAN	PP
Ionic interactions	−	+	−	+	+	−
Covalent bonds	+	+	−	+	−	−
Van der Waal forces	−	−	+	+	+	−
Cross-linking agents	+	+	+	−	−	−
Graft polymerisation	+	+	+	+	+	+

+ = possible, − = not possible, PES = polyester, PA = polyamide, PAN = polyacrylonitrile, PP = polypropylene

textiles. It is worth mentioning that these current techniques of fixation to various textile substrates have been summarized in Table 2 by Usha et al. (2011)

- Cross-linking
- Grafting
- Reactive fixation
- Disperse dyeing method
- Basic dyeing method
- Electrospinning
- Sol-gel process
- Enzymatic coupling
- Polymer extrusion

Many of plants and their parts contain phosphorous and other minerals. The flame-retardant functionality imparted by two such plant extracts of Banana pseudostem sap (BPS) and Spinach juice (SJ) have been extensively studied by Smanata et al. (2014) (Bajaj et al. 2000; Schinder 2004) for FR finishing of cellulosic and lignocellulosic textiles. BPS, being an agro-waste plant extract, and SJ, being a vegetable extract, are rich in phosphorous, nitrogen, chlorine, silicate and other many metallic compounds (Basak et al. 2014, 2015). Their presence has been reported

exclusively by the experimental findings in FTIR, EDX, and mass spectra. BPS and SJ produces a thick protective coating on the surface of the cotton fiber and TGA shows that the BPS mainly acts in the condensed phase by influencing pyrolysis of cellulosic polymer causing earlier char formation. A stable and protective char thus formed while burning reduces the chances of an exchange of oxygen and combustible volatile substance, thus suppressing flame propagation. BPS coating may act as an intumescent that swells on heating to protect the underlying cellulose polymer from heat or flame.

Unlike BPS, SJ can be applied to cotton textile directly without any premordanting. Even an 8 % add-on showed increased LOI to 30 from 18; the fiber neither caught flame nor presented afterglow for 400 s (the control sample burned completely within 60 s at 400–450 °C). However, a reduction in LOI from 30 to 22 after soap washing was noted. Both BPS and SJ, so therefore, can be regarded as semidurable finishings. It is interesting to note that these plant extract-based, cost-effective finishes showed no significant changes in fabric tensile or tear strength after the application plus they are abundantly available and produced from renewable sources. In addition, BPS and SJ resulted in excellent and effective UV-protective functionality; specifically when mordanted fabric was treated with BPS under alkaline conditions, the UPF value was >100 (without any mordant-40). The UV protection in BPS was credited to the presence of *N*,*N*-alkyl benzeneamine through GC-MS analysis. The UPF value reduced to 70 and 50, respectively, after the first and second ISO-1 wash. A UPF value of 125 was obtained from SJ-treated cotton fabric under alkaline conditions due to the presence of organic color and silicate molecules. Test results ensure that BPS and SJ can add multifunctional value to cellulosics—such a flame retardancy, UV protection and natural color—in a single step (Smanata et al. 2014; Basak et al. 2014, 2015). Both of the species are abundantly available in many countries and applied as a green, cost-effective flame-retardant. Such plants, rich in phosphorous, nitrogen, and other metallic constituents, can potentially be explored for further applications.

5.3 Plasma Deposition

Plasma technology application to textiles was reported approximately 40 years ago and even today they are being used in specific industrial domains such as paints, coatings and microelectronics (Liang et al. 2013). Plasma ingredients are mainly partially ionized gas containing many species such electrons, positive and negative ions, excited molecules, photons and UV lights. They can be employed for nano-engineering of textile substrates without altering their inherent bulk properties (Yasuda 1985). The functional and aesthetics of textiles can be altered for increasing water and oil absorbency/repellency, antistatic properties, adhesion, UV protection, antimicrobial properties, flame retardancy, dyeing, desizing and antifelting of wool (Samanta et al. 2009, 2010, 2012; Wakida et al. 1993; Panda et al. 2012) etc. The plasma reaction, with smaller molecules, can cause an increase in surface

roughness/area, oxidation, surface activation and need for cleaning. On the other hand, the use of larger molecules lead to plasma polymerization, coating, deposition and creation of nanostructures. However, the use of atmospheric pressure plasma is necessary for textile applications that have become commercially available just recently (Fig. 28).

Some of potential applications for flame retardancy are the modification/fictionalization of the surface by using nonpolymerizable gases (etching) and grafting of nonvolatile phosphorus species in cold plasma (Simionescu et al. 1982). Plasma treatment has been reported either as a pretreatment to increase the uptake of fire-retardant chemicals, for graft polymerization of acrylate phosphate and phosphonate derivatives, or as a posttreatment for better reaction (Fig. 29).

In such cases, organosilicon compounds are deposited by plasma polymerization (Akovali and Takrouri 1991; Akovali and Gundogan 1990; Bourbigot et al. 1999a, b). The use of nitrogen by cold remote plasma technique has also been studied (Bourbigot et al. 1999a, b; Quédé et al. 2002; Jimenez et al. 2010) as the use of acrylic monomers for grafting reactions (Shi 2000a, b). Atmospheric pressure plasma has become easily and efficiently applied to improve the functional properties of cotton fabrics as reported by Bourbigot and Duquesne (2007).

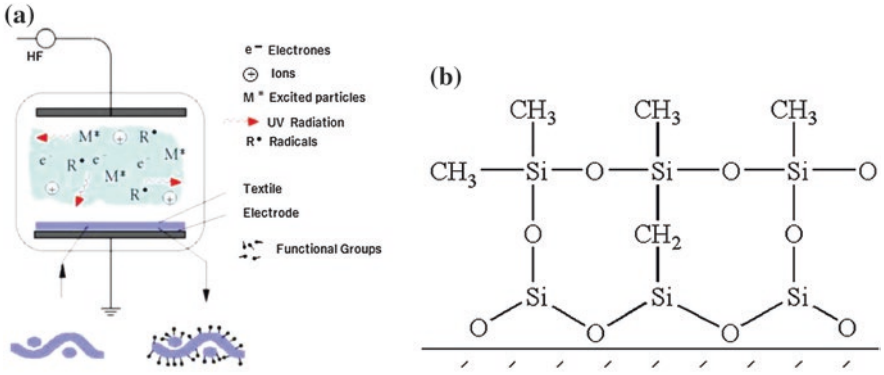


Fig. 28 **a** Plasma irradiation technique. **b** Plasma induced fictionalization/polymerization

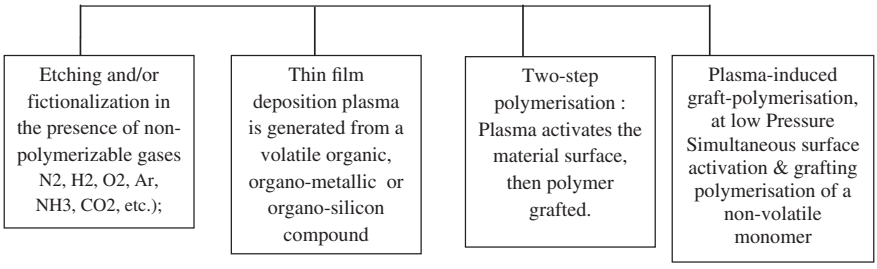


Fig. 29 Cold plasma techniques (Farag et al. 2013; Kamlangkla et al. 2011; Tsafack and Levalois-Grützmacher 2006a, b; Tsafack et al. 2004)

Argon plasma–preactivated polyester fabric was treated with (Raslan et al. 2011) different metal and/or metal oxide mixtures, such as aluminum oxide, nanosilver and titanium dioxide; shown improvement in flame retardancy and thermogravimetry as well as good antimicrobial properties. SiO_2-atmospheric pressure plasma (APP)-coated flame-retardant cotton textiles with enhanced thermal properties and improved flame retardancy have been obtained in a process where a dense, thin film of tetramethyldisiloxane (TDMS) monomer (premixed with oxygen) forms an SiO_2 network armor through hydrolysis and condensation of the precursor TEOS, which becomes cross-linked on the surface of the cotton fibre. The SiO_2 network was found to be stable on fabric surfaces irrespective of intense ultrasound washing (Bourbigot and Duquesne 2007). These types of deposits onto polyamides and polyamide nano-composites were also successful and reported to enhance the LOI greatly even at film thicknesses equal to 0.6 mm under burning conditions. These nanocomposite structure polymers form a surface protective layer the presence of carbonaceous and silica-like layers act as a barrier, which also slowed down toxic gas formation. A patented process by Arecent reports the successful use of atmospheric plasma to develop flash fire-resistant finishing FR cotton and poly(meta-aramid) fabrics using clay and a silicon-containing monomer, hexamethylene disiloxane (HMDSO), in various combinations (Li et al. 2010) (Fig. 30).

Polymerization of the mixture of 1.1.3.3-tetramethyl disiloxane (TMDS) monomer and oxygen gas in low-pressure cold plasma (Quede et al. 2002) on PA6 substrates has shown decreased RHR of 28 % and two- to three-fold increased ignition time (105 s to 219 to 315 s). Joëlle et al. used diethyl (acryloyloxyethyl) phosphoramidate (DEAEPN) monomer, photoinitiator and ethylene glycol diacrylate (EGDA) for simultaneous improvement in dyeing and flame retardancy (Grützmacher et al. 2012). *N*-methylol dimethylphosphonopropionamide (FR)—along with a melamine resin, a cross-linking (CL) agent, a catalyst asphosphoric acid (PA) and a titanium dioxide (TiO_2)/nano-TiO_2 co-catalyst—was added to the FR formulation to develop FR-CL-PA components (Kan et al. 2012). In similar fashion, plasma containing a phosphorus compound can induce the flame retardancy of viscose rayon, acrylic, and cotton (Shah and Shah 2013). In fact, many

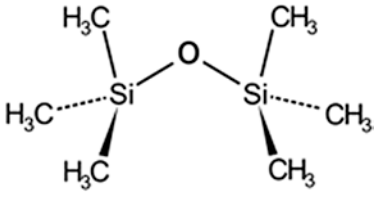


Fig. 30 Hexamethyldisiloxane (HMDSO)

vertical flame-spread test results ensure the effectiveness of the grafted phosphorus-containing polymer that promotes char formation although the fabrics were not self-extinguishing. These pretreatments can also be employed for PET (Tata et al. 2012; Carosio et al. 2011) and cotton (Alongi et al. 2011; Horrocks et al. 2011; Kaur and Sharma 2007). Low-pressure plasma-induced graft polymerisation (PIGP) may be the most promising FR treatment and worthy of industrial exploration as decribed by Tsafack and Levalois-Grützmacher (2006) and Tsafack et al. (2004). They observed 8 units of increased LOI in case of PAN fibres, depending on the type of grafted monomer of PIGP along with some acrylic phosphorus-based monomers.

5.4 Bio Micro Molecules

Recently the application of bio-macromolecules, such as proteins (whey proteins, caseins, and hydrophobins) and deoxyribonucleic acid (DNA), is gaining major momentum as a research topic because they have shown appreciable results of flame retardancy for cellulosic as well as synthetic substrates (Bosco et al. 2013; Alongi et al. 2013a, b, 2014). The major advantages can be outlined as follows:

1. Flame retardancy obtained is quite significant and cab be on par with conventional phosphorus-based flame retardants in some cases. However, the complete understanding of the mechanism by which to confer flame retardancy to fabrics is still under investigation.
2. Ease of application such as impregnation/exhaustion/layer-by-layer depositions are commonly practised for the chemical finishing of textiles.
3. Being bio-macromolecules, the process imposes a low environmental load and toxicity because they are usually dissolved or suspended at low concentrations in aqueous media; no volatile organic carbon (VOC) species are produced.
4. Some of these bio-macromolecules, such as caseins (whey proteins), can be considered as by-products/waste products from the agro-food industry.
5. The recovery and subsequent use of bio-macromolecules as flame retardants may be useful in the valorization of agro-food crops, thus avoiding their landfill.
6. Although bio-macromolecules are currently expensive, their availability has become more competitive with diminishing cost because a large-scale method of production was recently developed by Wang and co-workers. They proposed a new large-scale method of extraction and purification of DNA from salmon milt and roe sacs (Wang et al. 2001).

Whey proteins: These are globular molecules that are mostly composed of α-helix motifs containing fairly balanced distributed acidic/basic and hydrophobic/hydrophilic amino acids along the polypeptide chains (Ajgaonkar 1994). They have high nutritional value with essential amino acid content, particularly the sulfur-containing ones (methionine, cysteine) and constitute approximately 20 %

of the total proteins in milk (Wit and De 1998; Siso 1996). Whey proteins show good functional properties—such as high solubility, water absorption, gelatinization, emulsifying capacities and are available in three major forms: whey protein concentrate (WPC), whey protein isolate (WPI) and whey protein hydrolysate (WPH). The potential applications of whey protein are much explored as emulsifiers in nanoemulsions, stabilizers, and micro/submicro/nano encapsulation for food nutrients and drug delivery.

Caseins: These are the major fraction of milk proteins commonly known as "bovine caseins," which are family of phosphoproteins produced in bovine mammary gland. There exist four main types of casein comprising approximately 80 % of the total protein in bovine milk. The remaining protein components are termed "whey proteins": α-Lactalbumin = approximately 2 %, β-lactoglobulin = approximately 10 %, serum albumin = approximately 1 %, immunoglobulins: approximately 2 %, and other proteins = approximately 2 %.

In milk, caseins exist as the calcium salt arranged in micellar particles surrounded by soluble kappa-casein. The casein component of milk is relatively heat-stable capable of surviving pasturization at approximately 62–71 °C. Conversely, the whey protein component is denatured at these temperatures. Casein solubility is pH dependent and is also affected by ionic strength and composition (Table 13).

Phosphoseryl residues are high in caseins, which can be useful for micellar stability. In addition, caseins have a high proline content uniformly distributed through the polypeptide chain. The presence and position of phosphate moieties in the various caseins has important implications for functionality, (Fox and Mulvihill 1983) and it has recently been reported that they have potentials in nanoscience and biomedical applications (Liu and Liu 2013). In α-s1-casein, seven of the eight phosphate groups are between amino-acid residues 42–80 and three major hydrophobic regions in, namely, amino-acid residues 1–44, 90–13, and 132–199. Because of the disproportionate distribution of acidic amino acids, serine phosphate groups and hydrophobic amino acids in the polypeptide chain, hydrophilic regions with a high negative charge are interspersed with strongly hydrophobic regions on the same peptide chain. Thus, caseins tend to be strongly associated because of the combinations of hydrophobic, hydrogen, electrostatic, and disulfide bonding (β-casein) (Fox and Mulvihill 1983).

Hydrophobins (Malucelli et al. 2014)

Hydrophobins are a large family of small amphipathic proteins with low molecular masses (7–9 kDa) that are produced by lamentous fungi. Depending on the

Table 13 Four different types of bovine casein exist each with several genetic variants (Modler 1985)

Casein type	Total casein %	Mol. wt	Phosphates/mole	g protein/L in skim milk
α-s1	44–46	22,068–23,724	8–10	12–15
α-s2*	12	25,230	10–13	3–4
β	32–35	23,944–24,092	4–5	9–11
κ*	8–12	19,007–19,039	1	2–4

cysteine distribution and the clustering of hydrophobic and hydrophilic amino acid residues, they are classified into two main hydrophobin classes: (1) class I (HFBI) proteins form aggregates that are highly insoluble in aqueous solution with low wettability; and (2) class II (HFBII) proteins form aggregates that easily dissolve in aqueous media.

However, both classes have a characteristic pattern of eight cysteine residues forming four nonsequential disulphide bonds. Interestingly, at the hydrophobic–hydrophilic interfaces, some hydrophobins have the ability to be converted to hydrophobic surfaces from hydrophilic ones and vice versa by self-assembling amphipathic monolayers and they are well-known among the most surface-active molecules (Israeli-Lev 2014).

Deoxyribonucleic acid (Malucelli et al. 2014)

DNA are of double-helical shape consisting of two long-chain polymers of nitrogen-containing bases—adenine (A), guanine (G), cytosine (C) and thymine (T)—with backbones of deoxyribose units and phosphate groups connected through ester bonds as depicted in Fig. 31. Compared with other FRs, DNA shows unique FR properties because it contains, all in one molecule, the three main ingredients of an intumescent formulation. The phosphate groups produce phosphoric acid; the deoxyribose rings act as a carbon source and blowing agent (dehydrate forming char with water release); the nitrogenous bases A-G-C-T can release ammonia. DNA-treated cotton fabrics have shown excellent self-extinguishment properties.

DNA technology is immensely useful and DNA is recognized as a "generic" material with ease of incorporation and binding capability with other compounds, thus paving major inroads in the development of novel nanostructures,

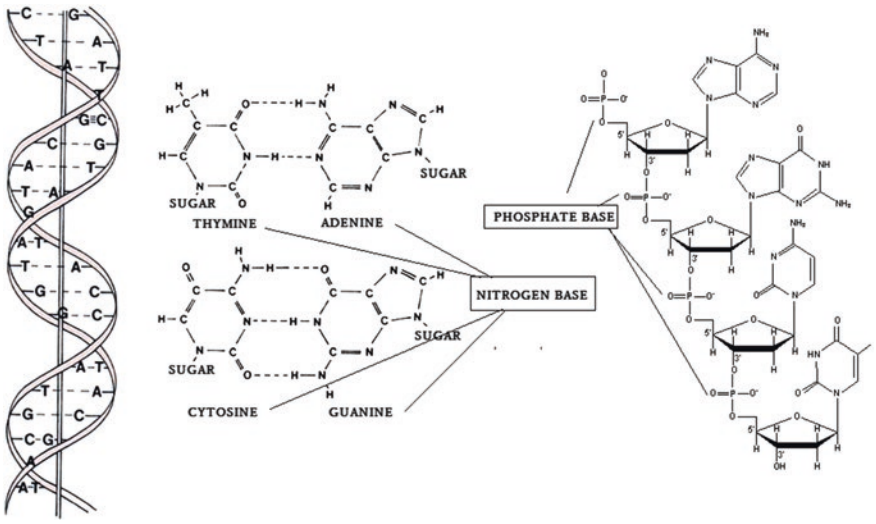


Fig. 31 Deoxyribonucleic acid

semiconductor particles, DNA-directed nanowires, DNA-functionalized carbon nanotubes, biosensors, biomedical diagnostics, biomimetic assembly and many more applications. The chitosan–DNA complex provides a platform for the development of non-toxic and effective delivery of biologically active macromolecules (Amaduzzi et al. 2014).

The flame retardancy of these green bio-macromolecules could be attributed to their chemical constitution along with their interaction with the underlying fabrics in forming a stable and protective char, i.e., carbonaceous residue upon heating that suppresses the exchange of oxygen and combustible volatile products. Caseins and hydrophobins, having phosphate groups and disulphide units, are capable of forming char during the process of cellulose pyrolysis. Whey proteins basically form a protective coating on cotton that exhibits great water vapour–adsorption fabrics. The effect may be regarded as intumescences as a combination of charring and foaming at the surface of the burning polymer, thus protecting the underlying material and interrupting the self-sustained combustion. Cotton fabrics with 30 wt % add-on of WPI products has shown a drastic reduction in burning rate (−3 %) (Bosco et al. 2013) but with very high final residues, whereas applying a DNA coating onto cotton fabrics (19 wt% add-on) did not cause the fabric to burn after applying a 2.5-cm methane flame twice for 3 s each time (Alongi et al. 2013). The phosphate groups, by generating phosphoric acid to catalyse the dehydration of cellulose, favoured the auto-cross linking to an aromatic char and thus reduced the production of volatile species. It has been reported that 10 wt% minimum add-on is necessary to achieve cotton with self-extinguishing properties and 19 wt% pick-up level to gain ignition resistance to an irradiating heat flux of 35 kW m^{-2} (Alongi et al. 2013). DNA–chitosan systems are thermally stable and when applied in the LbL assembly are able to impart remarkable flame resistance because the DNA layers promote the char formation of chitosan counterparts by releasing phosphoric and polyphosphoric acid.

6 Conclusions

The sustainability concerns about various hazardous textile chemicals has been paid much intensive research today, thus generating momentum to delve into natural greener alternatives. Novel flame-retardant products are demanded to meet not only a favourable ecological profile but also a durable, cost-effective and sustainable product. Nanotechnology approaches, such as nano-particle adsorption and layer-by-layer (LbL) assembly as well as Sol-gel, definitely prove an effective way of improving flame retardancy along with multi-functional finishes, but they need further research to overcome issues such as durability as well as toxicity risks. In fact, nanoparticles have more toxicity risk than larger particles because of their physicochemical properties, chemical reactivity, and biological activity. Plasma pretreatment proved to be effective in enhancing FR performance. In terms of eco-sustainability, the flame retardancy of green bio-macromolecules—specifically

whey proteins, DNA, and herbal extracts—seems to be promising. These may overcome the current limitations sooner given their outstanding performance, availability and ease of application with nontoxic cross-linkers or binders, such as cyclodextrin with ease of application. Natural herbal extracts, such as banana sap and spinach, have shown their potential applications as flame retardants although they semidurable. There exist many herbs and plants extracts that are rich in nitrogen, phosphorous and minerals. We can expect that more research will be conducted in the near futures in these directions to create textiles viable and sustainable. Along with ecology, the driving force for further investigation would be the durability, possible industrial scale-up costand sustenance of the inherent property of textiles.

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Potent Polyphenolic Natural Colorants Derived from Plants as Eco-friendly Raw Materials for the Dyeing Industry

Shahid-ul-Islam and Faqeer Mohammad

Abstract The reintroduction of colorants from vegetables sources, animals, and minerals is gaining popularity for use in different application fields due to the economical and ecological restrictions imposed by many countries on a number of synthetic colorants that are associated with allergic, toxic, carcinogenic, and harmful responses. Although various sources of natural colorants are known, the tannin colorants from plants are better options to replace or act as co-partners with synthetic dyes in view of their several advantages such as biodegradability and eco-friendliness. Tannins are naturally occurring compounds commonly found in roots, barks, leaves, flowers, skins, fruits, and shells of plants. This chapter discusses the phytoconstituents and coloring compounds in some well-known tannin dye-yielding plants such as cutch, pomegranate, harda, gallnut, and babool, which are grown all around the world.

Keywords Tannin dye · Pomegranate · Babool · Gallnut · Harda

1 Introduction

In view of their ecological and human health benefits, natural dyes derived from vegetables, minerals, and animals are gaining much popularity for their use in different application sectors including textile dyeing, food coloration, dye-sensitized

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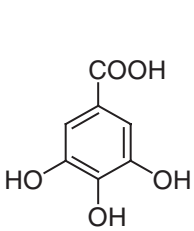
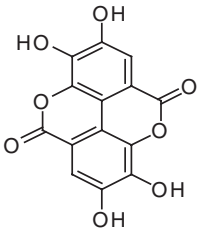
solar cells, and pH indicators (Batool et al. 2013; Chattopadhyay et al. 2013; Joshi et al. 2009; Vankar and Shanker 2008; Yusuf et al. 2015). During the last few decades, various investigations have been performed to explore and identify new color-yielding plants as well as their uses as alternative/co-partner sources to toxic synthetic dyes currently available on the market (Islam and Mohammad 2014, 2015; Islam et al. 2014; Khan et al. 2011a, b). Shahid et al. (2013) recently published a comprehensive article focussed on recent developments in traditional and newly discovered applications of natural colorants with special attention given to the technological development in natural textile dyeing and the use of natural dyes in functional finishing of textiles, food coloration, and dye-sensitized solar cells. Apart from this, a number of other review articles have been published on the subject of natural colorants. Islam et al. (2013) more recently highlighted the most important textile applications of environmentally friendly plant-based products including plant colorants.

A number of structurally diverse natural dyes, such as tannins, carotenoids, anthraquinones, naphthoquinones, and flavonoids, have been identified from all parts of different plant species (Rather et al. 2015a, b; Bechtold et al. 2006, 2007). Until the discovery of synthetic dyes by W.H. Perkin in 1956, they were the main colorants available for textile dyeing. Tannins are the potential class of colorants that have been used by mankind since prehistoric times for coloring skin, for painting, and for dyeing, and currently they are receiving much more attention worldwide for their use in the natural-dyeing industry (Khan et al. 2011; Hong et al. 2012; Koh and Hong 2014; Onal et al. 2005; Shahid et al. 2012; Ajmal et al. 2014).

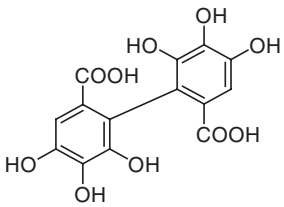
Tannins are astringent, water-soluble phenolic compounds with high molecular weights present in various plant parts including roots, barks, leaves, flowers, skins, fruits, and shells (Khanbabaee and van Ree 2001). Tannins are usually classified into two groups: hydrolysable and condensed tannins (Haslam 1996). Some of the monomers of both these groups are shown in Fig. 1. Polyphenols or tannins are mainly used in the preservation of leather, in glues, inks, and stains and as mordants for textile dyeing. One of the most important properties of polyphenols is their high complex-forming ability with different metal ions, a process which has been used for removal of some heavy metals from waste waters (Serrano et al. 2009; Haslam 2007). Tannins have also been reported to play an important role in dyeing with natural dyes by improving the affinity of fibres toward different dyes (Lee et al. 2014; Moiz et al. 2010). Depending on the chemical nature of mordants and fibres, tannin-metal complexes not only offer amazingly wide range of possible colors, they also enhance dye fixation on textile substrates. This chapter highlights dyeing principles and other phytochemicals isolated from some prominent tannin-rich plants with an emphasis on cutch, pomegranate, harda, gallnut, and babool.



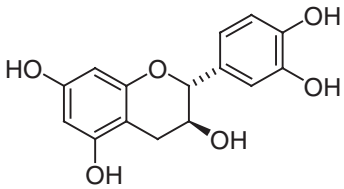
Gallic acid



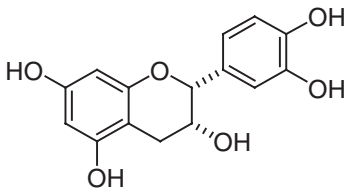
Ellagic acid



Hexahydroxy diphenic acid



(+)-catechin



(-)-epicatechin

Fig. 1 Structures of some monomers of hydrolysable and condensed tannins

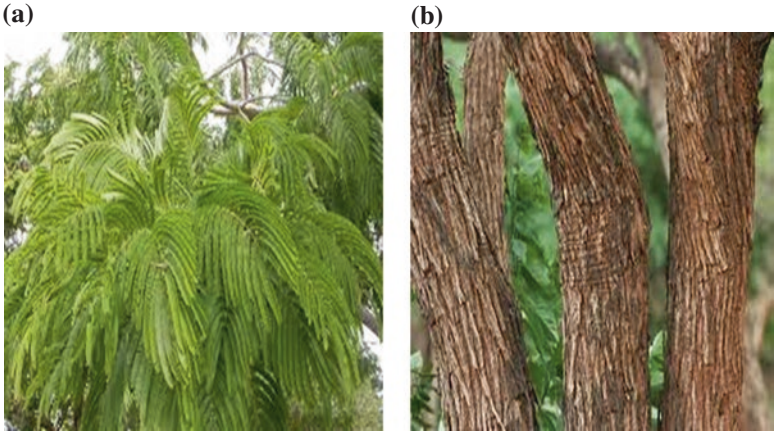


Fig. 2 **a** Cutch plant. **b** Bark

2 *Acacia catechu*

Acacia catechu is a moderate-sized tree commonly known as *katha*. It belongs to the family *Fabaceae*. *A. catechu* (Fig. 2a, b), is widely distributed throughout Asia, and is mainly found in Pakistan, India, Thailand, and Bangladesh (Perkin and Everest 1918). Various parts of this plant have been traditionally used to combat

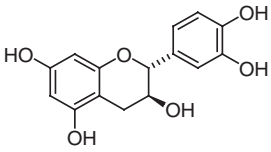
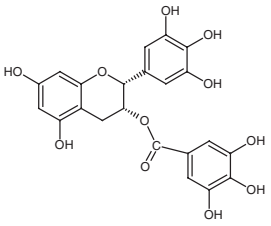
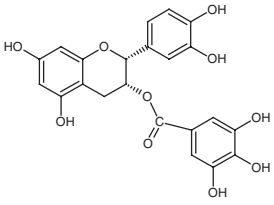
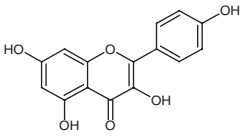
Chemical compound	Chemical structure
(+)-catechin	
epigallocatechin gallate	
epicatechin gallate	
kaempferol	

Fig. 3 Structures of chemical compounds present in cutch plant

various infections such as asthma, itching, skin disorders, dental caries, and sexual dysfunction (Anonymous 1948). The presence of active phytochemicals, mainly tannins and alkaloids, in *A. catechu* have been shown to possess remarkable antibacterial, antifungal, antioxidant, and hypoglycemic activity as well as wound-healing activities (Ray et al. 2006).

2.1 Phytochemistry and Coloring Compounds

Different natural products have been isolated from seeds, barks, roots, leaves, and stems of *A. catechu*. The most evident phytochemicals identified in *A. catechu* include catechin, kaempferol, (−) epicatechin, 3,4′,7-trihydroxyl-3′,5-dimethoxy-flavone, epigallocatechin, epicatechin gallate, afzelechin, epiafzelechin, ophioglonin, epigallocatechin gallate, rocatechin, phloroglucinol, procatechuic acid, catecutannic acid, quercetin, dihydrokaempferol, poriferasterol, poriferasterol acylglucosides, gallic acid, phlobatannins, and sugars (D-galactose, D-rhamnose, and L-arabinose) (Fig. 3) (Li et al. 2010; Lakshmi 2012).

The dyeing principle catechin is obtained from the heart wood of *A. catechu*. Heart wood is also rich in catechutannic acid. "Cutch" or dark catechu, has been used as a natural dye for dyeing cotton, silk, and wool (Vankar and Shanker 2008; Singh et al. 2005; Bhattacharya and Shah 2010). In addition to color, more recently cutch dye has been identified to impart antibacterial and antifungal properties to wool (Khan et al. 2011).

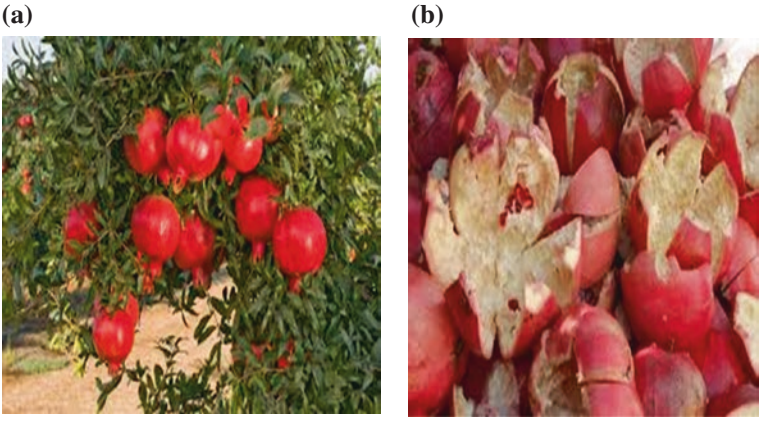


Fig. 4 **a** Pomegranate plant. **b** Peels

3 *Punica granatum*

Punica granatum is a small tree measuring 5–8 m tall belonging to the family *Punicaceae* (Fig. 4a, b). It is cultivated all around the world such as Iran, California, Turkey, Egypt, Italy, India, Chile, and Spain, and it originates from Afghanistan, Iran, China, and the Indian subcontinent (Fischer et al. 2011). It is mainly grown for its edible fruits. Pomegranate fruit in the form of juices, jams, and wines are widely consumed as healthy products. This plant has also been used in traditional medicines of different Asian cultures for the prevention and cure of a number of

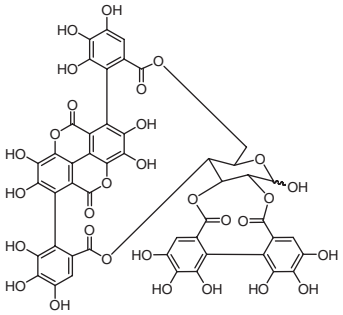
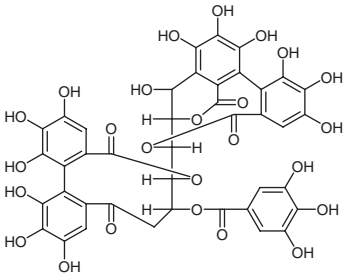
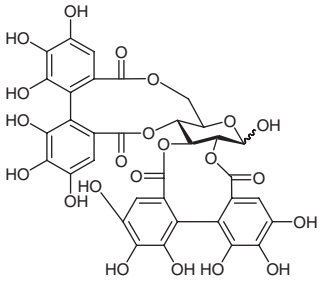
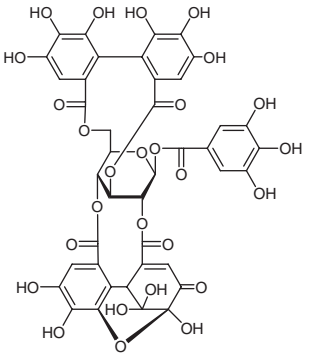
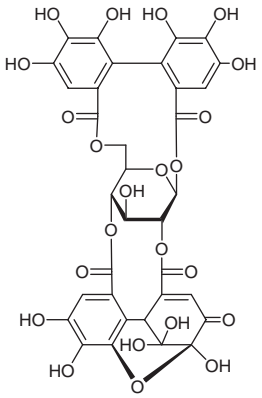
Chemical compound	Chemical structure
Punicalagin	
Casuarinin	
Pedunculagin	

Fig. 5 Chemical structures of compounds present in pomegranate peel

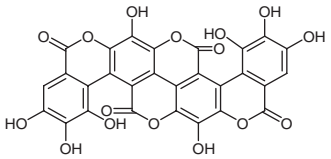
Granatin B



Granatin A



Gallagyldicton



Corialagin

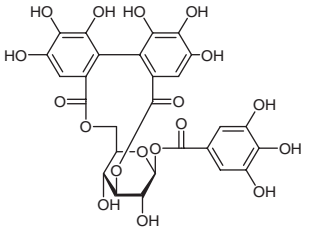


Fig. 5 (continued)

health disorders such as inflammation, colitis, headache, aphthae, diabetes, diarrhea, dysentery, and dental plaque (Ismail et al. 2012; Al-Zoreky 2009). Pomegranate by-product rinds, as waste materials from juice and concentrate industries, have been valorized as important and rich source of polyphenolic compounds that have recently attracted interest for use as natural food preservatives, antioxidants, nutraceuticals, and therapeutic and coloring agents (Singh et al. 2002; Lansky and Newman 2007; Viuda-Martos et al. 2010).

3.1 Phytochemistry and Dyeing Compounds

Extensive research investigations have been carried out in recent years to identify the main polyphenol bioactive compounds in pomegranate plant. A number of phytochemicals are present in pomegranate include punicalagins, punicalins, gallagalic acid, gallic acid, and ellagic acid (Madrigal-Carballo et al. 2009; Lu et al. 2007). The chemical structures of some important compounds isolated from pomegranate peels are shown in Fig. 5.

Pomegranate plant, being rich in polyphenols or tannins, is considered as a potential and promising source of natural colorants for textile dyeing and finishing industry (Ajmal et al. 2014). The rind of pomegranate fruit is the main source of natural yellow dye, which gives shades of beautiful yellowish brown to cotton, wool, silk, and polyester (Bhattacharya 2002). Different conventional and green technologies—including ultrasound-assisted, ultrasound-enzyme assisted, and microwave assisted extraction—have been employed for the extraction of natural colorants from the dry

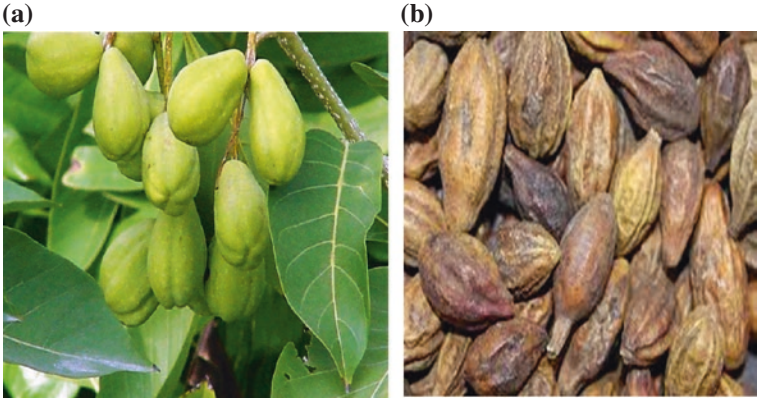


Fig. 6 **a** Harda plant. **b** Fruits

brown rinds of this plant (Tiwari et al. 2010). Several studies have more recently demonstrated the dyeing, fastness, and antimicrobial properties of pomegranate peels.

4 *Terminalia chebula*

Terminalia chubula (Fig. 6a, b) commonly known as *haritaki*, is a medium- to large-sized tree from the family *Combretaceae*, and it traditionally has been used in various medical systems to combat various disorders (Bag et al. 2013). The plant is distributed throughout South India and also along the sub-Himalayan tract of

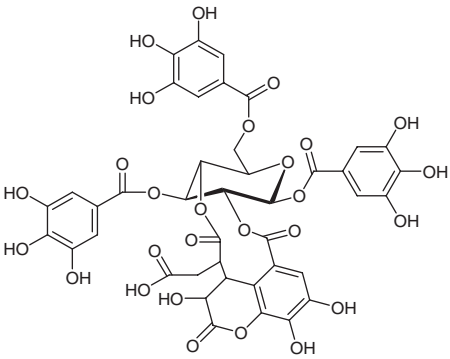
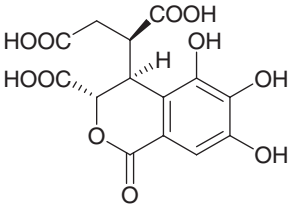
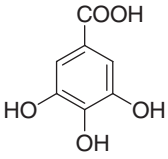
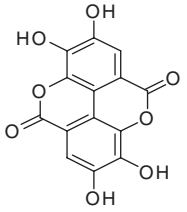
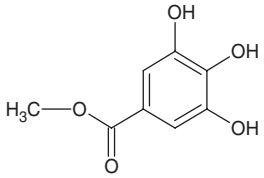
Chemical compound	Chemical structure
Chebulinic acid	
Chebulic acid	
Gallic acid	

Fig. 7 Chemical compounds present in harda

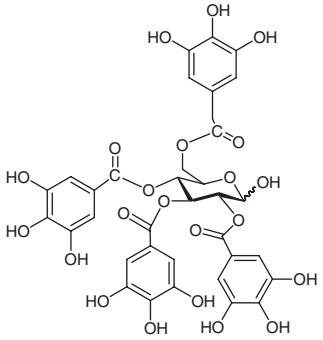
Ellagic acid



Methyl gallate



Tetra-O-galloyl-β-D-glucose



Penta-O-galloyl-β-D-glucose

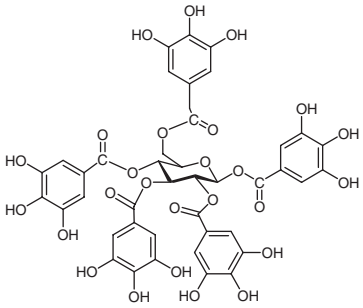


Fig. 7 (continued)

West Bengal and Assam. It is the source of one of the most important vegetable tanning materials and has been used in the Indian subcontinent for a long time as a tanning, mordanting, and dyeing material. The dried fruits yield a natural brown dye (Perkin and Everest 1918).

4.1 Phytochemistry and Dyeing Properties

Myrobalan extract is a complex mixture. The main phytochemicals identified from myrobalan extract include hydrolysable tannins, chebulic acid, chebulinic acid, gallic acid, ellagic acid, *tetra-O*-galloyl-β-D-*glucose, penta-O*-galloyl-β-D-*glucose, tannic acid*, and corilagin (Fig. 7). Other than tannins, the various compounds present in myrobalan are luteolin, rutin, and quercetin; terpenoids; and amino acids (Chang and Lin 2011; Kundu and Mahato 1993). A number of research investigations are available on the coloring of different textile materials with myrobalan extract.

5 *Quercus infectoria*

Quercus infectoria is an important medicinal plant of the family *Fagaceae* native to Greece, Asia Minor, Syria, and Iran (Fig. 8a, b). This tree has been used widely in traditional systems of medicine since antiquity to treat and cure various maladies such as coughs, phthisis, asthma, dysentery, skin diseases, menorrhagia, intestinal hemorrhage, eczema, spermatorrhea intertrigo, impetigo, hemorrhages,

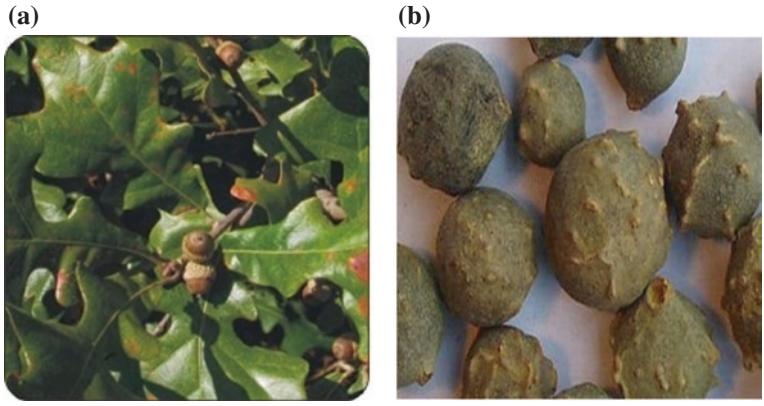


Fig. 8 **a** Gallnut plant. **b** Galls

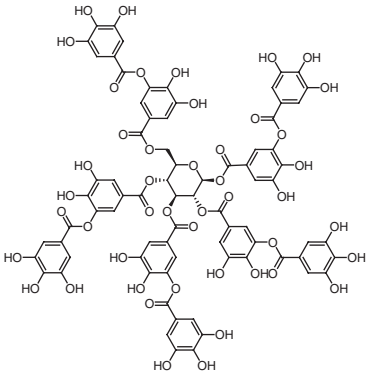
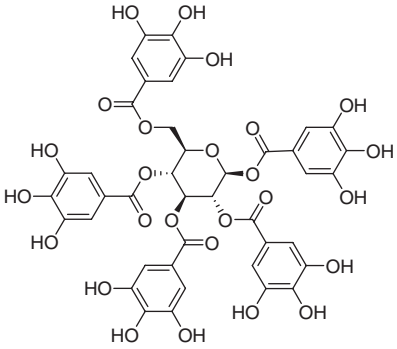
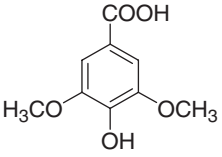
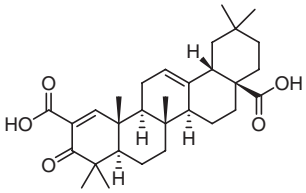
Chemical compound	Chemical structure
Gallotannic acid	
Pentagalloyl glucose	
Syringic Acid	

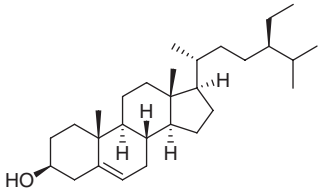
Fig. 9 Chemical structures of polyphenolic compounds from gallnut

chronic diarrhea, and trichomoniasis (Perkin and Everest 1918; Shrestha et al. 2014). The oak gall is an abnormal growth on oak tree (*Quercus infectoria* Oliv.) The bioactive compounds present in these galls exhibit a variety of pharmacological properties such as antidiabetic, astringent, antimicrobial, and antioxidant as well as wound-healing effects (Soon et al. 2007).

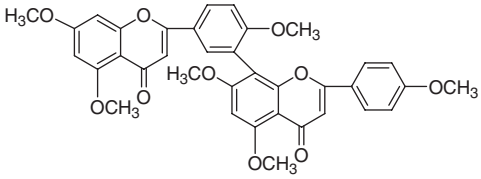
Methyl oleanate



β-sitosterol



Amentoflavone hexamethyl ether



Isocryptomerin

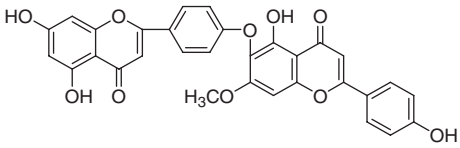


Fig. 9 (continued)

5.1 Phytochemistry and Dyeing Principles

The phytochemical studies carried out on this plant so far have revealed the presence of gallotannic acid, gallic acid, ellagic acid, syringic acid, β-sitosterol, amentoflavone hexamethyl ether, isocryptomerin, starch, essential oils, anthocyanins, methyl betulate, methyl-oleanate, and polygalloyl-glucose (Fig. 9) (Lim 2012; Asif et al. 2012).

The galls are reported to have wide range of application in tanning, mordanting, and dyeing, as well as the manufacturing of ink (Anonymous 1969). Gallnut extract contains ellagic acid, which is known to be the main coloring compound for use in dyeing different textile materials (Soon et al. 2007; Onal et al. 2005).

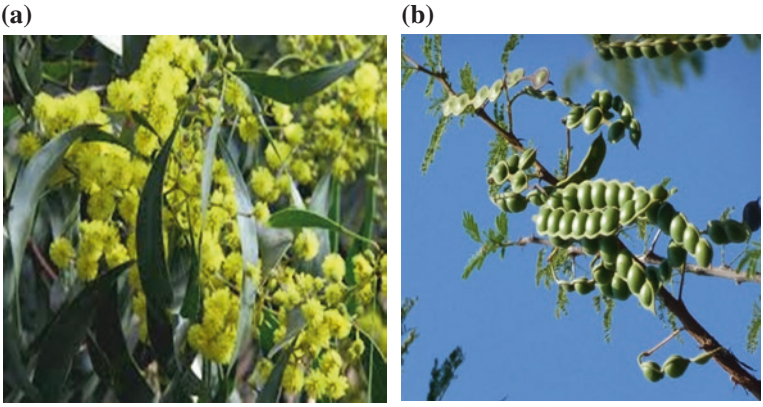


Fig. 10 **a** Babool plant. **b** Babool pods

Gallnut extract is currently extensively used in the coloring and functional finishing of cotton, wool, and silk fabrics. A few researchers have also studied its role in the development of antimicrobial clothing for hospital and medical textiles (Koh and Hong 2014; Shahid et al. 2012; Hong et al. 2012).

6 *Acacia nilotica*

Acacia nilotica, commonly known as "babool" is a well-known medicinal plant from the *Fabaceae* family (Fig. 10a, b). It is a small tree of up to 10 m in height with branched and fissured bark. It has stem diameter of 2–3 m having a low, spreading, and almost symmetrical crown. The leaves are 3–6 pinnate and 4.5–7 cm long with 10–30 pairs of leaflets. The flowers of babool are very fragrant and golden yellow or yellow in colour. The bark of this plant is an important source of gum, which has numerous potential health benefits.

6.1 Phytochemistry and Dyeing Compounds

Extensive research investigation carried out in last few decades on this important medicinal plant from the genus *Acacia* has yielded the isolation of several different classes of chemical compounds including tannins, flavonoids, alkaloids, fatty acids, polysaccharides (gums), and other miscellaneous compounds from all parts of this plant (Fig. 11) (Rather et al. 2015a, b). These compounds posses a wide range of pharmacological activities.

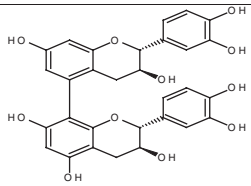
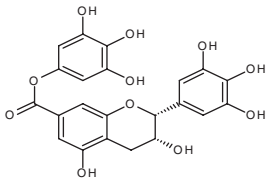
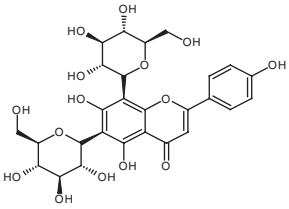
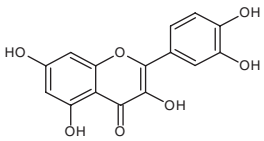
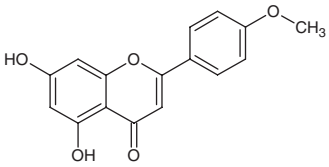
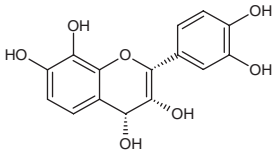
Chemical compound	Chemical structure
Dicatechin	
(-)- Epigallocatechin-7-gallate	
Apigenin-6,8-bis-C-β-D-glucopyranoside	
Quercetin	
Acacetin	
3-O-β-L-Arabinopyranosyl-L-arabinose	

Fig. 11 Chemical compounds present in *Acacia nilotica*

Melacacidin



N-Methyltryptamine (NMT)

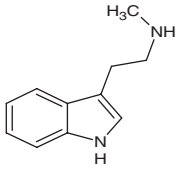


Fig. 11 (continued)

The bark of babool is a promising source of natural dye for the dyeing industry. Quercetin, a flavonoid, is the main coloring compound identified in this plant, and it is used in the dyeing of different textile materials (Adeel et al. 2014). This colorant was also recently used to impart fluorescent properties to wool fibres (Rather et al. 2015a, b).

7 Conclusion

The reintroduction of colorants from natural products for coloring skin, painting, and dyeing carpets, rugs, clothes, and food, etc., is coming our way. The great interest in using tannins—which are astringent vegetable products obtained from various plant parts including fruits, fruit pods, plant galls, leaves, bark, wood, and roots—for textile applications is growing faster due to their lower incidence of adverse reactions in comparison with their synthetic counterparts. Tannin-based colorants from plant materials impart textiles with novel properties, and they could be exploited as an attractive eco-friendly alternatives/copartners for textile dyeing and other functional applications. Also, from the viewpoint of sustainability, natural product-derived colorants, given some serious scientific efforts, could be alternatives/copartners to hazardous synthetic agents currently used in the textile industry.

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