Chapter one

Introduction

Milk is the fluid secreted by female mammals for the purpose of providing high level nutrition to their offspring in the first days or weeks of life. Mankind has, for millennia, domesticated a small number of mammalian species, e.g., cows, goats, sheep and buffalo, for the purpose of producing their milk over an artificially lengthened season, and consuming it either directly or after conversion into a range of dairy products. Today, a very significant proportion of food consumed worldwide has its origins in mammalian milk, and a huge and diverse dairy industry is at the forefront of the global food industry in terms of scale, economic significance and technological sophistication.

Definition of terms

- **Bulk Tank**: a refrigerated, stainless steel storage tank located at the dairy, designed to hold milk as soon as it leaves the cow. The milk is cooled immediately in the bulk tank, usually to 35-39 ^{o}F. The milk is then collected by a bulk tank truck and shipped to a processing plant.
- **Butter**: is produced by churning the fat from milk or cream until it solidifies.
- **Butter fat**: also known as milk fat, this is the fatty portion of milk.
- **Casein**: the dominant protein (80%) in cow's milk. It is vital to cheese making, and has a variety of uses in manufacturing as well.
- **Colostrum**: the first milk given by a dairy cow following birth that is rich in fat and protein and has immunity elements. Colostrum is given to newborn calves in the first 24 hours of life.
- **Cream**: milk is separated by large machines in bulk. Cream is the high fat milk product separated from milk. The cream is processed and used to produce various products with varying names, such as "heavy cream" or "whipping cream". Cream contains at least 18% milk fat. Some cream is dried and powdered and some is condensed by evaporation and canned.
- **Curd**: the clumps of protein and other milk components that are formed during the cheese making process. Curds are pressed into blocks or barrels for proper aging and curing of the cheese.
- **Homogenization**: a process applied to milk that result in fat globules being reduced in size to allow a smooth consistency.
- **Lactation**: the secretion of milk from the cow's udder.

- **Mastitis**: an inflammation of a dairy cow's milk ducts while she is lactating. Mastitis is usually caused by bacteria and can be treated with antibiotics.
- **Milking machines**: machinery used by dairy farmers to extract milk from cows. Electronic milking machines use a pulsating vacuum that stimulates the effect of a suckling calf. The machines do not cause any harm or discomfort to the cows and they keep the milk safe from external contamination
- **Milking parlor**: a specialized area on the dairy farm where the milking process is performed. Cows are brought into the parlor two or three times a day. Parlors come in many types and names, including flat barn, herringbone, parallel, swing, walk-through and rotary.
- **Pasteurization**: is a simple, effective method to kill harmful pathogens through heat treatments without affecting the taste or nutritional value of milk.
- **Processing plant**: a facility that pasteurizes, homogenizes and packages milk that comes directly from dairy farms.
- **Raw milk**: is milk that has not been pasteurized before consumption.
- **Skim milk (fat free milk)**: the product left after the cream is removed from milk.
- **Whey**: the watery part of milk that separates from the curds during the cheese making process. The composition of whey varies considerably, depending on the milk source and the manufacturing process involved. Typically it is rich in lactose, minerals, vitamins and protein.

SIGNIFICANCE OF MILK

Milk and its health benefits

Milk is a composite physiological fluid that facilitates postnatal adaptation of baby through digestive maturation simultaneously by providing the bioactive components and nutrients. It supports lymphoid tissues development and establishment of symbiotic micro flora. The importance, potency and the quantity of milk bioactive compounds are possibly more than old consideration. They comprise certain specific organic acids, vitamin A, B12, D, riboflavin, calcium, carbohydrates, phosphorous, selenium, magnesium, zinc, proteins, bioactive peptides and oligosaccharides. They mostly emerge during fermentation or digestive processes while in some cases these are components of fresh milk. The possible mechanisms for cholesterol decreasing or removal by probiotic bacteria and fermented dairy products include inhibition of intestinal cholesterol absorption. FAs having medium chain whey proteins and other minerals may add positive result of dairy products on body mass. The dairy proteins play a vital role in food intake regulation, satiety and metabolic distracts relating to obesity. Blood pressure may be affected by lactic acid bacteria, milk proteins, peptides and calcium. Milk fat contains certain components having the functional significance. Antimicrobial effects are exerted by sphingolipids and their active metabolites either directly or upon their digestion. Whey was studied as a medicine as well as an aphrodisiac and skin balm during the Middle Age. Whey proteins, i.e. α-lactalbumin, lactoferrin, lacto peroxidase, serum albumin and β-lacto globulin acquire important biological and nutritional properties particularly regarding disease prevention. Immuno-stimulatory, anti-carcinogenic and antimicrobial are other whey protein activities that promote health. Milk products and their components take part in regulating the body mass through satiety signals. Therefore, whey proteins include physiological milk components for individuals with metabolic syndrome and obesity. Whey protein in high protein milk products may improve insulin sensitivity and reduce fat deposition. The bioavailability of trace elements and minerals i.e. manganese, calcium, magnesium, iron, selenium and zinc is also improved by milk proteins and peptides.

The health benefits of milk and dairy products are known to humanity and may be attributed to the biologically active compounds that are existing in milk. Beside the modification of several milk components, proboscis may also act directly as preventive agents, or in therapy of some sever disease. The functional role of fermented dairy products is either directly through interaction with consumed microorganisms or, indirectly, as a result of action of microbial metabolites like nutrients, generated during the fermentation process. The health promoting mechanisms of probiotic action are mostly based on the positive effect they exert on the immunity response.

Milk facilitates the maturation of digestive tube and cell growth of a baby in gastrointestinal tract (GIT). Milk is a complex combination of nutrients such as particular bioactive saccharides, lipids and proteins content which assist to regulate the development of GIT by representing the important signals. Milk is a source of communication in case of mother and the newborn child that influences the role of mucosal immunity and minimizes the risk of infection. Milk has a wide various biologically active substances for instance, enzymes, immuno-globulins, oligosaccharides, antimicrobial peptides, hormones, cytokines, and the growth factors besides the basic saccharides, proteins and lipids. Milk components are particular parts of immune system of newborn and they assist to stimulate and sustain the baby immune homeostasis. Neutrophiles, macrophages and T-lymphocytes as the heterogeneous population of milk cells play an important role in the defense against pathogenic bacteria.

Economic importance of milk

- Milk is produced daily and therefore can provide a regular cash income.
- The farm gate milk price can be based on the milk's compositional quality, its hygienic quality, and the time of year.
- However, the price paid by small-scale processors in developing countries is often based on only the fat content of the milk.
- In addition to income from milk sales, dairy producers' sources of income include sales of culled animals and young stock, and other dairy farming returns, such as sales of manure and direct payments.
- Dairy production provides many **non-marketed economic benefits**, including manure for use on-farm as fuel or organic fertilizer (in several farming systems manure is the sole source of nutrients for crop production).
- Dairy animals are considered a means of **safeguarding savings** for sale in times of need (e.g., injury or disease of a household member), and a form of capital investment.

Chapter Two

Chemical and physical properties of milk

Physical Properties of Bovine Milks

Introduction

Milk is an extremely complex biological fluid with scores of nutrient chemicals contained in a fluid with characteristics of three physical phases: a dilute emulsion, a colloidal dispersion, and a solution. The emulsion can be broken by low-speed centrifugation and the milk separates into lipid and aqueous phases or compartments, each with a characteristic composition. With ultracentrifugation the casein micelles precipitate, bringing some other proteins, such as lysozyme lactoferrin from milks of animal species, with them. The supernatant remaining after this process has the characteristics of a true solution.

The physical properties of bovine milk have been thoroughly evaluated because of the importance of many of these parameters in processing and purity assessment. Values for few of these parameters are available for human and other animal milks as these are generally fed directly to the infant. Even for bovine milk, much of the information is available in technical publications and degree of variability and effects of physiological state are often not available. The physical properties are described below

I. **Electrical Conductivity**

This is defined as a measure of the electrical resistance of the solution in reciprocal ohms (mhos). It is used to assess the total ionic content of milk. The greatest contributors to conductivity are the sodium, potassium, and chloride ions.

II. **Freezing Point**

The freezing point of milk is lower than that of pure water due to dissolved components. This property is measured to determine whether bovine milk has been diluted with water and is employed as a legal standard. As with osmolality, the freezing point is stable. The major contributors to the freezing point are lactose and chloride. Since the freezing point and osmolality are proportional and dependent upon the number of dissolved particles, they can be determined with the same instrument.

III. **Boiling Point**

The boiling point in milk is higher than that of pure water again due to dissolved components. It is another of the colligative properties.

IV. **Osmolality or Osmotic Pressure**

Osmolality is a measure of the total number of dissolved particles in a given volume of solution given in osmoYkg. Osmolality is one of the colligative properties (dependent on the number of dissolved particles, not their properties) of milk along with freezing and boiling points. It is measured in the instrument used to determine the freezing point. The osmotic pressure of milk is quite constant being equal to the osmotic pressure of blood. A result is that the variation in the dissolved substances in normal milk, primarily lactose, is small. The total concentration of dissolved materials is responsible for osmolality. Osmolality is proportional to the freezing point of milk. As previously mentioned, osmolality remains constant in human and bovine milks because of the relationship between milk and blood. The potential renal solute load is calculated from the contents of sodium, chloride, potassium, and protein**.** Protein is included because it provides solutes from metabolism.

Potential renal solute loads (mosmoYliter) are: human milk, **93;** milk-based formula, **135;** soy-protein based formula, **165;** whole bovine milk, **308;** and skim milk, **326.** In addition to being low in iron, the potential renal solute load of the bovine milks is too high for them to be used as the sole food for young infants.

V. pH

The pH of milk as generally measured outside the animal is higher than milk within the mammary gland due to loss of **C02** to the ambient air. While important for human milk, immediate determination of pH in bovine milk is never done except for research purposes. The processing which is done to bovine milk removes dissolved gases. Assays of pH and of titrable acidity are used to assure that lactic acid is being produced at the desired rate by added microorganisms during the preparation of cheeses and fermented milks, e.g., yogurt. The casein in milk forms into a gel or curd at pH 4.6.

VI. Specific Gravity

Specific gravity is the ratio of the mass of a solution or substance to the mass of a similar volume of water. This property is used to assess nonfat solids in milk and the addition of water to milk, which lowers specific gravity. The dairy industry employs a special hydrometer, the lactometer, to determine specific gravity and total solids. Corrections are required for milk temperatures which differ from 20°C.

VII. Surface Tension

This is defined as the work required to increase the surface area of a solution and is usually expressed as dyneslcm^2. This property is used to follow the changes in surface-active components during milk processing, to follow release of fatty acids during lipolysis, and as a measure of the foaming tendency of milk. Fatty acids and their salts and mono acyl glycerol formed as a result of lipolysis are surface active and reduce surface tension. However, the method is not applied routinely for the assessment of lipolysis because the short-chain acids responsible for the flavor designated as hydrolytic rancidity are water soluble and do not affect surface tension.

The interfacial tension between the fat-soluble surface and the aqueous medium, of considerable potential importance in emulsion stability and access by lipolytic enzymes, cannot be determined directly.

VIII. Titratable Acidity

The amount of alkali required to bring the pH to neutrality (phenolphthalein) is titratable acidity. This property is used to determine bacterial growth during fermentations, such as during cheese making, as well as compliance with cleanliness standards. There is no lactic acid in fresh bovine milk. The titratable acidity is due mostly to the casein and phosphates. Lactic acid can be produced by bacterial contamination, although this is uncommon.

IX. Specific Heat

Specific heat is the ratio between the amount of heat necessary to raise a given weight of a substance to a specified higher temperature and the amount of heat necessary to raise an equal weight of water to the same temperature. It is important in processing for determining the amount of heat or refrigeration necessary to change the temperature of milk.

X. Coefficient of Expansion

This coefficient is the ratio of the increase in volume per unit increase in temperature to the increase in volume of water with the same temperature increase. It is used in the design of dairy equipment.

XI. Viscosity

This refers to the resistance to flow in centipoise units. It is used in the design of dairy processing equipment and to assess casein micellar aggregation.

TABLE I

Property	Goat milk	Bovine milk
Electrical conductivity		0.00465

		(0.0042-0.0048)
Freezing point(°c)	-0.582	-0.552 -(0.512-0.550)
Boiling point (°c)		100.17
Osmolality (mosmol/µg)		275
pH	6.37 (6.33-6.52)	6.62 (6.22-6.77) (0.2065-0.2075)
Specific gravity	1.033 (1.031-1.037)	1.030 (1.021-1.037)
Surface tension(dyneslcm^2)	52	52.8 (51.1-55)
Titratable acidity (percentage)		0.16 $\pm$ 0.02
Specific heat(°c) 0 15 40		 0.920 0.938 0.930
Coefficient of expansion (°c) 10 15.6 21.1		 0.9975 0.9985 1.000
Viscosity (centipoise)		1.6314

Physical Properties of Goat, and Bovine Milk

All values from Macy ***et al.*** (1971),From the National Dairy Council (1993), From Sherbon (1988), From Neubauer ***et al.*** (1993), From Allen ***et al.*** (1991).

Milk constituents (composition)

Milk contains more water than any other element, around 87% for dairy cows. The other elements are dissolved, colloidally dispersed, and emulsified in water. The quantities of the main milk constituents can vary considerably depending on the individual animal, its breed, stage of lactation, age and health status. Herd management practices and environmental conditions also influence milk composition. The average composition of cow's milk is shown in Table II.

Table II: Average composition of cow milk.

Main constituent	Range (%)	Mean (%)
Water	85.5 – 89.5	87.0
Total solids	10.5 – 14.5	13.0
Fat	2.5 – 6.0	4.0
Proteins	2.9 – 5.0	3.4
Lactose	3.6 – 5.5	4.8
Minerals	0.6 – 0.9	0.8

Milk fat

If milk is left to stand, a layer of cream forms on the surface. The cream differs considerably in appearance from the lower layer of skim milk. Under the microscope cream can be seen to consist of a large number of spheres of varying sizes floating in the milk. Each sphere is surrounded by a thin skin the fat globule membrane, which acts as the emulsifying agent for the fat suspended in milk (Figure 1).The membrane **protects the fat from enzymes and prevents the globules coalescing into butter grains**. The fat is present as an oil-in-water emulsion: this emulsion can be broken by mechanical action such as shaking.

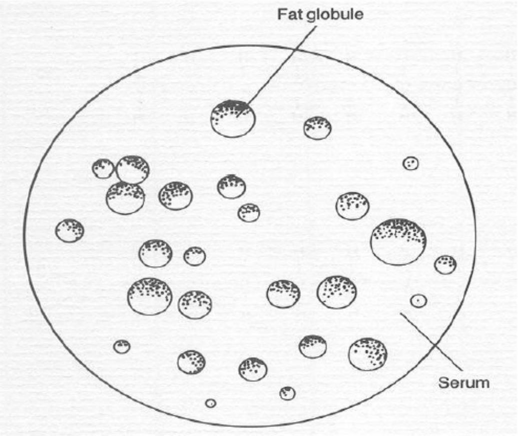
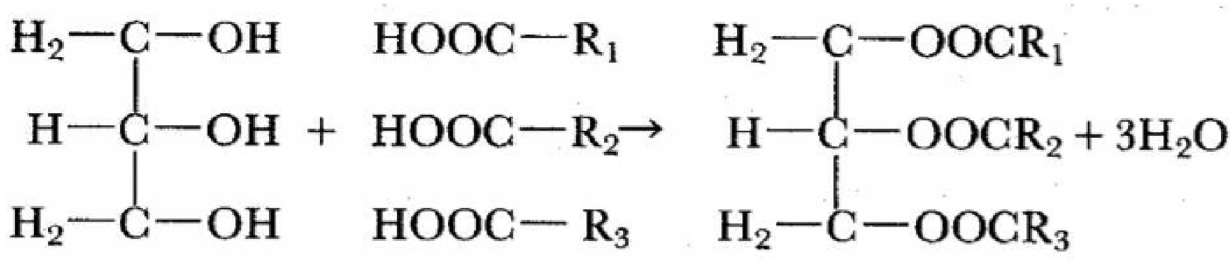


Figure1: fat globules in milk

Fats are partly solid at room temperature. The term oil is reserved for fats that are completely liquid at room temperature. Fats and oils are soluble in non-polar solvents, e.g. ether. About 98% of milk fat is a mixture of triacyl glycerides. There are also neutral lipids, fat soluble vitamins and pigments (e.g. carotene, which gives butter its yellow color), sterols and waxes. Fats supply the body with a concentrated source of energy: oxidation of fat in the body yields 9 calories/g. Milk fat acts as a solvent for the fat-soluble vitamins A, D, E and K and also supplies essential fatty acids (linoleic, linolenic and arachidonic). A fatty-acid molecule comprises a hydrocarbon chain and a carboxyl group (-COOH). In saturated fatty acids the carbon atoms are linked in a chain by single bonds. In unsaturated fatty acids there is one double bond and in poly-unsaturated fatty acids there is more than one double bond. Examples of each type of fatty acid.

Fatty acids vary in chain length from 4 carbon atoms, as in butyric acid (found only in butterfat), to 20 carbon atoms, as in arachidonic acid. Nearly all the fatty acids in milk contain an even number of carbon atoms.

Fatty acids can also vary in degree of unsaturation, e.g. C18:0 stearic (saturated), C18:1 oleic (one double bond), C18:2 linoleic (two double bonds), C18:3 linolenic (three double bonds). The most important fatty acids found in milk triglycerides are shown in Table 2. Fatty acids are esterified with glycerol as follows:



Glycerol + fatty acids → triglyceride (fat) + water

Table III: Principal fatty acids found in milk triglycerides

	Molecular formula	Chain length	Melting point
Butyric	$CH_3(CH_2)_2COOH$	C_4	-8°C
Caproic	$CH_3(CH_2)_4COOH$	C_6	-2°C
Caprylic	$CH_2(CH_2)_6COOH$	C_8	16°C
Capric	$CH_3(CH_2)_8COOH$	C_{10}	31.5°C
Lauric	$CH_3(CH_2)_{10}COOH$	C_{12}	44°C
Myristic	$CH_3(CH_2)_{12}COOH$	C_{14}	58°C
Palmitic	$CH_3(CH_2)_{14}COOH$	C_{16}	64°C
Stearic	$CH_3(CH_2)_{16}COOH$	C_{18}	70°C
Arichidonic	$CH_3(CH_2)_{18}COOH$	C_{20}	
Oleic	$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$	$C_{18:\,1}$	13°C
Linoleic	$CH_3(CH_2)_4(CH{=}CH.CH_2)_2(CH_2)_6COOH$	$C_{18:\,2}$	-5°C
Linolenic	$CH_3.CH_2(CH{=}CH.CH_2)_3(CH_2)_6COOH$	$C_{18:\,3}$	

The melting point and hardness of the fatty acid is affected by length of the carbon chain, and degree of unsaturation. *As chain length increases, melting point increases. As the degree of unsaturation increases, the melting point decreases.*

Fats composed of short-chain, unsaturated fatty acids have low melting points and are liquid at room temperature, i.e. oils. Fats high in long-chain saturated fatty acids have high melting points and are solid at room temperature. **Butterfat** is a mixture of fatty acids with different melting points, and therefore does not have **a distinct melting point**. Since butterfat melts gradually over the temperature range of 0-40°C, some of the fat is liquid and some solid at temperatures between 16 and 25°C. The ratio of solid to liquid fat at the time of churning influences the rate of churning and the yield and quality of butter.

Fats readily absorb flavors. For example, butter made in a smoked gourd has a

Smokey flavor.

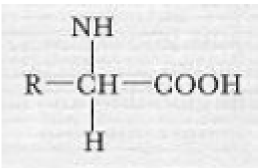
Fats in foods are subject to two types of deterioration that affect the flavor of food products.

1. ***Hydrolytic rancidity:*** In hydrolytic rancidity, fatty acids are broken off from the glycerol molecule by lipase enzymes produced by milk bacteria. The resulting free fatty acids are volatile and contribute significantly to the flavor of the product.

2. ***Oxidative rancidity:*** Oxidative rancidity occurs when fatty acids are oxidized. In milk products it causes tallowy flavors'. Oxidative rancidity of dry butterfat causes off flavors' in recombined milk.

Milk proteins

Proteins are an extremely important class of naturally occurring compounds that are essential to all life processes. They perform a variety of functions in living organisms ranging from providing structure to reproduction. Milk proteins represent one of the greatest contributions of milk to human nutrition. Proteins are polymers of amino acids. Only 20 different amino acids occur, regularly in proteins. They have the general structure:



R represents the organic radical. Each amino acid has a different radical and this affects the properties of the acid. The content and sequence of amino acids in a protein therefore affect its properties. Some proteins contain substances other than amino acids, e.g. lipoproteins contain fat and protein. Such proteins are called **conjugated proteins**:

- ***Phosphoproteins:*** Phosphate is linked chemically to these proteins. Examples include casein in milk and Phosphoproteins in egg yolk.
- ***Lipoproteins:*** These combinations of lipid and protein are excellent emulsifying agents.

  : Lipoproteins are found in milk and egg yolk.
- ***Chromoproteins:*** These are proteins with a colored prosthetic group and include hemoglobin and myoglobin.

Casein

Casein was first separated from milk in 1830, by adding acid to milk, thus establishing its existence as a distinct protein. In 1895 the whey proteins were separated into globulin and albumin fractions. It was subsequently shown that casein is made up of a number of fractions and is therefore heterogeneous. The whey proteins are also made up of a number of distinct proteins as shown in the scheme in figure 2.

The casein is a group name for the dominant class of protein in milk. Normal bovine milk contains about 3.5% protein, ok which casein constitutes about 80%. Casein is easily separated from milk, either by acid precipitation or by adding rennin. In cheese making most of the casein is recovered with the milk fat. Casein can also be recovered from skim milk as a separate product. Casein is dispersed in milk in the form of micelles. The micelles are stabilized by the (kappa casein) K-casein. Caseins are hydrophobic but K-casein contains a hydrophilic portion known as the glycol-macro-peptide and it is this that stabilizes the micelles. The structure of the micelles is not fully understood.

When the pH of milk is changed, the acidic or basic groups of the proteins will be neutralized. At the pH at which the positive charge on a protein equals exactly the negative charge, the net total charge of the protein is zero. This pH is called the isoelectric point of the protein (pH 4.6 for casein). If an acid is added to milk, or if acid-producing bacteria are allowed to grow in milk, the pH falls. As the pH falls the charge on casein falls and it precipitates. Hence milk curdles as it sours, or the casein precipitates more completely at low pH.

Whey proteins

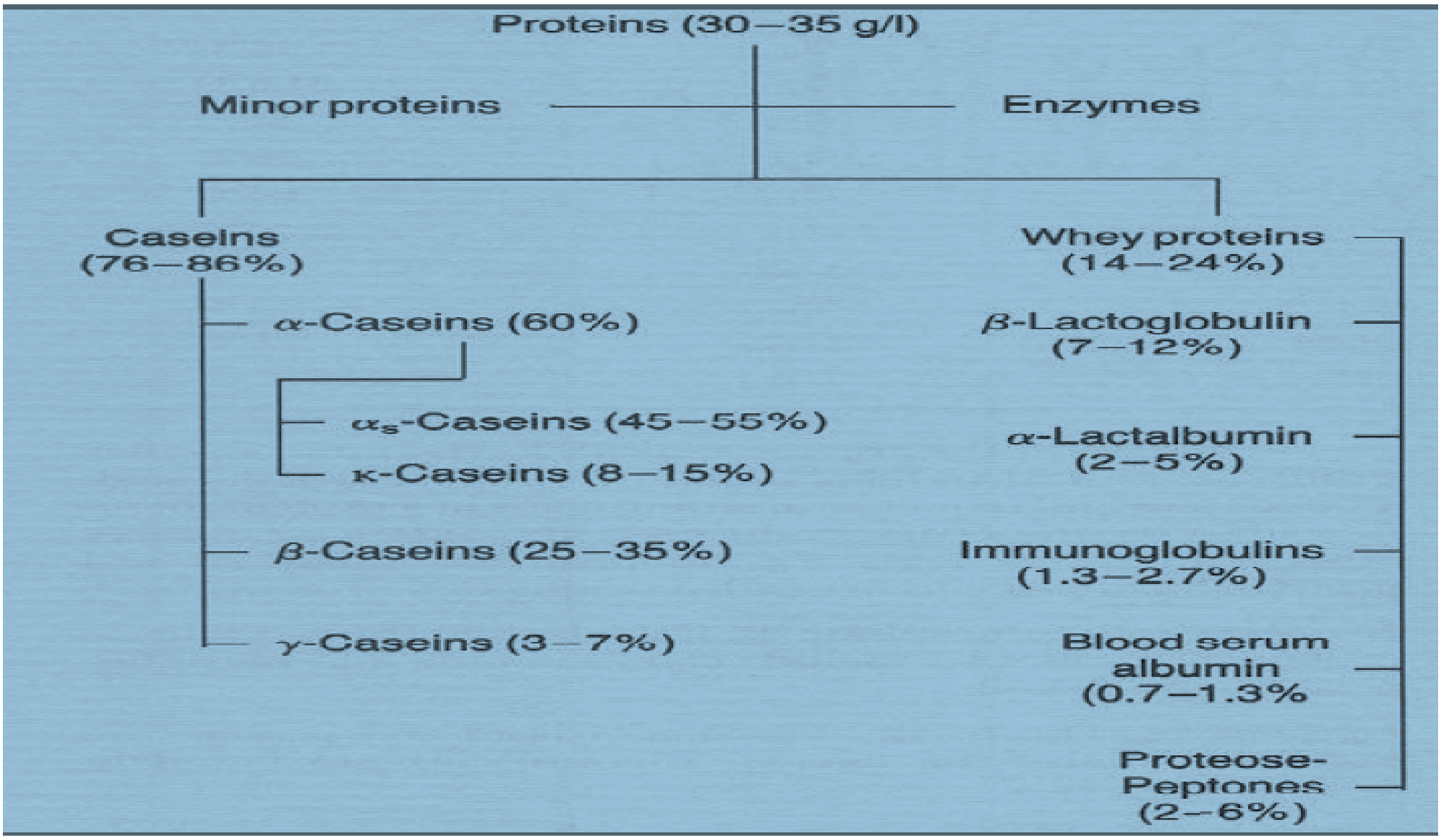
After the fat and casein have been removed from milk, one is left with whey, which contains the soluble milk salts, milk sugar and the remainder of the milk proteins. Like the proteins in eggs, whey proteins can be coagulated by heat. When coagulated, they can be recovered with caseins in the manufacture of acid-type cheeses. The whey proteins are made up of a number of distinct proteins, the most important of which are β-lactoglobulin and α-lactalbumin.

β - lacto-globulin accounts for about 50% of the whey proteins, and has a high content of essential amino acids. It forms a complex with K-casein when milk is heated to more than 75°C, and this complex affects the functional properties of milk. Denaturation of β-lactoglobulin causes the cooked flavor of heated milk.

Other milk proteins

In addition to the major protein fractions outlined, milk contains a number of enzymes. The main enzymes present are lipases, which cause rancidity, particularly in homogenized milk, and phosphatase enzymes, which catalyze the hydrolysis of organic phosphates. Measuring the inactivation of alkaline phosphatase is a method of testing the effectiveness of pasteurization of milk. Peroxidase enzymes, which catalyze the breakdown of hydrogen peroxide to water and oxygen, are also present. Lacto-peroxidase can be activated and use is made of this for milk preservation. Milk also contains protease enzymes, which catalyze the hydrolysis of proteins, and lactalbumin, bovine serum albumin, the immune globulins and lactoferrin, which protect the young calf against infection.

Figure 2: Milk protein fractions.



Milk carbohydrates

Lactose is the major carbohydrate fraction in milk. It is made up of two sugars, glucose and galactose (Figure 3). The average lactose content of milk varies between 4.7 and 4.9%, though milk from individual cows may vary more. Mastitis reduces lactose secretion.

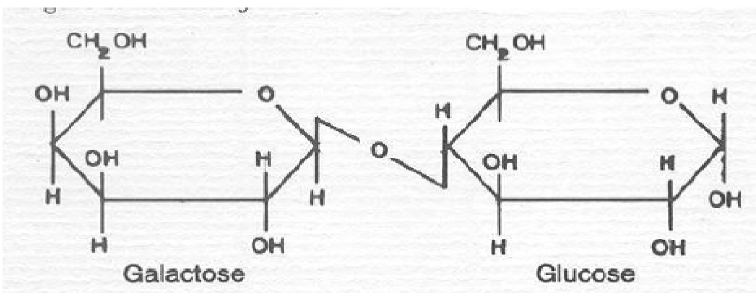


Figure 3: structure of lactose molecule

Lactose is a source of energy for the young calf, and provides 4 calories/g of lactose metabolized. It is less soluble in water than sucrose and is also less sweet. It can be broken down to glucose and galactose by bacteria that have the enzyme β-galactosidase. The glucose and galactose can then be fermented to lactic acid. This occurs when milk goes sour. Under controlled conditions they can also be fermented to other acids to give a desired flavor, such as propionic acid fermentation in Swiss-cheese manufacture.

Lactose is present in milk in molecular solution. In cheese making lactose remains in the whey fraction. It has been recovered from whey for use in the pharmaceutical industry, where its low solubility in water makes it suitable for coating tablets. It is used to fortify baby-food formula. Lactose can be sprayed on silage to increase the rate of acid development in silage fermentation. It can be converted into ethanol using certain strains of yeast, and the yeast biomass recovered and used as animal feed. However, these processes are expensive and a large throughput is necessary for them to be profitable. For smallholders, whey is best used as a food without any further processing.

Heating milk to above 100℃causes lactose to combine irreversibly with the milk proteins. This reduces the nutritional value of the milk and also turns it brown. Because lactose is not as soluble in water as sucrose, adding sucrose to milk forces lactose out of solution and it crystallizes. This causes sandiness in such products as ice cream. Special processing is required to crystallize lactose when manufacturing products such as instant skim milk powders. Some people are unable to metabolize lactose and suffer from an allergy as a result. Pre-treatment of milk with lactase enzyme breaks down the lactose and helps overcome this difficulty. In addition to lactose, milk contains traces of glucose and galactose. Carbohydrates are also present in association with protein. K-casein, which stabilizes the casein system, is a carbohydrate-containing protein.

Minor milk constituents

In addition to the major constituents discussed above, milk also contains a number of organic and inorganic compounds in small or trace amounts, some of which affect both the processing and nutritional properties of milk.

Milk salts

Milk salts are mainly chlorides, phosphates and citrates of sodium, calcium and magnesium. Although salts comprise less than 1 % of the milk they influence its rate of coagulation and other functional properties. Some salts are present in true solution. The physical state of other salts is not fully understood. Calcium, magnesium, phosphorous and citrate are distributed between the soluble and colloidal phases (Table IV). Their equilibria are altered by heating, cooling and by a change in pH.

Table IV: Distribution of milk salts between the soluble and colloidal phases.

	Total	Dissolved	Colloidal
	(mg/100 ml of milk)		
Calcium	1320.1	51.8	80.3
Magnesium	10.8	7.9	2.9
Total phosphorus	95.8	36.3	59.6
Citrate	156.6	141.6	15.0

In addition to the major salts, milk also contains trace elements. Some elements come to the milk from feeds, but milking utensils and equipment are important sources of such elements as copper, iron, nickel and zinc.

Milk vitamins

Milk contains the fat-soluble vitamins A, D, E and K in association with the fat fraction and water-soluble vitamins B complex and C in association with the water phase. Vitamins are unstable and processing can therefore reduce the effective vitamin content of milk.

Factor affecting the composition of milk

There are many factors that can affect milk composition generally genetic and environmental factors.

- **Genetic factors** (species variation, breed variations and individual variations: cow to cow variations, herd to herd variation)

Breed and individuality of the cow

Both milk yield and composition vary considerably among breeds of dairy cattle. Jersey and Guernsey breeds give milk with about 5% fat while the milk of Shorthorns and Friesians contains about 3.5% fat. Zebu cows can give milk containing up to 7% fat. Milk of individual cows within a breed varies over a wide range both in yield and in the content of the various constituents. The potential fat content of milk from an individual cow is determined genetically, as are protein and lactose levels. Thus selection for breeding on the basis of individual performance is effective in improving milk compositional quality. Herd recording of total milk yields and fat and solids-not-fat (SNF) percentages will indicate the most productive cows, and replacement stock should be bred from these.

Species variation

Milk from different mammals (human, farm animals and water mammals) vary considerably.

- ❖ **Environmental factors (management** and feed considerations, climate: seasonal variations and geographic variations, method of milking)

Feeding regime/level of nutrition

Underfeeding reduces both the fat and the SNF content of milk, although SNF content is the more sensitive to feeding level. Fat content and fat composition are influenced more by roughage (fiber) intake while, milk yield or volume of milk are influenced more by concentrate. The SNF content may fall if the cow is fed a **low-energy diet**, but is not greatly influenced by protein deficiency, unless the deficiency is acute.

Interval between milking

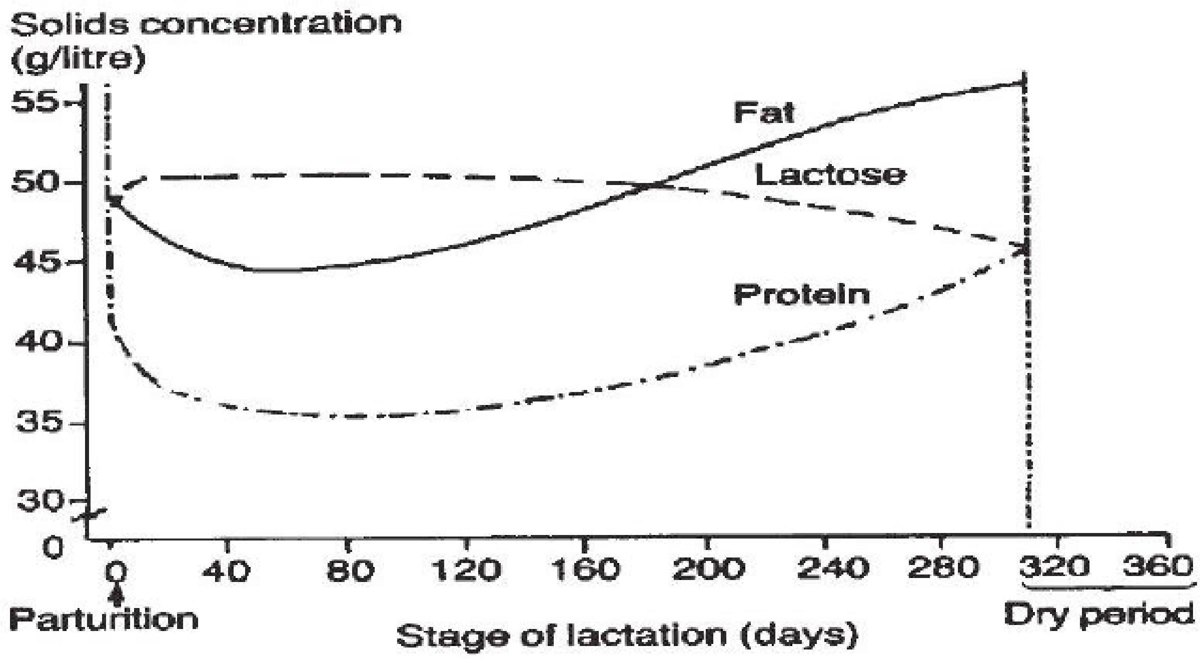
The fat content of milk varies considerably between the morning and evening milking because there is usually a much shorter interval between morning and evening milking than between evening and morning milking. If cows were milked at 12-hour intervals the variation in fat content between milking would be negligible, but this is not practicable on most farms. Normally, SNF content does not vary with the length of time between milking.

- ❖ **Physiological Factors (stage** of lactation, age of animal, estrus cycle)

Stage of lactation

The fat, lactose and protein contents of milk vary according to stage of lactation. **Solids not- fat** content is usually highest during the **first two to three weeks**, after which it decreases slightly. Fat content is high immediately after calving but soon begins to fall, and continues to do so for 10 to 12 weeks, after which it tends to rise again until the end of the lactation. The high protein content of early lactation milk is due mainly to the high globulin content. The variation in milk constituents throughout lactation is shown in

Figure 4: Changes in the concentrations of fat, protein and lactose over a lactation of a cow.



Age

As cows grow older the fat content of their milk decreases by **about 0.02 percentage** units per lactation while SNF is content fall much greater about **0.04 percentage** units. Both fat and SNF contents can be reduced.

Estrus cycle

During estrus/ heat period the milk yield decrease and estrogen hormone increase.

Completeness of milking

The first milk drawn from the udder contains about 1.4% fat while the last milk (or stripping) contains about 8.7% fat. Thus, it is essential to milk the cow completely and thoroughly mix all the milk removed before taking a sample for analysis. The fat left in the udder at the end of a milking is usually picked up during subsequent milking, so there is no net loss of fat.

- **Pathological factors** (disease and parasite: illness of the cows)

Disease

If the cow is infected by mastitis the density of the cow is highly increase because the number of minerals salt content increase acidity of the milk decrease- pH of the milk increase than the milk becomes very basic. Generally both fat and SNF contents can be reduced by disease, particularly mastitis.

Micro-organism is the term applied to all microscopically small living organisms. We tend to associate micro-organisms with disease. Micro-organisms which cause disease are called **pathogens**. However, few micro-organisms are pathogens and micro-organisms play a crucial part in the life of our planet. For example, they provide food for fish, they occur in soil where they provide nutrients for plants and they play an important role in ruminant digestion.

In dairying some micro-organisms are **harmful** e.g. spoilage organisms, pathogens while others are **beneficial** cheese and yoghurt starters, yeasts and moulds used in controlled fermentations in milk processing.

The micro-organisms principally encountered in the dairy industry are bacteria, yeasts, moulds, and viruses.

Bacteria

Bacteria are single-celled organisms. They are present in air, water and on most solid materials. Bacterial cells are very small and can only be seen with the aid of a microscope. When observed under a microscope the cells can be seen to differ in shape and in conformation of groups of cells. Cells are either spherical or rod-shaped (Figure 1). Spherical bacteria are called **cocci**; those that are rod shaped are called **bacilli**. This is the first basis for differentiating between bacterial cells.

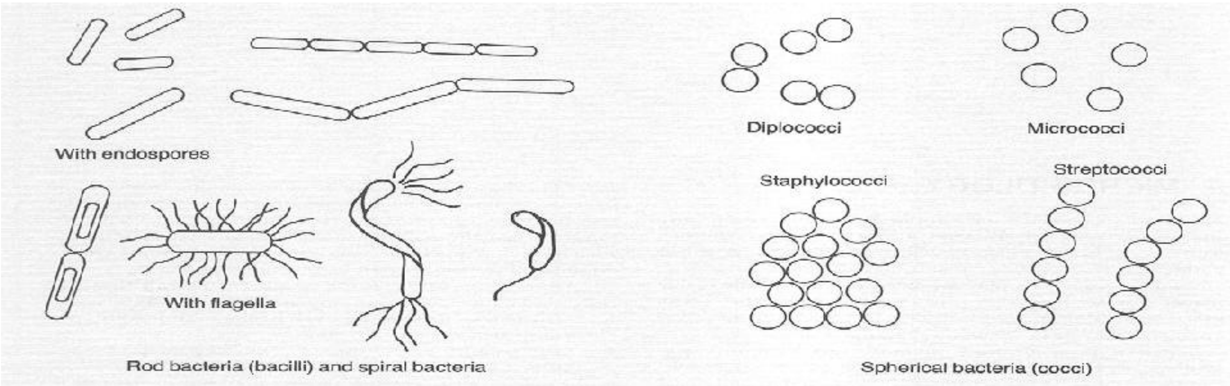


Figure 1. Rod-shaped (bacilli) and spherical (cocci) bacteria.

Bacteria are also classified according to cell cluster formation:

- Diplococci - two cocci cells paired
- Staphylococci: a number of cells clustered together
- Streptococci - a number of cells arranged in a chain

Some bacteria are capable of locomotion by means of **flagella** long, hair-like appendages growing out of the cell. Some rod-shaped bacteria contain spores. These are formed when the cells are faced with adverse conditions, such as high temperature: once suitable conditions are reestablished the spores germinate to form new cells.

Close examination of the simple cell reveals that it is composed of the following components (Figure 2):

- Cell wall-this gives the cell its shape and retains the constituents;
- Cell membrane-used for filtering in food constituents and discharging waste products;
- Nucleus-where the genetic material of the cell is stored;
- Cytoplasm-a semi liquid proteinaceous substance which contains starch, fat and enzymes.

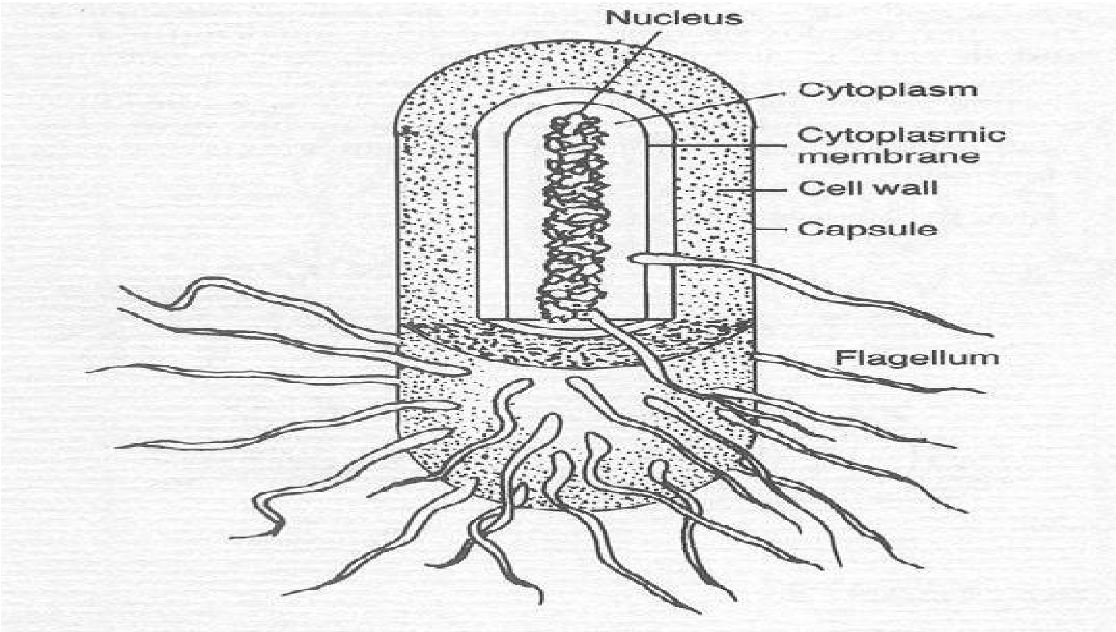


Figure 2*. Schematic illustration of bacterial structure.*

- cell membrane is semi permeable and allows the cell to feed by osmosis, i.e. the exchange of water between the cytoplasm of a living cell and the surrounding watery material. Only small molecules can pass in and out of the cell, e.g. with a sugar solution on one side of a semi permeable membrane and water on the other, water will diffuse in, diluting the sugar solution. The sugar molecules cannot pass out so a hydrostatic pressure, known as osmotic pressure, develops.

Bacteria can feed by selective intake of nutrients dissolved in water. They can also take in nutrients against the normal osmotic flow-active transport.

Bacterial growth

Bacterial growth refers to an increase in cell numbers rather than an increase in cell size. The process by which bacterial cells divide to reproduce themselves is known as binary transverse fission. The time taken from cell formation to cell division is called the generation time. The generation time can therefore be defined as the time taken for the cell count to double.

The curve shown in Figure 3 shows the phases of bacterial growth following inoculation of bacteria into a new growth medium. The following phases can be identified:

1. ***Lag phase:*** There is usually some delay in growth following inoculation of bacteria into a new medium, during which time the bacteria adapt to the medium and synthesize the enzymes needed to break down the substances in the growth medium.

2. ***Log phase:*** Once the bacteria have adapted to the new medium they start to reproduce quickly and their numbers multiply evenly for each increment of time. A plot of the log number of cells against time gives a linear relationship: this is therefore called the log phase. The cells are at their greatest activity in this phase. Transferring cultures to a fresh medium at regular intervals can maintain the cells in an active state. An active culture can rapidly dominate any new environment.

3. ***Stationary phase:*** As the bacteria dominate the growth medium, they deplete the available nutrients or toxic waste products accumulate, slowing the rate of reproduction. At the same time, cells are dying off: A state of equilibrium is reached between the death of old cells and formation of new cells, resulting in no net change in cell numbers. This phase is called the stationary phase.

4. ***Death phase:*** In the next phase the formation of new cells ceases and the existing cells gradually die off: This is called the death phase.

5. The log phase can be prolonged by removing toxic waste, by adding more nutrients or both.

The log phase can be prolonged by removing toxic waste, by adding more nutrients or both.

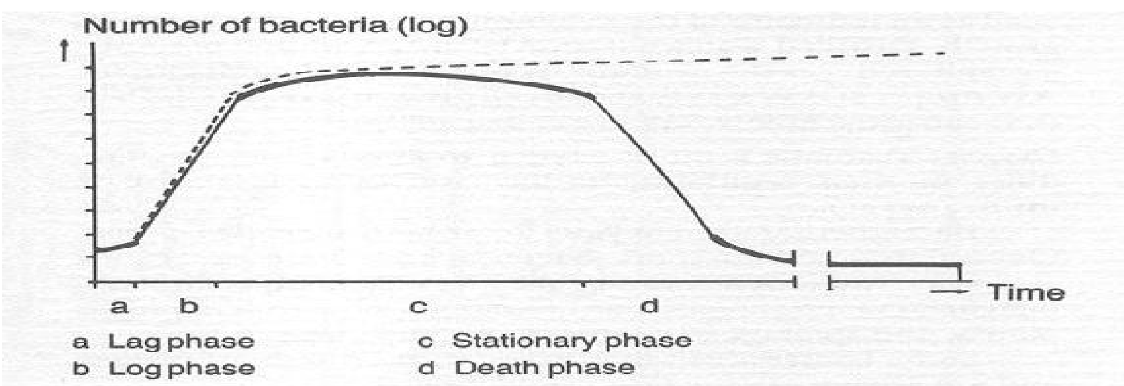


Figure 3. The four phases of bacterial growth.

Factors affecting bacterial growth

Bacterial growth is affected by temperature, nutrient availability, water supply, oxygen supply, and acidity of the medium.

1. Temperature: Theoretically, bacteria can grow at all temperatures between the freezing point of water and the temperature at which protein or protoplasm coagulates. Somewhere between these maximum and minimum points lies the optimum temperature at which the bacteria grow best.

Temperatures below the minimum stop bacterial growth but do not kill the organism. However, if the temperature is raised above the maximum, bacteria are soon killed. Most cells die after exposure to heat treatments in the order of 70°C for 15 seconds, although spore forming organisms require more severe heat treatment, e.g. live steam at 120°C for 30 minutes.

Bacteria can be classified according to temperature preference: ***Psycrophilic*** bacteria grow at temperatures below 16°C, ***mesophilic*** bacteria grow best at temperatures between 16 and 40°C, and ***thermophilic*** bacteria grow best at temperatures above 40°C.

2. Nutrients: Bacteria need nutrients for their growth and some need more nutrients than others. Lactobacilli live in milk and have lost their ability to synthesis many compounds, while *Pseudomonas* can synthesis nutrients from very basic ingredients.

Bacteria normally feed on organic matter; as well as material for cell formation organic matter also contains the necessary energy. Such matter must be soluble in water and of low molecular weight to be able to pass through the cell membrane. Bacteria therefore need water to transport nutrients into the cell.

If the nutrient material is not sufficiently broken down, the micro-organism can produce exo-enzymes which split the nutrients into smaller, simpler components so they can enter the cell. Inside the cell the nutrients are broken down further by other enzymes, releasing energy which is used by the cell.

3. Water: Bacteria cannot grow without water. Many bacteria are quickly killed by dry conditions whereas others can tolerate dry conditions for months; bacterial spores can survive dry conditions for years. Water activity (AW) is used as an indicator of the availability of water for bacterial growth. Distilled water has an AW of 1. Addition of solute, e.g. salt, reduces the availability of water to the cell and the AW drops; at AW less than 0.8 cell growth is reduced. Cells that can grow at low AW are called ***osmophiles***.

4. Oxygen: Animals require oxygen to survive but bacteria differ in their requirements for, and in their ability to utilize, oxygen.

Bacteria that need oxygen for growth are called ***aerobic***. Oxygen is toxic to some bacteria and these are called ***anaerobic***. Anaerobic organisms are responsible for both beneficial reactions, such as methane production in biogas plants, and spoilage in canned foods and cheeses.

Some bacteria can live either with or without oxygen and are known as ***facultative anaerobic*** **bacteria**.

5. Acidity: The acidity of a nutrient substrate is most simply expressed as its pH value. Sensitivity to pH varies from one species of bacteria to another. The terms pH optimum and pH maximum are used. Most bacteria prefer a growth environment with a pH of about

7, i.e. neutrality.

Bacteria that can tolerate low pH are called ***aciduric***. Lactic acid bacteria in milk produce acid and continue to do so until the pH of the milk falls to below 4.6, at which point they gradually die off. In canning citrus fruits, mild heat treatments are sufficient because the low pH of the fruit inhibits the growth of most bacteria.

Bacteria in milk

Milk fresh from a healthy cow contains few bacteria, but contamination during handling can rapidly increase bacterial numbers. Milk is an ideal food and many bacteria grow readily in it.

Some bacteria are useful in milk processing, causing milk to sour naturally, and leading to products such as *irgo.* However, milk can also carry pathogenic bacteria, such as *Salmonella, Tuberculosis bovis* and *Brucella,* and can thus transmit disease. Other bacteria can cause spoilage of the milk, and spoilage and poor yields of products.

Moulds

Moulds are a heterogeneous group of multi-celled organisms which reproduce asexually either by spore formation or by fragmentation. They can grow on a wide variety of substrates and are generally regarded as spoilage organisms. However, moulds are used in the production of antibiotics and in certain cheese varieties. Moulds are aerobic organisms and their growth on foods can be retarded by excluding air through careful packaging. They can be killed by relatively mild heat treatments, but mould spores are more resistant to heat. The structure of moulds is shown in Figure 4.

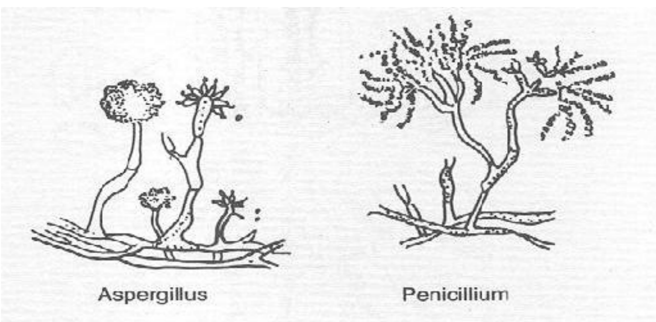


Figure 4. ***Structure of moulds.***

Yeasts

Yeasts are unicellular organisms which reproduce asexually by **budding**. They are used industrially to ferment carbohydrates to such products as alcohol and citric acid. Yeasts are not usually used in milk processing and are normally regarded as spoilage organisms in dairy products. The structure of yeasts is shown in Figure 5.

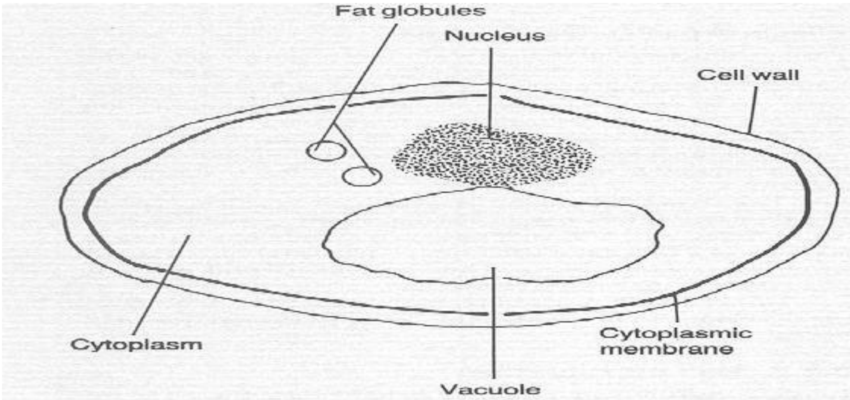


Figure 5. ***Structure of a yeast cell.***

Viruses

Viruses are extremely small organisms comprising a spherical head containing the genetic material and a cylindrical tail. They cannot reproduce themselves, and must invade other cells in order to reproduce. Viruses that attack bacterial cells are known as **bacteriophages**: bacteriophages that attack acid-producing bacteria inhibit acid production in milk.

3.1 Beneficial bacteria

Lactococcus. This genus contains a group of organisms formerly known as mesophilic lactic streptococci—*S. lactis, S. cremoris,* and *S. diacetylactis.* These organisms are classified in Lancefield group N and have complex growth requirements. Several strains are capable of producing nisin and bacteriocins which can inhibit foodborne pathogens. The lactococci can produce lactic acid and other compounds responsible for the characteristic flavor and aroma of fermented milk products such as cheeses, cultured buttermilk, and sour cream. Some strains of *L. lactis* subsp. *lactis* are also known to cause malty off-flavor in milk and dairy products. *L. lactis* var. *diacetylactis* can metabolize citric acid to produce CO2 and diacetyl; the latter is responsible for the characteristic "nutty," or "buttery" aroma of cultured butter, buttermilk, and sour cream. Some strains can also produce H2O2 and acetic acid and inhibit pseudomonads, coliforms, and other contaminating organisms, including salmonella. The types of organisms present in raw milk are influenced by temperatures and time of storage as well as methods of handling during and after milking.

Lactobacillus. These organisms are facultative or microaerophilic, Gram-positive, nonmotile rods of varying morphology ranging from coryneform coccobacillary or short rods to long and slender rods (0.5 to 1.6 /zm X 1.5 to 11.0 */mi),* capable of homo- or heterofermentative metabolism. *L. delbrueckii* subsp. *lactis* and *L. delbrueckii* subsp. *bulgaricus,* previously known as *L. lactis* and *L. bulgaricus,* and *L. helveticus* are thermophilic starter cultures used in the production of yogurts and Swiss and Italian cheeses. Both of these organisms require vitamins and amino acids as growth factors. The optimum growth temperature for these organisms is ~40℃. Among other lactobacilli important as starter cultures in the dairy industry are L. *acidophilus, L. casei,* and *L. brevis.*

3.2 Spoilage organisms

Gram-negative psychrotrophic bacteria

The growth of psychrotrophic bacteria is of major concern when raw milk is kept at low temperature, which is the normal practice in the modern dairy industry. During growth of these bacteria, heat-stable enzymes such as proteases and lipases are formed and consequently cause protein and lipid breakdown and related defects. Therefore, the metabolic processes of psychrotrophs are considered more important than the total numbers of organisms.

Pseudomonas spp.

Species of the Pseudomonas genus are the most important because of their ability to produce heat-stable enzymes (particularly proteases and lipases) during growth under refrigerated storage. They are motile, gram-negative rods, with the ability to grow at temperatures just above freezing, despite their optimum growth temperature being between 25 and 30◦ C. This genus is represented by species with short generation times (growth rate) at 0–7◦ C; their generation times can be even shorter in the presence of air. The generation times of the most rapidly growing psychrotrophic Pseudomonas spp. isolated from raw milk are 8–12 h at 3◦ C and 5.5–10.5 h at 3–5◦ C. These growth rates are sufficient to cause spoilage within 5 days at these temperatures if the milk initially contains only 1 colony count unit (cfu) mL^{-1}.

About50%of Pseudomonas spp. are the fluorescent type, characterised by the production of a diffusible pigment (pyoverdin) during growth. Pseudomonas fluorescens and Pseudomonas fragi, common milk contaminants, are notorious for producing heatstable protease and lipase.

Enterobacteriaceae

Enterobacteriaceae account for 5–33% of psychrotrophic microflora present in raw milk. These organisms are small, motile, gram-negative rods. Their optimum growth temperature (>30◦ C) tends to be higher than that of pseudomonads, but they adapt well to growth at refrigeration temperature. Coliforms belonging to this group are able to ferment lactose with production of acid and gas at 32◦ C within 48 h. Members of the genera Enterobacter and Klebsiella are most often associated with coliform spoilage, while Escherichia spp. only occasionally exhibit sufficient growth to produce a defect.

Other psychrotrophic bacteria

Other types of psychrotrophs commonly found in raw milk include Flavobacterium, Achromobacter, Aeromonas, Alcaligenes and Chromobacterium. They, like pseudomonads, are gram-negative rods capable of growing at lowtemperature. Acinetobacter and Psychrobacter are of limited spoilage potential, because their growth at low temperatures is slower than that of other psychrotrophs and so they are often overgrown by Pseudomonas spp.

Gram-positive bacteria

Spore-forming bacteria

Spore-forming bacteria in raw milk are predominantly Bacillus spp. (Jay, 1996). Bacillus contamination levels, although variable, are found up to 105 cfu mL−1. The optimum growth temperature for most Bacillus spp. is 20–40◦ C, although for some, such as Bacillus stearothermophilus (now Geobacillus stearothermophilus), it is higher. Therefore, the generation and lag times of psychrotrophic Bacillus spp. at 2–7◦ C are considerably longer than those of Pseudomonas spp., although psychrotrophic spore-formers may become the dominating microflora in spoiled milk at 10◦ C. Of the Bacillus spp. found in milk, B. licheniformis, B. cereus, B. subtilis and B. megaterium are most commonly isolated. These grampositive motile, spore-forming, rod-shaped organisms have also been implicated as the cause of a variety of proteolytic defects. B. cereus is a common contaminant of raw milks, being present in over 80% of raw milk samples. There is a distinct seasonality in the occurrence of the organism in raw milk supplies with the highest levels being in late summer and early fall, indicating that contamination occurs at the farm. B. cereus usually gives rise to milk spoilage defects such as bitty cream, sweet curdling and various off-flavors.

Clostridium spp. are present in raw milk at such low levels that enrichment and most probable number techniques must be used for quantification. Populations in raw milk vary seasonally. In temperate climates, clostridia are at higher levels in raw milk collected in the winter than that collected in the summer, because in the winter, in many countries, cows are housed and lie on spore-contaminated bedding materials and are more likely to consume spore-laden silage.

Lactic acid bacteria

Spoilage of raw milk resulting from growth of acid-producing fermentative lactic acid bacteria occurs when storage temperatures are sufficiently high for these microorganisms to outgrow psychrotrophic bacteria or when product composition is inhibitory to gram-negative aerobic organisms. This particularly occurs in countries where milk is still stored on farm and transported in unrefrigerated containers. Spoilage can occur, especially in hot weather, before milk is delivered to the factory. Species of Streptococcus, Enterococcus, Lactobacillus, Leuconostoc, Lactococcus and Pediococcus are involved. Lactococcus lactis subsp. lactis is the main species responsible for spoilage of raw milk at 10–37◦ C, being able to produce acid (about 0.25%, mostly lactic acid but also small amounts of acetic and propionic acids) to cause milk to sour. Some Enterococcus isolates can grow at 7◦ C and have detectable proteolytic activity. These microorganisms constitute only a minor population of the microflora in raw milk, but their numbers may be proportionally higher in pasteurized milk because of their resistance to pasteurization.

3.3 Pathogenic organisms

Numerous milk borne pathogens have been isolated from raw milk. The prevalence of these varies considerably, depending on geographical area, season, farm size, number of animals on farm, hygiene and farm management practices. Although the growth of these pathogens in milk is known to be inhibited by cooling and competing non-pathogenic microorganisms, outbreaks of illness caused by Campylobacter jejuni, Shiga toxin-producing Escherichia coli, Staphylococcus aureus, Listeria monocytogenes, Salmonella spp. and Yersinia enterocolitica have been reported following consumption of raw milk.

Pathogenic organisms in raw milk are of two types: those that are involved in bovine mastitis and those that externally contaminate milk. The bacteria causing mastitis, which vary geographically and with different animal husbandry practices, include S. aureus, Streptococcus agalactiae, Str. dysgalactiae, Str. uberis, Listeria spp. and E. coli. The staphylococci are of concern to the dairy industry and public health as some of them, particularly S. aureus, produce heat-stable enterotoxins that can cause food poisoning. Str. agalactiae causes bacteraemia and meningitis, which are potentially fatal to infected infants.

Salmonellae and thermoduric Campylobacter strains are the most common pathogenic bacteria from sources external to the udder. Salmonellae, particularly, continue to be a major concern for the dairy industry because they have been implicated in numerous outbreaks of illness. The emergence of multiple antibiotic-resistant strains of Salmonella ser. typhimurium DT104 should be of greater concern to public health authorities since this organism is reportedly resistant to antibiotics commonly used in medical and veterinary practice.

SOURCES OF CONTAMINATION

This section starts with some general remarks about ecological aspects. Subsequently, the sources of microorganisms in the environment of the cow are described, and then the way in which they contaminate milk.

MICROBIAL ECOLOGY

Microorganisms have inhabited our planet since the early stages of evolution. Selective pressures in the course of time have resulted in the development of a broad diversity of microbes by mutation and adaptation. It is, therefore, not surprising that today microorganisms, especially bacteria, are everywhere. Whether a given type of microorganism is present in a certain ecosystem is determined by the biotic (presence and abundance of other organisms) and abiotic components (chemical composition, temperature, etc.) of the system. Each microorganism finds its ecological niche, i.e., an environment in which it can find nutrients, generate energy, grow, and compete with other organisms and tolerate adverse conditions. This implies an interaction between microorganisms and environment: the latter determines which organisms can proliferate, but the organism in turn alters the environment, affecting its suitability for other organisms. For example, lactic acid bacteria growing in milk produce lactic acid from lactose and decrease the redox potential, thereby eventually precluding growth of most other bacteria (and themselves); some yeasts, however, can tolerate these conditions.

Raw milk left in contact with the external environment is essentially an open ecosystem, and it may contain a wide range of bacterial species. In a temperate climate, and in the absence of cooling machines, lactic acid bacteria tend to predominate in any place where milk is kept: they can grow fast and outcompete most other organisms. Because of the large-scale introduction of cooling tanks

on the farm, this has changed dramatically: it is psychrotrophs that predominate now. In tropical countries, still other types of bacteria may prevail.

Many milk products are closed or controlled ecosystems, and the microbial changes occurring greatly depend on the particular contamination by bacteria that occurred. Not only are species and numbers of bacteria important, but so is their physiological state, which especially depends on the growth phase, and the possible presence of bacteriophages. The effect of the environment is usually different for growth, fermentation, and, for certain species, germination of spores. Generally, conditions permitting growth are more restricted than those for catabolism (fermentation). For instance, several lactic acid bacteria do not grow to any extent near 5°C, but, other conditions being favorable, they may go on producing lactic acid from lactose.

Conditions inducing germination of spores are usually quite restricted.

MICROORGANISMS PRESENT IN THE UDDER

A distinction should be made between healthy and unhealthy cows, although it may not be clear-cut, especially for some types of mastitis.

Healthy Cows

In most cows, no microorganisms are present in the milk in the alveoli, ducts, cistern, and teat cistern, but they are present in the teat canal and the sphincter of the teat, mainly non-heat-resistant *Micrococcus* and *Staphylococcus* spp. And *Corynebacterium bovis*. Sometimes other bacteria are also involved. During milking, these bacteria enter the milk. Directly after milking, their number varies widely among cows, from hardly any to about 15,000 ml−1; the colony count of aseptically

drawn milk of healthy cows is usually low, often <100 ml−1. At 5°C the bacteria hardly grow and, after low pasteurization, these organisms can often not be detected. Obviously, microbially high-grade milk can be collected from healthy cows. The cow has several defense mechanisms to keep microorganisms away from the udder:

• The sphincter of the teat has some circular muscles that can keep the opening closed.

• Bacteriostatic and bactericidal agents present in the keratin material of the teat canal and in the milk itself, and the leukocytes in the milk.

• The ‘rinsing effect’ due to discharge of the milk.

Unhealthy Cows

When a cow is ill due to microbial infection, the organisms involved can enter the milk. In the case of mastitis, pathogenic organisms are already present in the udder and, thereby, in the milk. Because of this, mastitic milk usually has a high count. Some of these mastitic organisms, including certain streptococci, *Staphylococcus aureus*, and certain strains of *Escherichia coli*, are also pathogenic to humans. If organs other than the udder are inflamed, pathogens may directly enter the milk through the body, especially if the cow is also mastitic. Naturally, the organisms can also enter the milk through, for instance, dung or urine.

Among such organisms that are pathogenic to humans are *Leptospira interrogans*, *Mycobacterium tuberculosis*, *Campylobacter jejuni*, *Listeria monocytogenes*, *Bacillus anthracis* (causes anthrax), and *Brucella abortus* (causes an illness resembling Malta fever in humans). Obviously, it is essential to exclude milk of diseased animals from being processed, and to heat the milk in order to kill any pathogens.

CONTAMINATION DURING AND AFTER MILKING

The hygienic measures taken during and after (mechanical) milking essentially determine what foreign microorganisms enter the milk, including human pathogens. This applies also to their numbers. The count of properly drawn mixed milk from healthy cows is about 10,000 ml−1, sometimes even less. If, however, the level of hygiene during milking is poor, freshly drawn mixed milk can have a much higher count, up to one million ml−1. Potential sources of contamination of milk, together with the characteristic microorganisms involved, will now be discussed.

The Cow

During milking, microorganisms can enter the milk from the skin of the teats, which often are contaminated by dung, soil, or dust. Flakes of skin, hairs, and dirt from the feet and flanks can also enter the milk. Several types of microorganisms can contaminate the milk, including coliforms, fecal streptococci, other intestinal bacteria, bacterial spores (mostly *Clostridium* spp.), yeasts, and molds. Some of these microorganisms are human pathogens. Appropriate housing and care of the cows is an essential measure to promote clean udders. As a result, dry treatment, including removal of loose dirt, suffices during milking. Such dry treatment, moreover, causes less leakage of milk against the teats. Fewer bacteria then become detached from the teat skin. Dirty udders have to be cleaned thoroughly before milking. However, the complete removal of bacteria is impossible.

Soil, Dung, and Dust

All these contaminants can reach the milk and thereby increase counts. Moreover, spores of bacteria, yeasts, and molds also occur in air. Well known is *B. subtilis*, originating from hay dust. The spores can enter the milk through air sucked in during mechanical milking or fall directly into it during milking in open pails. The cleanliness of the milking parlor and the restfulness of the cows during milking are among the factors determining contamination of the milk.

The Feed

Feed often contains large numbers of microorganisms. Feed can sometimes fall directly into the milk but, more significantly, certain microorganisms in the feed survive passage through the digestive tract and subsequently enter the milk through dung; it includes some human pathogens. Spore-forming bacteria, including *Bacillus cereus*, *B. subtilis*, and *Clostridium tyrobutyricum*, which can spoil milk and milk products, are especially involved. Large numbers of *C. tyrobutyricum* occur in silage of inferior quality. The bacterial spores survive low pasteurization of cheese milk, to which a more intense heat treatment cannot be applied and may cause “late blowing” in some types of cheese. Accordingly, high quality silage is of paramount importance, and contamination of the milk, e.g., by dung, should be rigorously combated. In some regions, the use of silage is strictly prohibited, e.g., in areas of Switzerland and northern Italy where Emmentaler and Parmesan cheese, respectively, are made. Incidentally, when the cows suffer from diarrhea (caused, for instance, by feeding too much concentrate), the contamination

of the milk by dung is increased.

Milking Unit

Contact infection poses the largest threat of contamination to almost all foods, including milk. Poorly cleaned and disinfected milking equipment can contain large numbers of microorganisms. Because these organisms generally originate from milk, they will grow rapidly and can decrease quality. Residual milk often contains about 109 ml−1 of bacteria, and even 1 ml of such milk entering 100 l of milk during the following milking would increase the count by 10,000 ml−1. The methods of cleaning and disinfection applied largely determine the species of the contaminating organisms. If high temperatures are used and cleaning and disinfection of milking utensils are unsatisfactory, the main species will be heat resistant, including micrococci, *Microbacterium lacticum*, some streptococci, and spore-forming bacteria. If, on the other hand, ambient temperatures are used, lactic acid bacteria, e.g., *Lactococcus lactis*, pseudomonads, and coliforms will mainly be involved. Use of milking equipment that can be adequately cleaned and disinfected

is thus paramount. Small cracks in worn-out rubber units and ‘dead ends’ in the equipment that are insufficiently rinsed should be avoided.

Water Used

Tap water may be of good quality. Any private water supply must be examined at intervals. Surface water can contain many microorganisms, including human pathogens, and it must therefore on no account be used for cleaning and rinsing.

Gram-negative rods such as *Pseudomonas*, *Achromobacter*, *Flavobacterium*, and *Alcaligenes* spp., most of which are psychrotrophic, often occur in contaminated water (also in dung, soil, and poorly cleaned utensils). Especially in the tropics, water may have very high counts.

The Milker

Milkers influence many of the preceding factors and thereby the microbiological quality of the milk. They can also contaminate the milk directly, e.g., with the hands. If they suffer from microbial infections, they might directly contaminate the milk with pathogens.

Chapter four: Milk processing

4.1 why processing milk?

There are many reasons to process milk into dairy products, such as the following:

- Many dairy products can be kept longer than fresh milk, therefore the milk does not have to be consumed immediately.
- The demand for fresh milk may be limited, and there may be more interest in dairy products.
- If the daily amount of fresh milk for sale is limited, it may be more economical to process the milk into less perishable products, store them, and sell them later in greater quantities.
- There may be no market for fresh milk close by, and only preserved products can be sold at markets at a greater distance.
- Greater financial gain may be obtained.

Apart from these reasons, it should also be realized that many population groups in Asia and Africa cannot or can hardly consume milk because of so-called lactose intolerance. Lactose intolerance implies that the body is almost or entirely unable to digest the milk sugar, lactose, which is found in milk. Only small amounts of milk (up to 200 ml) consumed several times a day can be digested. Dairy products in which a proportion of the milk sugar is converted during production, such as cheese, curd, yoghurt and sour milk or buttermilk, do not cause many problems in this respect.

Before processing surplus milk, one must consider whether it is profitable to do so. The processing is not always easy and there may be losses. For example, a waste product of cheese making is whey, which contains many valuable nutrients. If the whey is not used, a valuable part of the milk is lost. Furthermore, while milk is being processed quality deterioration may occur and it can go off. Only when milk is drunk immediately can you be sure that nothing is lost.

4.2 Milk processing techniques

Pasteurization

Pasteurization is a heat treatment aimed at reducing the number of harmful microorganisms, if present, to a level at which they do not constitute a significant health hazard. Pasteurization can be carried out either as a batch operation ('batch pasteurization') with the product heated and held in an enclosed tank or as a continuous operation ('High Temperature Short Time, HTST pasteurization') with the product heated in a heat exchanger and then held in a holding tube for the required time (FAO, 2005).

Pasteurization conditions are designed to effectively destroy the organisms Myco-bacterium tuberculosis (Rowe et al., 2000; Klijn et al., 2001) and Coxiella burnettii. As C. burnettii is the most heat-resistant non-sporulating pathogen likely to be present in milk, pasteurization is designed to achieve at least a 5log reduction of C. burnettii in whole milk (Codex Alimentarius, 2003; FAO, 2005). According to validations carried out on whole milk, the minimum pasteurization conditions are those having bactericidal effects equivalent to heating every particle of the milk to 72°C for 15 s (continuous- flow pasteurization) or 63°C for 30 min (batch pasteurization).

To confirm sufficient pasteurization, the residual alkaline phosphatase levels in heat -treated milk have to be below 10 μg p-nitrophenol equivalent ml^{-1} (FAO, 2005). Low-pasteurized milk should also be lacto-peroxidase-positive. For highly pasteurized milk, the lacto-peroxidase test has to be negative. Lactulose in pasteurized milk should be below the detection limit and may not exceed 50 mg l^{-1} in highly pasteurized milk (Mortier et al., 2000). In the near future, it will also be required that the concentration of non-denatured β-lactoglobulin should be more than 2600 mg l^{-1} for pasteurized milk and 2000 mg l^{-1} for highly pasteurized milk (Mortier et al., 2000).

Cooling

The pasteurized fluid milk products are rapidly cooled to less than 4.4◦ C/40◦ F, packaged in appropriate plastic bottles/paper cartons and stored in cold refrigerated rooms for delivery to grocery stores or warehouse for distribution.

Souring by fermentation or acidification

Acidification, which gives the milk a tart taste, is achieved either through bacterial fermentation or through the addition of an acid, such as lemon juice or vinegar. The acid causes milk to coagulate and thicken, inhibiting the growth of harmful bacteria and improving the product's shelf life.

Milk separation

The fat fraction separates from the skim milk when milk is allowed to stand for 30 to 40 minutes. This is known a `creaming'. The creaming process can be used to remove fat from milk in a more concentrated form. A number of methods are employed to separate cream from milk. An understanding of the creaming process is necessary to maximize the efficiency of the separation process.

1. Gravity separation

Fat globules in milk are lighter than the plasma phase, and hence rise to form a cream layer. The rate of rise (V) of the individual fat globule can be estimated using Stokes' Law which defines the rate of settling of spherical particles in a liquid:

$$V = (r^2 (d_1 - d_2) g)/9\eta$$

Where r = radius of fat globules

d_1 = density of the liquid phase

d_2 = density of the sphere

g = acceleration due to gravity, and

η = specific viscosity of the liquid phase

Particle r^2: As temperature increases, fat expands and therefore r^2 increases. Since the sedimentation velocity of the particle increases in proportion to the square of the particle diameter, a particle of radius 2 (r^2 = 4) will settle four times as fast as a particle of radius 1 ($r^2 = 1$). Thus, heating increases sedimentation velocity.

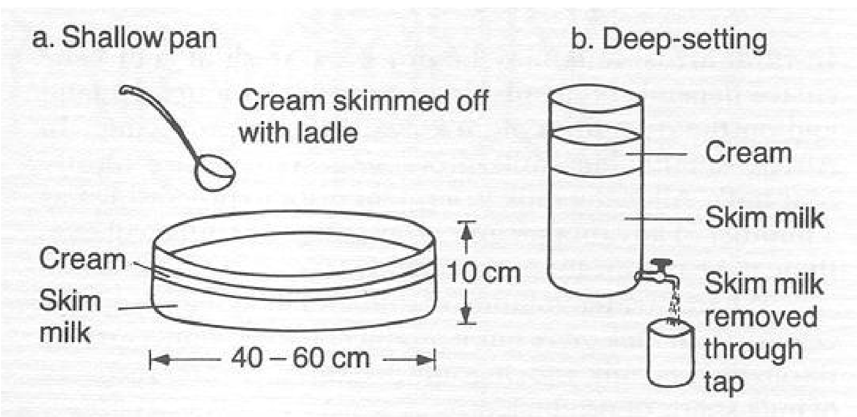
D1- d2: Sedimentation rate increases as the difference between d_1 and d_2 increases. Between 20 and 50°C, milk fat expands faster than the liquid phase on heating. Therefore, the difference between d_l and d_2 increases with increasing temperature.

g: Acceleration due to gravity is constant. This will be considered when discussing centrifugal separation.

η: Serum viscosity decreases with increasing temperature. Calculation of the sedimentation velocity of a fat globule reveals that it rises very slowly, as shown in the equation; the velocity of rise is directly proportional to the square of the radius of the globule. Larger globules overtake smaller ones quickly. When a large globule comes into contact with a smaller globule the two join and rise together even faster, primarily because of their greater effective radius. As they rise, they come in contact with other globules, forming clusters of considerable size. These clusters rise much faster than individual globules. However, they do not behave strictly in accordance with Stokes' Law because they have an irregular shape and contain some milk serum.

Factors affecting creaming: Cream layer volume is greatest in milk that has high fat content and relatively large fat globules, because such milk contains more large clusters. However, temperature and agitation affect creaming, irrespective of the fat content of the milk. Heating to above 60°C reduces creaming; milk that is heated to above 100°C retains very little creaming ability.

Excessive agitation disrupts normal cluster formation, but creaming in cold milk may be increased by mild agitation since such treatment favors larger, loosely packed clusters. ***Batch separation by gravity:*** Cream can be separated from milk by allowing the milk to stand in a setting pan in cool place. There are two main methods.



Shallow pan: Milk, preferably fresh from the cow, is poured into a shallow pan 40 to 60 cm in diameter and about 10 cm deep. The pan should be in a cool place. After 36 hours practically all of the fat capable of rising by this method will have come to the surface, and the cream is skimmed off with a spoon or ladle. The skim milk usually contains about 0.5 to 0.6% butterfat.

Batch separation of milk by gravity: (a) Shallow pan method, (b) deep-setting method

Deep-setting: Milk, preferably fresh from the cow, is poured into a deep can of small diameter. The can is placed in cold water and kept as cool as possible. After 24 hours the separation is usually as complete as it is possible to secure by this method. The skim milk is removed through a tap at the bottom of the can (Figure 12). Under optimum conditions, the fat content of the skim milk averages about 0.2 or 0.3 %.

The pans should be rinsed with water immediately after use, scrubbed with hot water and scalded with boiling water.

2.Centrifugal separation

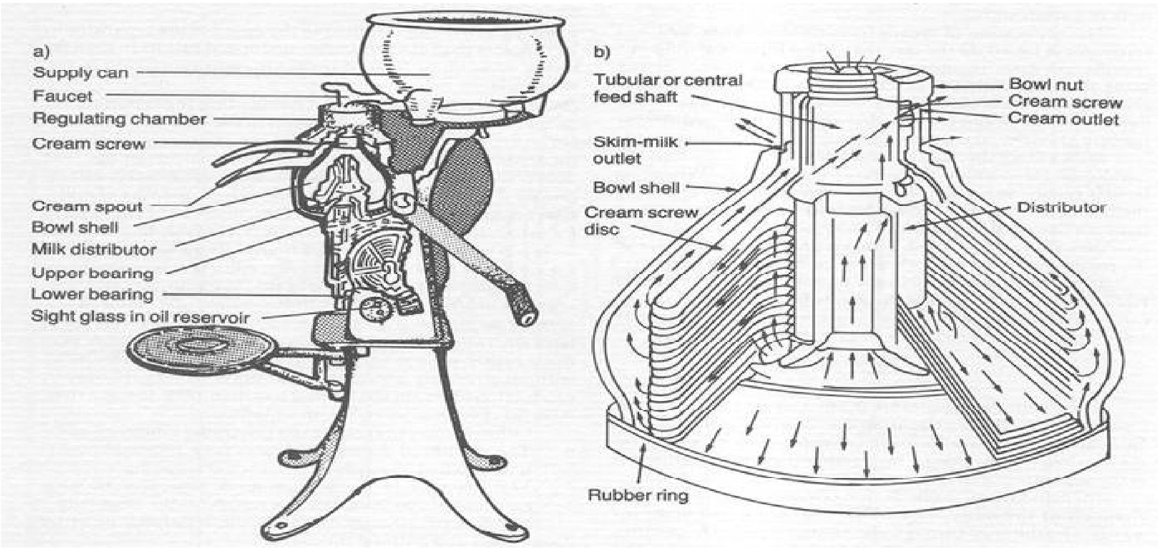
Gravity separation is slow and inefficient. Centrifugal separation is quicker and more efficient, leaving less than 0.1% fat in the separated milk, compared with 0.5-0.6% after gravity separation.

The centrifugal separator was invented in 1897. By the turn of the century it had altered the dairy industry by making centralized dairy processing possible for the first time.

It also allowed removal of cream and recovery of the skim milk in a fresh state.

The separation of cream from milk in the centrifugal separator is based on the fact that when liquids of different specific gravities revolve around the same center at the same distance with the same angular velocity, a greater centrifugal force is exerted on the heavier liquid than on the lighter one. Milk can be regarded as two liquids of different specific gravities, the serum and the fat.

Milk enters the rapidly revolving bowl at the top, the middle or the bottom of the bowl. When the bowl is revolving rapidly the force of gravity is overcome by the centrifugal force, which is 5000 to 10 000 times greater than gravitational force. Every particle in the rotating vessel is subjected to a force which is determined by the distance of the particle from the axis of rotation and its angular velocity.



Cutaway diagrams of (a) hand-operated milk separator and (b) the bowl showing the paths of milk and cream fractions. If we substitute centrifugal acceleration expressed as $r_1\omega^2$ (where r_1 is the radial distance of the particle from the center of rotation and ω^2 is a measurement of the angular velocity) for acceleration due to gravity (g), we obtain:

$$V = (r^2 (d_1 - d_2) r_1 \omega^2)/9\eta$$

Thus, sedimentation rate is affected by $r_1\omega^2$. In gravity separation, the acceleration due to gravity is constant. In centrifugal separation, the centrifugal force acting on the particle can be altered by altering the speed of rotation of the separator bowl.

In separation, milk is introduced into separation channels at the outer edge of the disc stack and flows inwards. On the way through the channels, solid impurities are separated from the milk and thrown back along the undersides of the discs to the periphery of the separator bowl, where they collect in the sediment space. As the milk passes along the full radial width of the discs, the time passage allows even small particles to be separated. The cream, i.e. fat globules, is less dense than the skim milk and therefore settles inwards in the channels towards the axis of rotation and passes to an axial outlet. The skim milk moves outwards to the space outside the disc stack and then through a channel between the top of the disc stack and the conical hood of the separator bowl. Efficiency of separation is influenced by four factors: the speed of the bowl, residence time in the bowl, the density differential between the fat and liquid phase and the size of the fat globules.

Speed of the separator. Reducing the speed of the separator to 12 rpm less than the recommended speed results in high fat losses, with up to 12% of the fat present remaining in the skim milk.

Residence time in the separator: Overloading the separator reduces the time that the milk spends in the separator and consequently reduces skimming efficiency. However, operating the separator below capacity gives no special advantage it does not increase the skimming efficiency appreciably but increases the time needed to separate a given quantity of milk. ***Effect of temperature:*** Freshly drawn, uncooled milk is ideal for exhaustive skimming. Such milk is relatively fluid and the fat is still in the form of liquid butterfat. If the temperature of the milk falls below 22°C skimming efficiency is seriously reduced. Milk must therefore be heated to liquify the fat. Heating milk to 50°C gives the optimum skimming efficiency.

Effect of the position of the cream screw: The cream screw regulates the ratio of skim milk to cream. Most separators permit a rather wide range of fat content of cream (18-50%) without adversely affecting skimming efficiency. However, production of cream containing less than 18% or more than 50% fat results in less efficient separation. Other factors that affect the skimming efficiency are:

The quality of the milk: Milk in poor physical condition or which is curdy will not separate completely.

Maintenance of the separator: A separator in poor mechanical condition will not separate milk efficiently.

When separation is complete the separator must be dismantled and cleaned thoroughly.

3. Hand separator

In order to understand how centrifugal separation works, we shall follow the course of milk through a separator bowl. As milk flows into a rapidly revolving bowl it is acted upon by both gravity and the centrifugal force generated by rotation. The centrifugal force is 5000 to 10 000 times that of gravity, and the effect of gravity thus becomes negligible. Therefore, milk entering the bowl is thrown to the outer wall of the bowl rather than falling to the bottom. Milk serum has a higher specific gravity than fat and is thrown to the outer part of the bowl while the cream is forced towards the center of the bowl.

Assembling the bowl

1. Fit the milk distributor to the central feed shaft.

2. Fit the discs on top of each other on the central shaft.
3. Fit the cream screw disc.
4. Next, fit the rubber ring to the base of the bowl.
5. Put on the bowl shell, ensuring that it fits to the inside of the base.
6. Finally, screw the bowl nut on top.

Now the bowl is assembled and ready for use. The rest of the separator is essentially a set of gears so arranged as to permit the spindle, on which the bowl is carried, to be turned at high speed. The gears are normally enclosed in an oil-filled case. The bowl is usually supported from the bottom and has two bearings; one to support its weight and the second to hold it upright. The upper bearing is usually fitted inside a steel spring so that it can keep the bowl upright even if the frame of the machine is not exactly level. The assembled bowl is lowered into the receptacle, making sure that the head of the spindle fits correctly into the hollow of the central feed shaft.

Operation

1. When the bowl is set, fit the skim milk spout and the cream spout.
2. Fit the regulating chamber on top of the bowl.
3. Put the float in the regulating chamber.
4. Put the supply can in position, making sure that the tap is directly above and at the center of the float.
5. Pour warm (body temperature) water into the supply can.
6. Turn the crank handle, increasing speed slowly until the operating speed is reached: This will be indicated on the handle or in the manufacturer's manual of operation. The bell on the crank handle will stop ringing when the correct speed is reached.
7. Open the tap and allow the warm water to flow into the bowl. This rinse and heats the bowl and allows a smooth flow of milk and increases separation efficiency.
8. Next, put warm milk (37 - 40°C) into the supply can. Repeat steps 6 and 7 above and collect the skim milk and cream separately.
9. When all the milk is used up and the flow of cream stops, pour about 3 liters of the separated milk into the supply can to recover residual cream trapped between the discs.
10. Continue turning the crank handle and flush the separator with warm water.

Cleaning the separator: Many of the impurities in the milk collect as slime on the wall of the separator bowl. This slime contains remnants of milk, skim milk and cream, all of which will decompose and ferment unless removed promptly.

If not washed and freed from all impurities the separator bowl becomes a source of microbial contamination. Skimming efficiency is also reduced when the separator bowl and discs are dirty. Milk deposits on the separator can cause corrosion.

Washing the separator: After flushing the separator with warm skim milk, the bowl should be flushed with clean water until the discharge from the skim milk spout is clean. This removes any residual milk solids and makes subsequent cleaning of the bowl easier. The bowl should then be dismantled. Wash all. Parts of the bowl, bowl cover, discharge spouts, float supply tank and buckets with a brush, hot water and detergent. Rinse with scalding water. Allow the parts to drain in a clean place protected from dust and flies. This process should be followed after each separation.

Cream screw adjustment

The cream screw should be adjusted so that the fat content of the cream is about 33%. Producing excessively thin cream reduces the amount of separated milk available for other uses and increases the volume of cream to be handled. Low-fat cream is also more difficult to churn efficiently.

Cream containing more than 45% fat clogs the separator and causes excessive loss of fat in skim milk. Cream of abnormally high fat content also gives butter a greasy body due to lack of milk SNF. When adjusting the cream screw, it is important to remember that it is very sensitive; a quarter turn of the screw is sufficient to change the percentage fat in the cream appreciably. The fat content of whole milk influences the fat content of cream and this must be considered when adjusting the cream screw. For example, if the cream screw is set to separate milk at a ratio of 85 parts of separated milk to 15 parts of cream then, with all other conditions constant and assuming efficient separation, milk of 3% fat produces cream of 20% fat whereas milk of 4.5% fat produces cream of 30% fat.

The fat content of the cream can be calculated using the following equation:

$Fc = (Wm \times Fm)/WC$

Wm = weight of milk, Fm = fat content of milk, WC = weight of cream, Fc = fat content of cream

In the first example, $Fc = (100 \times 3)/15 = 20$

In the second example, $Fc = (100 \times 4.5)/15 = 30$

Therefore, the setting of the cream screw depends on the fat content of the milk being separated. The milk should be mixed thoroughly prior to separation to ensure even distribution of cream in the milk.

Separator maintenance

The gears must be well lubricated. Follow the directions of the manufacturer. The level of the lubricant must be kept constant; observe the oil level through the sight glass. The bowl must be perfectly balanced. The bowl should be cleaned thoroughly immediately after use to ensure proper functioning of the separator and for hygiene.

Calculations

Once milk passes through a separator it is recovered in two fractions, the high-fat cream fraction and the low-fat skim milk.

Assuming negligible loss of fat in the separator, the amount of fat entering the separator with the whole milk will be collected at the other side of the separator in either the cream or the skim milk. Therefore, if we separate 200 kg of milk containing 4.5% butterfat, what weight of cream containing 30% butterfat can we expect?

Let, Wm = weight of milk

Fm = fat content of the milk

Wc = weight of cream

Fc = fat content of the cream

Ws = weight of skim milk

Assuming that all of the fat present in the milk is recovered in the cream, then:

Wm × Fm = WC ×Fc

And, **Wm - WC = Ws**

And, **Wm - Ws = WC**

Since, **Wm × Fm = WC× Fc**

(Wm× Fm)/Fc= WC

Therefore, **Ws = Wm (Wm × Fm)/Fc = WC**

In this case: Ws = 200 - (200 × 4.5)/30 = 200/30 = 170 kg

Since WC = Wm – Ws, WC = 200 - 170 = 30 kg

Percentage yield of skim milk: =Ws × 100)/Wm = (170 × 100)/200 = 85% Percentage cream (%WC) = %Wm - %Ws = 100 - 85 = 15%

If in practice we obtain only 28 kg of cream containing 30% butterfat, then (2 × 0.30) kg or

0.6 kg of butterfat has not been recovered in the cream. Since it is assumed that there are no significant losses of fat in the cream separator, the fat not recovered in the cream is lost in the skim milk. Since 28 kg of cream was produced, and Ws = Wm – Wc, then Ws = 200 - 28 = 172 kg Thus there is 0.6 kg of fat in 172 kg of skim milk. The fat percentage of the skim milk is therefore: (0.6 × 100)/172= 0.35%** The skim milk contains 0.35% fat, which may be incorporated in cottage cheese. If the skim milk is consumed, no nutritional loss occurs, but a financial loss is incurred since the fat is more valuable if sold as butter than as cottage cheese or if it is consumed directly.

The percentage of fat in milk and in cream influences Wc and Ws, where the fat is recovered in the cream.

If, Fm = 3 % Fc = 30% Wm = 100

Then Wc = Wm - Fm/Fc

Wc = 100 × 3/30 = 10 kg, Ws = Wm – Wc, = 100 – 10 = 90 kg

Whereas if Fm = 4%, Fc = 30, WC = 100

Then Wc =100 × 4/30 = 13.3 kg, Ws = 100 - 13.3 =86.6 kg

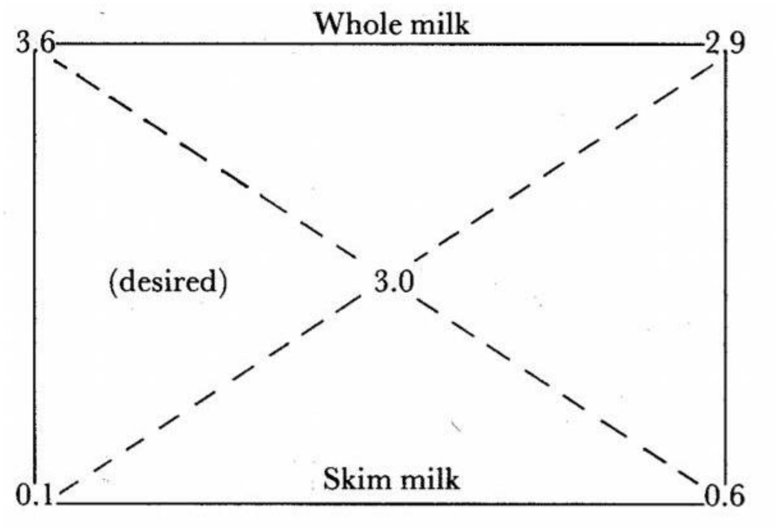
4. Standardization of milk and cream

If fine adjustment of the fat content of cream is required, or if the fat content of whole milk must be reduced to a given level, skim milk must be added. This process is known as standardization.

The usual method of making standardization calculations is the Pearson's Square technique. To make this calculation, draw a square and write the desired fat percentage in the standardized product at its center and write the fat percentage of the materials to be mixed on the upper and lower left-hand corners. Subtract diagonally across the square the smaller from the larger figure and place the remainders on the diagonally opposite corners. The figures on the right-hand corners indicate the ratio in which the materials should be mixed to obtain the desired fat percentage.

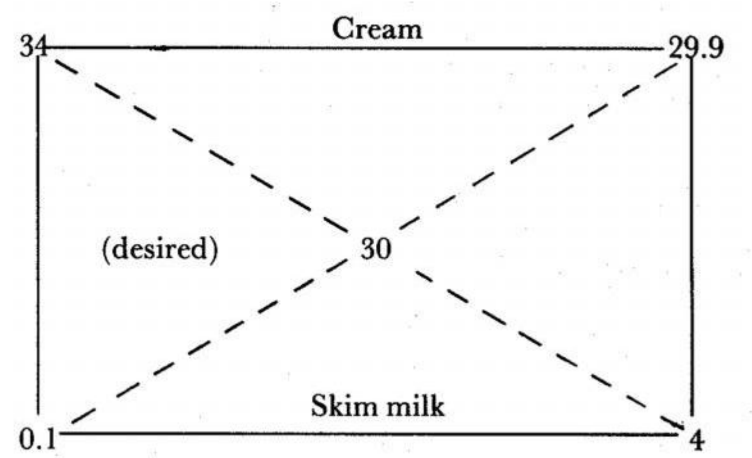
The value on the top right-hand corner relates to the material on the top left-hand corner and the figure on the bottom right relates to the material at the bottom left corner.

Example 1



In this example, the fat content of whole milk is to be reduced to 3.0%, using skim milk produced from some of the whole milk. Using Pearson's Square, it can be seen that for every 2.9 liters of whole milk, 0.6 liters of skim milk must be added.

Example 2

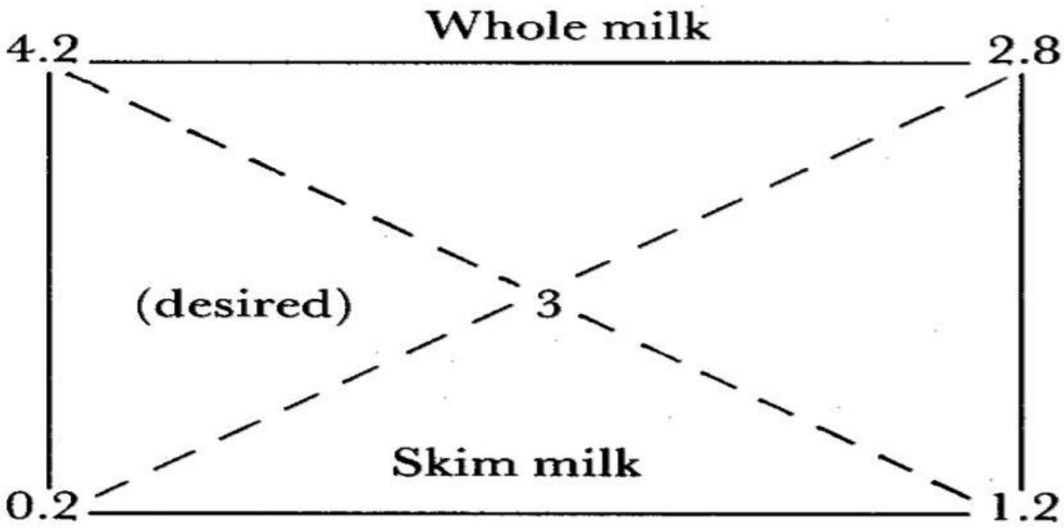


How much skim milk containing 0.1 % fat is needed to reduce the percentage fat in 200 kg of cream from 34% to 30%?

If 29.9 parts of cream require 4 parts of skim milk, 200 parts of cream require x parts of skim milk.

Weight of skim milk needed = x = (200 × 4)/29.9 = 26.75 kg

Example 3



The fat content of 300 kg of whole milk must be reduced from 4.2% to 3% using skim milk containing 0.2% fat.

Every 4.0 kg of the mixture will contain 2.8 kg of whole milk and 1.2 kg of skim milk.

If 2.8 kg of whole milk requires 1.2 kg skim milk, 300 kg of whole milk requires

$(1.2 \times 300)/2.8 = 128.6$ kg of skim milk

Thus, 128.6 kg of skim milk (0.2% fat) must be added to 300 kg of whole milk (4.2% fat) to give 428.6 kg of milk containing 3% fat.

Example 4

The fat content of milk must be reduced from 4.5 to 3% prior to sale as liquid milk but skim milk for standardization is not available.

In this case, we must calculate (a) what proportion of the milk must be separated to provide enough skim milk to standardize the remaining whole milk and (b) the expected yield of cream.

Assume that the fat content of 100 kg of milk containing 4.5% milk fat must be reduced to

3%. The amount of cream to be removed can be calculated as follows:

Let M = weight of milk to be standardized in this example, 100 kg. Therefore M = 100

Fm = fat content of the original milk = 4.5

C = weight of cream

Fc = fat content of the cream = 35

SM = weight of standardized milk

Fsm = fat content of the standardized milk = 3.0

Since the milk is separated into cream and standardized milk

$SM + C = M$

(1) Or $SM + C = 100$

There are no fat losses; therefore, the weight of fat in the original milk will be equal to the weight of fat in the standardized milk and cream.

(Weight of fat in a product is the weight of product × % fat/100) Therefore $(SM \times Fsm)/100 + (C \times Fc)/100 = (M \times Fm)/100$

Or $(3 \times SM)/100 + (35 \times C)/100 = (100 \times 4.5)/100$ (2) Or $0.03SM + 0.35C = 4.5$

Equations (1) and (2) give two equations with two unknowns, so they can be solved as follows:

(1) $SM + C = 100$

(3) Or $0.03SM + 0.03C = 3$

Subtracting (3) from (2) $0.32\ C = 1.5$, $C = 4.6875$, $= 4.7$ corrected to one decimal place

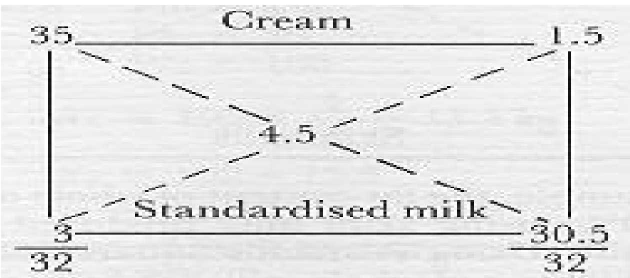
The weight of cream is thus 4.7 kg. Therefore, the weight of standardized milk is 95.3 kg.

Answer check

The original milk contained 4.5 kg of fat. The cream contains (4.7 × 35)/100 =1.645 kg of fat Therefore 4.5 - 1.645 = 2.855 kg of fat in the standardized milk. The fat percentage of the standardized milk is (2.855 × 100)/95.3 = 3%

The calculation can also be made using Pearson's Square. This is essentially a reverse standardization, i.e. "how much cream containing 35% fat and milk containing 3% fat should be mixed to get milk containing 4.5% fat?" is mathematically the same as "how much cream containing 35% fat must be removed from milk containing 4.5% fat to standardize the milk to 3% fat content?"

1. Place the fat content of whole milk in the center.
2. Place the fat content of cream on the top left-hand corner.
3. Place the desired fat content of the standardized milk on the bottom left-hand corner.



4. For every 32 parts of whole milk, there are 1.5 parts of cream to be removed and 30.5 parts of standardized milk.

Therefore WC = (1.5)/32 × 100 = 4.6875 = 4.7

Wsm = Wm - Wc = 95.3

The Wsm and fat to be removed can be calculated in a number of ways. Whatever method is used to calculate the amount of cream to be removed, it is then necessary to calculate the amount of milk to be separated to achieve the desired reduction in fat content.

Wm × Fm = Wc × Fc

Therefore Wm × 4.5 = 4.7 × 35

And Wm = (4.7 × 35)/4.5 = 36

Therefore, 36.5 kg of milk are separated and the skim milk is then combined with the remaining whole milk.

Standardization such as this can be used to increase income from milk production as follows:
Assume liquid milk price of 70 cents/kg Assume butter price of EB* 10/kg Income from 100 kg of milk = EB 70
Income from 95.3 kg of milk = 66.71
Fat removed = WC × Fc = 4.7 × 0.35 = 1.645
Expected butter yield = 1.9 kg
Income from butter = EB 19
Total income = EB 85.76
Margin = EB 15.76/ 100 kg of milk
*EB = Ethiopian birr (US$ 1 = EB 2.07)

Manufacturing of Dairy Products

Butterfat can be recovered from milk and converted to a number of products, the most common of which is butter. Butter is an emulsion of water in oil and has the following approximate composition:

Fat	80%
Moisture	16%
Salt	2%
Milk SNF	2%

In good butter the moisture is evenly dispersed throughout the butter in tiny droplets. In most dairying countries legislation defines the composition of butter; and butter makers conform to these standards in so far as is possible.
Butter can be made from either whole milk or cream. However, it is more efficient to make butter from cream than from whole milk.

Butter-making theory

To make butter, milk or cream is agitated vigorously at a temperature at which the milk fat is partly sold and partly liquid. Churning efficiency is measured in terms of the time required to produce butter granules and by the loss of fat in the buttermilk. Efficiency is influenced markedly by churning temperature and by the acidity of the milk or cream.
In churning, cream is agitated in a partly filled chamber. This incorporates a large

amount of air into the cream as bubbles. The resultant whipped cream occupies a larger volume than the original cream. As agitation continues the whipped cream becomes coarser. Eventually the fat forms semi-solid butter granules, which rapidly increase in size and separate sharply from the liquid buttermilk. The remainder of the butter-making process consists of removing the buttermilk, kneading the butter granules into a coherent mass and adjusting the water and salt contents to the levels desired.

Theory of the mechanism of churning

In considering the mechanism of churning the following factors must be taken into account:

- ✓ The function of air;
- ✓ The release of stabilizing material from the fat globule surface into the buttermilk;
- ✓ The differences in structure between butter and cream; and
- ✓ The temperature dependence of the process.

Air is thought to be necessary for the process, but some workers have demonstrated that milk or cream can be churned in the absence of air, although it takes longer.

About one half of the stabilizing material is liberated into the buttermilk during churning. It is thought that during churning the fat globule membrane substance spreads out over the surface of the air bubbles, partly denuding the globules of their protective layer, and that a liquid portion of the fat exudes from the globule and partly or entirely covers the globule, rendering it hydrophobic. In this condition the globules tend to stick to the air bubbles. Free fat destabilases the foam, causing it to collapse. The partly destabilized globules clinging to the air bubbles thus collect in clusters cemented together by free fat. These clusters appear as butter grains.

Churning cream

Cream prepared by gravitational or mechanical separation can be used. Good butter can be made in any type of churn provided it is clean and in good repair.

Churn preparation

The churn is prepared by rinsing with cold water, scrubbing with salt and rinsing again with cold water. Alternatively, it can be scalded with water at 80°C. After the butter has been removed, the churn should be washed well with warm water, scalded with boiling water and left to air. When not in use wooden churns should be soaked occasionally with water. A new churn should first be washed with tepid water, scrubbed with salt and then washed with hot water until the water comes away clear. A hot solution of salt should then be allowed to stand in the churn for a short time. After rinsing again with hot water, the churn should be left to air for at least one day before being used.

Churning temperature

The temperature of the cream during churning is of great importance. If too cool, butter formation is delayed and the grain is small and difficult to handle. If the temperature is too high, the yield of butter will be low, because a large proportion of the fat will remain in the buttermilk, and the butter will be spongy and of poor quality. Cream should be churned at

10 -12°C in the hot season and at 14 -17°C in the cold season. The temperature may be raised by standing the vessel containing the cream in hot water, or may be lowered by standing the vessel in cold spring water for a few hours before the cream is churned. The churning temperature may also be adjusted by the water used to dilute the cream. In the hot season, the coldest water available should be used, preferably water that has been stored in a refrigerator.

The amount of cream to be churned should not exceed one half the volumetric capacity of the churn. An airtight churn should be ventilated frequently during the first 10 minutes of churning to release gases driven out of solution by the agitation. If butter is slow in forming, adding a little water which is warmer than the churning temperature, but never over 25°C, usually causes it to form more quickly. When the butter appears like wet maize meal, water (1 liter per 4 liters of cream) at 2°C below the churning temperature should be added. It may be necessary to add water a second time to maintain butter grains of the required size. Churning should cease when the butter grains are as large as small wheat grains.

Washing the butter

When the desired grain size is obtained, the buttermilk is drained off and the butter washed several times in the churn. Each washing is done by adding only as much water as is needed to float the butter and then turning the churn a few times. The water is then drained off: As a general rule two washings will suffice but in very hot weather three may be necessary before the water comes away clear. In the hot season the coldest water available should be used for washing, and in the cold season water about 2 to 3°C colder than the churning temperature should be used.

Salting, working and packing the butter

Equipment for working may consist of a butter worker or a tub or keeler. Good-quality spatulas are important, and a sieve and scoop facilitate the removal of butter from the churn. This equipment must be clean (refer to method of cleansing and preparing a churn). The butter is spread on the worker, which has been soaked previously y with water of the same temperature as the washing water. If salted butter is required, the butter should be salted before working at a rate of 16 g salt/kg or according to taste. The salt used should be dry and evenly ground and of the best quality available.

The butter is then either rolled out 8 to 10 times or ridged with the spatulas to remove excess moisture. If the butter is to be heavily salted, it must be worked more in proportion to the amount of salt used, as uneven distribution of the salt causes uneven color. The butter should be worked until it seems dry and solid, but it must not be worked too much or it will become greasy and streaky.

The butter is then weighed and packed for storage. It should be packed in polythene -lined wooden or cardboard cartons and stored in a cool, dry place. The butter should be firm and of uniform color.

Washing the churn and butter-making equipment after use

The churn and butter-making equipment should be washed as soon as possible, preferably while the wood is still damp.

Churn: Wash the inside of the churn thoroughly with hot water. Invert the churn with the lid on in order to clean the ventilator; this should be pressed a few times with the back of a scrubbing brush to allow water to pass through. (N.B. The ventilator should be dismantled occasionally for complete cleansing.)

Remove the rubber band from the lid and scrub the groove. Scald the inside of the churn with boiling water. This step is very important. Invert and leave to air. Dry the outside and treat steel parts with Vaseline to prevent rusting. The rubber band should not be placed in boiling water; dipping in warm water is sufficient.

Butter worker/keeler: Place the sieve, scoop and spades on the butter worker or keeler. Pour hot water over all of them and scrub well to remove all traces of grease. Scald with boiling water and leave to air. Treat the steel part of the butter worker with Vaseline to prevent rusting.

Storage of butter

Surplus good-quality butter can be stored, but should contain more salt than usual at least

30 g/kg. Low moisture content is desirable. The butter must be packed in clean containers, such as seasoned boxes or glazed crocks, and stored in a cold room or in a cold, airy place. If a box is used, it should be lined with good-quality polythene. The container should be filled to capacity from one churning. The more firmly butter is packed, the better; it may be covered with a layer of salt, but this is not essential.

The container should be securely covered with a lid or a sheet of strong paper.

Overrun and produce in butter-making

Overrun

An enterprise engaged in butter-making must be able to measure the efficiency of the process, i.e. by measuring the yield of butter from the butterfat purchased. First, the theoretical yield of butter has to be estimated. Butter contains an average of 80% butterfat. Thus, for every 80 kg of butterfat purchased 100 kg of butter should be produced, or for every 100 kg of butterfat purchased 125 kg of butter should be produced.

The difference between the number of kilograms of butterfat churned and the number of kilograms of butter made is known as the overrun. This difference is due to the fact that butter contains non-fatty constituents such as moisture, salt, curd and small amounts of lactic acid and ash in addition to butterfat.

The overrun is financially important to the dairy industry and constitutes the margin between the purchase price of butterfat and the sale price of butter. The dairy unit depends largely on overrun to cover manufacturing costs and to defray expenses incurred in the purchase of milk.

As stated above, the maximum legitimate overrun is 25%. In commercial operation, however, it is not possible to establish the degree of accuracy that is assumed in the calculation of theoretical overrun, and the actual overrun shows the difference between the amount of butter churned out and the amount of butterfat bought.

Overrun is affected by: Accuracy of weighing milk received.

Accuracy of sampling and testing milk for fat.[1]

Notes:

[1] The need for care when sampling milk is referred to in the section dealing with butterfat testing. For example, if careless sampling and testing results in a reading of 3.6% butterfat against an actual content of 3.2% butterfat, what will be the effect on the overrun from 100 kg of milk?

Fat paid for = 100 × 0.036 = 3.6 kg of butterfat.

Maximum theoretical yield of butter = 3.6 × 1.25 kg = 4.5 kg

Fat received = 100 × 0.032 = 3.2 kg

Maximum theoretical yield = 3.2 × 1.25 = 4 kg

Our overrun therefore is Butter made = 4 kg Butterfat paid for = 3.6 kg

Overrun = 4/3.6 =1.11=11%.

Thus, carelessness at the testing stage can result in serious manufacturing losses. Losses at any stage in the process should be avoided. If overrun is low, each step of the process should be checked carefully in order to trace the loss.

Butter quality

Butter quality can be discussed under two main headings:

- Compositional quality,
- Organoleptic quality

The compositional quality of butter can be further divided into two subsections:

- Chemical composition
- Bacteriological composition

Compositional quality

The chemical composition of butter is determined at the processing stage when the salt, moisture, curd and fat contents of the product are regulated. Once these parameters have been set there is little one can do to change them. The microbiological quality of butter is also determined during the production and processing stages.

Chemical composition affects butter yield, while butter of poor microbiological quality will deteriorate rapidly and become unacceptable to consumers. The butter may also contain pathogens. Cleanliness at all stages of production is, therefore, essential.

Organoleptic quality

The organoleptic quality of butter can be described as the customer's reaction to its color, texture and flavor. It has been said that the consumer tastes with his or her eyes, and it is true that a person's initial impression of a food will often determine whether or not he or she will buy it. It is important, therefore, to produce butter that has an even color, clean flavor and close texture. It is also important that it be free from defects such as loose moisture. It should be packed attractively, both to attract customer attention and to retain its quality.

Butter produced carelessly and without the use of preservatives has a very short shelf life. Preservation of butter quality can assist the smallholder in two ways:

- The less perishable the product the longer the smallholder can retain it to obtain a good price.

- He or she can store the surplus made during the production season for consumption during the season in which he or she cannot produce butter.

  The first step the producer can take to ensure a high-quality product is to make it in a clean, hygienic manner.

  This results in fewer spoilage organisms being present in the butter. Another step is to take care in the handling and storage of the butter.

  The use of permitted preservatives is by far the most effective means of maintaining butter quality when used in conjunction with the above precautions. Salt sodium chloride is an excellent preservative, and salting butter to 3% extends its storage life: salted butter can be stored for up to 4 months without significant deterioration. A salt concentration in excess of 3% gives little advantage and can adversely affect the flavor of the butter.

Aside from the influence of salt on the flavor and keeping quality of the butter, adding salt is of economic importance as it increases overrun.

Adding salt to butter disturbs the equilibrium of the emulsion (the butter). This, in turn, changes the character of the body and alters its color. Unless the butter is subjected to sufficient working to regain the original equilibrium of the emulsion, it will tend to have a coarse, leaky body and uneven color.

Salt is added to butter most commonly using the dry-salting method, in which dry salt is sprinkled evenly over the butter and worked in.

Butter must be adequately worked if it is to be stored for a long time. First, working distributes the salt uniformly in the moisture and this helps inhibit microbial growth. Secondly, it distributes the salt solution into many tiny droplets rather than fewer large ones. For a given level of microbial contamination, the microbes will be more isolated in small droplets and will have less of the butter's nutrients available to them for growth.

After salting, the butter should be stored in a clean container, and the container sealed. It should then be stored in a cool, dark place.

Ghee, butter oil and dry butterfat

These products are almost entirely butterfat and contain practically no water or milk SNF. Ghee is made in eastern tropical countries, usually from buffalo milk. An identical product called *samn* is made in Sudan. Much of the typical flavour comes from the burned milk SNF remaining in the product. Butter oil or anhydrous milk fat is a refined product made by centrifuging melted butter or by separating milk fat from high-fat cream.

Ghee is a more convenient product than butter in the tropics because it keeps better under warm conditions. It has low moisture and milk SNF contents, which inhibits bacterial growth.

Milk or cream is churned as described in the sections dealing with churning of whole milk or cream. When enough butter has been accumulated it is placed in an iron pan and the water evaporated at a constant rate of boiling. Overheating must be avoided as it burns the curd and impairs the flavour. Eventually a scum forms on the surface: this can be removed using a perforated ladle. When all the moisture has evaporated the casein begins to char, indicating that the process is complete. The ghee can then be poured into an earthenware jar for storage.

A considerable amount of moisture and milk SNF can be removed prior to boiling by melting the butter in hot water (80°C) and separating the fat layer. The fat can be separated either by gravity or using a hand separator. The fat phase yields a product containing 1.5% moisture and little fat is lost in the aqueous phase.

Alternatively, the mixture can be allowed to settle in a vessel similar to that used in the deep-setting method for separating whole milk. Once the fat has solidified the aqueous phase is drained. The fat is then removed and heated to evaporate residual moisture. Products made using these methods exhibited excellent keeping qualities over a 5- month test period.

Cheese-making

Cheese is a concentrate of the milk constituents, mainly fat, casein and insoluble salts, together with water in which small amounts of soluble salts, lactose and albumin are found. To retain these constituents in concentrated form, milk is coagulated by direct acidification, by lactic acid produced by bacteria, by adding rennet, or a combination of acidification and addition of rennet.

Rennet coagulation theory

Rennet, a proteolytic enzyme extracted from the abomasum of suckling calves, was traditionally used for coagulating milk. Originally, the abomasum was itself immersed in milk. The extraction of rennet that could be stored as a liquid was the first step towards refining this procedure.

This was followed by purification and concentration of the enzyme. The purified enzyme was originally called rennin, and is now called chymosin.

On weaning, the chymosin of the suckling calf is replaced by bovine pepsin. With the decrease in the practice of slaughtering calves, chymosin became scarce, resulting in a search for chymosin substitutes. Rennet is a general term currently used to describe a variety of enzymes of animal, plant or microbial origin used to coagulate milk in cheese- making.

Rennet transforms liquid milk into a gel. While the process is not fully understood, rennet coagulation is thought to take place in two distinct phases, the first of which is regarded as being enzymatic, the second non-enzymatic. The first, or primary phase, can be illustrated as:

Water

Casein > para casein + glycomacropeptide

Rennet

Since k-casein stabilises the other caseins and its hydrol ysis leads to the coagulation of the casein fraction, the primary phase can also be expressed as:

$$\kappa\text{-casein} \xrightarrow[\textbf{rennet}]{\textbf{water}} \underset{\text{(insoluble)}}{\text{para-}\kappa\text{-casein}} + \underset{\text{(soluble)}}{\text{glycomacropeptide}}$$

The effect of milk coagulants on the other caseins is thought to be negligible at this stage. The second, or secondary, phase is the non-enzymatic precipitation of para casein by calcium ions. Para casein, in association with the calcium ions, is thought to produce a lattice structure throughout the milk. This traps the fat and whey is gradually exuded. The coagulum then contracts, a process known as syneresis. This is accelerated by increasing the temperature and reducing pH to as low as pH 4.6.

Rennet also has a tertiary action on milk proteins. This occurs during cheese ripening, during which rennet hydrolyses milk proteins. If the desired hydrol ysis is not obtained, the cheese becomes bitter. While a wide variety of proteolytic enzymes coagulate milk, the tertiary action of many of these on milk proteins causes undesirable flavors' in cheese, which limits the range of coagulants that can be used.

Cheese varieties

Many cheese varieties are manufactured around the world but they are all broadly classified by hardness (i.e. very hard, hard, semi-soft and soft) according to their moisture content.

Cheese is usually made from cow's milk, although several varieties are made from the milk of goats, sheep or horses.

Queso blanco (White cheese)

Queso blanco is a Latin-American fresh, white cheese. It is usually made from milk containing 3% fat, using an organic acid, without starter or rennet.

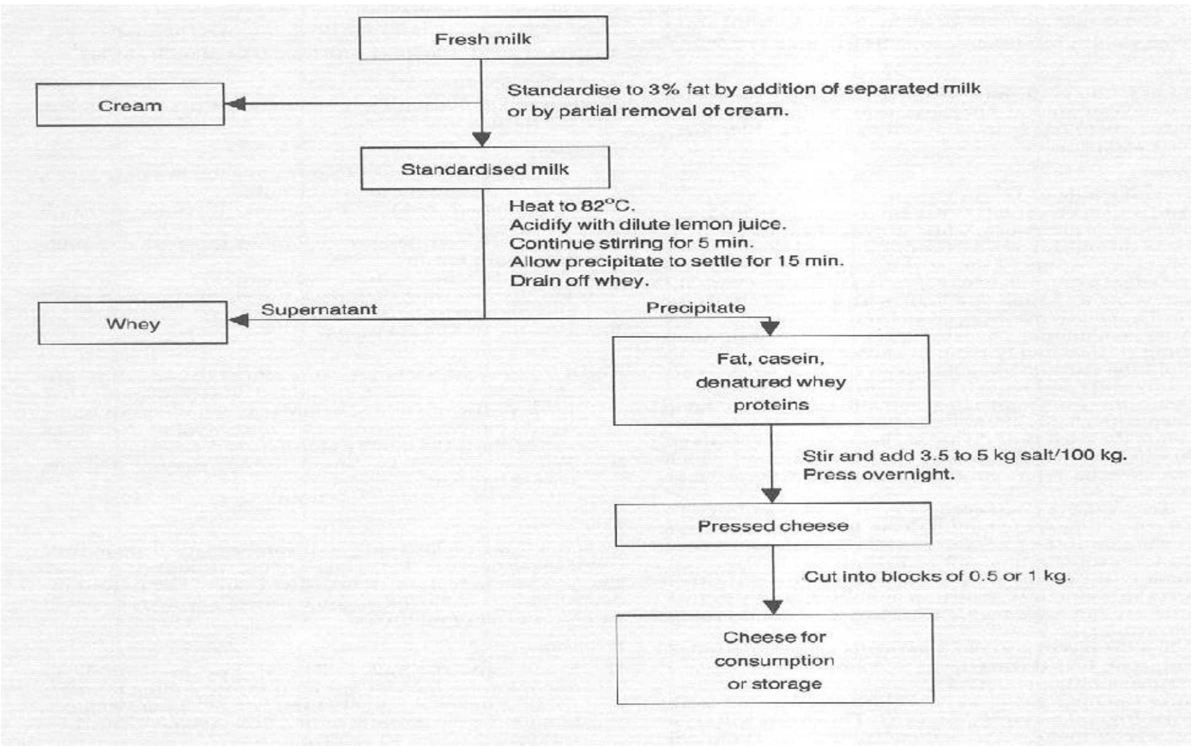
Procedure

1. Take fresh whole milk and determine its fat content. If the fat content is higher than 3%, standardise using skim milk.
2. Transfer the standardised milk to a cheese vat, preferably a double-jacketed standard cheese vat, and heat to 82°C.
3. While the milk is being heated measure out lemon juice of pH about 2.5 in a measuring jar. About 3 ml of lemon juice should be added per 100 ml of milk.
4. Dilute the lemon juice with an equal amount of clean, fresh water.

5. When the milk temperature reaches 82°C, add the diluted lemon juice carefully and uniformly while stirring. For even distribution of the juice, add in three separate amounts.
6. The curd precipitates almost immediately. Continue to stir for 3 minutes after adding the juice, then allow the curd to settle for 15 minutes
7. Drain the whey through a metal sieve or cheese cloth.
8. While draining the whey, stir the curd to prevent excess matting.
9. Distribute a total of about 3.5 to 5 kg of salt to 100 kg curd, in three applications.
10. Prepare a cylindrical or square hoop by lining with cheese cloth and scoop the salted curds into it.
11. Press the curd overnight at room temperature.
12. Remove the pressed cheese and cut into blocks of 0.5 or 1 kg.

Queso Blanco is made without starter or rennet. A variety of acidulants can be used for its manufacture. Heating the milk to 82°C pasteurizes the milk and denatures the whey proteins, so that they are recovered with the curd.

This increases cheese yield. The cheese has good keeping quality and is thus suitable for manufacture in rural areas. Expected yield: 1 kg of cheese from 8 kg of milk (12.5%).



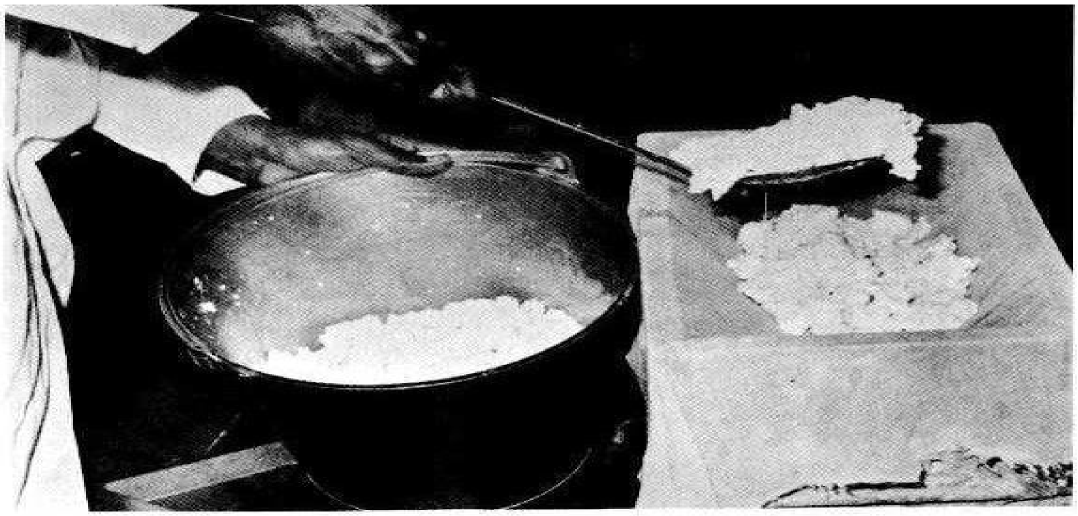
Manufacturing steps for Queso blanco cheese. Halloumi

Halloumi is the curd, formed by coagulating whole milk using rennet or similar enzymes, from which part of the moisture (whey) has been removed by cutting (bleeding), warming and pressing.

Procedure

1. Heat the milk to 32-35°C.
2. Add rennet or a similar enzyme according to the manufacturer's directions, while stirring the milk.
3. Hold the milk at 32-35°C until the curd sets.
4. Check for setting of the curd by applying pressure to the edge of the milk where it comes in contact with the vat, using a spatula or a knife with a round tip. If the curd is set it comes away clean from the wall of the vat.
5. After coagulation, the curd is cut into 3-5 mm cubes using vertical and horizontal knives.
6. Hold the curd in whey for about 20 minutes, stirring gently and continuously, and then allow it to settle.
7. Drain the whey and scoop out the curd into a hoop lined with cheese cloth. Press the curd.
8. While the curd is in the press, heat the whey to about 80-90°C. This precipitates the whey proteins, which can then be removed and pressed to make a whey cheese (*anari*).
9. Take out the pressed curd, cut it into pieces of 10 × 10 × 3 cm and heat at about 80°C in hot whey. Continue heating until the pieces of curd float on the surface of the whey and become soft and elastic.
10. Remove the pieces of curd when still warm and either press in the hands, folded or unfolded and rub in a little dry salt mixed with dried leaves of *Mentha viridis* (spearmint).
11. When the pieces are cold, put them in containers filled with cool, boiled whey brine and store in a cool place to ripen for about 30 days.
12. After ripening put in an airtight container and store in a refrigerator at less than 12°C. The cheese will keep for several months under these conditions. Halloumi cheese is best after 40 days but can also be consumed just after manufacture.

Note: 15% salt concentration in whey brine is normally used. Expected yield: 1 kg of cheese from 9 kg of milk (11 %).



Manufacturing steps for Halloumi cheese. Domiati -Gybna beyda

Known as Domiati in Egypt and Gybna beyda in Sudan, this is a hard, white cheese.

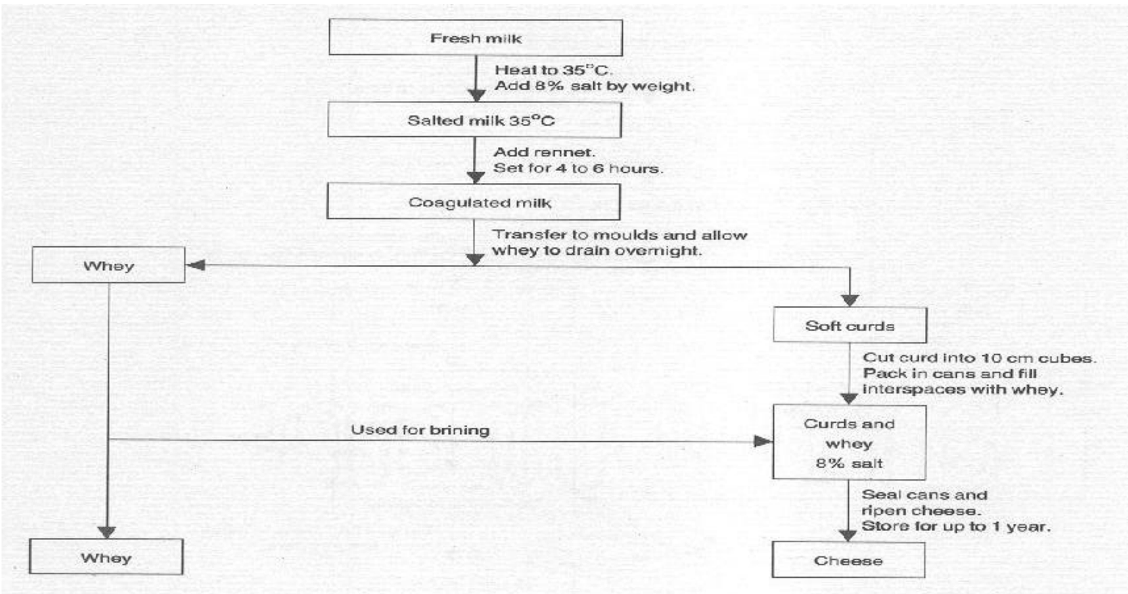
Procedure

1. Heat fresh milk to 35°C and add enough salt to give 7 to 10% salt solution in the milk.
2. Add enough rennet to coagulate the milk in 4 to 6 hours.
3. Once set, transfer the coagulum to wooden moulds lined with muslin.
4. Allow the whey to drain overnight.
5. On the following day, pack the cheese in tins and fill the interspaces with whey.
6. Seal the tins by soldering.

Notes: 1 and 2. In some area's rennet is added before salting. In this procedure, salt is not added until a coagulum has formed. If salt is added before rennet it is not advisable to add more rennet to shorten the coagulation time, as this reduces the quality of the cheese.

7. Whey expulsion continues during storage and the cheese hardens.

Expected yield: 1 kg of cheese from 7 kg of milk (15%).



Manufacturing steps for Domiati/Gybna beyda cheese.

Feta

This is a brine-pickled cheese. It can be made from milk of cows, sheep or goats. Feta can be made without starter and can also be made from standardized milk. The procedure described here is for the manufacture of a feta-type cheese without starter or additives.

Procedure

1. Standardize the milk to 3% fat, heat to about 32°C and allow to ripen for one hour before

adding rennet.

2. Add commercial rennet at the rate of 25 ml/ 100 liters of milk. Leave the milk until a firm clot has formed this usually takes 40 to 50 minutes.

3. Cut the curd into 2- to 3-cm cubes to facilitate whey drainage. Allow 15 minutes for the whey to separate. Stir intermittently during this time.

4. Allow the curds to settle and decant the supernatant whey.

5. Transfer the curds and some whey to cheese moulds lined with muslin. Place the lid on the mould and invert at half-hourly intervals in the first few hours to facilitate whey drainage.

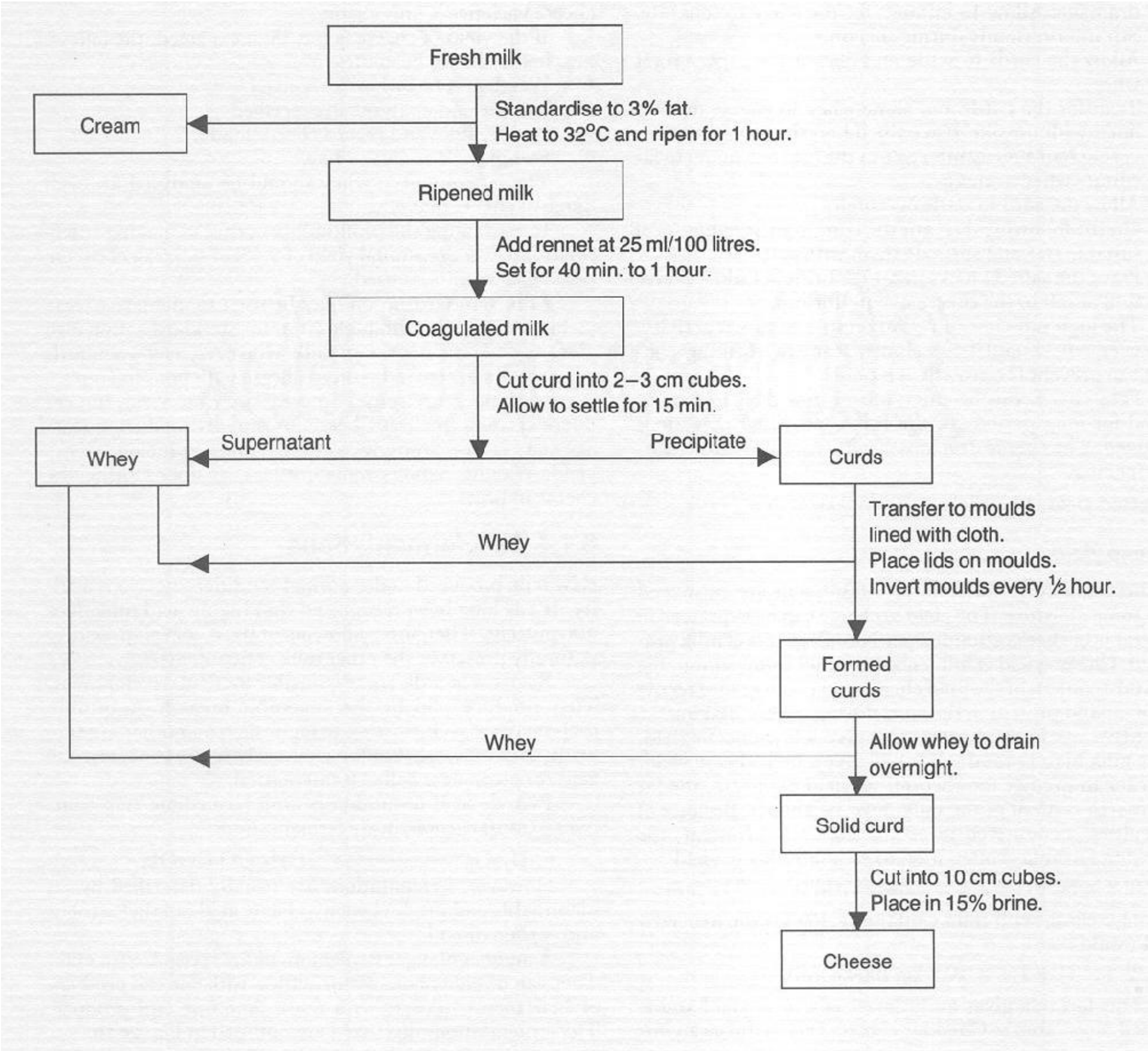
6. Allow the curd to settle overnight.

7. On the following day, cut the curd mass into blocks of suitable size and sprinkle them with salt.

8. Place the salted blocks in a 15% brine solution to give 6-8% salt in the cheese at equilibrium.

The high salt concentration retards bacterial activity. However, air should be excluded from the brining container to prevent the growth of moulds.

Feta cheese can be eaten after a few days or can be stored for long periods in the brine, provided that air is excluded. The cheese develops a soft, crumbly texture during ripening. Expected yield: 1 kg of cheese from 9 kg of milk (11 %).



Manufacturing steps for Feta cheese.

5.8.1. Cheese yield

In cheese-making, the milk fat and casein are recovered with some moisture. The yield of cheese can be expressed in kilograms of cheese obtained per 100 kilograms of milk processed. Cheese yield is influenced by milk composition, the moisture content of the final cheese and the degree of recovery of fat and protein in the curd during cheese- making.

Milk low in total solids will give a low cheese yield, while milk high in total solids will give a high cheese yield. In order to predict the theoretical yield of cheese, the fat and casein content of the milk must be known. Because of difficulties encountered in estimating casein content, the following formula is often used to estimate cheese yield:

$(2.3 \times \text{fat } \%) + 1.4 = \text{cheese yield (kg/ 100 kg milk)}$

Therefore, with milk containing 4% fat the expected yield would be: $(2.3 \times 4) + 1.4 = 10.6$ kg/ 100 kg milk

This formula gives an estimate of cheese yield and is applied most often to Cheddar cheese. It is useful as an immediate check on efficiency, but a universal yield factor for cheese varieties is unrealistic.

If the yield of cheese is less than expected, the following checks should be made:

- Weigh and record milk received.
- Sample and analyze milk received.
- Weigh, store and record cheese made.
- Sample and analyze whey.

The fat content of whey should be analyzed for each batch of cheese made. In estimating the profitability of cheese-making enterprises, an average annual yield of 9.5%, i.e. 9.5 kg of cheese per 100 kg of milk, is used.

Milk standardization may be used to increase cheese yield, particularly with high-fat milk. Standardization also gives a good return for skim milk. However, over-standardizing results in coarse-textured cheese with poor flavor.

High moisture content increases cheese yield, but reduces keeping quality. Cheese loses moisture during storage if it is not properly wrapped, thus reducing cheese yield. Waxing reduces moisture loss, as does storing the cheese in brine.

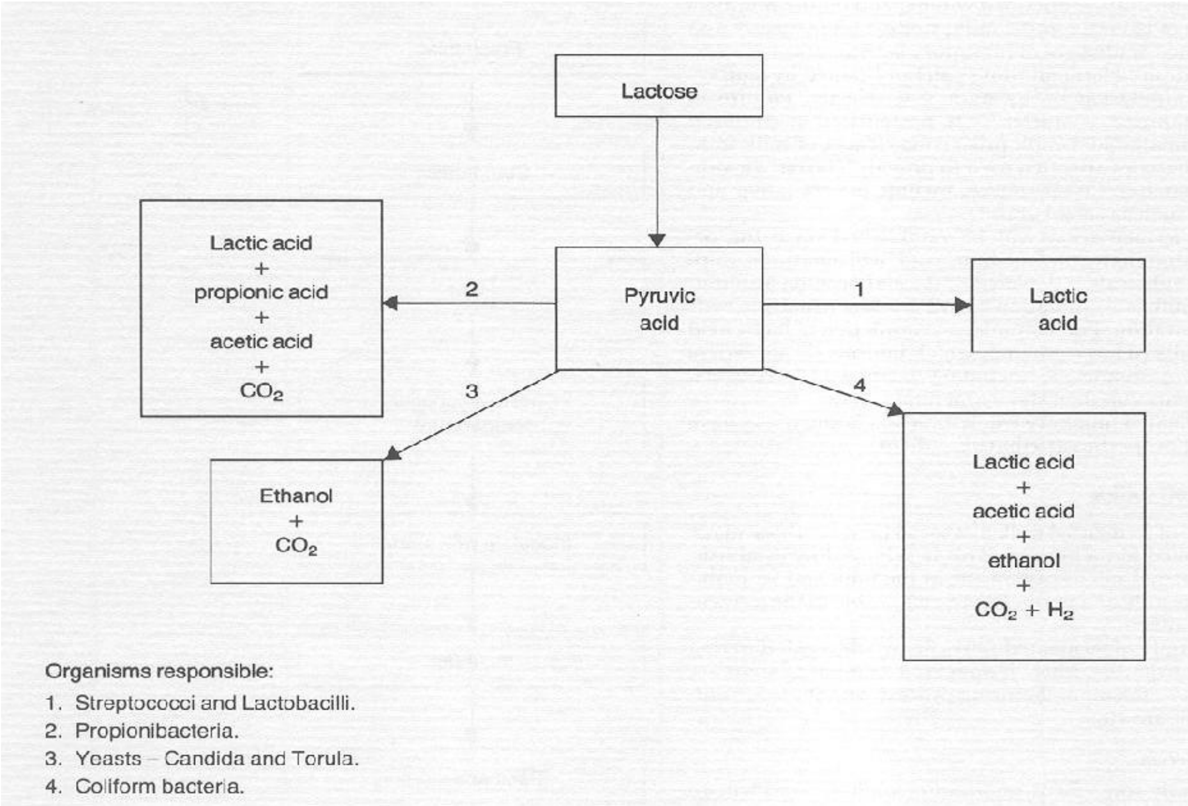
Milk fermentations

Raw milk produced under normal conditions develops acidity. It has long been recognized that highly acid milk does not putrefy. Therefore, allowing milk to develop acidity naturally preserves the other milk constituents.

Bacteria in milk are responsible for acid development. They produce acid by the anaerobic breakdown of milk carbohydrate-lactose-to lactic acid and other organic acids. Anaerobic breakdown of carbohydrate to organic acids or alcohols is called fermentation. Pyruvic acid formation is an intermediate step common to most carbohydrate fermentations:

$C_6H_{12}O_6$ -------> 2 $CH_3.CO.COOH$

However, fermentations are usually described by an identifiable end product such as lactic acid or ethyl alcohol and carbon dioxide. A number of sugar fermentations



are recognized in milk. They can be either homo fermentative, with one end product, or hetero fermentative, with more than one end product.

Outline of four important lactose fermentations.

Organisms responsible:

1. **Streptococci and Lactobacilli**.
2. **Propionibacteria**.
3. **Yeasts - Candida and Torula**.
4. **Coli form bacteria**.

The lactic acid fermentation is the most important one in milk and is central to many processes. Propionic fermentation is mixed-acid fermentation and is used in the manufacture of Swiss cheese varieties. Alcohol fermentation can be used to prepare certain fermented milks and also to make ethyl alcohol from whey.

The coli form gassy fermentation is an example of spoilage fermentation. Large numbers of coli form bacteria in milk indicates poor hygiene. The coli form gassy fermentation disrupts lactic acid fermentation, and also causes spoilage in cheese.

The factors that affect microbial growth also affect milk fermentation. Fermentation rates will generally parallel the microbial growth curve up to the stationary phase. The type of fermentation obtained will depend on the numbers and types of bacteria in the milk, storage temperature and the presence or absence of inhibitory substances.

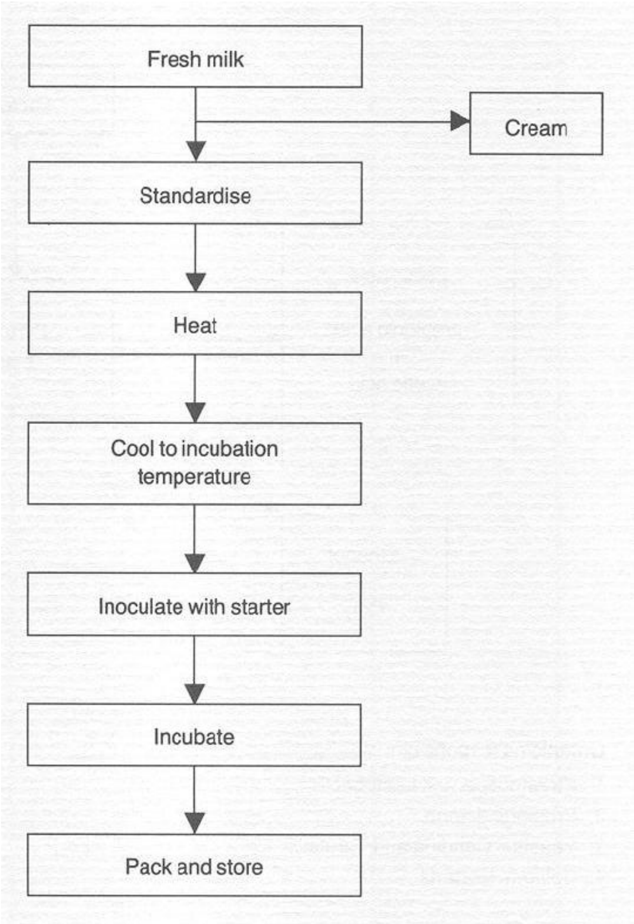
The desired fermentations can be obtained by temperature manipulation or by adding a selected culture of micro-organisms-starter-to pasteurised or sterilised milk. In smallholder milk processing, traces of milk from previous batches are often used to provide `starter' for subsequent batches. Other sources include the container and additives such as cereal grains.

The fermentation will be established once the organisms dominate the medium and will continue until either the substrate is depleted or the end product accumulates. In milk, accumulation of end product usually arrests the fermentation. For example, accumulation of lactic acid reduces milk pH to below 4.5, which inhibits the growth of most micro- organisms, including lactic-acid producers. The fermentation then slows and finally stops. Fermented milks are wholesome foods and many have medicinal properties attributed to them.

Fermented milks

The types of fermented milk discussed here are those made by controlled fermentation. This is achieved by establishing the desired micro-organisms in the milk and by maintaining the milk at a temperature favourable to the fermentative organism.

A variety of fermented milks are made, each dithering markedly from the other.



Flow diagram of fermented milk manufacture. Standardization

Occasionally some fat is removed or milk SNF added. In some instances, the removal of moisture during heating increases the proportion of solids in the final product.

Heating

Milk is heated to kill pathogens and spoilage organisms and to provide a cleaner medium in which the desired micro-organisms can be established. Heating also removes air from the milk, resulting in a more favorable environment for the fermentative organisms, and denatures the whey proteins, which increases the viscosity of the product.

After heating, the milk must be cooled before it is inoculated with starter, otherwise the starter organisms will also be killed.

Inoculation with starter

Starter is the term used to describe the microbial culture that is used to produce the desired fermentation and to flavor the product. When preparing the starter, care must be taken to avoid contamination with other micro-organisms. Companies that supply starter cultures detail the precautions necessary. Care should also be taken to avoid contamination when inoculating the milk with starter.

Incubation

After inoculation the milk is incubated at the optimum temperature for the growth of the starter organism. Incubation is continued until the fermentation is complete, at which time the product is cooled. Additives may be added at this stage and the product packed. The manufacturing procedures for a number of fermented milks are given in Table 7.

Table 7. ***Manufacturing procedures for yoghurt, acidophilus milk and kefir.***

Product	Milk	Standardise	Sterilise	Starter	Incubation temperatur	Incubation Time
Yoghurt	Cows	Optional	95°C 30 min	*S. thermophilus L.*	37°C	4-6 hours
Acidophilus milk	Cows	Optional	120°C 20 min	*L. acidophilus*	38°C	18-24 hours
Kefir	Cows Ewes Goats Mare	-	85°C 30 min	Kefir grains*	22°C	12 hours

* Kefir grains are irregular granules in which bacteria and yeast grow. When they are introduced into the milk, the micro-organisms on the granules bring about the fermentation.

Preparation of the fermentation vessel

The fermentation vessel is first washed to remove visible dirt. It is then dried and smoked by putting burning embers of *Olea africana,* wattle or acacia into the vessel and closing the lid. The vessel is then shaken vigorously and the lid opened to release the smoke. This procedure is repeated until the inside of the vessel is hot. Smoking flavors the product and is also thought to control the fermentation by retarding bacterial growth. While it is known that smoke contains compounds that retard bacterial growth, the precise effects of smoking on fermentation have not been investigated.

Once smoking is complete the vessel may be cleaned with a cloth to remove charcoal particles. However, in some areas the charcoal particles are retained to add color to the product.

Milk treatment

In some processes the milk is boiled prior to fermentation. It is then allowed to cool and the surface cream removed. In other processes the milk is not given any pre fermentation treatment.

Fermentation

The milk is placed in the smoked vessel and allowed to ferment slowly in a cool place at a temperature of about 16-18°C. The fermentation is almost complete after 2 days, but may be continued for a further 2 days, by which time the flavor is fully developed. The milk must ferment at low temperature; otherwise fermentation is too vigorous, with much wheying off and gas production.

The product has a storage stability of 15 to 20 days.

Concentrated fermented milks

Concentrated fermented milks are prepared by removing whey from fermented milk and adding fresh milk to the residual milk constituents. The fermentation vessel is prepared as for fermented milk. The milk is allowed to ferment in a cool place for up to 7 days, during which milk may be added daily. After 7 days a coagulum has formed and the clear whey is removed. Fresh milk is then added and, following further fermentation, whey is again removed. In this way the casein and fat are gradually concentrated in a product of extended keeping quality. The actual degree of concentration depends on the amount of whey removed and of fresh milk added.

Milk

Fat **Casein**	**}**	**Coagulum—— > Stored**
Whey proteins —— >Whey—— > Fed to calves		

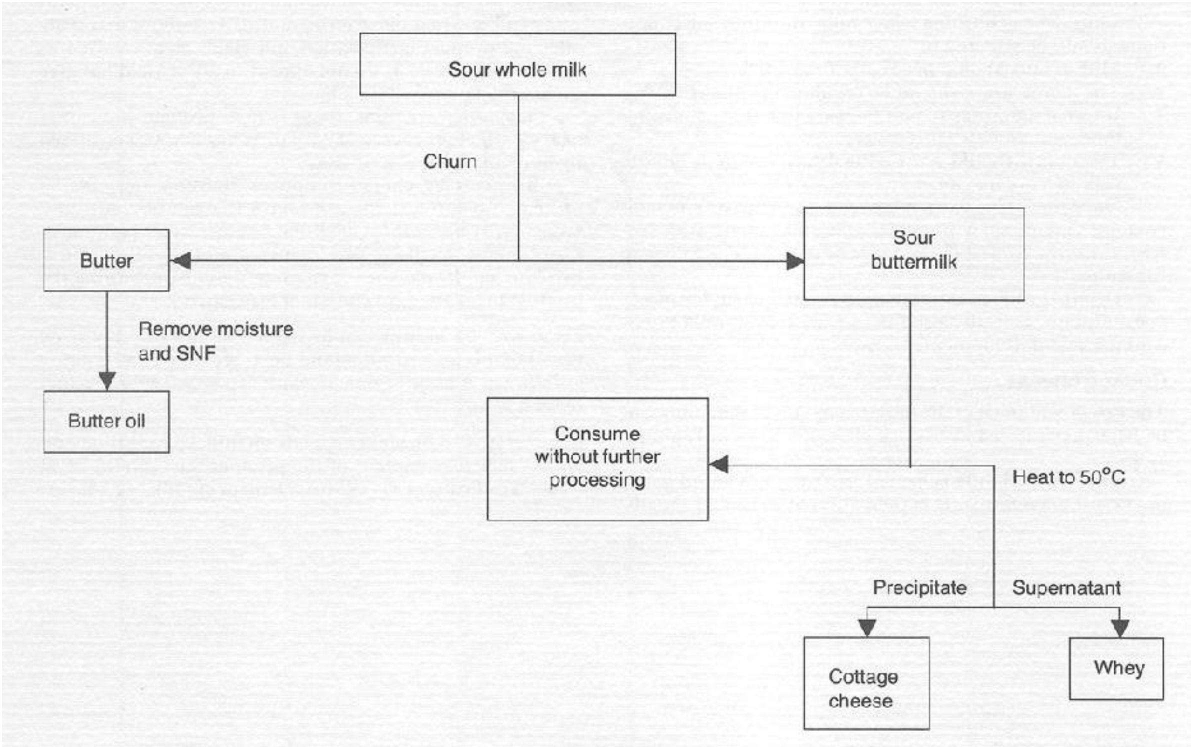
Sour-milk technology

Smallholder milk processing is based on sour milk. This is due to a number of reasons, including high ambient temperatures, small daily quantities of milk, consumer preference and increased keeping quality of sour milk.

Products made from sour milk include fermented milks, concentrated fermented milks, butter, ghee, cottage cheese and whey. Other products made are cheese and products made by mixing fermented milk with boiled cereals.

The equipment required for processing sour milk is simple and is all available locally. Milk vessels can be made from clay, gourds and wood, and can be woven from fibre, such as the *gorfu* container used by the Borana pastoralists in Ethiopia.

Making butter and cottage cheese from sour whole milk



Products and byproducts of butter-making from sour whole milk.

Butter-making from sour whole milk

This is a very important process in many parts of Africa. Smallholders produce 1 to 4 liters of milk per day for processing. Under normal storage conditions the milk becomes sour in 4 to 5 hours. The souring of milk has a number of advantages. It retards the growth of undesirable microorganisms, such as pathogens and putrefactive bacteria, and makes the milk easier to churn.

Milk for churning is accumulated over several days by adding fresh milk to the milk already accumulated. The churn holds about 20 liters and the amount of milk churned ranges from 4 to 10 liters. The milk is normally accumulated over 2 or more days. Butter is made by agitating the milk until butter grains form. The churn is then rotated slowly until the fat coalesces into a continuous mass. The butter thus formed is taken from the churn and kneaded in cold water.

The milk is usually agitated by placing the churn on a mat on the floor and rolling it to and from. It can also be agitated by shaking the churn on the lap or hung from a tripod.

A number of factors influence churning time and recovery of butterfat as butter:

- Milk acidity
- Churning temperature
- Degree of agitation, and
- Extent of filling the churn

Effect of acidity: Fresh milk is difficult to churn: churning time is long and recovery of butterfat is poor. Milk containing at least 0.6% lactic acid is easier to churn. Acidity higher than 0.6% does not significantly influence churning time or fat recovery.

Effect of temperature*: Sour milk is normally churned at between 15 and 26°C, depending on environmental temperature. At low temperatures churning time is long; butter-grain formation can take 5 hours or longer. As churning temperature increases churning time decreases. This becomes marked at temperatures above 20°C, but as little as

60% of the butterfat may be recovered as butter at 26°C. Control of temperature is therefore critical.

It is difficult to isolate the effects of temperature and acidity on churning efficiency because while the milk is ripening it is also cooling and the fat is crystallizing. Direct acidification of fresh milk increases butter yield, but allowing milk to develop acidity during a ripening period of 2 to 3 days allows considerable fat crystallization.

Degree of agitation: Increasing agitation reduces churning time. Fitting an agitator to a traditional churn reduces churning time and increases butter yield. The percentage of fat recovered as butter is increased, with as little as 0.2% fat remaining in the buttermilk. However, the process is very temperature-dependent and churning at temperatures above

20°C results in short churning times with poor recovery of fat. The optimum churning temperature is between 17 and 19°C.

Extent of filling the churn: Churns should be filled to between a third and half their volumetric capacity. Filling to more than half the volumetric capacity increases churning time considerably but does not reduce fat recovery.

Thus, when churning whole milk, the following conditions should be adhered to:

- Milk acidity should be greater than 0.6%.
- The temperature should be regulated to about 18°C.

Internal agitation should be used to reduce churning time and increase fat recovery. The churn should not be filled to more than half its volumetric capacity.

Once the fat has been recovered, the soured skim milk contains casein, whey proteins, milk salts, lactic acid, lactose, the unrecovered fat and some fat-globule-membrane constituents. Defatted milk is suitable, and is often used, for direct consumption. It is also used to inoculate fresh milk to encourage acid development.

Cottage cheese

The casein and some of the unrecovered fat in skim milk can be heat-precipitated as cottage cheese, known in Ethiopia as ***Ayib.***

The defatted milk is heated to about 50°C until distinct curd mass forms. It is then allowed to cool gradually and the curd is ladled out. Alternatively, the curd can be recovered by filtering the cooled mixture through a muslin cloth. This facilitates more complete recovery of the curd and also allows more effective moisture removal. Temperature can be varied between 40 and 70°C without markedly affecting product composition and yield. Heat treatments between 70 and 90°C do not appear to affect yield but give the product a cooked flavor.

The whey contains about 0.75% protein, indicating near-complete recovery of casein. Whey can be consumed by humans or fed to animals. The cottage cheese comprises 79.5% water, 14.7% protein, 1.8% fat, 0.9% ash and 3.1 % soluble milk constituents. It has a short shelf-life because of its high moisture content.

Shelf-life can be increased by adding salt or by reducing the moisture content of the cheese. Storing the product in an air-tight container also extends storage life.

Equipment: Skim milk can be heated in any suitably sized vessel that is able to withstand heat. Heating can be direct or indirect. A ladle or muslin cloth can be used for product recovery.

Expected yield: The yield depends on milk composition and on the moisture content of the product, but should be at least 1 kg of cottage cheese from 8 liters of milk (12.5%).

Milk and milk product quality measurement

Good quality raw milk has to be free of debris and sediment; free off – flavors and abnormal color and odor, low in bacterial count; free of chemicals (e.g., antibiotics, detergents); and of normal composition and acidity. The quality of raw milk is the primary factor determining the quality of milk products. Good quality milk products can be produced only from good quality raw milk.

The hygienic quality of milk is of crucial importance in producing milk and milk products that are safe and suitable for their intended uses. To achieve this quality, good hygiene practices should be applied throughout the dairy chain. Among the causes of small-scale dairy producers' difficulties in producing hygienic products are informal and unregulated marketing, handling and processing of dairy products; lack of financial incentives for quality improvement; and insufficient knowledge and skills in hygienic practices.

Milk testing and quality control should be carried out at all stages of the dairy chain. Milk can be tested for:

- Quantity: - measured in volume or weight;
- Organoleptic characteristics: - appearance, taste and smell;
- Compositional characteristics: - especially fat, solid and protein contents;
- Physical and chemical characteristics;
- Hygienic characteristics: - hygienic conditions, cleanliness and quality
- Adulteration: - with water, preservatives, added solids, etc.;
- Drug residues.

  Examples of simple milk testing methods suitable for small scale dairy producers and processors in developing countries include taste, smell and visual observation(organoleptic tests); density meter or lactometer tests to measure the specific density of milk; clot on boiling testing to determine whether the milk is sour or abnormal; acidity testing to measure the lactic acid in milk and Gerber test to measure the amount of fat in the milk.

CHAPTER five: Meat processing

Introduction

Meat consumption in developing countries has been continuously increasing from a modest average annual per capita consumption of 10 kg in the 1960s to 26 kg in 2000 and will reach 37 kg around the year 2030 according to FAO projections. This forecast suggests that in a few decades, developing countries' consumption of meat will move towards that of developed countries where meat consumption remains stagnant at a high level.

The rising demand for meat in developing countries is mainly a consequence of the fast progression of urbanization and the tendency among city dwellers to spend more on food than the lower income earning rural population. Given this fact, it is interesting that urban diets are, on average, still lower in calories than diets in rural areas. This can be explained by the eating habits urban consumers adopt. If it is affordable to them, urban dwellers will spend more on the higher cost but lower calorie protein foods of animal origin, such as meat, milk, eggs and fish rather than on staple foods of plant origin. In general, however, as soon as consumers' incomes allow, there is a general trend towards incorporating more animal protein, in particular meat, in the daily diet.

Man's propensity for meat consumption has biological roots. In ancient times meat was clearly preferred; consequently, time and physical efforts were invested to obtain it, basically through hunting. This attitude contributed decisively to physical and mental development of humankind.

Despite the growing preference in some circles for meatless diets, the majority of us will continue eating meat. It is generally accepted that balanced diets of meat and plant food are most effective for human nutrition.

Quantitatively and qualitatively, meat and other animal foods are better sources of protein than plant foods (except soy bean products). In meat, the essential amino acids – the organic acids that are integral components of proteins and which cannot be synthesized in the human organism – are made available in well balanced proportions and concentrations. As well, plant food has no Vitamin B12; thus, animal food is indispensable for children to establish B12 deposits. Animal food, in particular meat, is rich in iron, which is of utmost importance to prevent anemia, especially in children and pregnant women.

In terms of global meat production, over the next decade there will be an increase from the current annual production of 267 million tons in 2006 to nearly 320 million tons by 2016. Almost exclusively, developing countries will account for the increase in production of over 50 million tons. This enormous target will be equivalent to the levels of overall meat production in the developing world in the mid-1980s and place an immense challenge on the livestock production systems in developing countries. The greater demand for meat output will be met by a further shift away from pastoral systems to intensive livestock production systems. As these systems cannot be expanded indefinitely due to limited feed availability and for environmental reasons, other measures must be taken to meet growing meet demand. The only possible alternatives are making better use of the meat resources available and reducing waste of edible livestock parts to a minimum.

This is where meat processing plays a prominent role. It fully utilizes meat resources, including nearly all edible livestock parts for human food consumption. Meat processing, also known as further processing of meat, is the manufacture of meat products from muscle meat, animal fat and certain non-meat additives. Additives are used to enhance product flavor and appearance. They can also be used to increase product volume. For specific meat preparations, animal by-products such as internal organs, skin or blood, are also well suited for meat processing. Meat processing can create different types of product composition that maximizes the use of edible livestock parts and are tasty, attractive and nourishing.

The advantage of meat processing is the integration of certain animal tissues (muscle trimmings, bone scraps, skin parts or certain internal organs which are usually not sold in fresh meat marketing) into the food chain as valuable protein-rich ingredients. Animal blood, for instance, is unfortunately often wasted in developing countries largely due to the absence of hygienic collection and processing methods and also because of socio-cultural restrictions that do not allow consumption of products made of blood. While half of the blood volume of a slaughtered animal remains in the carcass tissues and is eaten with the meat and internal organs, the other half recovered from bleeding represents 5-8 percent of the protein yield of a slaughter animal. In the future, we cannot afford to waste such large amounts of animal protein. Meat processing offers a suitable way to integrate whole blood or separated blood fractions (known as blood plasma) into human diets.

Thus, there are economic, dietary and sensory aspects that make meat processing one of the most valuable mechanisms for adequately supplying animal protein to human populations, as the following explains:

• All edible livestock parts that are suitable for processing into meat products are optimally used. In addition to muscle trimmings, connective tissue, organs and blood, this includes casings of animal origin that are used as sausage containers.

• Lean meat is one of the most valuable but also most costly foods and may not regularly be affordable to certain population segments. The blending of meat with cheaper plant products through manufacturing can create low-cost products that allow more consumers access to animal protein products. In particular, the neediest, children and young women from low-income groups, can benefit from products with reduced but still valuable animal protein content that supply essential amino acids and also provide vitamins and minerals, in particular iron.

• Unlike fresh meat, many processed meat products can be made shelf-stable, which means that they can be kept without refrigeration either as

(1) Canned heat sterilized products, or

(2) Fermented and slightly dried products or

(3) Products where the low level of product moisture and other preserving effects inhibit bacterial growth. Such shelf-stable meat products can conveniently be stored and transported without refrigeration and can serve as the animal protein supply in areas that have no cold chain provision.

• Meat processing "adds value" to products. Value-added meat products display specific flavour, taste, colour or texture components, which are different from fresh meat. Such treatments do not make products necessarily cheaper; on the contrary in many cases they become even more expensive than lean meat. But they offer diversity to the meat food sector, providing the combined effect of nutritious food and food with excellent taste.

Processing Technology

Meat processing technologies were developed particularly in Europe and Asia. The European technologies obviously were more successful, as they were disseminated and adopted to a considerable extent in other regions of the world by way of their main creations of burger patties, frankfurter-type sausages and cooked ham. The traditional Asian products, many of them of the fermented type, are still popular in their countries of origin. But Western-style products have gained the upper hand and achieved a higher market share than those traditional products. In Asia and Africa, there are a number of countries where meat is very popular but the majority of consumers reject processed meat products.

This is not because they dislike them but because of socio-cultural reasons that prohibit the consumption of certain livestock species, either pork or beef depending on the region. Because processed products are mostly composed of finely comminuted meat, which makes identifying the animal species rather difficult, or are frequently produced from mixes of meat from different animals, consumers stay away from those products to avoiding eating the wrong thing. But when the demand for meat increases and a regular and cost-effective supply can only be achieved by fully using all edible livestock parts, consumers will need to adjust to processed meat products, at least to those where the animal source can be identified. Younger people already like to eat fast-food products such as beef burgers or beef frankfurters. Outlet chains for such products and other processed meat products will follow when the demand increases.

Meat, Fat and Other Edible Carcass Parts

(Types, structure, biochemistry)

Sources of meat, fat and animal by-products.

Meat, fat and other carcass parts used as raw materials for the manufacture of processed meat products are mainly derived from the domesticated animal species **cattle**, **pigs** and **poultry** and to a lesser extend from **buffaloes**, **sheep** and **goats**. In some region's other animal species such as **camels**, **yaks**, **horses** and **game animals** are used as meat animals but play only a minor role in meat processing.

In this context, **meat** can be defined as "the muscle tissue of slaughter animals". The other important tissue used for further processing is **fat**.   Other edible parts of the slaughtered animal and often used in further processing are the **internal organs**1 (tongue, heart, liver, kidneys, lungs, diaphragm, esophagus, intestines) and other slaughter byproducts (blood, soft tissues from feet, head). A special group of internal organs are the **intestines**. Apart from being used as food in many regions in particular in the developing world, they can be processed in a specific way to make them suitable as sausage casings. Some of them are eaten with the sausage; others are only used as container for the sausage mix and peeled off before consumption.

The **skin** of some animal species is also used for processed meat products. This is the case with pork skin and poultry skin, in some cases also with calf skin (from calf heads and legs). For more details on the utilization of animal tissues for processed meat products see also chapter "Selection and grading of meat materials for processing".

Muscle meat

Chemical composition of meat

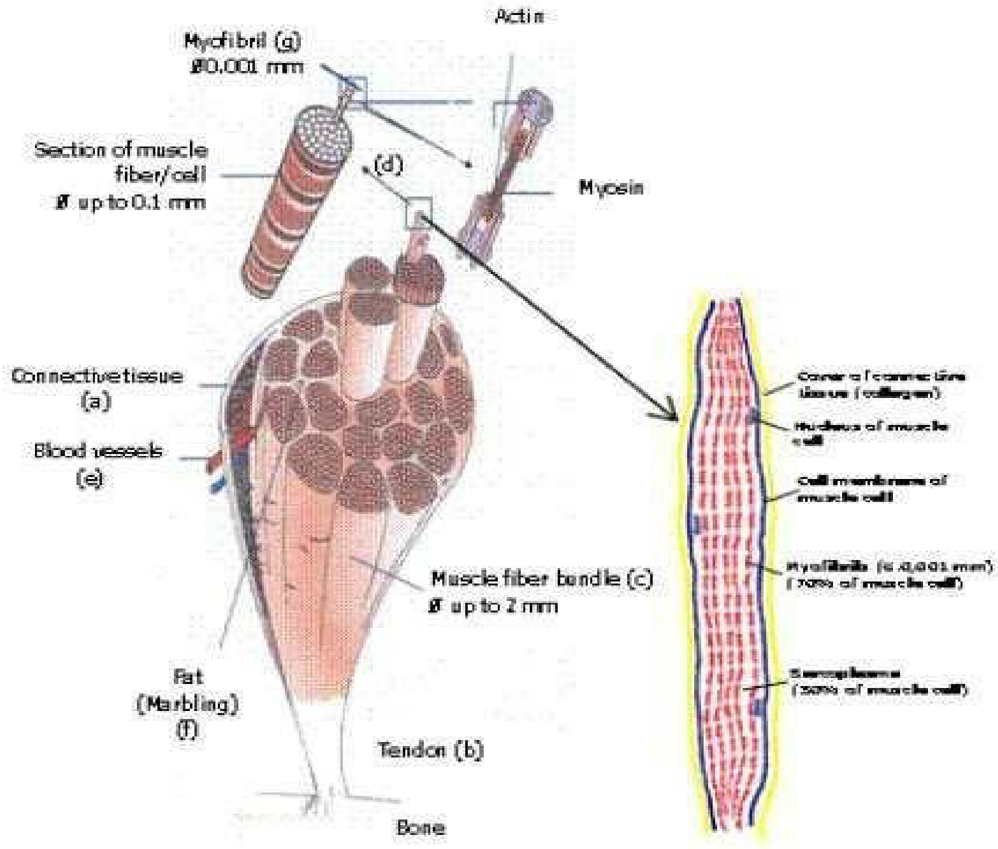
In general, meat is composed of **water**, **fat**, **protein**, **minerals** and a small proportion of **carbohydrate**. The most valuable component from the nutritional and processing point of view is protein. Protein contents and values define the quality of the raw meat material and its suitability for further processing. Protein content is also the criterion for the quality and value of the finished processed meat products.

Histological structure of muscle tissue

The muscles are surrounded by a connective tissue membrane, whose ends meet and merge into a tendon attached to the skeleton (b). Each muscle includes several **muscle fibre bundles** which are visible to the naked eye (c), which contain a varying number (30-80) of **muscle fibres** or muscle cells (d) up to a few centimeters long with a diameter of 0.01 to 0.1 mm. The size and diameter of muscle fibres depends on age, type and breed of animals. Between the muscle fibre bundles are blood vessels (e) as well as connective tissue and fat deposits. Each muscle fibre (muscle cell) is surrounded by a cell membrane (sarcolemma) (blue).

Inside the cell are **sarcoplasma** (white) and a large number of filaments, also called **myofibrils** (red). The *sarcoplasma* is a soft protein structure and contains amongst others the red muscle pigment **myoglobin**. *Myoglobin* absorbs oxygen carried by the small blood vessels and serves as an oxygen reserve for contraction of the living muscle. In meat the *myoglobin* provides the red meat colour and plays a decisive role in the curing reaction.

The *sarcoplasma* constitutes about 30 percent of the muscle cell. The *sarcoplasmatic proteins* are **water soluble**. About 70 percent of the muscle cell consists of thousands of *myofibrils*, which are solid protein chains and have a diameter of 0.001 – 0.002 mm. These proteins, which account for the major and nutritionally most valuable part of the muscle cell proteins, are **soluble in saline solution**. This fact is of utmost importance for the manufacture of certain meat products, in particular the *raw-cooked products* and *cured- cooked products*. A characteristic of those products is the heat coagulation of previously liquefied myofibril proteins. The achieved structure of the coagulated proteins provides the typical solid-elastic texture in the final products.



Muscle structure

(Skeletal muscle) Entire muscle fibre or muscle cell, 0.01-0.1mm

Changes of pH

Immediately post-mortem the muscle contains a small amount of muscle specific carbohydrate, called **glycogen**1 (about 1%), most of which is broken down to lactic acid in the muscle meat in the first hours (up to 12 hours) after slaughtering. This biochemical process serves an important function in establishing acidity (low pH) in the meat.

The so-called **glycolytic cycle** starts immediately after slaughter in the muscle tissue, in which glycogen, the main energy supplier to the muscle, is broken down to **lactic acid**. The buildup of lactic acid in the muscle produces an increase in its acidity, as measured by the **pH**. The pH of normal muscle at slaughter is about 7.0 but this will decrease in meat. In a normal animal, the ultimate pH (expressed as pH24 = 24 hours after slaughter) falls to around **pH 5.8-5.4**. The degree of reduction of muscle pH after slaughter has a significant effect on the quality of the resulting meat.

The typical **taste** and **flavor** of meat is only achieved after sufficient drop in pH down to 5.8 to 5.4. From the *processing* point of view, meat with pH 5.6-6.0 is better for products where good water binding is required (e.g. frankfurters, cooked ham), as meat with higher pH has a higher water binding capacity. In products which lose water during fabrication and ripening (e.g. raw ham, dry fermented sausages), meat with a lower pH (5.6–5.2) is preferred as it has a lower water binding capacity.

The pH is also important for the **storage life** of meat. The lower the pH, the less favorable conditions for the growth of harmful bacteria. Meat of animals, which had depleted their glycogen reserves before slaughtering (after stressful transport/handling in holding pens) will not have a sufficient fall in pH and will be highly prone to bacterial deterioration.

PSE and DFD

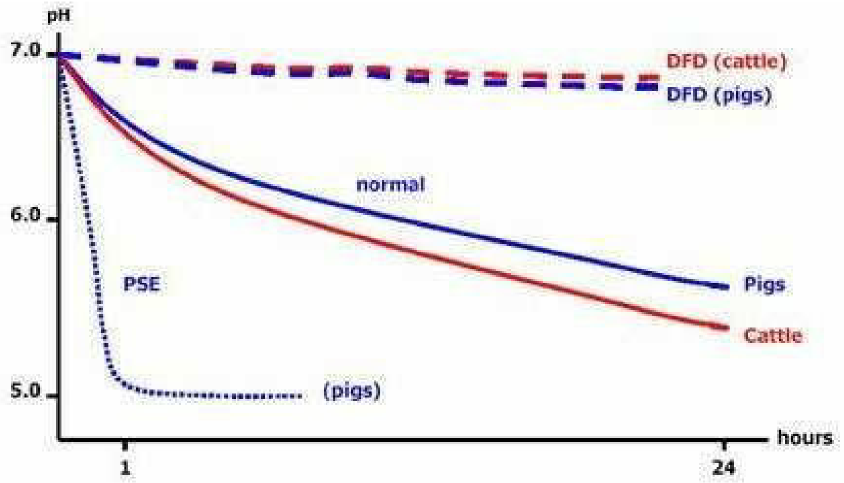
In stress susceptible animal's pH may fall very quickly to pH 5.8 – 5.6 while the carcass is still warm. This condition is found most often in pork. It can be recognized in the meat as a pale colour, a soft, almost mushy texture and a very wet surface (**pale, soft, exudative = PSE meat**). PSE meat has lower binding properties and loses weight (water) rapidly during cooking resulting in a decrease in processing yields.

A reverse phenomenon may arise in animals which have not been fed for a period before slaughter, or which have been excessively fatigued during transportation and lairage. In these cases, most of the muscle glycogen has been used up at point of slaughter and pronounced acidity in the meat cannot occur. The muscle pH24 does not fall below pH 6.0. This produces **dark, firm,dry (DFD) meat**. The high pH causes the muscle proteins to retain most of their bound water, the muscle remains swollen and they absorb most of the light striking the meat surface, giving a dark appearance.

Dark meat has a "sticky" texture. Less moisture loss occurs during curing and cooking as a result of the higher pH and the greater water-holding capacity but salt penetration is restricted. Conditions for growth of microorganisms are therefore improved resulting in a much shorter "shelf life". DFD conditions occur both in beef and pork.

DFD meat should not be confused with that resulting from mature animals through the presence of naturally dark pigmentation. PSE and DFD conditions can to a certain extend be prevented or retarded through humane treatment and minimization of stress to animals prior to slaughter.

PSE and DFD meat is **not unfit** for human consumption, but not well suited for cooking and frying (PSE loses excessive moisture and remains dry due to low water binding capacity while DFD meat remains tough and tasteless due to the lack of acidity). Nevertheless, for meat processing purposes, PSE and DFD meat can still be utilized, preferably **blended** with normal meat. PSE meat can be added to meat products, where water losses are desirable, such as dry-fermented sausages, while DFD meat can be used for raw-cooked products (frankfurter type) where high water binding is required.



Changes of pH

Meat colouring

The red pigment that provides the characteristic color of meat is called **myoglobin**. Similar to the blood pigment haemoglobin it transports oxygen in the tissues of the live animal. Specifically, the myoglobin is the oxygen reserve for the muscle cells or muscle fibers. Oxygen is needed for the biochemical process that causes muscle contraction in the live animal. The greater the myoglobin concentration, the more intense the colour of the muscle.

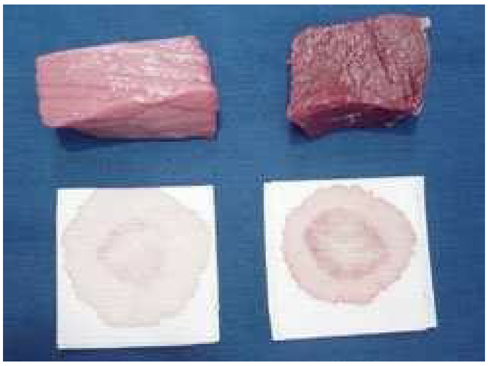
This difference in myoglobin concentration is the reason why there is often one muscle group lighter or darker than another in the same carcass.

Fresh meat cut (beef) with intense red meat colour

Myoglobin concentration in muscles also differs among animal species. Beef has considerably more myoglobin than pork, veal or lamb, thus giving beef a more intense color. The maturity of the animal also influences pigment intensity, with older animals having darker pigmentation. The different myoglobin levels determine the curing capability of meat. As the red curing color of meat results from a chemical reaction of myoglobin with the curing substance nitrite, the curing color will be more intense where more muscle myoglobin is available.

Water holding capacity

The water holding capacity (WHC) of meat is one of the most important factors of meat quality both from the consumer and processor point of view. Muscle proteins are capable of holding many water molecules to their surface. As the muscle tissue develops acidity (decrease of pH) the water holding capacity decreases.



Compression test1,

Different water holding capacity of muscles. Left: Sample with low WHC. Right: Dark meat sample with good WHC (less water pressed out) Water bound to the muscle protein affects the eating and processing quality of the meat. To obtain good yields during further processing including cooking, the water holding capacity y needs to be at a high level. Water holding capacity varies greatly among the muscles of the body and among animal species. It was found that beef has the greatest capacity to retain water, followed by pork, with poultry having the least.

Tenderness and flavor

Meat tenderness plays an important role, where entire pieces of meat are cooked, fried or barbecued. In these cases, some types of meat, in particular beef, have to undergo a certain ripening or ageing period before cooking and consumption in order to achieve the necessary tenderness. In the fabrication of many processed meat products the toughness or tenderness of the meat used is of minor importance.

Many meat products are composed of comminuted meat, a process where even previousl y tough meat is made palatable. Further processing of larger pieces of meat (e.g. raw or cooked hams) also results in good chewing quality as these products are cured and fermented or cured and cooked, which makes them tender.

Aging/ripening of beef hind quarter in cooling room

The taste of meat is different for different animal species. However, it may sometimes be difficult to distinguish the species in certain food preparations. For instance, in some dishes pork and veal may taste similar and have the same chewing properties.

Mutton and sometimes lamb have a characteristic taste and smell, which originates from the fat. Even small quantities of **fat**, e.g. inter- and intramuscular fat, may imprint this typical smell and taste on the meat, particularly of meat from old animals.

Feed may also influence the taste of meat (e.g. fish meal). In addition, the **sex** of the animal may also give a special taste and smell to the meat. The most striking example is the pronounced urine-like smell when cooking old boar's meat. Meat fit for human consumption but with slightly unt ypical smell and flavor, which may not be suitable for meat dishes, can still be used for certain processed meat products. However, it should preferably be blended with "normal" meat to minimize the off-odour. Also, intensive seasoning helps in this respect. The typical desirable taste and odor of meat is to a great extend the result of the formation of **lactic acid** (resulting from glycogen breakdown in the muscle tissue) and organic compounds like amino acids and di- and tripeptides broken down from the meat proteins.

In particular the aged ("matured") meat obtains its characteristic taste from the breakdown to such substances. The "meaty" taste can be further enhanced by adding **monosodium glutamate (MSG)** (0.05-0.1%), which can reinforce the meat taste of certain products. MSG is a frequently used ingredient in some meat dishes and processed meat products in particular in Asian countries.

Beef top round slice Pork rib chops from loin

Beef top round slice **Pork rib chops from loin**

Lamb ribs **Chicken leg**

The typical desirable taste and odor of meat is to a great extend the result of the formation of **lactic acid** (resulting from glycogen breakdown in the muscle tissue) and organic compounds like amino acids and di- and tripeptides broken down from the meat proteins.

In particular the aged ("matured") meat obtains its characteristic taste from the breakdown to such substances. The "meaty" taste can be further enhanced by adding **monosodium glutamate (MSG)** (0.05-0.1%), which can reinforce the meat taste of certain products. MSG is a frequently used ingredient in some meat dishes and processed meat products in particular in Asian countries.

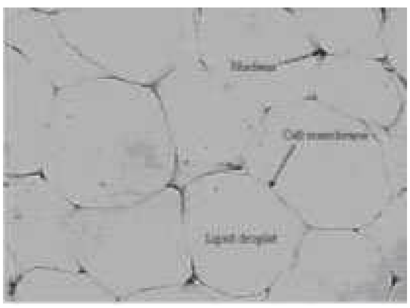
Animal Fats

Fatty tissues are a natural occurring part of the meat carcass. In the live organism, fatt y tissues function as

Energy deposits (store energy)

Insulation against body temperature losses

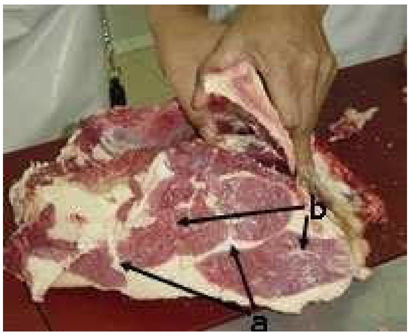
Protective padding in the skin and around organs, especially kidney and heart. Fatt y tissue is composed of cells, which like other tissue cells, have cell membranes, nucleus and cell matrix, the latter significantly reduced to provide space for **storing fat**. Fats, in the form of triglycerides, accumulate in the fat cells. Well-fed animals accumulate large amounts of fat in the tissues.



Fatty tissue (fat cells filled with lipids)

In periods of starvation or exhaustion, fat is gradually reduced from the fat cells.

In the animal body there are **subcutaneous fat deposits** (under the skin) (a/b) and (a), fat **deposits surrounding organs** (e.g. kidney, heart) (d) and a)) or fat deposits between muscles (**intermuscular fat**, (a). Fat deposits between the muscle fibre bundles of a muscle are called **Intramuscular fat** (b) and lead in higher accumulations to *marbling*. Marbling of muscle meat. Contributes to tenderness and flavor of meat. Many consumers prefer marbling of meat for steaks and other roasted meat dishes.



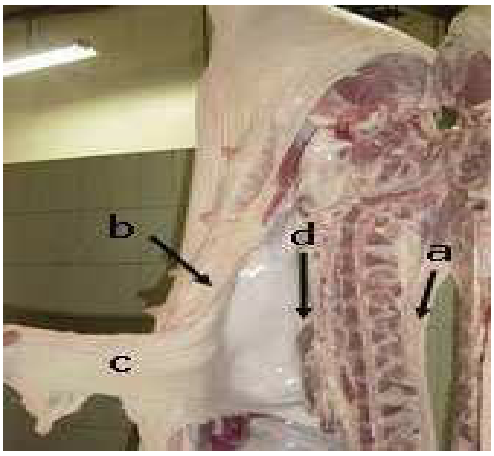
Intermuscular fat
(a) (Around individual muscles) and intramuscular fat (b) (inside muscle tissue)

For *processed meat* products, fats are added to make products ***softer*** and also for ***taste*** and ***flavour improvement***. In order to make best use of animal fats, basic knowledge on their selection and proper utilization is essential.
Fatty tissues from certain animal species are better suited for meat product manufacture, fats from other species less or not suited at all. This is mainly for sensory reasons as taste and flavour of fat varies between animal species. Strong differences are also pronounced in older animals, with the well-known example of fat from old sheep, which most consumers refuse. However, this aspect is to some extent subjective as consumers prefer the type of animal fat they are used to. Availability also plays a role when fatty tissues are used for processing.

Some animal species have higher quantities of fatty tissue (e.g. pigs), others lesser quantities (e.g. bovines). Pig fat is favored in many regions for processing purposes. It is often readily available but and has a suitable tissue structure, composition and unpronounced taste which make it readily usable. Fresh pork fat is almost odor- and flavorless. Body fats from other animal species have good processing potential for the manufacture of meat products, but the addition of larger quantities is limited by availability and some undesirable taste properties.

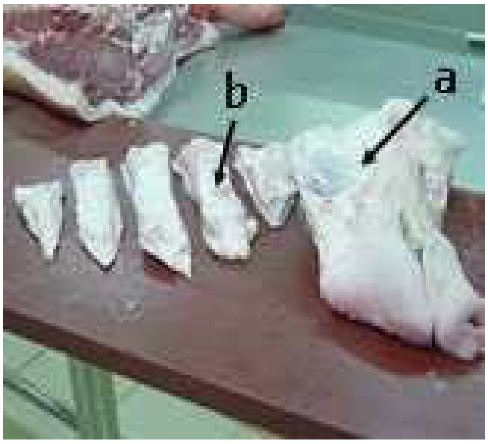
Pork fat

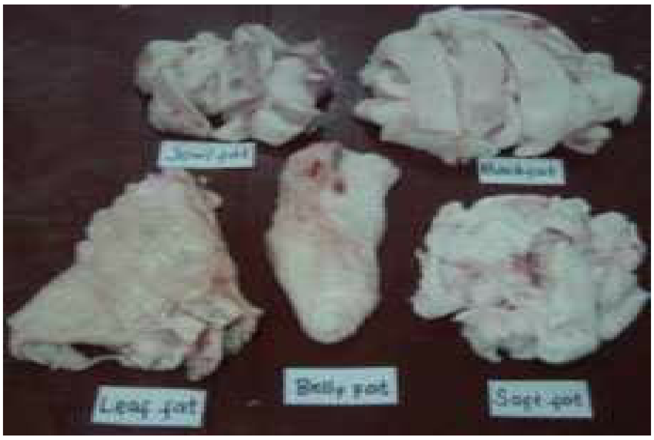
The ***subcutaneous fats*** from pigs are the best suited and also most widely used in meat processing, e.g. **back fat** (a), **jowl fat** (b), and **belly** (b) These fatty tissues are easily separated from other tissues and used as separate ingredients for meat products. Also, the ***intermuscular fats occurring*** in certain locations in muscle tissues are used. They are either trimmed off or left connected (e.g. intermuscular fat in muscle tissue) and processed together with the muscle meat. Subcutaneous and intermuscular fats are also known as “body fats”. Another category is the ***depot -fats***, located in the animal body around internal organs.



Pork carcass with back fat
(a), belly (b), leafe fat (c) and kidney fat (d)

These fats can also be manually separated. In rare cases mesenterical (**intestinal**) fats of pigs are used for soft meat products (e.g. liver sausage), but only in small quantities can cause untypical mouth feel in final products. The **kidney fat** (d) and **leafe fat** (c), of pigs are not recommended for processed meat products due to their hardness and taint, but are used for lard production.



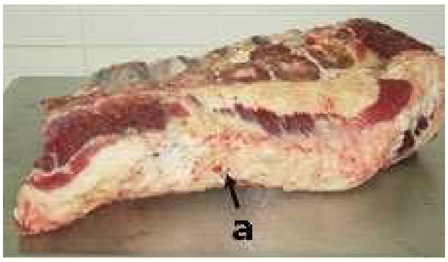


Jowl fat removed from pig head

(a) and cut into strips (b). Behind: Rest of pork carcass with back fat

Beef fat

Beef fat is considered less suitable for further processing than pork fat, due to its firmer texture, yellowish colour and more intensive flavour. When used for processing, preference is usually given to **brisket fat** (a) and (b) and other **body fats** preferably from younger animals.



Brisket fat (a) on beef cut (brisket)

Such fats are used for specific processed beef products when pork fats are excluded for socio-cultural or religious reasons. Some tropical cattle breeds have a large subcutaneous fat depot in the shoulder region known as "hump". Fat is the predominant tissue of the hump together with stabilizing connective tissue and muscle meat. The **hump tissue** (a) is often cut into slices and roasted/barbecued as a delicacy or used for processed products. **Buffalo fat** has a whiter colour than beef fat and is therefore well suited for processing. The limiting factor for utilization of beef/buffalo fat is its scarce availability, as beef/buffalo carcasses do not provide high quantities of body fats suitable for the manufacture of meat products such as frank furters,bologna etc., where amounts of fatt y tissues in the range of 20% are required. However, for the manufacture of products with a lower animal fat content, e.g. burgers, fresh sausages for frying etc., mixtures of beef and beef fat are well suited.

Beef carcass,

Front part with external subcutaneous fat (a) and brisket fat (b), Hump with fatty tissue (a) of tropical cattle and Kidney fat (a) in beef carcass

Mutton fat of adult animals is for most consumers absolutely unsuitable for consumption due to its typical unpleasant flavor and taste. Fats from lamb are relatively neutral in taste and commonly eaten with lamb chops. Lamb fat can be used as a fat source when producing Halal meat products.

Fat from chicken

Chicken fat is neutral in taste and well suited as a fat component for pure chicken products. Chicken fat adheres as intermuscular fat to chicken muscle tissue and is processed without separating it from the lean meat. However, the majority of chicken fat derives from chicken skin with its high subcutaneous fat content. For processing, chicken skin is usually minced and further processed into a fat emulsion before being added during chopping.

Chicken skin to be removed from cuts and used as fat ingredient

The nutritional value of meat and meat products a. Proteins

The nutritional value of meat is essentially related to the content of high quality **protein**. High quality proteins are characterized by the content of **essential amino acids** which cannot be synthesized by our body but must be supplied through our food. In this respect the food prepared from meat has an advantage over those of plant origin. There are vegetable proteins having a fairly high **biological value**, for instance soy protein, the biological value of which is about 65% of that of meat. Soy protein concentrates are also very useful ingredients in many processed meat products, where they not only enhance the nutritional value but primarily the water binding and fat emulsifying capacity.

The contractile proteins or myofibrillar proteins are quantitatively the most important (some 65%) and are also qualitatively important as they have the **highest biological value**. Connective tissues contain mainly collagen, which has a **low biological value**. Elastin is completely indigestible. Collagen is **digestible** but is devoid of the essential amino acid tryptophan. Blood proteins have a high content of tryptophan but are nevertheless of a lower biological value than meat due to their deficiency of the essential amino acid isoleucine.

b. Fats

Animal **fats** are principally trigl ycerides. The major contribution of fat to the diet is energy or calories. The fat content in the animal carcass varies from 8 to about 20% (the latter only in pork). The fatty acid composition of the fatty tissues is very different in different locations.

External fat ("body fat") is much softer than the internal fat surrounding organs due to a higher content of **unsaturated** fat in the external parts. The unsaturated fatty acids (linoleic, linolenic and arachidonic acid) are physiologically and nutritionally important as they are necessary constituents of cell walls, mitochondria and other intensively active metabolic sites of the living organism. The human body cannot readily produce any of the above fatty acids, hence they have to be made available in the diet. Meat and meat products are relatively good sources, but in some plant sources such as cereals and seeds, linoleic acid is usually present at about 20 times the concentration found in meat.

In recent years it has been suggested that a high ratio of unsaturated /saturated fatty acids in the diet is desirable as this may lower the individual's susceptibility to cardiovascular diseases in general, and to coronary heart disease in particular. There is evidence to indicate that a diet which predominantly contains **relatively saturated fats** (such as those of meat) raises the level of **cholesterol** in the blood. To avoid possible health risks from the consumption of the meat, vulnerable groups should reduce the animal fat intake.

In this context, the **"hiding" of high fat contents** in some processed meat products can be a dietary problem. Improved processing equipment and techniques and/or new or refined ingredients have made it possible to produce meat products with relatively high fat contents, which may be difficult to recognize by consumers. In particular in products like meat loaves, frankfurter type sausages or liver pate, where meat and fat are finel y comminuted and the fat particles are enclosed in protein structures, the fat is difficult to detect visibly. Fat contents of up to 40% may be hidden this way, which is profitable for the producer as fat is a relatively cheap raw material. For some consumer groups, such diets are not recommended. On the other hand, there are many physically active hard working people or undernourished people, in particular in the developing world, where meat products with higher fat content may be beneficial in certain circumstances, predominantly as energy sources.

Meat loaves with different fat contents; Left lower fat (20%) and right high fat (35%)

c. Vitamins

Meat and meat products are excellent sources of the B-complex vitamins. Lean pork is the best food source of Thiamine (vitamin B1) with more than 1 mg / 100 g as compared to lean beef, which contains only about 1/10 of this amount. The daily requirement for humans of this rarely occurring vitamin is 1-1.5 mg. Plant food has no vitamin B12, hence meat is a good source of this vitamin for children, as in their organisms deposits of B12 have to be established. On the other hand, meat is poor in the fat soluble vitamins A, D, E, K and vitamin C.

However, internal organs, especially liver and kidney generally contain an appreciable percentage of vitamin A, C, D, E and K. Most of the vitamins in meat are relatively stable during cooking or processing, although substantial amounts may be leached out in the drippings or broth. The drip exuding from the cut surface of frozen meat upon thawing also contains an appreciable portion of B-vitamins. This indicates the importance of conserving these fractions by making use of them in some way, for example through direct processing of the frozen meat without previous thawing (which is possible in modern meat processing equipment).

Thiamine (vitamin B1) and to a lesser extent vitamin B6 are heat-labile. These vitamins are partially destroyed during cooking and canning.

Average content of vitamins in meat (micrograms per 100g)

Food	B_1	B_2	B_6	B_{12}	A	C
Beef, lean, fried	100	260	380	2.7	20	1
Pork, lean, fried	700	360	420	0.8	10	1
Lamb, lean, fried	105	280	150	2.6	45	1
Veal, lean, fried	70	350	305	1.8	10	1
Pork liver, fried	260	2200	570	18.7	18000	24

d. Minerals

The mineral contents of meat ("ash") include calcium, phosphorus, sodium, potassium, and chlorine, magnesium with the level of each of these minerals above 0.1%, and trace elements such as iron, copper, zinc and many others. Blood, liver, kidney, other red organs and to a lesser extent lean meat, in particular beef are good sources of iron. Iron intake is important to combat anaemia, which particularly in developing countries is still widespread amongst children and pregnant women. Iron in meat has a higher bio- availability, better resorption and metabolism than iron in plant products.

Principles of Meat Processing Technology

Meat processing technology comprises the steps and procedures in the **manufacture of processed meat products**. Processed meat products, which include various different types and local/regional variations, are food of animal origin, which contribute valuable animal proteins to human diets. Animal tissues, in the first place *muscle meat* and *fat*, are the main ingredients, besides occasionally used other tissues such as *internal organs*, *skins* and *blood* or *ingredients of plant origin*.

All processed meat products have been in one way or another physically and/or chemically treated. These treatments go beyond the simple cutting of meat into meat cuts or meat pieces with subsequent cooking for meat dishes in order to make the meat palatable. Meat processing involves a wide range of **physical and chemical treatment methods**, normally combining a variety of methods. Meat processing technologies include:

Cutting/chopping/comminuting (size reduction)

Mixing/tumbling

Salting/curing

Utilization of spices/non-meat additives Stuffing/filling into casings or other containers Fermentation and drying
Heat treatment

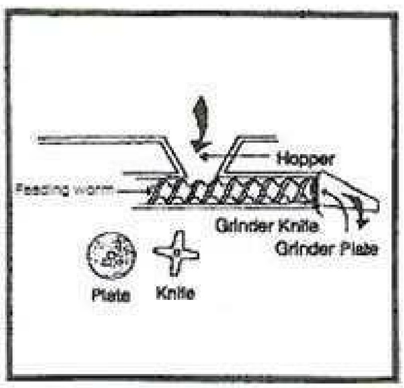
Smoking

Equipment Used In Meat Processing

In modern meat processing, most of the processing steps can be mechanized. In fact, modern meat processing would not be possible without the utilization of specialized equipment. Such equipment is available for small-scale, medium-sized or large-scale operations. The major items of meat processing equipment needed to fabricate the most commonly known meat products are listed and briefly described here under.

Meat grinder (Mincer)

A meat grinder is a machine used to force meat or meat trimmings by means of a feeding worm (auger) under pressure through a horizontally mounted cylinder (barrel). At the end of the barrel there is a cutting system consisting of star-shaped knives rotating with the feeding worm and stationary perforated discs (grinding plates).

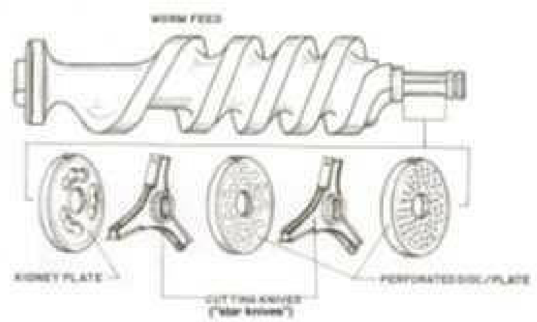


Schematic drawing of grinder

The perforations of the grinding plates normally range from 1 to 13mm. The meat is compressed by the rotating feeding auger, pushed through the cutting system and extrudes through the holes in the grinding plates after being cut by the revolving star knives.

Simple equipment has only one star knife and grinder plate, but normally a series of plates and rotary knives is used. The degree of mincing is determined by the size of the holes in the last grinding plate. If frozen meat and meat rich in connective tissue is to be minced to small particles, it should be minced first through a coarse disc followed by a second operation to the desired size. Two different types of cutting systems are available, the "Enterprise System" and the "Unger System":

The "Enterprise System" is mainly used in smaller meat grinders with orifice diameters up to 98 mm and consists of one star knife, sharpened only on the side facing the disc, and one grinder plate. Hole diameters can vary from 13 to 5 mm. The "Unger System "is used in meat grinders with orifice diameters up to 440 mm and consists of the kidney plate, one or two star knives sharpened on both edges and one or two grinder plates.



Grinder: Worm feed

(feeding worm/auger) and cutting set with plates and knives (system)"Unger")

For a final particle size above 8 mm the recommended setting is kidney plate – star knife – grinder plate. For a final particle size <8 mm the recommended setting is kidney plate – star knife – grinder plate (13 mm) – star knife –grinder plate (6 to 1 mm) .

Grinder plates of different hole size, star knives and spacer rings for tightening of cutting assembl y

The smallest type of meat grinder is the **manual grinder** designed as a simple stuffing grinder, i.e. meat material is manually stuffed into the feeder. For all these small machines the Enterprise cutting system is used with one star knife and one grinder plate. These machines are very common everywhere in food processing but their throughput and production capacity is limited due to the small size and manual operation.

The intermediate size meat grinder, also designed as a **stuffing grinder**, has orifice diameters up to 98 mm. It is driven by a built-in single-phase electrical motor (250 V) and available as both a table and floor model. The meat is put onto the tray and continuously fed by hand into a vertical cylindrical hole leading to the feed auger. The meat or fat is forced by its own weight into the barrel with the rotating feed auger. This type of meat grinder is the most suitable for commercial small-scale operations. Some brands use the Enterprise cutting system, others the Unger system.

Manual grinder, Grinder as table model and Grinder as floor model

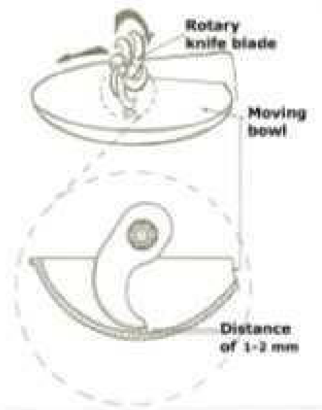
Large **industrial meat grinders** are driven by a three-phase electrical motor (400 V) and equipped with the Unger cutting system. The orifice cylinder diameter of this type of grinder ranges from 114 - 400 mm. Industrial grinders are either designed as stuffing grinders with either tray or hopper or as an automatic mixing grinder. The automatic mixing grinder has a big hopper and the meat falls automatically onto the mixing blades and the feeding worm (auger). The mixing blades and feeding worm can be operated independently with mixing blades rotating in both directions but the feeding worm only towards the cutting set.

Most of the industrial meat grinders are also equipped with a device for separating tendons, bone particles and cartilage. The bowl cutter is the commonly used meat chopping equipment designed to produce small or very small ("finely comminuted") lean meat and fat particles. Bowl cutters consist of a horizontally revolving bowl and a set of curved knives rotating vertically on a horizontal axle at high speeds of up to 5,000 rpm. Many types and sizes exist with bowl volumes ranging from 10 to 2000 litres. The most useful size for small- to medium-size processing is 20 to 60 litres. In bigger models bowl and knife speed can be regulated by changing gears.

Bowl cutters are equipped with a strong cover. This lid protects against accidents and its design plays a crucial role in the efficiency of the chopping process by routing the mixture flow. Number, shape, arrangement, and speed of knives are the main factors determining the performance of the cutter (see page 304). Bowl cutters should be equipped with a thermometer displaying the temperature of the meat mixture in the bowl during chopping.

Fig1 Small 20 litre bowl cutter, single-phase motor

Fig. 2 Bowl cutter assembled w ith 6 knives



Bowl cutter, schematic,

Bowl cutter–grinder combination (twin model) with bowl cutter (60 litres Capacity) and meat grinder (114 mm orifice diameter).


Bowl cutter filled with meat for chopping and vacuum cutter; lid can be hermetically closed for vacuum treatment of batter in the bowl

Modern large scale bowl cutters may have devices to operate under a vacuum, which helps to improve color and texture of the meat products by keeping oxygen out of the meat mixes and avoid air pockets. Cutter knives should be adjusted to a distance of 1-2 mm from the bowl for optimal cutting (check the manufacturers recommendations for each model). Most of the large and high-speed bowl cutters are equipped with mechanical discharger devices for emptying the cutter. The process of chopping in a bowl cutter is used for producing fine comminuted products such as frankfurters, bologna, liver sausage etc., and enables processors to offer a much wider range of products.

Meat Processing Technologies – Standard Practices

Meat processing technologies include on the one hand purely technical processes such as

- Cutting, chopping, comminuting
- Mixing, tumbling
- Stuffing/filling of semi-fabricated meat mixes into casings, synthetic films, cans etc.
- Heat treatment

On the other hand, chemical or biochemical processes, which often go together with the technical processes, are also part of meat processing technology such as

- Salting and curing
- Utilization of spices and additives
- Smoking
- Fermentation and drying

These processes are described hereunder and in the following chapters.

1. Cutting (reducing meat particle size)

There are five methods of mechanical meat cutting for which specialized machinery is used:

Mincing (grinding) of lean and fatty animal tissues

Larger pieces of soft edible animal tissues can be reduced in size by passing them through meat grinders. Some specially designed grinders can also cut frozen meat, others are equipped with devices to separate “hard” tissues such as tendons and bone particles from the “soft” tissues (minced muscle meat particles).

Chopping animal tissues in bowl cutter (discontinuous process)

Bowl cutters are used to chop and mix fresh or frozen lean meat, fat (and/or edible offal, if required) together with water (often used in form of ice), functional ingredients (salt, curing agents, additives) and extenders (fillers and/or binders).

Chopping animal tissues in emulsifying machines (continuous process)

The animal tissues to be emulsified must be pre-mixed with all other raw materials, functional ingredients and seasonings and pre-cut using grinders or bowl cutters. Thereafter they are passed through emulsifiers (also called colloid mills) in order to achieve the desired build-up of a very finely chopped or emulsified meat mix.


Mincing and chopping

Of raw meat material for processed meat products in meat grinders and Chopping of meat mixture in bowl cutter; lid opened after finalizing chopping, cutter knives visible

Chopping animal tissues in emulsifying machines (continuous process)

The animal tissues to be emulsified must be pre-mixed with all other raw

materials, functional ingredients and seasonings and pre-cut using grinders or bowl cutters. Thereafter they are passed through emulsifiers (also called colloid mills) in order to achieve the desired build-up of a very finely chopped or emulsified meat mix.

Frozen meat cutting

Boneless frozen meat blocks can be cut in slices, cubes or flakes by frozen meat cutters or flakers. The frozen meat particles (2-10 cm) can be directly chopped in bowl cutters without previous thawing thus avoiding drip losses, bacterial growth and discoloration which would happen during thawing. For small operations the manual cutting of frozen meat using cleavers or axes is also possible.

Cutting of fatty tissues

Back fat is cut in cubes of 2-4 cm on specialized machines to facilitate the subsequent chopping in cutters/emulsifiers. In small-scale operations this process can be done manually.

2. Salting / curing

Salting – Salt (sodium chloride NaCl) adds to the **taste** of the final product. The content of salt in sausages, hams, corned beef and similar products is normally 1.5-3%. Solely common salt is used if the cooked products shall have a greyish or greyish-brown colour as for example steaks, meat balls or “white” sausages. For production of a red colour in meat products see “Curing”.

Chemical aspects of salting

The water **holding capacity** of meat can be increased with the addition of salt up to a concentration of about **5%** in lean meat and then decreases constantly. At a concentration of about 11% in the meat, the water binding capacity is back to the same level as in fresh unsalted meat. Sodium chloride has only a very low capacity to destroy microorganisms, thus almost **no bacteriological effect**. Its **preserving power** is attributed to the capability to bind water and to deprive the meat of moisture. The water loosely bound to the protein molecules as well as “free” water will be attracted by the sodium and chloride ions causing a reduction of the water activity (aw) of the product. This means that less water will be available and the environment will be less favorable for the growth of microorganisms. Bacteria do **not** grow at a water activity **below 0.91**, which corresponds to a solution of **15g NaCl/100 ml water** or about 15% salt in the product. These figures explain how salt has its preservative effect. Such salt concentrations (up to 15%) are too high for palatable food. However, for the preservation of natural casings this method is very useful Heat treatment of meat salted with NaCl results in conversion of the red meat pigment **myoglobin** (Fe^{+2}) to the brown **metmyoglobin** (Fe^{+3}). The color of such meat turns brown to grey.

Besides adding to flavor and taste, salt also is an important functional ingredient in the meat industry, which assists in the extraction of soluble muscle proteins. This property is used for **water binding** and **texture** formation in certain meat products.

The **preservation** effect, which is microbial inhibition and extension of the shelf-life of meat products by salt in its concentrations used for food (on average 1.5-3% salt), is low. Meat processors should not rely too much on this effect unless it is combined with other preservation methods such as reduction of moisture or heat treatment.

Curing – Consumers associate the majority of processed meat products like hams, bacon, and most sausages with an attractive pink or red color after heat treatment. However experience shows that meat or meat mixes, after kitchen-style cooking or frying, turn brownish-grey or grey. In order to achieve the desired red or pink color, meat or meat mixes are salted with common salt (**sodium chloride NaCl**), which contains a small quantity of the curing agent **sodium nitrite ($NaNO_2$).** Sodium nitrite has the ability to react with the red meat pigment to form the heat stable red curing color. Only very small amounts of the nitrite are needed for this purpose.

Pieces of cooked meat (pork)

4 pieces with common salt only (right) and 3 with common salt containing small amounts of nitrite (left) and Two sausage cuts one produced with salt only (right)

and the other with salt and small amounts of nitrite (left)

Nitrite can be safely used in tiny concentrations for food preservation and coloring purposes. Traces of nitrite are not poisonous. In addition to the reddening effect, they have a number of additional beneficial impacts so that the meat industries widely depend on this substance. Levels of 150 mg/kg in the meat product, which is 0.015%, are normally sufficient.

To reduce the risk of overdosing of nitrite salt, a safe approach is to make nitrite available only in a homogeneous mixture with common salt generally in the proportion **0.5% nitrite** and the balance of **sodium chloride (99.5%)**. This mixture is called **nitrite curing salt.** At a common dosage level of 1.5-3% added to the meat product, the desired salty flavor is achieved and at the same time the small amount of nitrite needed for the curing reaction is also provided. Due to the sensory limits of salt addition (salt contents of 4% are normally not exceeded), the amounts of nitrite are kept low accordingly.

Chemical and toxicological aspects of curing

In meat or meat mixes to be cured the nitrite curing salt must be evenly distributed. During mixing the nitrite is brought in close contact with the muscle tissue and its red meat pigment, the myoglobin. Due to the acidification in meat after slaughter, the pH of such meat or meat mixes is always below 7, which means slightly acidic. The acidity may be enhanced through curing accelerators such as ascorbic acid or erythorbate.

Nitrite **(NaNO2)**, or rather nitrogen oxide, NO, which is formed from nitrite in an acid environment, combines with **myoglobin** to form **nitrosomyoglobin**, a bright red compound. The nitrosomyoglobin is **heat stable** i.e. when the meat is heat treated the bright red color remains. The addition of nitrite curing salt in quantities of approximately

2%, which is the usual salt level, generates nitrite content in the meat products of approximately 150ppm (parts per million or 150 mg/kg). This nitrite content is **not toxic** for consumers. Upon reaction of the nitrite with the myoglobin (which is the genuine curing reaction), there will be on average a residual level of nitrite of 50-100ppm remaining in the product. In any case the amount of residual nitrite in the finished product should not exceed 125ppm. The maximum ingoing amount for processed meat products is normally up to 200mg/kg of product (Codex Alimentarius, 1991).

Apart from its poisoning potential (which is unlikely when using nitrite curing salt), there is a debate concerning the possible health hazards of nitrite curing as under certain conditions nitrite can form **nitrosamines**, some of which can be carcinogenic in the long term. However, nitrosamines can only be found in strongly cooked or fried meat products which were previously cured with nitrite. Fresh meat for cooking and fresh burgers or sausages for frying do usually not contain nitrite but salt only. Hence the risk of formation of nitrosamines does not exist in such products. One product, where such conditions may be met, is bacon. Keeping the residual nitrite content low in bacon minimizes the risk of formation of nitrosamines.

Sodium or potassium nitrate (Na/KNO3) ("saltpetre") may also be used for curing but it is limited to certain dry cured products such as raw hams, which require long curing and aging periods. Nitrate must be broken down by bacteria to nitrite, which is the substance to react through its NO with the muscle pigment myoglobin. The bacterial process is rather slow and time consuming. As most products require an immediate curing effect, the nitrite is the substance of choice in most cases and there is little use for nitrate.

A great deal of research has been done with regard to the utilization of nitrite and it can be said that nitrite in meat products is safe if basic rules are adhered to. Nitrite is now recognized a substance with multifunctional beneficial properties in meat processing:

The primary purpose of nitrite is to create a **heat resistant red** colour in a chemical reaction with the muscle pigment, which makes cured meat products attractive for consumers.

Nitrite has a certain **inhibitory effect on the growth of bacteria**. This effect is particularly pronounced in canned meat products which are usually stored without refrigeration, where small numbers of heat resistant bacteria may have survived but their growth is inhibited by the presence of nitrite.

Nitrite has the potential of **attributing a specific desirable curing flavor** to cured products.

In the presence of nitrite **fats are stabilized** and rancidity in meat products retarded i.e., an antioxidant effect.

Many attempts have been made to replace nitrite by other substances, which would bring about the same beneficial effects as listed above. Up to now no alternative substance has been found. As the above desirable effects are achieved with extremely low levels of nitrite, the substance can be considered safe from the health point of view. Currently the known advantages of nitrite outweigh the known risks.

Curing of chopped/comminuted meat mixtures

Curing is applied for most **chopped meat mixtures** or **sausage mixes** for which a reddish color is desired. The curing agent nitrite is added in **dry form** as nitrite curing salt. The reaction of nitrite with the red meat pigment starts **immediately**. Due to homogenous blending the meat pigments have instant contact with the nitrite. Higher temperatures during processing, e.g. “reddening” of raw-cooked type sausages at 50oC or scalding/cooking of other products at 70-80oC, accelerate the process.

3. Smoking

Smoke for treatment of meat products is produced from raw wood. Smoke is generated through the thermal destruction of the wood components **lignin** and **cellulose**. The thermal destruction sets free more than **1000** desirable or undesirable firm, liquid or gaseous components of wood.

These useful components contribute to the development of the following desirable effects on processed meat products:

Meat preservation through aldehydes, phenols and acids (anti-microbial effect) Antioxidant impact through phenols and aldehydes (retarding fat oxidation) Smoke flavour through phenols, carbonyls and others (smoking taste) Smoke colour formation through carbonyls and aldehydes (attractive colour) Surface hardening of sausages/casings through aldehydes (in particular for more rigid structure of the casing)

The most known **undesirable effect** of smoking is the risk of **residues of benzopyrene** in smoked products which can be carcinogenic if the intake is in high doses over long periods. With normal eating habits, a carcinogenic risk is normally not associated with moderately smoked food such as smoked meat products.

Depending on the product, smoke is applied at different temperatures. There are two principal smoking techniques:

- Cold smoking

- Hot smoking

The principle of both methods is that the smoke infiltrates the outside layers of the product in order to develop flavor, color and a certain preservation effect.

Cold Smoking – This is the traditional way of smoking of meat products and was primarily used for **meat preservation**. Nowadays it serves more for **flavor** and **color formation**, for example in sausages made from precooked materials such as liver sausage and blood sausage.

The combination of cold smoking and drying/ripening can be applied to ferment sausages and salted or cured entire meat pieces, in particular many raw ham products. In long-term ripened and dried hams, apart from providing color and flavor, the cold smoking has an important preservative effect as it prevents the **growth of moulds** on the meat surfaces.

The optimal temperature in "cold" smoking is 15 to 18°C (up to 26°C). Sawdust should be burned slowly with light smoke only and the meat hung not too close to the source of the smoke. Cold smoking is a long process which may take several days. It is not applied continuously, but in intervals of a few hours per day.

Hot Smoking – Hot smoking is carried out at temperatures of +60 to 80°C. The thermal destruction of the wood used for the smoking is normally not sufficient to produce these temperatures in the smoking chamber. Hence, **additional heat** has to be applied in the smoking chamber.

Hotdogs are placed in the smokehouse for hot smoking

The figure Indicate (pale colour before smoking) and After completion of the smoking process (brown-red colour after smoking)

The relatively high temperatures in hot smoking assure a rapid colour and flavour development. The treatment period is kept relatively short in order to avoid excessive impact of the smoke (too strong smoke colour and flavour).

Hot smoking periods vary from not much longer than 10 minutes for sausages with a thin calibre such as frankfurters to up to one hour for sausages with a thick calibre such as bologna and ham sausage and products like bacon and cooked hams.

Products and smoking – Cold smoking is used for fermented meat products (raw-cured ham, raw-fermented sausage) and precookedcooked sausage (liver and blood sausages). Hot smoking is used for a range of raw-cooked sausages, bacon and cooked ham products. Smoke treatment can only be applied; if meat the products are filled in casings permeable to smoke .All natural casings are smoke permeable, as are cellulose or collagen basis synthetic casings.

Smoke permeable casings can also be treated using a new technology, where a liquid smoke solution is applied on the surface. This can be done by dipping in solution, showering (outside chamber) or atomization (spraying inside chamber). Polyamide or polyester based synthetic casings are not permeable to smoke. If smoke flavor is wanted for products in such casings, small quantities of suitable smoke flavor (dry or liquid) are added directly to the product mix during manufacture.

Production of liquid smoke

Liquid smoke can be used as an ingredient to sausages in smoke impermeable casings in order to achieve a certain degree of smoke flavour. As impermeable casings do not allow the penetration of gaseous smoke, liquid smoke can be added to the sausage mix during the manufacturing process. The starting point for the production of liquid smoke is natural smoke, generated by burning/smouldering wood under controlled temperatures with the input of an air supply. There are basically two different methods used for the subsequent processing of liquid smoke:

direct condensation of natural wood smoke to liquid smoke

penetration of the smoke into a carrier substance on the basis of water or oil and using this “smoked” carrier substance as an ingredient for meat products

Selection and Grading Of Raw Materials for Meat Processing

The *two main components of processed meat products* are *animal muscle meat* and *animal fat*. Apart from pure muscle tissue, **muscle meat** also contains some connective tissue and inter- and intramuscular fat, which determine the quality of muscle meat. **Animal fats** are of firmer or softer texture depending on their location in the animal body. In addition to the animal species, the texture of fats determines their processing quality. **Edible animal by- products** such as skin, internal organs and blood also play a role as raw materials for meat processing. By-products are not generally used; they are part of specific processed meat products.

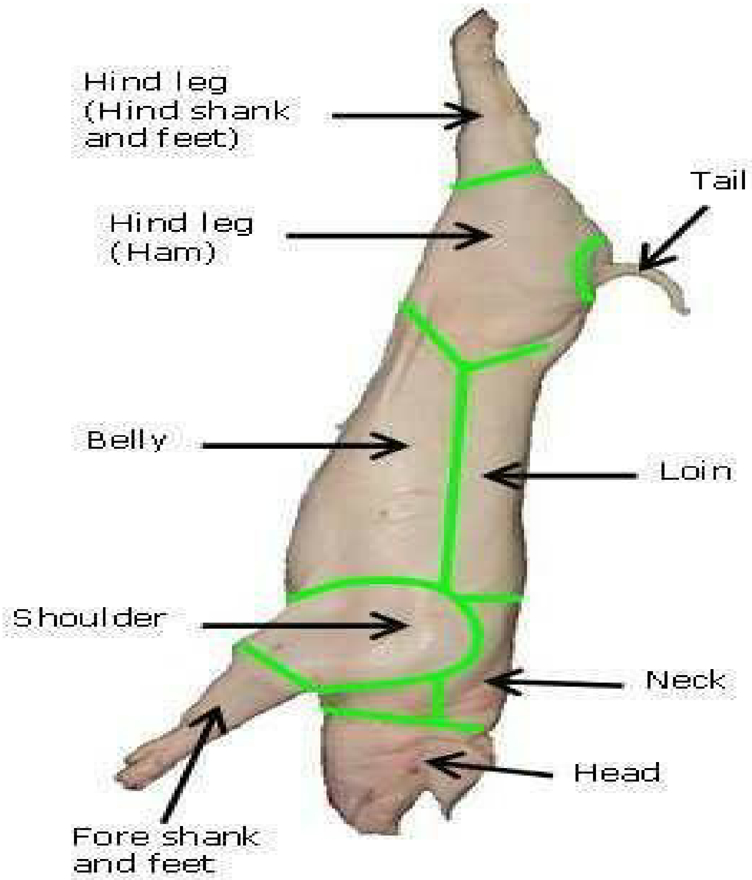
The first preparatory step for processing of meat into meat products is the product-oriented selection of raw animal materials, taking into account their quality and processing suitability and the characteristics of the meat products to be fabricated. Some meat products require lean meat without adhering fat or connective tissue, while others have a higher fat and/or connective tissue contents. Other products require firm animal fats, for others soft fats are better suited. Choosing appropriate raw materials is indispensable for efficient meat processing and is best done by visual **selection and grading** according to the tissue-specific properties.

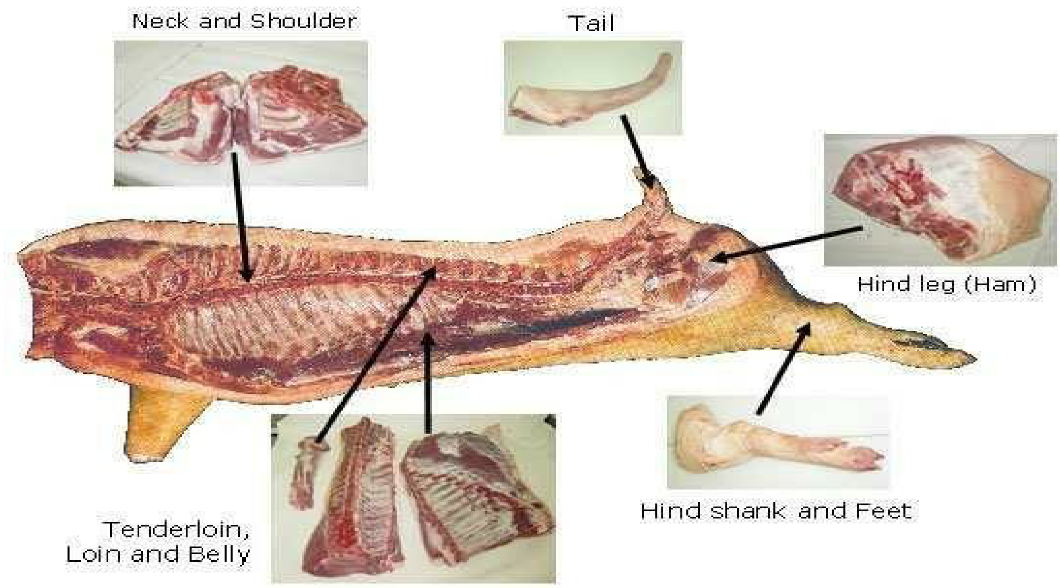
Meat processors are advised to develop **enterprise-specific standards** of raw material composition for each meat product fabricated. The proper grading of raw materials, which needs skills and experience, has a decisive impact on the quality of the meat products and resulting revenues which can be generated. For the needs of small to medium sized meat processing plants, simple grading schemes are described hereunder, with raw materials from pigs, cattle/buffaloes and other ruminants as well as poultry.

Selection and grading of manufacturing meat from pigs

The below proposal for selection and grading of pig meat refers to the utilization of the entire carcass for **meat processing**. Naturally, in many meat plants, valuable meat cuts may be excluded from further processing and marketed as **fresh meat**.

In these cases only the remaining carcass meat is used for **further processing**. Common cuts for fresh meat sales are tenderloin, loin, rump, the entire ham or parts of the ham (topside, silverside, knuckle) and parts of the neck and shoulder. The proportion of carcass meat going into fresh meat sales or into further processing is decided by the operator on a case-by-case basis. If higher amounts of lean meat are required for further processing, more primal cut meat will be used for this purpose and vice versa. Hereunder, a **grading scheme** for manufacturing-meat from pigs consisting of six grades is proposed. This standard can be refined or simplified as determined by consumer demand.

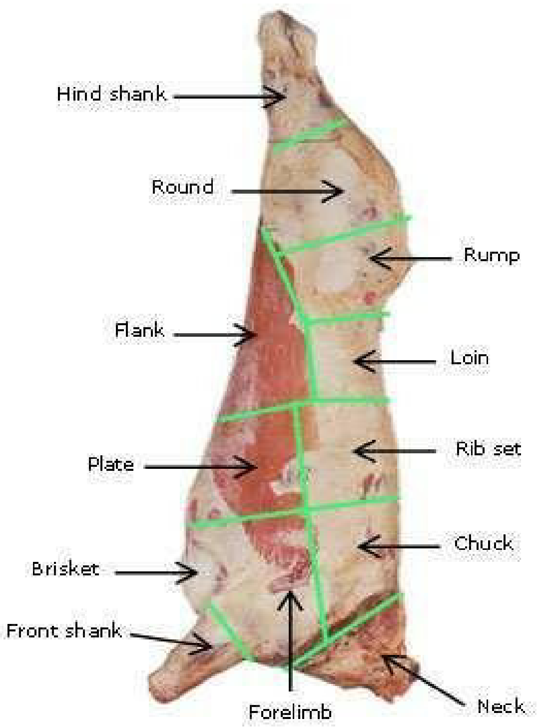




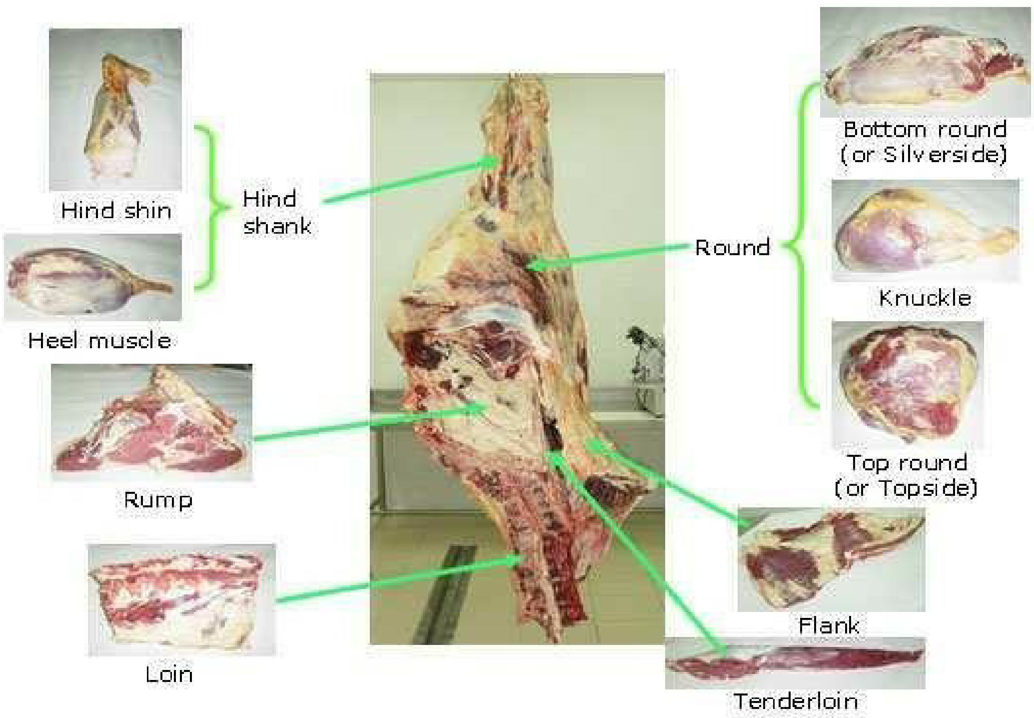
Pork carcass Schematic

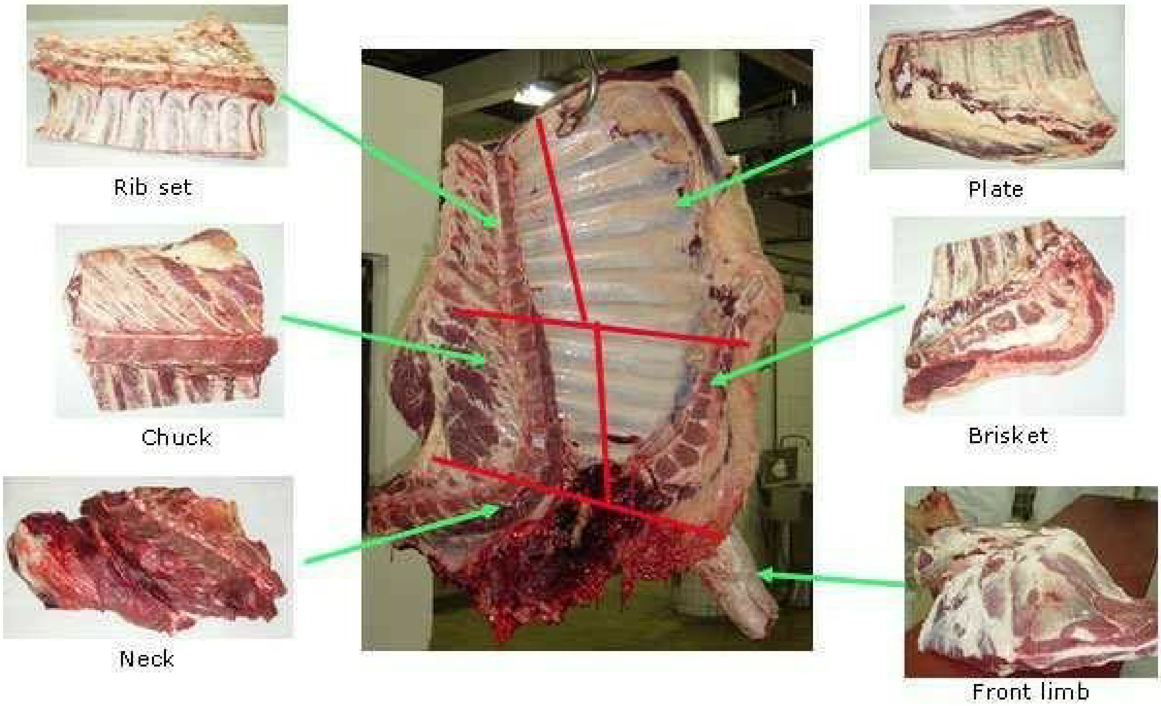
Selection and grading of manufacturing-meat from cattle

Similar to pork, valuable meat cuts (choice cuts) from beef are usually excluded from further processing and marketed as fresh meat. The most common fresh meat cuts are tenderloin, sirloin, topside, silverside, rump and parts of the neck and shoulder. The rest of the carcass meat as well as trimmings derived during the preparation of the above mentioned choice cuts are used as manufacturing-meat for all types of processed products.



Beef carcass schematic





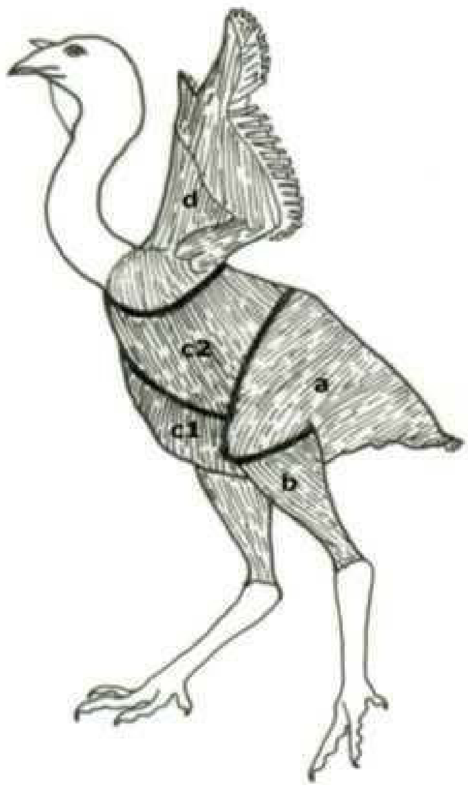
Beef carcass and its cuts

The **functional properties** of beef are influenced to a large extend by the age of the animal. Meat from younger animals has a much higher water binding capacity than meat derived from a carcass of an older animal. For this reason meat from younger animals should be used for products requiring high binding and water holding capacity and meat from older animals is more suited for products undergoing a drying and fermentation process.
Similar to the grading scheme for pig meat, a simple scheme is proposed for the **selection and grading of beef**, which is considered suitable for small and medium operations. For beef, three grades of manufacturing meat are sufficient to cater for the needs of small to medium size manufacturing. Beef fat and skin are usually not a raw material for meat processing.

Selection and grading of manufacturing-meat from poultry

In global meat production poultry meat is taking the second place after pork. Due to its widespread availability and popularity and its mostly very competitive production cost, poultry meat has an increasing share as a raw material in processed meat. Turkey and chicken meat is very suitable for further processing purposes.

Turkey meat, which has darker and brighter muscle components deriving from the same carcass is well suited for processed meat products. In some developed countries there are sizeable meat industries, with outlets for processed turkey meat products, such as bologna/frankfurters/ham sausage type sausages, and cooked turkey hams. Such products are similar to the equivalent ones fabricated with beef and pork, but they are usually leaner. A widely practiced approach is to classify turkey carcasses in two grades. Grade A is top quality with no defects on the meat surface and general appearance. Entire frozen carcasses as retail goods belong to this category. Grade B is the lower category and this meat is usually taken for further processing.



Muscle meat of chicken carcass a/b leg

(a=thigh, b= drumstick); c1/c2 breast meat (c1=breast, c2=filet); d=wing

When producing turkey cuts (Fig. 47), those cuts not needed or suitable for fresh meat sales, can also go into further processing. In developing countries, the production of **chicken meat** is by far more important than the production of turkey meat. Chicken meat can be produced industrially around population centres and it is in high demand, particularly where pork is not consumed for socio-cultural or religious reasons.

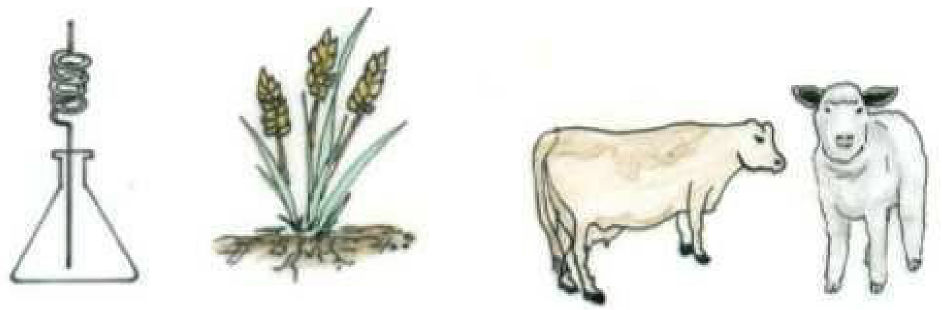
Non-Meat Ingredients

Categories of non-meat ingredients

Along with the main components ***meat*** and animal ***fat***, a wide range of substances of ***nonmeat origin*** are used as ingredients in processed meat products. Some of them are absolutely necessary, such as salt and spices. Others are used for specific products. One way of categorizing nonmeat ingredients is by source.

They are either

- **Chemical substances** or
- Of **plant origin** or
- Of **animal origin**.



Chemical substances Plant origin Animal origin

Sources of non-meat ingredients

Other classification criteria for non-meat ingredients are, whether they are *additives* or *full foods* ("food by itself") or whether they have *functional* properties or not.

Additives are usually substances, which are not normally consumed as food by itself, but which are added to develop certain technological and quality characteristics (for examples salt, curing agents, spices, water binding and gelation enhancing substances). In contrast, vegetables, flours, eggs, etc. the figure could be considered as full food ingredients.

Mixed food items

Additives

Mixed food items Additives

Most ingredients are **functional**, which describes their ability to introduce or improve certain quality characteristics. The functional properties of ingredients include their impact on:

- taste flavour appearance colour texture
- water binding
- counteracting fat separation preservation

Ingredients which are solely functional without any other effect such as filling or extending the volume of the product, are normally used in small amounts (e.g. common salt 1,5-3%, nitrite 0.01-0.02%, phosphates 0.05-0.5%, ascorbic acid 0.03%, isolated soy protein or non-fat dried milk proteins 2%).

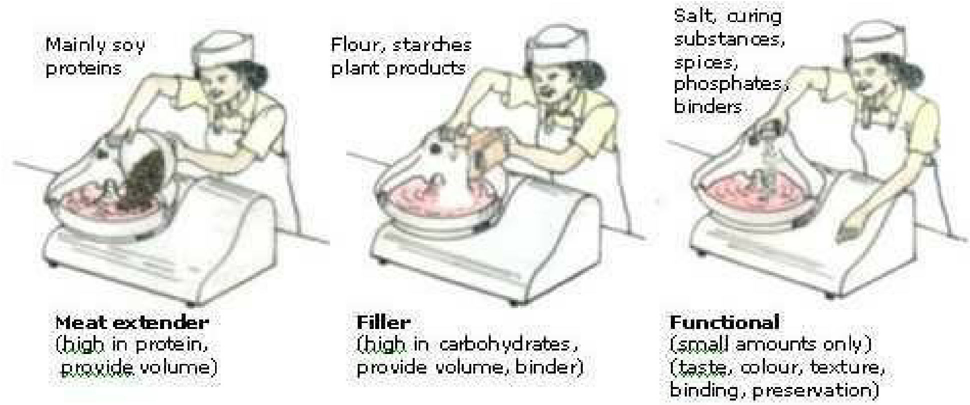
Example of effect of functional ingredients

Meat loaf cut, left with curing colour, centre without color, and right with artificial colour

The criteria for the utilization of **functional** non-meat ingredients are:

- safe for consumers, and
- Improve of processing technology and/or sensory quality of the products.

In contrast to the exclusively functional substances, there is another group of ingredients that are not primarily intended for change of appearance or quality improvements but serve to *add volume* to the meat products. They are called **meat extenders** and **fillers**. Their main purpose is to make meat products *lower-cost*. Meat extenders and fillers include cereals, legumes, vegetable, roots and tubers and are used in larger quantities, on average
between 2 and 15% .



Types of non-meat ingredients

Meat extenders are primarily plant ***proteins*** from legumes, with *soybeans* as the major source. ***TVP*** is the most common soy bean extender. These cheaper plant proteins ***"extend"*** the more expensive meat proteins, resulting in acceptable overall protein contents of lower cost meat products. Extenders are added in sizeable amounts that increase the bulk of the meat products, but this may also alter their quality. From animal protein sources, whole milk and eggs can be considered as meat extenders. In some countries, replacement of meat by fish is gaining popularity resulting in fish products which may be meat and fish mixes or entirely made of fish materials, e.g. "fish viennas", made using the same technology and process as viennas made of meat.

Fish sausage

Fillers are also mostly plant substances, low in protein and high in ***carbohydrates*** such as cereals, roots, tubers and vegetables and some refined products such as *starches* and *flours*. Pure meat products are very low in carbohydrates. Hence the addition of carbohydrate-rich substances is not an "extension" of the protein mix, but some new components ***"fill-up"*** the product volume. Apart from their volume filling capacity, some fillers, in particular starches and flours, are also used for their capability to absorb extensive quantities of water.

Extenders and fillers are ***not*** standard ingredients in processed meats, in fact high quality products are often manufactured without them. But they are useful tools in ***cost reduction*** enabling the manufacture of lower cost but still nutritive meat products. Such products are particularly suitable to supply valuable animal proteins in the diets of consumers who cannot regularly afford expensive meat and meat preparations.

As another definition for specific non-meat ingredients, the term **binder** is used for substances of animal or plant origin, which have a significant high level of protein that serves for both ***water*** *and* ***fat binding***. Such substances include ***high-protein soy, wheat*** *and* ***milk products***, such as soy isolate, wheat gluten, milk protein (caseinate). They are not extenders in the first place due to the low quantities added (approx. 2%), but act through their high quality proteins that are instrumental in water binding and protein network structuring. On the other hand, some substances with little or no protein level, like ***starches*** and ***flours*** mentioned above under "fillers", can bind water and fat by means of physical entrapment and could also be considered "binders".

The above aspect illustrates that clear definitions in the wide range of non-meat ingredients are difficult to establish. While most substances have one ***dominating effect***, there are in many cases also desirable ***side effects*** that, however, complicate their clear grouping. Even those substances like textured vegetable protein/TVP, which are primarily intended for non-functional purposes, namely meat extension, have a water binding effect, which qualifies them also as moderately functional. Also soy isolates or dried milk powders, which are used as binders, also have a slight extension effect as the amounts added moderately increases the protein level. Most substances have double or even multiple effects.

Therefore, in order to provide an overview of the most common substances used as non

- meat ingredients, they are listed hereunder according to their origin, namely *chemical* (a) or of *animal* (b) or *plant origin* (c):

a) Chemical substances used as ingredients

There are various chemical substances approved for the different kinds of food processing, but in the specific case of **meat processing** the number of approved chemical substances is rather limited in most countries. The following are of significance:

Salt (for taste, impact on meat proteins, shelf-life) ***Nitrite*** (for curing colour, flavour, shelf-life) ***Ascorbic acid*** (to accelerate curing reaction)
Phosphates (for protein structuring and water binding)

Chemical preservatives (for shelf-life)

Antioxidants (for flavour and shelf-life)

Monosodium glutamate MSG (for enhancement of flavour)

Food colouring substances (synthetic and of plant origin)

Chemical additives have exclusively functional properties, they are used in small amounts usually below 1% (with nitrate as low as 0.05%). Only salt is in the range of 2% (with up to 4% in some fermented dried products).

b) Non-meat ingredients of animal origin

Ingredients of animal origin are not commonly applied but may be useful for specific meat preparations. They all have functional properties (except whole milk), in particular improvement of water binding and prevention of fat separation during heat treatment. Apart from their functional properties, some of them can also be considered meat extenders, as mentioned below.

Milk caseinate (90% protein; used in small quantities (2%); have functional water and fat binding properties)
Whole milk or ***non-fat dried milk*** (=skim milk) (sometimes used in indigenous meat preparations as a protein extender)
Gelatine (binding properties and meat extender)

Blood plasma (predominantly binding properties)

Eggs (extender and binding ingredient for meat pieces and fried sausages)

Transglutaminase* (exclusively binding properties)

c) Ingredients of plant origin

All ***spices*** are of plant origin. They are predominantly *functional* and used in small quantities to provide or add flavour and taste to meat products. Another group of predominantly *functional* substances of plant origin with high protein content are used as ***binders*** to increase water binding and fat retention, in particular in intensively heat treated products. The most commonly used substances are
• ***isolated soy protein*** (90% protein) and

• ***wheat gluten*** (80% protein) and, less importantly, protein isolates from other legumes.

A third group of ingredients of plant origin are used as ***meat extenders*** (if rich in proteins) or ***fillers*** (if rich in carbohydrates) for meat product and sausage formulations. The purpose is to replace expensive meat for lower- or medium-grade products by cheaper ingredients of plant origin for cost reduction and volume increase.
Meat extenders

Plant products with high protein content are

Soy flour (50% protein)

Soy concentrate (70% protein)

Other food legumes (***beans***, ***peas***, ***lentils***), used for special products only.

Fillers / Carbohydrate products with low protein content (usually added in quantities of

2%-15%, some of them – in particular roots and vegetable – up to 50%). These are the typical ***fillers***. Apart from cost reduction and adding to volume, some flours and starches belonging to this group of fillers also act to some extend as *binders*. This property serves important functions such as increasing water binding for more juiciness or fat binding for improved texture.

Cereal flours from wheat, rice and corn

Starches from wheat, rice, corn, potato and cassava

Breadcrumbs

Rusk (derived by mixing and baking wheat flour) ***Cereals*** to be added without milling, e.g. rice, corn ***Roots*** and ***tubers***, e.g. cassava, sweet potato

Vegetable and ***fruits***, e.g. onions, bell pepper, carrots, green vegetables, bananas

Polysaccharides (Hydrocolloids)**:**

Carrageenan (is the only hydrocolloid product of this group popular in meat processing, added in quantities of max. 1%, improves sliceability and cohesiveness). The substance can be considered both *binder* and *filler*.

Application of non-meat ingredients

For the application of ingredients listed above to meat products, various methods are deployed, depending upon the properties of the ingredient and the meat product. A **uniform distribution** is crucial for equal intensity of flavour, colour, texture or any other quality characteristic expected from the product.

Methods of application

a) **During grinding**

Chemical additives and smaller quantities of other fine or coarse nonmeat ingredients or granulated substances (such as TVP) are easily incorporated in ground meat products by **mixing** them with the raw meat materials prior to grinding. In small scale operations, the mix of meat and non-meat ingredients is then simply passed through the grinder plates. **Manual** or **mechanical blending** can be added if necessary. In larger industrial operations and for heavily extended products, ground meat materials, chemical additives and other non-meat ingredients are usually combined in a blender.

b) **During chopping**

In finely comminuted or chopped meats, non-meat ingredients are easily dispersed by **mixing** them with the rest of the batter in comminuting equipment. Non-meat ingredients such as binders (isolated soy protein/ISP, milk caseinate) are preferably added in emulsion form, finely milled fillers (flours, starches) in dry form. In smaller calibre low-cost sausages such as hotdogs, also larger quantities of extenders (e.g. re-hydrated TVP) and coarse fillers (rusk, breadcrumbs, etc) are incorporated during the chopping process.

c) Application to non-comminuted meat

The addition of non-meat ingredients to larger meat pieces or intact muscles is more complex. **Injection** of ingredients as part of the curing brine, if they are water soluble or can be dispersed in water (salt, nitrite, spices, ascorbate, phosphates, soy products, Carrageenan), is the most rapid method of equal distribution. The **surface application** of such dry substances (e.g. nitrite curing salt, spices) or **immersion** of meat in salt/curing salt and flavouring solutions is another way of application, but requires days or weeks to diffuse throughout the muscle tissue.

Malpractices in meat preservation

Formalin or Formaldehyde is a strong disinfectant ; if illegally used to control bacterial growth on meat surfaces, it may get into the food chain, may cause kidney damage and is carcinogenic in the long term.

Borax = Sodiumtetraborate, an ingredient in washing powders and used in paper and leather manufacture; is harmful by ingestion if illegally used for meat surface treatment or in meat mixes.

Chlorine (Cl_2) is an effective disinfectant e.g. for drinking water (0.4-0.6 ppm), also sometimes used for microbial control of water for spin chillers in poultry slaughter (up to 20 ppm). "Bleach" which is calcium hypochlorite ($CaOCl_2$), reacts with water and releases chlorine ions, which may affect taste and create harmful residues.

Hydrogen peroxide (H_2O_2), when applied to meat surfaces etc. it disintegrates into oxygen and water, whereby the oxygen develops the antimicrobial and bleaching effect. It causes colour changes on meat surfaces, sometimes used for bleaching cattle stomachs (tripes). Another substance used for bleaching tripes is Calcium carbonate ($CaCO_3$)

Antibiotics such as nisin (= bacteriocin deriving from Strept. Lactis bacteria), suppresses bacterial growth, used for some foods (dairy industries), but generally not allowed and discouraged for use in meat industries; or sulphamethazine used as an antibiotic in pigs with possible residues occurring in the meat.

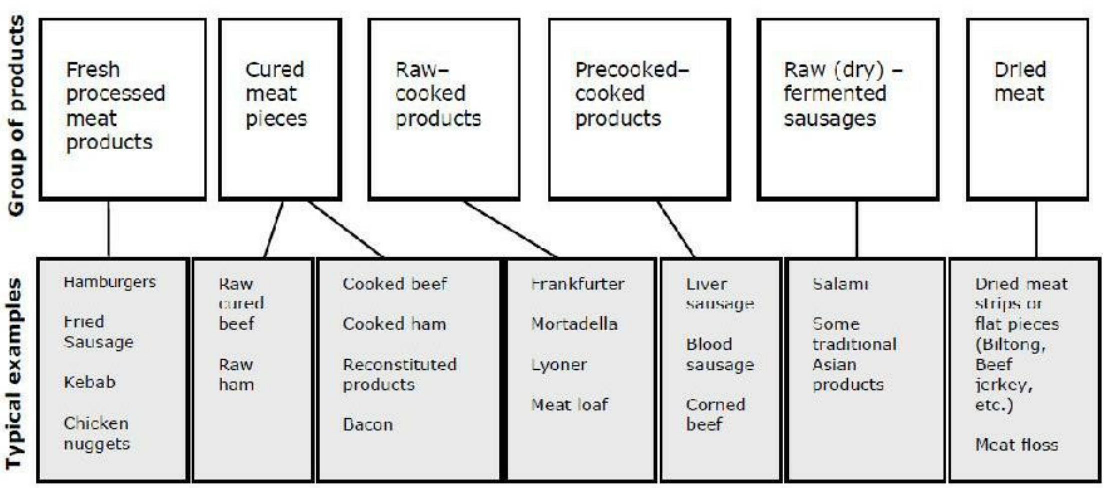
Sulphur dioxide, is widely legally used in food manufacturing (fruits, juices), but use in the meat sector discouraged or forbidden, as it would further add to the daily intake by consumers and, most importantly, it may make poor quality products open to adulteration. The substance has a notable effect on raw red meat, in particular on the hygienically very sensitive minced meat, as it can reverse dark brownish colours of overstored products causing them to lighten and reddening in colour. Moreover, also the beginning bacterial spoilage can be masked through the substance's inhibitory effect on microorganisms.

Categories of Processed Meat Products

When viewing meat products of various size, shape and colour in butcher shops or meat sections of supermarkets, there appears to be is a great variety of such products with different taste characteristics. In some countries there may be several hundred different meat products, each with its individual product name and taste characteristics. At a closer look, however, it turns out that many of the different products with different product names have great similarities. This issue can be even better understood and becomes more transparent when the processing technologies are analyzed. Based on the **processing technologies used and** taking into account the treatment of raw materials and the individual processing steps, it is possible to categorize processed meat products in **six broad groups**.

Based on the grouping the meat products and their processing technologies are described in detail in the respective chapters. Hereunder, a definition of each group is given:

Meat products grouped according to the processing technology Applied



Based on the grouping the meat products and their processing technologies are described in detail in the respective chapter's .Hereunder, a definition of each group is given:

Fresh processed meat products

Definition

These products are meat mixes composed of comminuted **muscle meat,** with varying quantities of **animal fat**. Products are **salted only**, curing is not practiced. **Non-meat ingredients** are added in smaller quantities for improvement of flavor and binding, in low - cost versions larger quantities are added for volume extension. All meat and non -meat ingredients are added **fresh** (raw). Heat treatment (**frying, cooking**) is applied immediately prior to consumption to make the products palatable. If the fresh meat mixes are filled in casings, they are defined as **sausages** (e.g. frying sausages). If other portioning is customary, the products are known as **patties, kebab,** etc. Convenience products, such as **chicken nuggets**, have a similar processing technology and can also be included in this group. In contrast **to** the rest of the group, **chicken nuggets** etc. are already fried in oil at the manufacturing stage during the last step of production.

Fresh raw beef, fried fresh and Chicken nuggets patties sausages (left) and beef patties (right)

Cured meat cuts

Entire pieces of muscle meat and reconstituted products

Definition

Cured meat cuts are made of **entire** pieces of muscle meat and can be sub-divided into two groups, **cured-raw meats** and **cured cooked meats.** The curing for both groups, **cured- raw and cured-cooked**, is in principle similar: The meat pieces are treated with small amounts of nitrite, either as dry salt or as salt solution in water.

The difference between the two groups of cured meats is:

Cured-raw meats do not undergo any heat treatment during their manufacture. They undergo a processing period, which comprises curing, fermentation and ripening in controlled climatized conditions, which makes the products palatable. The products are consumed raw/uncooked.

Cured-cooked meats, after the curing process of the raw muscle meat, always undergo heat treatment to achieve the desired palatability.

Raw-cooked meat products

Definition

The product components *muscle meat, fat* and *non-meat ingredients* which are processed raw, i.e. uncooked by comminuting and mixing. The resulting viscous mix/batter is portioned in sausages or otherwise and thereafter submitted to heat treatment, i.e. “cooked”. The heat treatment induces protein coagulation which results in a typical firmelastic texture for raw-cooked products. In addition to the typical texture the desired palatability and a certain degree of bacterial stability is achieved.

Cured-raw ham and Cured-cooked products

Viennas, hotdogs and Sausages and meat loaf of the raw-cooked type