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Dairy Processing and Quality Assurance: An Overview

Ramesh C. Chandan

Global Technologies, Inc., Coon Rapids, MN 55448, USA

INTRODUCTION

Dairy processing involves conversion of raw milk into fluid milk products, and an array of dairy products such as butter, yogurt and fermented milks, cheeses, dry milk powders, dry whey products, ice cream, and frozen desserts, and refrigerated desserts.

Factors related to the cow such as breed, intervals of milking, stages of milking, different quarters of udder, lactation period, season, feed, nutritional level, environmental temperature, health status, age, weather, estrus cycle, gestation period and exercise are known to cause variations in fat, protein, lactose and mineral levels in milk derived from individual cows. In general, these variations tend to average out and display an interesting pattern in commercial milk used by the processors. However, the seasonal variations in major milk constituents are relevant to the processor since they impact important properties of finished products. In general, in the United States, approximately 10% variation in fat and protein is observed in milk received in July–August (lowest level) as compared to milk delivered in October–November (highest level). Subsequently, functional contribution of milk proteins (viscosity in yogurt, buttermilk as well as curd firmness in cheese manufacture) also follows similar trend. Furthermore, cheese yield and whey protein production are also negatively affected by seasonal variations in milk composition.

The concentration of minerals such as chloride, phosphates, and citrates of potassium, sodium, calcium, and magnesium in milk is important in processing, nutritive value, and shelf life of dairy products. Their concentration is <1% in milk but are involved in heat stability of milk, alcohol coagulation of milk, age-thickening of sweetened condensed milk, feathering of coffee cream, rennin coagulation, and clumping of fat globules on homogenization. All the minerals considered essential for human nutrition are found in milk (Chandan, 2007a).

From consumer standpoint, quality factors associated with milk are appearance, color, and sensory attributes such as aroma, flavor, and mouthfeel.

The color of milk is perceived by consumer to be indicative of purity and richness. The white color of milk is due to the scattering of reflected light by the inherent ultramicroscopic particles, fat globules, colloidal casein micelles, and calcium phosphate. The intensity of white color is directly proportional to size and number of particles in suspension. Homogenization increases the surface area of fat globules significantly as a result of breakup of larger globules. Accordingly, homogenized milk and cream are whiter than nonhomogenized counterparts. After the precipitation of casein and fat by the addition of a dilute acid or rennet, whey is separated, which possesses a green–yellow color due to the pigment riboflavin. The depth of color varies with the

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amount of fat remaining in the whey. Lack of fat globules gives skim milk a blue tinge. Physiological disturbances in the cow make the milk bluer.

Cow's milk contains pigments carotene and xanthophylls, which tend to give golden yellow color to the milk. Guernsey and Jersey breeds produce especially golden yellow milk. Milk from goats, sheep, and water buffalo tends to be much whiter in color because their milk lacks the pigments.

The flavor (taste and aroma) of milk is critical to its assessment criterion of quality by the consumer. Flavor is an organoleptic property where both odor and taste interact. The sweet taste of lactose is balanced against the salty taste of chloride, and both are somewhat moderated by proteins. This balance is maintained over a fairly wide range of milk composition even when chloride ion varies from 0.06 to 0.12%. Saltiness can be detected organoleptically in samples containing 0.12% or more of chloride ions and becomes marked in samples containing 0.15%. Some workers attribute the characteristic rich flavor of dairy products to the lactones, methyl ketones, certain aldehydes, dimethyl sulfide, and certain short chain fatty acids. As lactation advances, lactose declines while chlorides increase, so that the balance is slanted towards "salty". A similar dislocation is caused by mastitis and other udder disturbances. Accordingly, milk flavor is related to its lactose/chloride ratio.

Freshly drawn milk from any mammal possesses a faint odor of a natural scent peculiar to the animal. This is particularly true of the goat, mare, and cow. The "cow" odor of cows' milk is variable, depending upon the individual season of the year, and the hygienic conditions of milking. A strong "cowy" odor frequently observed during the winter months may be due to the entry into milk of acetone bodies from the blood of cows suffering from ketosis. Feed flavors in milk originate from feed aromas in the barn; for instance, aroma of silage. In addition, some feed flavors are imparted directly on their ingestion by the animal. Plants containing essential oils impart the flavor of the volatile constituent to the milk. Garlic odor and flavor in milk is detected even after 1 minute of feeding garlic. Weed flavor of chamomile or mayweed arises from the consumption of the weed in mixtures of ryegrass and clover. Cows on fresh pasture give milk with a less well-defined "grassy" flavor, due to coumarin in the grass. A "clovery" flavor is observed when fed on clover pasture and these taints are not perceptible when dried material is fed. Prolonged ultraviolet radiation and oxidative taints lead to "mealiness", "oiliness", "tallowiness," or "cappy" odor. Traces of copper (3 ppm) exert development of metallic/oxidized taints in milk. Microbial growth in milk leads to off-flavors such as acid (sour), proteolytic (bitter), and rancid. Raw milk received at the plant should not exhibit any off-flavors. Certain minor volatile flavor could be volatilized off by dairy processing procedures.

Dairy technology may be defined as the application of theoretical and applied scientific knowledge to transforming milk into articles of commerce. Dairy processing involves chemical, microbiological, physical, and engineering principles and it is imperative to understand them for effective management of a dairy plant. Additionally, meeting consumer expectations by controlling the processes to deliver quality, safety, and shelf life of the products is paramount to successful dairy processing operation. In the recent past, major advances in dairy processing have resulted in improvement in safety and quality of products. Such developments have led to increased sophistication in mechanization, automation, computerization, sanitation, ultra-pasteurization, and aseptic packaging in dairy plants. Research and development work undertaken at the university, government, and private industry level has further added basic and applied knowledge to dairy industry. The work has benefited consumer by making products safer and extending their shelf life for making them available over wider distribution areas. Furthermore, research and development efforts have led to the introduction of an array of new products providing a wide variety of new products in market place.

The industry continues to consolidate and make large investments in new dairy processing facilities handling significantly more volume of milk than ever before. Chapter 2 discusses the production and consumption trends in dairy industry. The consolidated plant operations have taken advantage of innovations in plant design and machinery and new systematic quality management programs like Hazard Analysis Critical Control Points (HACCP) to insure product quality and safety. Developments in electronic data processing and process control are routinely practiced in many dairy plants. In addition, modern membrane technologies like ultrafiltration, reverse osmosis, and electrodialysis in whey and cheese manufacture have resulted in profitable utilization of erstwhile waste streams from dairy product manufacturing. Sewage treatment facilities attached to manufacturing plants have helped in control of effluent pollution problems. Furthermore, advances in biotechnology of lactic cultures and enzymes have been adopted for optimization in cheese production and ripening as well as for efficiencies in yogurt and fermented milk processes. Ultra-pasteurization techniques and aseptic packaging systems have presented the consumer with extended and long shelf-life products.

Dairy personnel are the key to the operation of a dairy plant. They make sure that raw materials of optimum quality and prescribed specifications are available, stored, and utilized in a timely manner. They apply the standard analytical procedures (approved by regulatory authorities) for optimum processing and packaging, storage, and shipment of the final products. In this area, they make crucial decisions relative to acceptance or rejection of raw materials as well as of finished products. In short, they are responsible for quality control programs for raw materials, in-process controls, and finished product specifications to insure compliance with regulatory and proprietary standards. All the sensory, chemical, physical, and microbiological aspects must be met for proper functioning of the plant. In addition, approved sanitation programs and other quality systems have to be implemented for successful management of the plant.

This chapter deals with major dairy products and outlines of basic dairy processes used for making them. The details of the processes and quality assurance procedures follow in succeeding chapters of this book.

BASIC STEPS IN MILK PROCESSING

Major components of commercial raw milk are illustrated in the in Figure 1.1. Chapter 3 deals with the biosynthesis and origin of milk constituents. And, Chapter 4 discusses the chemical composition, physical, and functional properties of milk and milk ingredients.

On dry basis, raw whole milk contains 29.36% fat, 26.98% protein (22.22% casein, 4.76% whey proteins), 38.1% lactose, and 5.56% ash. The composition of nonfat solids of skim milk is: 52.15% lactose, 38.71% protein (31.18% casein, 7.53% whey protein), 1.08% fat, and 8.06% ash.

In the United States, milk production, transportation, and processing are regulated by Grade A Pasteurized Milk Ordinance (U.S. Department of Health and Human Services, 2011). Figure 1.2 shows journey of milk from the farm to supermarket, including processing at the milk plant. Basic microbiology of milk is discussed in Chapter 5. Chapters 6 and 7 are dedicated to regulatory control of milk production and transportation to milk processing plant.

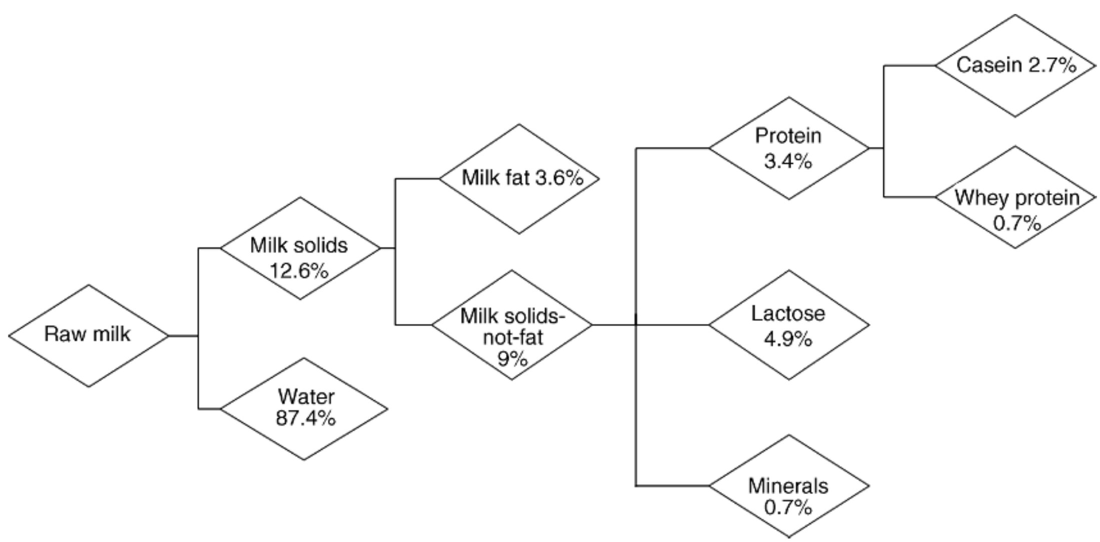

Figure 1.1. Gross composition of pooled raw milk.

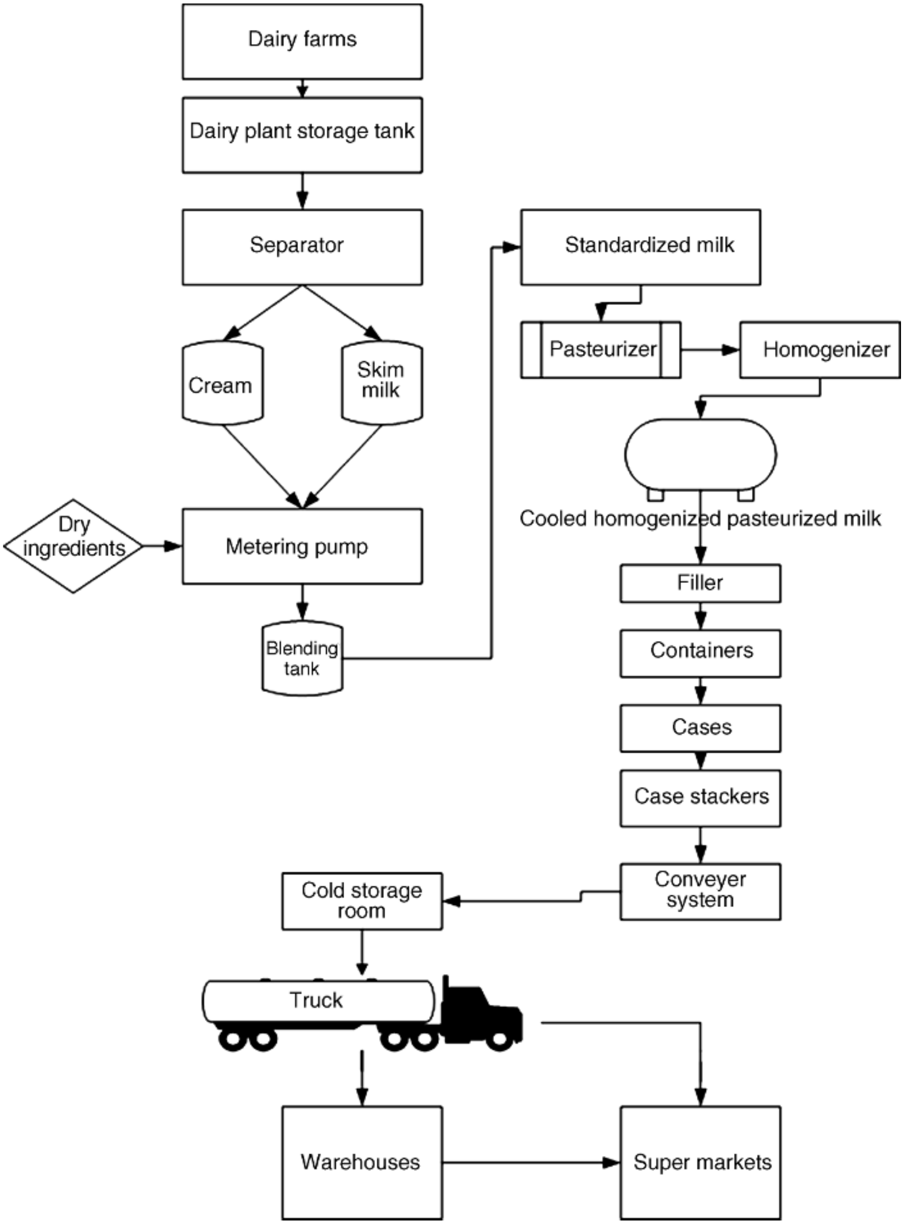

Figure 1.2. Journey of milk from farms to supermarkets.

Basic Processing Steps in a Dairy Plant

Basic dairy processing principles are described elsewhere (Kilara, 2013). New and emerging processing technologies are enumerated in Chapter 22.

A summary of various stages is given below.

Bulk Milk Handling and Storage

It is a key position in handling of good quality milk. Dairy farms produce sanitary raw milk under the supervision of U.S. Public Health Services. Chapter 5 discusses the microbiological aspects of milk processing. Chapters 6 and 7 deal with details of regulations relative to milk production, handling, and storage at the dairy processing plant. In particular, milk production under Grade A regulations protects consumers from contracting milk-borne diseases, which in the past were commonly associated with contaminated milk consumption. The regulations help in the movement of assured quality milk across interstate lines.

Virtually, all the raw milk at the plant is delivered in tank trucks. Unloading of milk involves agitation of truck, inspection for the presence of off-flavors, taking a representative sample, and connecting the unloading hose to the truck outlet. After opening the tank valve, a high capacity transfer pump is used to pump milk to a storage tank or silo. The weight of milk transferred is registered with a meter or load cells. The tank truck is then cleaned by plant personnel by rinsing with water, cleaning with detergent solution, rinsing again with water followed by a chlorine/iodine sanitizing treatment. A clean-in-place line may be inserted into the tank through the manhole. Payment of milk is based on the hauler receipt.

Storage tanks may be refrigerated or insulated. They hold milk up to a period of 72 hours (usually 24 hours) before processing. The tanks may be horizontal or vertical in configuration. Grade A milk for pasteurization must be stored at 1.7–4.4 °C (35–40 °F). Maximum bacterial count of at this stage is mandated at 300,000 CFU/mL as opposed to 100,000 CFU/mL, the maximum allowed at the farm (Frye, 2013a). The higher count is justified because pumping breaks the clumps of bacteria giving higher counts and there is more opportunity of contamination of milk as it comes in contact with more equipment during handling and transfer. Also, longer time of storage adds more bacterial numbers. For equipment design, the 3-A sanitary standards are followed (Frye, 2013b).

Separation

The purpose of this step is to separate milk into cream and skim milk. All incoming raw milk is passed through separators, which are essentially high-speed centrifuges. They separate milk into lighter cream fraction and heavier skim milk fraction. A separator of adequate bowl capacity should collect all the “slime” material containing heavy casein particles, leukocytes, larger bacteria, body cells from cow’s udder, dust and dirt particles, and hair. If the particulate fraction of raw milk is not removed, homogenized milk will develop sediment upon storage. Skim milk and cream are stored separately for further processing.

Standardization

Use of a separator also permits fractionation of whole milk into standardized milk (or skim milk, low-fat milk) and cream. Skim milk should normally contain 0.01% fat or less.

Standardization valve on the separator permits the operator to get separated milk of predetermined fat content. Increased back pressure on cream discharge port will increase fat content in standardized milk. By blending cream and skim milk fractions, various fluid milk and cream products of required milk fat content can be produced.

Heat Treatment

The main purpose of heat treatment of milk is to kill all the disease-producing (pathogenic) organisms and to enhance its shelf life by removing approximately 95% of all the contaminating organisms. Heat treatment is an integral part of all processes used in dairy manufacturing plants. Intensive heat treatment brings about interactions of certain amino acids with lactose resulting in color changes in milk (Maillard browning) as observed in sterilized milk and evaporated milk products.

Among milk proteins, caseins are relatively stable to heat effects. Whey proteins tend to denature progressively by severity of heat treatment, reaching 100% denaturation at 100 °C (212 °F). In the presence of casein in milk, denatured whey proteins complex with casein and no precipitation is observed. In contrast to milk, whey that lacks casein, heat treatment at 75–80 °C (167–176 °F) results in precipitation of the whey proteins.

From a consumer standpoint, heat treatment of milk generates several sensory changes (cooked flavor)

Table 1.1. Minimum Time–Temperature Requirements for Legal Pasteurization in Dairy Operations

Process	Milk—Whole Low-Fat, Skim/Nonfat	Milk Products with Increased Viscosity, Added Sweetener, or Fat Content 10% or More	Eggnog, Frozen Dessert Mixes
Vat (batch)	30 minutes at 63 °C (145 °F)	30 minutes at 65.6 °C (150 °F)	30 minutes at 69 °C (155 °F)
High temperature, short time	15 seconds at 72 °C (161 °F)	15 second at 74.4 °C (166 °F)	25 seconds at 80 °C (175 °F) 15 seconds at 83 °C (180 °F)
Higher heat, shorter time	1.0 second at 89 °C (191 °F) 0.5 second at 90 °C (194 °F) 0.1 second at 94 °C (201 °F) 0.05 second at 96 °C (204 °F) 0.01 second at 100 °C (212 °F)	1.0 second at 89 °C (191 °F) 0.5 second at 90 °C (194 °F) 0.1 second at 94 °C (201 °F) 0.05 second at 96 °C (204 °F) 0.01 second at 100 °C (212 °F)	1.0 second at 89 °C (191 °F) 0.5 second at 90 °C (194 °F) 0.1 second at 94 °C (201 °F) 0.05 second at 96 °C (204 °F) 0.01 second at 100 °C (212 °F)
Ultra-pasteurized	2.0 seconds at 137.8 °C (280 °F)	2.0 seconds at 137.8 °C (280 °F)	2.0 second at 137.8 °C (280 °F)

depending on intensity of heat. In general, pasteurized milk possesses the most acceptable flavor. Ultra-pasteurized milk and UHT milk exhibit slightly cooked flavor. Sterilized milk and evaporated milk possess exceedingly cooked flavor and off-color.

The U.S Food and Drug Administration has defined pasteurization time and temperature for various products. The process is regulated to assure public health. Using plate heat exchangers with a regeneration system, milk is pasteurized to render it free of all pathogenic organisms and to reduce approximately 95% of other microbial load. The process of pasteurization involves heating every particle of milk or milk product in properly designed and operated equipment to a prescribed temperature and held continuously at or above that temperature for at least the corresponding specified time. Minimum temperature–time requirements for pasteurization are based on thermal death time studies on the most resistant pathogen that might be transmitted through milk. Table 1.1 gives the various time–temperatures for legal pasteurization of dairy products.

Most refrigerated cream products are now ultra-pasteurized by heating to 125–137.8 °C (257–280 °F) for 2–5 seconds and packaged in sterile cartons in clean atmosphere. Milk for ambient storage is UHT treated at 135–148.9 °C (275–300 °F) for 4–15 seconds, followed by aseptic packaging. In some countries, sterilized/canned milk is produced by sterilizing treatment of 115.6 °C (240 °F) for 20 minutes. It has a brown color and a caramelized flavor.

Homogenization

This process reduces the size of fat globules of milk by pumping milk at high pressure through a small orifice, called valve. The device for size reduction is called a homogenizer, which subjects fat particles to a combination of turbulence and cavitation. Homogenization is carried out at temperatures higher than 37 °C (99 °F). The process causes splitting of original fat globules (average diameter approximately 3.5 μm) into a very large number of much smaller fat globules (average size <1 μm). As a consequence, a significant increase in surface area is generated. The surface of the newly generated fat globules is then covered by new membrane formed from milk proteins. Thus, the presence of a minimum value of 0.2 g of casein/g fat is desirable to form to coat the newly generated surface area. As milk is pumped under high-pressure conditions, the pressure drops causing breakup of fat particles. If the pressure drop is engineered over a single valve, the homogenizer is deemed to be single-stage homogenizer. It works well with low-fat products or in products where high viscosity is desired as in creams and sour cream manufacture. On the other hand, homogenizers reducing fat globule size in two stages are called dual-stage homogenizers. In the first stage, the product is subjected to high pressure, for example, 13.8 MPa (2,000 psi), which results in breakdown of the particle size (diameter) to an average of less than 1 μm. Then the product goes through the second stage of 3.5 MPa (500 psi) to break the clusters of globules formed in the first stage. The dual-stage homogenization is appropriate for fluids with high fat and solids-not-fat content or whenever low viscosity is needed.

Homogenized milk does not form a cream layer (creaming) on storage. It displays whiter color, fuller body, and flavor characteristics. Homogenization leads to better viscosity and stability in cultured products by fully dispersing stabilizers and other ingredients in ice cream, yogurt, and other formulated dairy products.

Cooling, Packaging, and Storage

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. Chapter 21 gives a detailed description of packaging materials and machinery.

MANUFACTURE OF FLUID MILK PRODUCTS

Dairy products may be classified as fluid milk products, butter and butter products, concentrated and dry milk products, cultured milk products, cheese products, whey products, and ice cream and frozen desserts.

Approximate composition of fluid milk products is shown in Table 1.2. Chapter 9 of this book deals with the fluid milk and milk products.

Milk

Commercial milk is available in various milk fat contents. The term "milk" is synonymous with whole milk, which must contain not less than 3.25% milk fat and 8.25% solids-not-fat. Addition of vitamins A and D is optional. If the vitamins are added, vitamin A must be present at a level of not less than 2,000 International Units/quart and Vitamin D must be present at 400 International Units/quart of milk (Frye, 2013a,b).

Fat-reduced milks are labeled according to their contribution of grams of fat per Reference Amount (RA) of 240 mL. Low-fat milk contributes less than 3 g fat per RA, while nonfat milk contributes less than 0.5 g of fat per RA. Accordingly, milk containing 2% milk fat does not qualify to be labeled as low-fat milk and is labeled reduced-fat milk. Low-fat milk available

Table 1.2. Typical Composition of Fluid Milk, Cream, and Fluid Dairy Ingredients

Dairy Ingredient	% Water	% Fat	% Protein	% Lactose	% Ash
Whole milk	87.4	3.8	3.2	4.9	0.7
Skim milk	90.9	0.1	3.3	5.0	0.7
Half and half	80.2	11.5	3.1	4.5	0.7
Light cream	74.0	18.3	2.9	4.2	0.6
Light whipping cream	62.9	30.5	2.5	3.6	0.5
Heavy whipping cream	57.3	36.8	2.2	3.2	0.5
Plastic cream	18.2	80.0	0.7	1.0	0.1
Fluid UF* whole milk	70–75	11–14	10–12	<5	>2.5
Fluid UF* skim milk	80–85	<0.5	10–12	<5	>2.5
Fluid UF* skim milk, diafiltered	80–82	<0.5	<16–17	<1	>1.5

Source: Adapted from Chandan (1997) and Chandan and O'Rell (2013).
*UF: ultrafiltered.

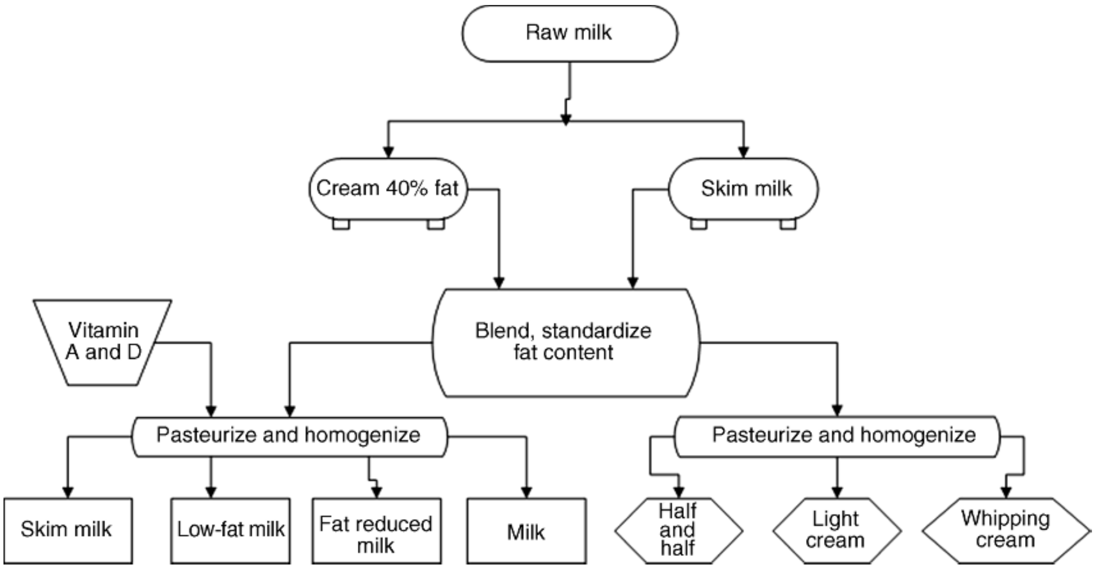

Figure 1.3. Fluid milk processing flow sheet.

in the market place has 1% milk fat and nonfat/fat free/ skim milk can legally have 0.2% fat. However, in reality nonfat milk contains less than 0.1% fat. All the fluid milk beverages may have added vitamins A and D.

Figure 1.3 shows the steps in production of fluid milk and cream products.

The figure shows general processes for manufacture of whole milk, reduced fat milk, low fat milk and skim milk. It also shows how cream and other fluid products are made.

The shelf life of milk is a function of the microbial quality of raw milk, temperature and time exposure during storage and handling, pasteurization conditions, equipment sanitation, packaging conditions, and subsequent distribution practices. The shelf life of milk purchased from grocery stores is dependent largely on the storage temperature. Fluid milk products display maximum shelf when stored at temperature close to freezing point (4 °C/32 °F). Let us assume the shelf life of pasteurized milk is 40 days at storage temperature of 0 °C/32 °F. It has been demonstrated that the shelf life gets shortened to 20 days by storage at 2 °C/35.6 °F, 10 days at 4 °C/39.2 °F, 5 days at 7 °C/44.6 °F, and progressively to fewer days at higher temperatures. This illustration underscores the importance of maintaining refrigerated storage temperature as low as possible (close to 32°F) to achieve maximum shelf life of milk.

Ultra-pasteurized products are packaged in a near-aseptic atmosphere in presterilized containers and held refrigerated to achieve an extended shelf life (ESL). When ultra-pasteurized product (UHT) is packaged aseptically in specially designed multilayer container, it displays shelf life even longer than any other packaged fluid milk and cream products. UHT products subjected to aseptic heat treatment and packaged aseptically in specially designed containers can be stored at ambient temperatures for 6 months.

Cream

Cream is prepared from milk by centrifugal separation. Heavy cream contains not less than 36% fat and may be called “heavy whipping” cream. Light whipping cream contains 30% or more milk fat, but less than 36% milk fat and may be labeled as whipping cream. Light cream, coffee cream, or table cream contains not less than 18% milk fat, but less than 30% milk fat. Half and half is normally a blend of equal proportion of milk and cream, containing 10.5% milk fat. Legally, it contains not less than 10.5% milk fat but not more than 18% milk fat.

Cream to be used as an ingredient in processing contains 36–40% fat. By standardizing with skim milk, cream of different fat levels can be produced. Light cream, and half and half are homogenized products. Specific homogenization and heat treatments generate desirable grades of viscosity in cream products. They are processed and packaged similar to fluid milks.

Plastic cream contains 80% milk fat. It resembles butter in consistency but compared to butter, it is still oil-in-water type emulsion. It can be stored in frozen form.

Milk and other dairy products are used as ingredients in various food products. They perform an important nutritional and functional role. The functional properties of dairy ingredients are related to their chemical composition and specific processing conditions to which they may be subjected in order to modify their performance in a given food system. Chapter 8 gives detailed information on dairy ingredients.

CONCENTRATED MILK FAT PRODUCTS

Butter

Butter is a concentrated form of milk fat, containing at least 80% fat (Fearon, 2011). It can be converted to shelf stable products such as butter oil, anhydrous milk fat, and ghee. Table 1.3 shows the approximate composition of butter and its products.

Figure 1.4 gives a flow sheet diagram for the manufacture of butter, butter oil, and certain dry milk products. The diagram also displays interrelationships between these products.

Butter is obtained by churning of cream. The temperature of churning is an important parameter to follow. The churning temperature is determined by an optimum ratio of crystalline fat, solid fat, and liquid fat. The churns are either batch type or continuous type. For batch-type churns, cream of 35–45% fat is used. For continuous-type churns, cream of 42–44% fat is used. Cream is pasteurized at 73.8 °C (165 °F) for 30 minutes or at 85 °C (185 °F) for 15 seconds and is then cooled to about 7 °C (45 °F) for crystallization of fat. The crystallization process is completed by holding the cream for approximately 16 hours. The cream, which registers an increase in temperature to 10 °C (50 °F) is then transferred to sanitized churn. Annatto coloring may be incorporated, if required. The churn is rotated to convert oil-in-water type of emulsion (cream) to water-in-oil type emulsion (butter). This conversion is known as phase inversion. This is accompanied by the appearance of butter granules of the size of popcorn or peas. During phase inversion, cream starts foaming. Free fat, generated by rupture of fat globules of cream, cements some of the remaining fat globules to form clumps or butter granules. There is a clear separation of butter granules and surrounding liquid called buttermilk. At this stage, the buttermilk is drained out, followed by the addition of an aliquot of clean cold water (1–2 °C/33.8–35.6 °F) to the churn. The total volume of wash water is equal to the volume of buttermilk. The washing continues until the rinse is almost clear. Salt at 1.6% level is added and blended with butter. The next step is called "working" in which the remaining fat globules are disrupted to liberate free fat. All the free fat then forms the continuous phases in which water droplets are dispersed to form butter. Working of butter is accomplished by continuing rotation of the churn until the body of butter is closely knit to show a waxy character with no visible pockets of surface moisture. The "working" of butter is continued to standardize moisture until fat content of butter is 80%. Butter is then pumped and packaged.

Continuous butter churns are now widely in use. They accelerate churning process and washing of butter is not necessary. Cream of 42–44% fat is introduced into a cylinder where it is churned. Buttermilk is drained; butter granules are worked to obtain the typical waxy body and texture of butter, and packaged. In another

Table 1.3. Typical Composition of Milk Fat Concentrates

Product	% Water	% Fat	% Protein	% Lactose	% Ash	Added Ingredient
Butter	16.5	80.5	0.6	0.4	2.5	0–2.3% salt
Anhydrous milk fat	0.1	99.8	0.1	0	0	0
Butter oil	0.3	99.6	0.1	0	0	0
Ghee	<0.5	99–99.5	0	0	0	0

Source: Adapted from Chandan (1997) and Aneja et al. (2002).

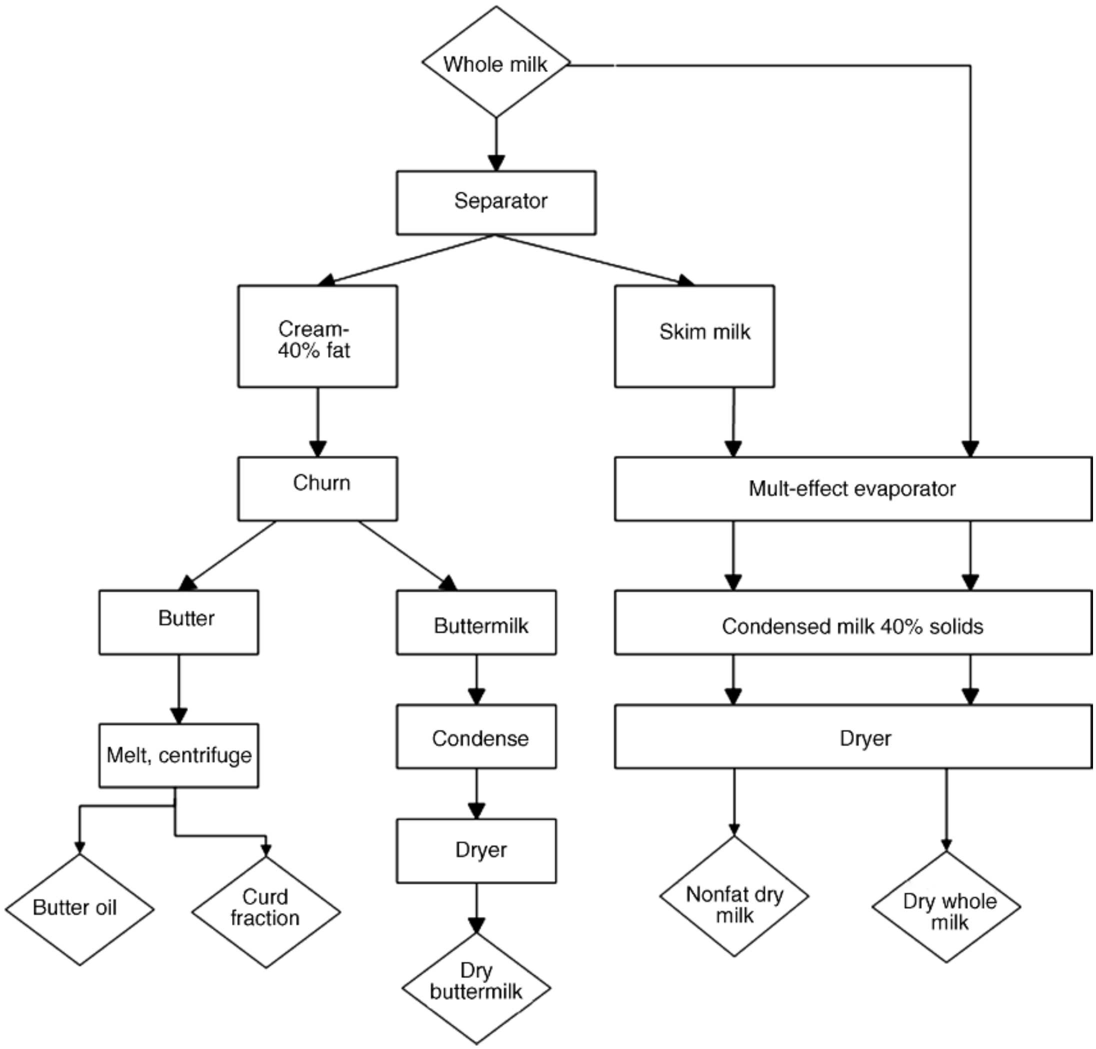

Figure 1.4. A flow sheet for the manufacture of butter, butter oil, dry buttermilk, nonfat dry milk, and whole milk powder.

process, cream is separated to get plastic cream of 80% fat. The phase inversion is carried out by chilling. The butter granules are worked to achieve typical butter body and texture.

In some countries, butter is churned from cultured cream. Cultured cream butter has a distinct flavor and can be easily distinguished from sweet cream butter.

The processing conditions affect the physical properties such as crystallization and melting behavior of butterfat. The crystal formation is mediated by nucleus formation and subsequent growth of crystals. The size of crystals is dependent on rate of crystallization. Melting behavior influences the application of butter in food products. The rate of transformation of solid fat fraction into liquid milk fat is important and is characterized by melting point range, thermal profile, and solid fat content. Melting point temperature is the temperature at which milk fat melts completely to a clear liquid. It occurs at a range of 32–36 °C (90–97 °F) and assumes completely liquid state at 40 °C (104 °F) and completely solid state at −75 °C (−103 °F). At ambient temperature, it is a mixture of crystals and liquid phases. By manipulating temperature, butterfat can be fractionated into three fractions exhibiting distinct functionalities. Low-melting fraction melts below 10 °C (50 °F), middle-melting fraction melts between 10–20 °C (50–68 °F), and high-melting fraction melts above 20 °C (68 °F). Low-melt fraction contains significantly lower levels of saturated fatty acids. Butter made with very low-melt fraction spreads at refrigerated temperature. Further fractionation leads to very high-melting fraction that melts at >50 °C (>122 °F), behaving like cocoa butter in confectionery products.

Light/Reduced Fat Butter

Light/reduced fat butter contains 40% fat. The reduced fat form cannot be used for baking. Other spreads may contain a blend of milk fat and vegetable fat.

Chapter 11 of this book gives detailed information on butter and spreads.

Butter Oil

Butter oil is at least 99.6% fat and contains <0.3% moisture, and traces of milk solids-not-fat. Butter is melted by heating gently to break the emulsion and centrifuged in a special separator to collect milk fat, followed by vacuum drying.

Anhydrous Milk Fat

Anhydrous milk fat or anhydrous butter oil is obtained from plastic cream of 70–80% fat. Phase inversion takes place in a special unit (separator) and the moisture is removed by vacuum drying. It contains at least 99.8% milk fat and no more than 0.1% moisture.

Ghee

Ghee is another concentrated milk fat, which is widely used in tropical regions of the world, especially in South Asian countries. It is a clarified butterfat obtained by desiccation of butter at 105–110 °C (221–230 °F). The intense heat treatment generates characteristic aroma and flavor brought about by complex interactions of components of milk solids of butter. Detailed manufacturing procedure is given elsewhere (Aneja et al., 2002)

CONCENTRATED/CONDENSED FLUID MILK PRODUCTS

An outline for manufacturing dry whole milk, nonfat dry milk, and dry buttermilk powder is also given in Figure 1.4. For detailed description of these products, the reader is referred to Chapters 13 and 14. The functional properties of concentrated milk products including nonfat dry milk can be manipulated by specific heat treatment (Augustin and Clarke, 2011). It also affects the keeping quality of whole milk powder. The temperature and time combinations can vary widely depending on the required functional properties. Invariably, the milk for manufacture of concentrated milk products is pasteurized (high-temperature, short time) by heating to at least 161 °F (72 °C), and holding at or above this temperature for at least 15 seconds. An equivalent temperature/time combination can be used. With condensed milk and nonfat dry milk, the extent of heat treatment can be measured by the whey protein nitrogen index, which measures the amount of undenatured whey protein.

Removal of a significant portion of water from milk yields a series of dairy ingredients (Augustin and Clarke, 2011). Consequently, these ingredients offer tangible savings in costs associated with storage capacity, handling, packaging, and transportation.

The composition of concentrated milk products is shown in Table 1.4.

Concentrated Milk or Condensed Whole Milk

Concentrated milk or condensed whole milk is obtained by removal of water from milk and contains at least 7.5% milk fat and 25.5% milk solids. Condensed milk is available in whole milk, low-fat, and nonfat varieties. Condensed whole milk is purchased largely by confectionary industries. It is pasteurized but not sterilized by heat. It may be homogenized and supplemented with vitamin D (Farkye and ur-Rehman, 2011). Chapter 13 gives detailed description of condensed and evaporated milk.

Condensed Skim Milk

Condensed skim milk is commonly used as a source of milk solids in dairy applications and in the manufacture of ice cream, frozen yogurt, and other frozen desserts. Condensed milks are generally customized orders. User

Table 1.4. Typical Composition of Condensed Milk Products

Products	% Water	% Fat	% Protein	% Lactose	% Ash	Added Ingredient
Sweetened condensed whole milk	26.1	8.7	7.9	11.3	1.8	44.2% Sucrose
Sweetened condensed skim milk	28.4	0.3	10.0	16.3	2.3	42.7% Sucrose
Condensed whole milk	74.5	7.5	6.2	9.4	1.6	
Condensed skim milk (medium solids)	70.0	0.4	10.8	15.5	2.3	
Condensed skim milk (high solids)	59.9	0.4	14.4	22.3	3.0	
Evaporated whole milk	74.0	7.6	6.8	10.0	1.6	
Evaporated low-fat milk	79.0	0.2	7.6	11.4	1.8	

Source: Adapted from Chandan (1997). Reproduced with permission of AACC.

plants specify total solids concentration, fat level, heat treatment, and processing conditions. The dairy concentrates offer economies of transportation costs, and storage space. They have to be transported and stored at 4.4 °C (40 °F), and used within 5 days to preserve quality.

Depending on the end user requirements, raw milk is standardized to desired milk fat and nonfat solids ratio. In general, the original milk volume is reduced to about one third to yield about 25–40% solids in the final product. The standardized milk is preheated to 93.3 °C (200 °F) and held for 10–20 minutes. The objective of preheat treatment is to destroy microorganisms and enzymes, and to increase heat stability of milk. In addition, the viscosity of condensed milk is controlled by time–temperature regime during preheat treatment. The heated milk is concentrated in energy efficient multieffect evaporators that operate in high-vacuum condition to boil off water at moderate temperatures of 46.1–54.4 °C (115–130 °F). The concentrated milk is continuously separated from water vapor to achieve desirable concentration of milk solids. It may be homogenized prior to cooling and packaging or pumped to insulated trucks for transportation to user plants.

Sweetened Condensed Milk

Sweetened condensed milk contains 60% sugar in the water phase, which imparts a preservative effect. Consequently, it has enhanced shelf life. When packaged properly, the product is stable for many months at ambient storage temperature. Since it does not need high-heat treatment for sterilization, it possesses a much better color and flavor than evaporated milk. Condensed milk may be low fat and nonfat variety. It is derived from milk after the removal of 60% of its water. It must contain at least 8% milk fat and 28% milk solids. The viscosity of the product is high, approximating 1,000 times that of milk. Sweetened condensed milk is used in confectionery manufacture as well in the manufacture of exotic pies and desserts.

Manufacture of sweetened condensed milk resembles the manufacture of condensed skim milk given above. The addition of sugar and control of lactose crystal size require special processing procedure. The standardized milk is preheated at 135 °C (275 °F) for 5 seconds or 110–120 °C (230–248 °F) for 10–20 seconds. The ultraheat treatment is preferred over high temperature–short time treatment because it leads to lower viscosity in sweetened condensed milk. Following homogenization at 70 °C (158 °F) at 3.5 MPa (500 psi), milk is concentrated in an efficient evaporator at 82.2 °C (180 °F) and liquid sucrose is blended. At this stage, the mix is standardized to 8.5% fat, 20% nonfat solids, and 44% sucrose. The blend is then pasteurized at 82.2 °C (180 °F) for 30 seconds and further standardized to desirable solids in the finishing pan. The product is cooled to 60 °C (140 °F), followed by seeding with finely ground lactose at the rate of 0.03% (dry matter basis). At this stage, the mixture is agitated vigorously while cooling to 18.3 °C (65 °F). The lactose crystal size must be less than 10 μm to avoid settling in storage and resulting sandiness in the product. Sweetened condensed milk is packaged in metal or plastic containers and sealed. For bulk sales, it is pumped into insulated trucks for transport and delivery to user plants.

Evaporated Milk

Evaporated milk is also concentrated milk that is homogenized and heat sterilized in sealed cans or

Table 1.5. Typical Composition of Dry Milk Products

Products	% Water	% Fat	% Protein	% Lactose	% Ash
Dried whole milk	3.0	27.5	26.4	37.2	5.9
Nonfat dry milk	3.2	0.8	36.0	52.0	8.0
Dried butter milk	3.0	5.3	32.4	51.3	8.0
Spray-dried cream (from 20% cream)	0.6	71.1	11.1	14.7	2.5

Source: Adapted from Chandan (1997) and Chandan and O'Rell (2013).

bottles. It is made by boiling off 60% of the water content of milk. It must contain at least 6.5% milk fat, 16.5% nonfat milk solids, and 23% milk solids. Evaporated milk is heat-sterilized. The sterilization process renders the product safe for consumption and can be stored at room temperature for several months without deterioration of flavor. Current processing trend is to subject the product to ultraheat treatment, followed by aseptic packaging. This process gives a better color and flavor in the product than the in-can sterilized product. Typically, the concentration factor is of the order of 2.1×, giving milk fat level of approximately 8% and nonfat solids of approximately 18%. Low-fat evaporated milk composition is 4% fat and 20% nonfat solids, while nonfat evaporated milk contains 0.1% fat and 22% nonfat solids. Evaporated milk is mainly a retail canned product used by the consumer as a convenience ingredient in the preparation of meals, snacks, and desserts.

Manufacture of evaporated milk involves standardization of milk to desired fat to nonfat solids ratio and preheating to 135 °C (275 °F) for 30 seconds. The milk is concentrated in vacuum evaporator at 68.3 °C (155–180 °F) and homogenized at 65 °C (149 °F) and 20.7 MPa (3,000 psi), first stage and 3.5 MPa (500 psi), second stage. It is then cooled to 10 °C (50 °F) and stabilized with disodium hydrogen phosphate to reduce age thickening during subsequent storage. The product is packaged in metal cans and sealed, followed by sterilization at 120 °C (248 °F) for 15 minutes. In a more recent process, the product is vacuum-concentrated and stabilized with disodium hydrogen phosphate as in the conventional process. It is then sterilized at 140.6 °C (285 °F) for 15 seconds, cooled to 60 °C (140 °F), and homogenized at 41.3 MPa (6,000 psi). After cooling to 10 °C (50 °F), evaporated milk is packaged aseptically in appropriate containers.

DRY MILK PRODUCTS

Table 1.5 gives typical composition of dry milk products.

Nonfat Dry Milk

Nonfat dry milk is the product resulting from the removal of fat and water from milk and contains the lactose, milk proteins, and milk minerals in the same relative proportions as in the fresh milk from which it was made. It contains not over 5% by weight of moisture. The fat content is not over 1.5% by weight unless otherwise indicated. Nonfat dry milk is utilized in dairy products, bakery, dry mixes, chemicals, meat processing, and in homes for cooking. Nonfat dry milk is manufactured by spray drying of condensed skim milk.

Spray drying involves atomizing concentrated milk into a hot air stream 356 °–392 °F (180 °–200 °C). The atomizer may be either a pressure nozzle or a centrifugal disc. By controlling the size of the droplets, the air temperature, and the airflow, it is possible to evaporate almost all the moisture while exposing the solids to relatively low temperatures. Spray drying yields concentrated and dry milk ingredients with excellent solubility, flavor, and color.

The spray drying process is typically a two-stage process that involves the spray dryer at the first stage with a static fluid bed integrated in the base of the drying chamber. The second stage is an external vibrating fluid bed.

Product is moved through the two-stage process quickly to prevent overheating of the powder. Powder leaves the dryer and enters a system of cyclones that simultaneously cools it.

Roller drying is another process, which is currently not widely used in the manufacture of most dry milk products. This process involves direct contact of a layer of concentrated milk with the hot surface of rotating rollers. This process causes adverse effects of excessive heat on milk components. In this process, heat often causes irreversible changes such as lactose carmelization, Maillard reaction, and protein denaturation. Roller drying typically results in more scorched powder particles and poorer powder solubility than spray drying. However, roller-dried milk absorbs more moisture than spray-dried powder and is preferred in some food applications such as bakery products.

Instant nonfat dry milk is a processed nonfat dry milk to improve its dispersion properties. It reconstitutes readily in cold water. Instantizing process involves agglomeration, a process of increasing the amount of air incorporated between powder particles. In one process, a small amount of moisture is incorporated in dry milk particles suspend in air, forming porous aggregates followed by redrying, and grinding the agglomerated particles. The process results in dry milk with improved reconstitution properties. During reconstitution, the air is replaced by water and incorporated air enables a larger amount of water to come into contact immediately with the powder particles.

Dry Whole Milk

Dry whole milk is the product resulting from the removal of water from milk and contains not less than 26, nor more than 40% milk fat, and not more than 5.0% moisture (as determined by weight of moisture on a milk solids-not-fat basis). It is manufactured by spray drying of whole milk with added wetting agent, soya lecithin.

Reconstituted extra grade whole milk powder possesses sweet, pleasant flavor. It may have a slight degree of feed flavor, a definite degree of cooked flavor, and no off-flavors. The products should be free of graininess on reconstitution and exhibit no burnt particles.

Dry whole milk is used primarily in confectionery, dairy, and bakery.

Dry Buttermilk

Dry buttermilk is the product resulting from the removal of water from liquid buttermilk derived from the churning of butter. It contains not less than 4.5% milk fat and not more than 5% moisture. The protein content of dry buttermilk is not less than 30%. Dry buttermilk is used in dairy foods such as ice cream, and in other foods like bakery, dry mixes, and confectionery.

Dry buttermilk contains higher milk fat than nonfat dry milk. It contains significant level of phospholipids, which act as emulsifying agents. Shelf life due to phospholipids is considerably reduced because they are prone to degradation causing fishy odors and flavor defects.

Dry Buttermilk Product

Another form of dry buttermilk is called dry buttermilk product. This designation indicates that it does not meet the specification of protein content of 30% minimum. This product denotes protein content on the label. Except protein content, dry buttermilk product meets all other standards of dry buttermilk.

Dry buttermilk product is the product resulting from the removal of water from liquid buttermilk derived from the churning of butter. It shall contain not less than 4.5% milk fat and not more than 5% moisture. Dry buttermilk product contains less than 30% protein, the label of which should specify the minimum protein content.

Dry milk products are discussed in details in Chapter 14 of this book.

FERMENTED/CULTURED DAIRY PRODUCTS

Approximately, 400 diverse products derived from fermentation of milk are consumed around the world. Fermentation conserves vital nutrients of milk. Simultaneously, it modifies certain milk constituents to enhance their nutritional status, and furnishes to the consumer live and active cultures in significant numbers to provide distinct health benefits beyond conventional nutrition. The fermented milk products may be termed as "functional foods".

Diversity of fermented milks may be ascribed to:

- Use of milk obtained from various domesticated animals,
- Application of diverse microflora,
- Addition of sugar, condiments, grains, fruits to create variety of flavors and textures,
- Application of additional preservation methods, for example, freezing, concentrating, and drying.

Figure 1.5 shows an outline for the manufacture of cultured/fermented milks including yogurt, cultured buttermilk, sour cream, cream cheese, and cottage cheese.

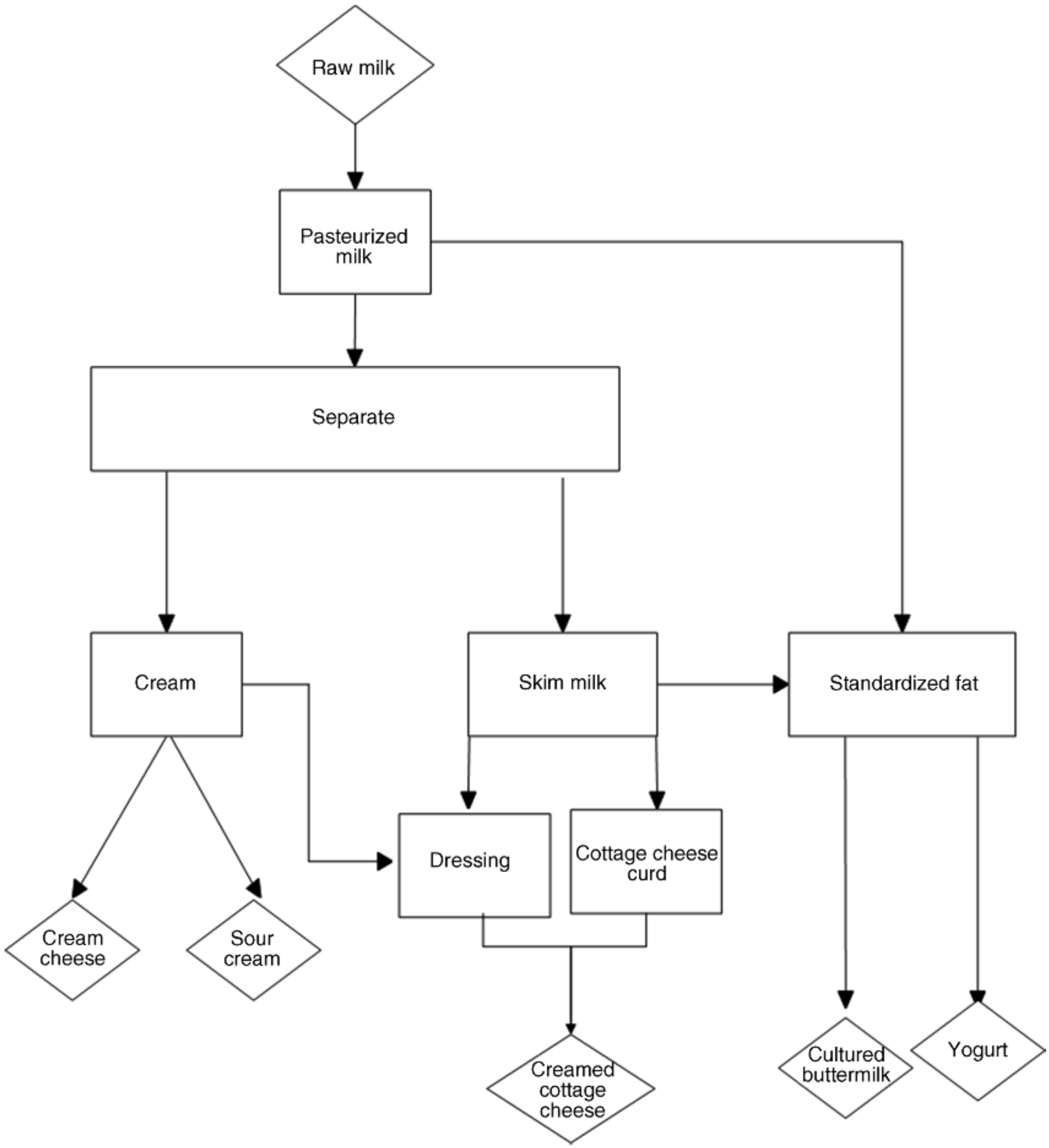

Figure 1.5. An outline of manufacture of cultured dairy products.

Yogurt

Yogurt is a semisolid fermented product made from a heat-treated and standardized milk mix by the activity of a symbiotic blend of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. Current trend for using probiotic cultures and prebiotics in the manufacture of fermented milks and yogurt products is in response to consumer expectations for functional or

Table 1.6. Typical Formulation of Certain Types of Yogurt Bases

Composition	Low-Fat Plain Yogurt	Full-Fat Plain Yogurt	Full-Fat Blended Yogurt	Low-Fat Blended Yogurt	Nonfat Blended Yogurt
Milk fat (%)	1.0	3.25–3.50	3.25–3.50	>0.5–<2.0	0.3–0.5
Milk solids-not-fat (%)	14.2	11.0–12.0	10.5–11.0	10.5–12.0	11.0–12.0
Sugar solids (%)	0	0	6.0–10.0	6.0–10.0	6.0–10.0
Stabilizer (%)	0–0.75	0–1.0	0.4–1.6	0.3–1.4	0.3–1.2

Source: Adapted from O'Rell and Chandan (2013) and Chandan (1997).

wellness foods. The beneficial effects documented in numerous studies and reviews include prevention of cancer, reduction in diarrhea associated with travel, antibiotic therapy, and rotavirus, improvement of gastrointestinal health, enhancement of immunity of the host, amelioration of lactose tolerance symptoms, protection from infections caused by food-borne microorganisms, control of vaginitis, and vaccine adjuvant effects.

Yogurt is classified into various types. Plain yogurt is the basic style and forms an integral component of fruit-flavored yogurt (Chandan and Nauth, 2012; Chandan and O'Rell, 2013; O'Rell and Chandan, 2013). It contains no added flavors or sugar.

Table 1.6 shows typical formulation of plain and blended style yogurt.

Figure 1.6 gives a flow sheet diagrams for the manufacture of plain yogurt.

Fruit-flavored yogurt may have fruit added on the bottom of plain or sweetened yogurt base or may have fruit blended throughout. Figure 1.7 gives process flow diagram for blended style yogurt.

Other types of yogurt are Greek style yogurt (Kilara and Chandan, 2013a), aerated yogurt, frozen-yogurt, and yogurt smoothies. Greek style yogurt has now become popular in the United States accounting for approximately 40% of the total yogurt market. It contains twice as much protein as normal yogurt. It is prepared from plain yogurt by centrifugal removal of part of the whey. The concentrated product is then blended with sugar and fruit preparations and flavors. A fruit-on-the bottom variant of Greek yogurt is also popular.

Yogurt products now are supplemented with prebiotics, probiotics, and other functional ingredients. Prebiotics are nondigestible food ingredients that improve the host's health by selectively stimulating the growth and/or activity of the beneficial bacteria of the colon. Probiotics are live organisms introduced into the gastrointestinal system of humans to improve the balance or metabolic activity of beneficial organisms. Functional ingredients such as plant sterols, omega fatty acids, antioxidants are ingredients shown by clinical trials to promote health, prevent disease, or help in the treatment of certain disorders.

Cultured Buttermilk

Cultured milk is obtained from pasteurized skim or part skim milk cultured with lactococci and aroma producing bacteria leuconostocs (White, 2013). Table 1.7 shows typical formulation for cultured buttermilk.

Table 1.7. Typical Formulation of Cultured Buttermilk and Cultured (Sour) Cream

Product	Milk Fat (%)	Milk Solids-Not-Fat (%)	Salt (%)	Sodium Citrate (%)
Buttermilk (nonfat)	0.1	10.3	0.18	0.1
Buttermilk (low fat)	1.0–1.2%	10.0	0.18	0.1
Sour cream (regular)	18.5	9.0–10.0	0	0

Source: Adapted from Chandan (1997). Reproduced with permission of AACC.

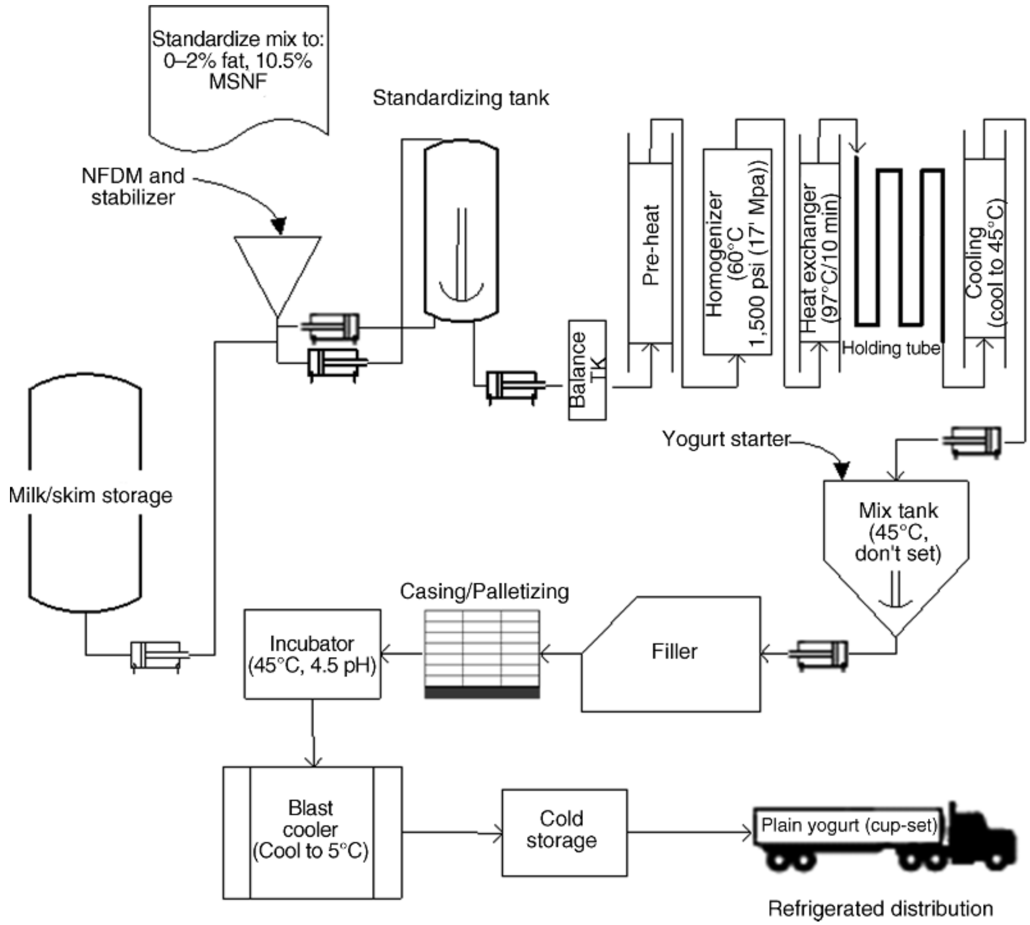

Figure 1.6. Flow sheet diagram for the manufacture of cup-set plain yogurt. From O'Rell and Chandan (2013). Reproduced with permission of John Wiley & Sons.

The product is bottled in paper/plastic containers. Figure 1.8 illustrates the process flow diagram for cultured buttermilk.

Sour/Cultured Cream

Sour/cultured cream manufactured by culturing pasteurized cream with lactococci and aroma producing bacteria, leuconostocs has butter-like aroma and flavor (Born, 2013). Table 1.7 gives typical formulation for sour cream. Crème Fraiche resembles sour cream, except it contains up to 50% fat as compared to 18% fat in sour cream and has a higher pH of 6.2–6.3 (Goddik, 2012). Cultured cream is used in making dips.

Figure 1.9 gives the process for manufacture of sour/cultured cream.

Culture-Containing Milks

Culture-containing milks are seeded but unfermented milks delivering significant doses of probiotic microorganisms (Vedamuthu, 2013). The product is based on pasteurized and chilled low-fat milk to which a concentrate of *Lactobacillus acidophilus* culture has been incorporated to deliver a minimum of one million organisms per milliliter. In this case, the growth of the culture is intentionally avoided to preserve the fresh taste of milk. Accordingly, the product is maintained at

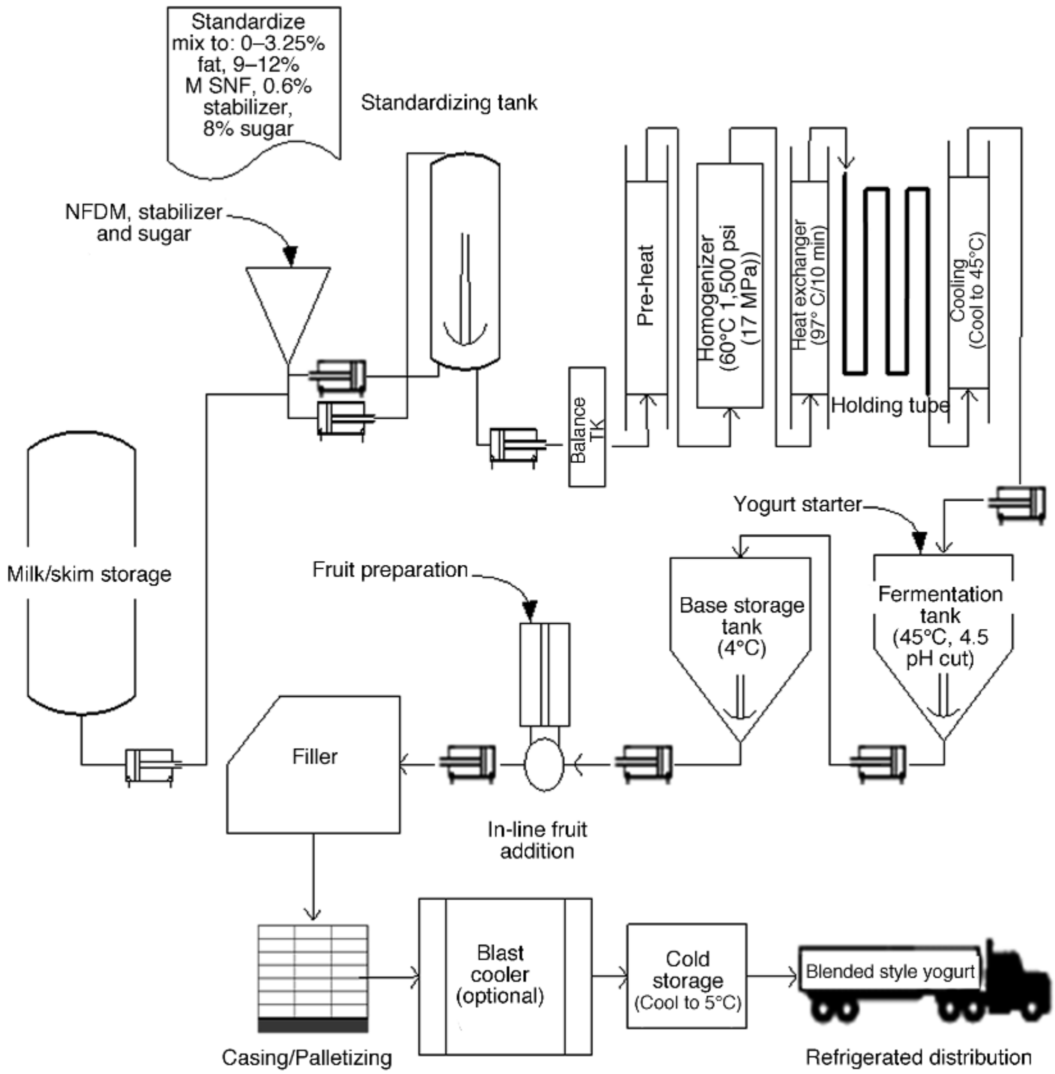

Figure 1.7. Flow sheet diagram for the manufacture of blended style yogurt. From O'Rell and Chandan (2013). Reproduced with permission of John Wiley & Sons.

refrigeration temperature at all times with a shelf life of 2–3 weeks. Several probiotic organisms like Bifidobacteria, *L. delbrueckii* subsp. *bulgaricus, Sterptococcus thermophilus or Lactobacillus casei* may be included. With the rise of yogurt and yogurt products in the market place, the culture-containing milks have lost popularity.

Scandinavian and Eastern European Fermented Milks

Scandinavian and Eastern European fermented milk have a distinctive flavor and texture. They are generally characterized by a ropy and viscous body. *Villi*, a fermented milk of Finland is cultured with *Lactococcus*

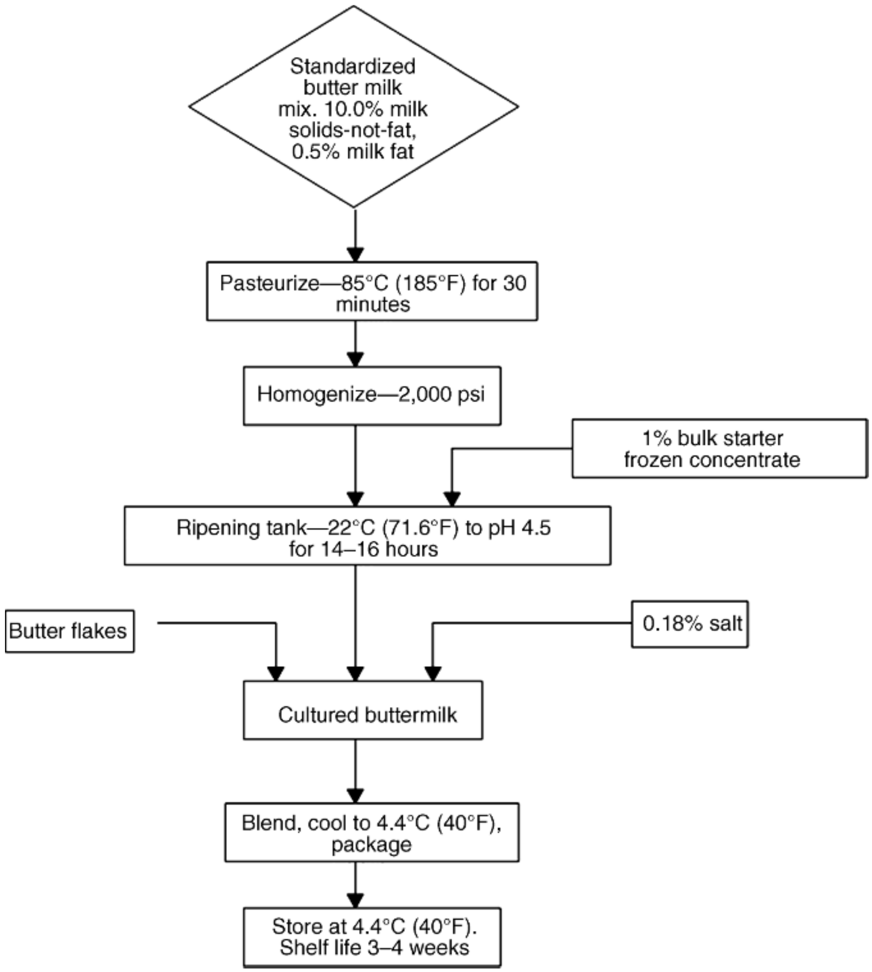

Figure 1.8. An outline of manufacturing cultured buttermilk.

lactis subsp. *lactis, Leuconostoc mesenteroides* subsp. *cremoris* and a fungus *Geotrichum candidum.* The cream layer traps the fungus giving a typical musty odor to the product (Kahala and Joutsjoki, 2012). The fermentation process also elaborates mucopolysaccharides imparting ropiness and viscosity to the product.

Ymer is a Danish product with characteristic high protein (5–6%) and pleasant acidic flavor with buttery notes. The traditional process involves removal of whey by draining curd after fermentation or by inducing separation of whey by heating curd followed by its removal. It is cultured with mesophilic culture consisting of a blend of *L. lactis* subsp. *lactis* biovar, *diacetylactis*, and *Leuconostoc mesenteroides* subsp. *cremoris.*

Skyr is another Scandinavian product. In Iceland, this product is obtained by fermenting skim milk with yogurt culture and a lactose-fermenting yeast. A small amount of rennet may be used to develop heavier body. Skyr has a flavor profile consisting of lactic acid, acetic acid, diacetyl, acetaldehyde, and ethanol.

Kefir is popular fermented milks in Russia, Eastern Europe, and certain Asian countries. In addition to lactic fermentation, this product employs yeast fermentation as well. Thus, a perceptible yeast aroma, and

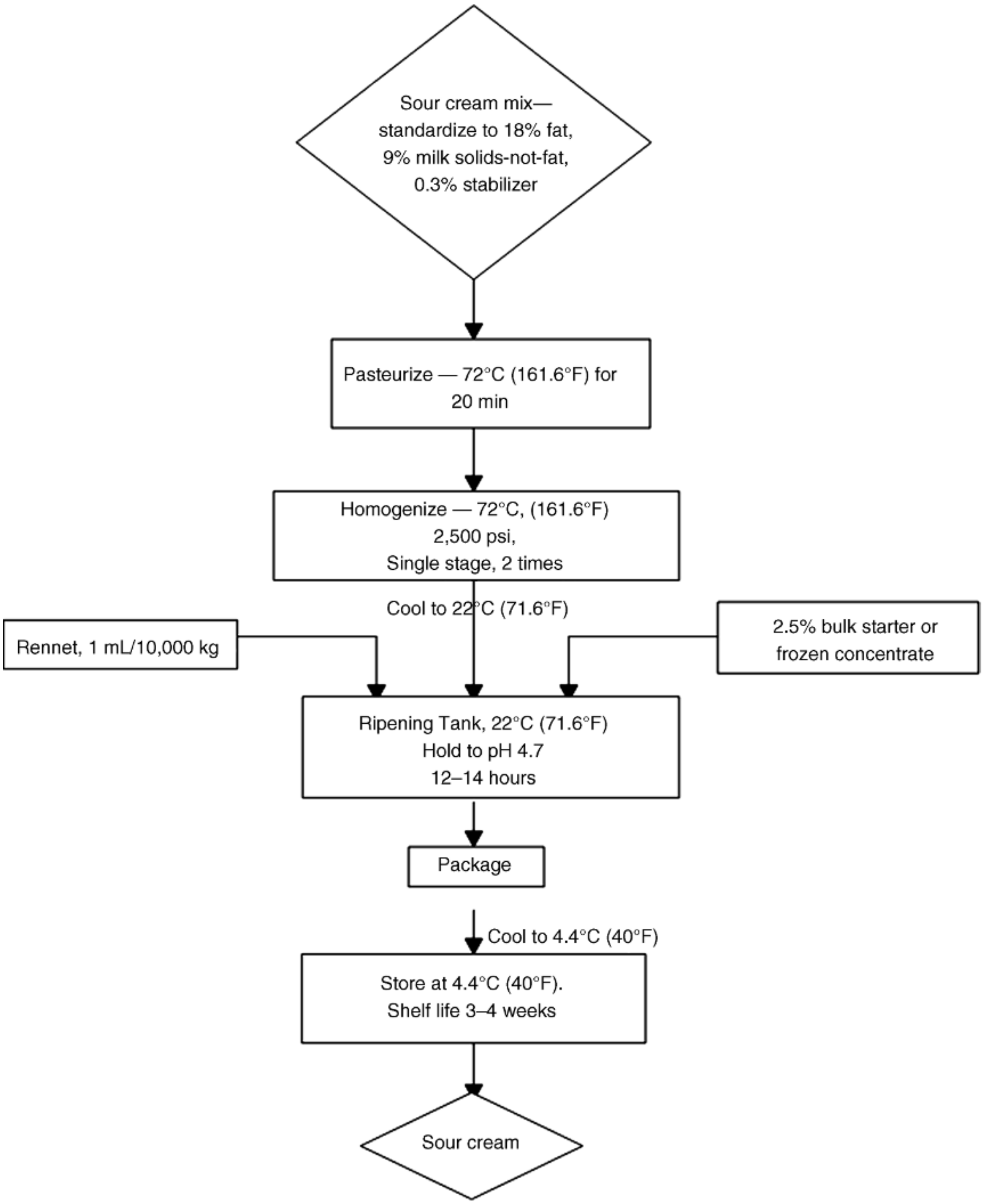

Figure 1.9. A flow diagram for sour cream manufacture.

alcohol content characterize these products. Also, a fizz is noticed due to production of carbon dioxide as a result of yeast growth. Kefir utilizes natural fermentation of cow's milk with kefir grains. Kefir grains are a curd-like material, which is filtered off after each use and reused for inoculation of the next batch. Kefir grains contain polysaccharides and milk residue embedded with bacteria *Lactobacillus kefir*, *Lactobacillus kefirogranum* and species of leuconostocs, lactococci, and lactobacilli. Along with bacteria, the grains contain yeasts including *Saccharomyces kefir, Candida kefir*, and *Torula species*.

Koumiss is obtained from mare's milk or cow's milk, using a more defined culture containing *L. delbrueckii* subsp. *bulgaricus*, *Lactobacillus acidophilus* and yeasts belonging to genera Torula, Torulopsis, Saccharomyces, and Candida (Zsang and Zsang, 2012). This therapeutic product has perceived health benefits.

Fermented Milk and Their Products of Middle East

Laban and its variants are reviewed by Beal and Chammas (2012). Laban rayeb is prepared at home by pouring raw whole milk in clay pots and allow the fat to rise at room temperature. The top cream layer is removed and partially skimmed milk is allowed to undergo spontaneous fermentation. Some variations of the product exist. One is called laban khad, which is fermented in a goat pelt. The other is named Laban zeer, which is distinctly fermented in earthenware pots. The organisms responsible for fermentation are thermophilic lactobacilli in summer season and mesophilic lactococci in winter season (Vedamuthu, 2013).

Kishk is obtained from Laban zeer. Wheat grains are soaked, boiled, sun dried, and ground into powder. The blend of wheat and Laban zeer is allowed to ferment further for another 24 hours and portioned into small lumps and sun dried. The dried Kishk has 8% moisture and 1.85% lactic acid. After proper packaging, its shelf life is of the order of several years. Kishk may contain spices. Labneh is prepared by concentrating fermented milk after fermentation process is completed. Milk is fermented with yogurt culture and then concentrated using Quarg separator. This product contains 7–10% fat. A processing procedure for industrial production of Lebaneh (resembling Greek yogurt) is given in another publication (Kilara and Chandan, 2013b). Zabady is an Egyptian product obtained by fermenting milk, which has been concentrated by boiling and then fermented with yogurt culture. Further concentration of milk solids is achieved by heating it and separating the whey.

Fermented Milk Products of South Asia

Dahi is the most common fermented milk in South Asia (Aneja et al., 2002). Also called curd, dahi is a semisolid product obtained from heat treated and cooled buffalo milk or a mixture of cow and buffalo milk by souring natural or otherwise, by a harmless lactic acid or other bacterial culture. A mixed culture containing *L. lactis* subsp. *lactis, L. lactis* subsp. *diacetilactis*, *or Leuconostoc* species, *L. lactis* subsp. cremoris in the ratio of 1:1:1 may be used. In addition, *S. thermophilus* may be a component of dahi culture.

For detailed discussion on the manufacture of yogurt and fermented milks, the reader is referred to the book by Chandan and Kilara, 2013). Chapter 19 in this book contains additional discussion on various fermented milks in the world.

CHEESE AND CHEESE PRODUCTS

Cheese connotes transformation and preservation of vital milk constituents from fluid form to semisolid or solid form. There are at least 400 cheese varieties. The main milk components (proteins, fat, and minerals) are concentrated and protected from rapid deterioration by spoilage microorganisms. Cheese is therefore a concentrated milk food. It provides sound nutrition, variety, convenience of use, portability, food safety, and novelty of flavors and textures to the consumer. Cheese and cheese products are consumed as such or are used as ingredients in entree, side dishes, and ready-to-eat snacks. These products are designed to be consumed as a spread, as slices in sandwiches and function as a dip or topping on snacks. The science, technology, and applications of major varieties of cheese are discussed in recent publications (Law and Tamime, 2010; Chandan and Kapoor, 2011a,b; Fox and Guinee, 2013; Chandan, 2014).

Natural Cheese

Natural cheese is made directly from milk (or whey). It is made by coagulating or curdling milk, stirring and heating the curd, draining off the whey and collecting or pressing the curd. Desirable flavor and texture are

Table 1.8. Typical Composition of Natural and Process Cheeses

Product	Water (%)	Fat (%)	Protein (%)	Lactose (%)	Ash (%)
Cottage cheese curd	79.8	0.4	17.3	1.8	0.7
Cottage cheese, creamed	79.0	4.4	12.5	2.7	1.4
Cream cheese	53.7	34.9	7.5	2.7	1.2
Neufchatel	62.2	23.4	10.0	2.9	1.5
Limburger	48.4	27.2	20.0	0.6	3.8
Camembert	51.8	24.3	19.7	0.5	3.7
Brie	48.4	27.7	20.7	0.5	2.7
Feta	55.2	21.3	14.2	4.1	5.2
Brick	41.1	29.7	23.3	2.8	3.2
Munster	41.8	30.0	23.4	1.1	3.7
Blue	42.4	28.7	21.4	2.2	5.1
Roquefort	39.5	30.6	21.5	2.0	6.4
Gorgonzola	36.0	32.0	26.0	1.0	5.0
Cheddar	36.8	33.1	24.9	1.3	3.9
Colby	38.2	32.1	23.7	2.6	3.4
Swiss	37.2	27.4	28.5	3.4	3.5
Gouda	41.5	27.4	25.0	2.2	3.9
Edam	41.4	27.8	25.0	1.6	4.2
Parmesan	29.2	25.8	35.7	3.2	6.0
Romano	30.9	26.9	31.8	3.6	6.7
Provolone	40.9	26.6	25.6	2.1	4.7
Mozzarella	54.1	21.6	19.4	2.2	2.6
Ricotta	71.7	13.0	11.3	3.0	1.0
Primost	13.8	30.2	10.9	36.6	NA
American process cheese	39.2	31.2	22.1	1.6	5.8
American process cheese food, cold pack	43.1	24.5	19.7	8.3	4.4
American process cheese spread	47.6	21.2	16.4	8.7	6.0
Swiss process cheese	42.3	25.0	24.9	2.1	5.8
Swiss process cheese food	43.7	24.1	21.9	4.5	5.8

Source: Adapted from Chandan and Kapoor (2011a,b) and Chandan (2014).

obtained in many cheeses by curing process at a specified temperature, humidity, and time period. Typical composition of various cheeses is shown in Table 1.8.

Natural cheeses are classified based on several criteria.

A. **Based on Moisture**

- Very high moisture cheeses contain 56–80% moisture. These are Cottage, Ricotta, Impastata, Neufchatel, and Cream cheeses.
- High moisture cheeses contain 46–55% moisture and include Mozzarella, Camembert, Brie, Pizza, and Blue cheeses.
- Medium moisture cheeses contain 34–45% moisture and include Edam, Gouda, Brick, Swiss, Cheddar and Provolone cheeses.
- Low moisture cheeses contain 13–33% moisture and include Romano, Parmesan, Dry ricotta, Mysost, and Gjetost cheeses.

B. **Based on Texture and Body**

- *Very hard cheeses* (grating) types and ripened by bacteria include Asiago old, Parmesan, Romano, Sapsago, and Spalen.
- *Hard cheeses*, ripened by bacteria and cheese *without* eyes include Cheddar, Granular or Stirred curd, and Caciocavallo. In addition, hard cheeses, ripened by bacteria but cheeses with eyes include Swiss, Emmental, and Gruyere.
- *Semisoft cheeses*, ripened mainly by bacteria include Brick and Muenster. Cheeses ripened by bacteria and surface microorganisms are Limburger, Port du Salut and Trappist. Cheeses ripened by blue mold in the interior include Roquefort, Gorgonzola, Blue, Stilton, and Wensleydale.
- *Soft cheeses* may be ripened or unripened. The ripened soft cheeses include Bel Paese, Brie, Camembert, Cooked, Hand, and French Neufchatel. The unripened soft cheeses include Cottage, Pot, Bakers, Cream, Quarg, Tvorog, Neufchatel, Mysost, Primost, and Ricotta.

C. **Based on Curing/Ripening and Type of Ripening**

- *The unripened cheeses* are made by coagulating milk with acid generated by culturing include cheeses like Cottage, Cream, Neufchatel, Quarg, and Tvorog. Cheeses made by direct acidification of hot milk include Latin American white cheeses and Paneer (Chandan, 2007c).
- *The ripened cheeses* are made by rennet addition and culturing.

Bacterial-ripened cheeses may be ripened by internal bacteria. They include Cheddar, Swiss, Colby, Edam, Gouda, Gruyere, Romano, Provolone, and Parmesan. However, the bacterial ripening may be seen on the surface of cheese body. Such cheeses are Brick, Trappist, Limburger, Muenster, Bel Paese, Monterey Jack, and Port de Salut.

The mold ripened cheeses may be internal or external ripened. The internally ripened mold cheeses are Blue, Roquefort, Gorgonzola, and Stilton. The surface ripened mild cheeses include Camembert and Brie cheeses.

Figure 1.10 gives an outline for manufacture of Cream cheese.

Figure 1.11 illustrates basic steps in the manufacture of Cheddar and Mozzarella cheeses.

Pasteurized Process Cheese

Pasteurized process cheese is the food prepared by comminuting and mixing, with the aid of heat, one or more cheese of the same or two or more varieties (except cream cheese, Neufchatel cheese, cottage cheese, creamed cottage cheese, cook cheese, hard grating cheese, semisoft part-skim cheese, part-skim spice cheese, and skim milk cheese for manufacturing) with an emulsifying agent into a plastic homogeneous mass. Heating is at not less than 65.5 °C (150 °F) and for not less than 30 seconds. The moisture content is required not to exceed 1% more than constituent natural cheeses, but cannot exceed 43%.

Process cheese is a pasteurized blend of American cheeses of different ages. It comes in different flavors. American process cheese has mild Cheddar flavor. Sharp American has sharp or aged Cheddar flavor. American Swiss has mild Swiss flavor. Consistency of process cheese is relatively semifirm, creamy, and smooth as compared to natural cheese counterparts. Functionalities available are sliceability, extra-melt (melting easily on heating, does not thicken and can withstand high temperature hold for long periods), and slow melt (maintains shape at high temperature). It may be flavored with seasonings. Moisture content is 40% maximum and fat in dry matter is 50% minimum. Figure 1.12 illustrates the main steps involved in the production of process cheese, loaf, and slices.

Pasteurized Process Cheese Food

Pasteurized process cheese food is similar to pasteurized process cheese, except it must contain moisture not exceeding 44%, and fat content is not less than 23%. It contains optional dairy ingredients: cream, milk, skim milk, buttermilk, cheese whey solids, anhydrous milk fat, and skim milk cheese for manufacturing. The pH is adjusted to not below 5.0 with vinegar, lactic acid, citric acid, phosphoric acid, and acetic acid. It cannot contain more than 3% emulsifying agents, and 0.2% sorbic acid. It is obtained by blending American cheeses of different ages with nonfat dry milk and whey and other permissible ingredients, followed by pasteurization. It melts quickly to give a smooth liquid. Cold product can be sliced easily. Major uses include entrees, Au Gratin potatoes, sandwiches, and Mexican dishes. It may be

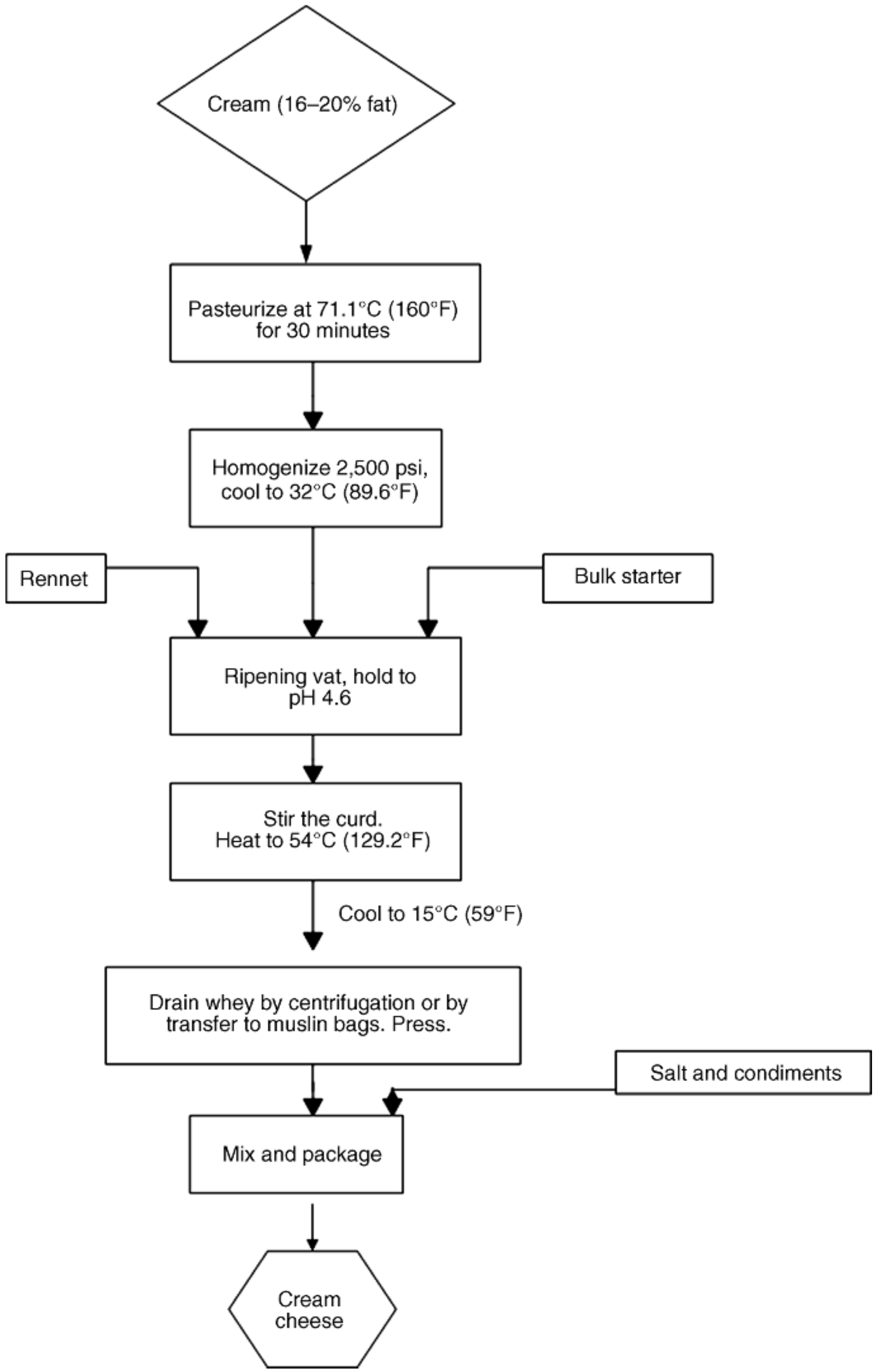

Figure 1.10. An outline for manufacturing cream cheese.

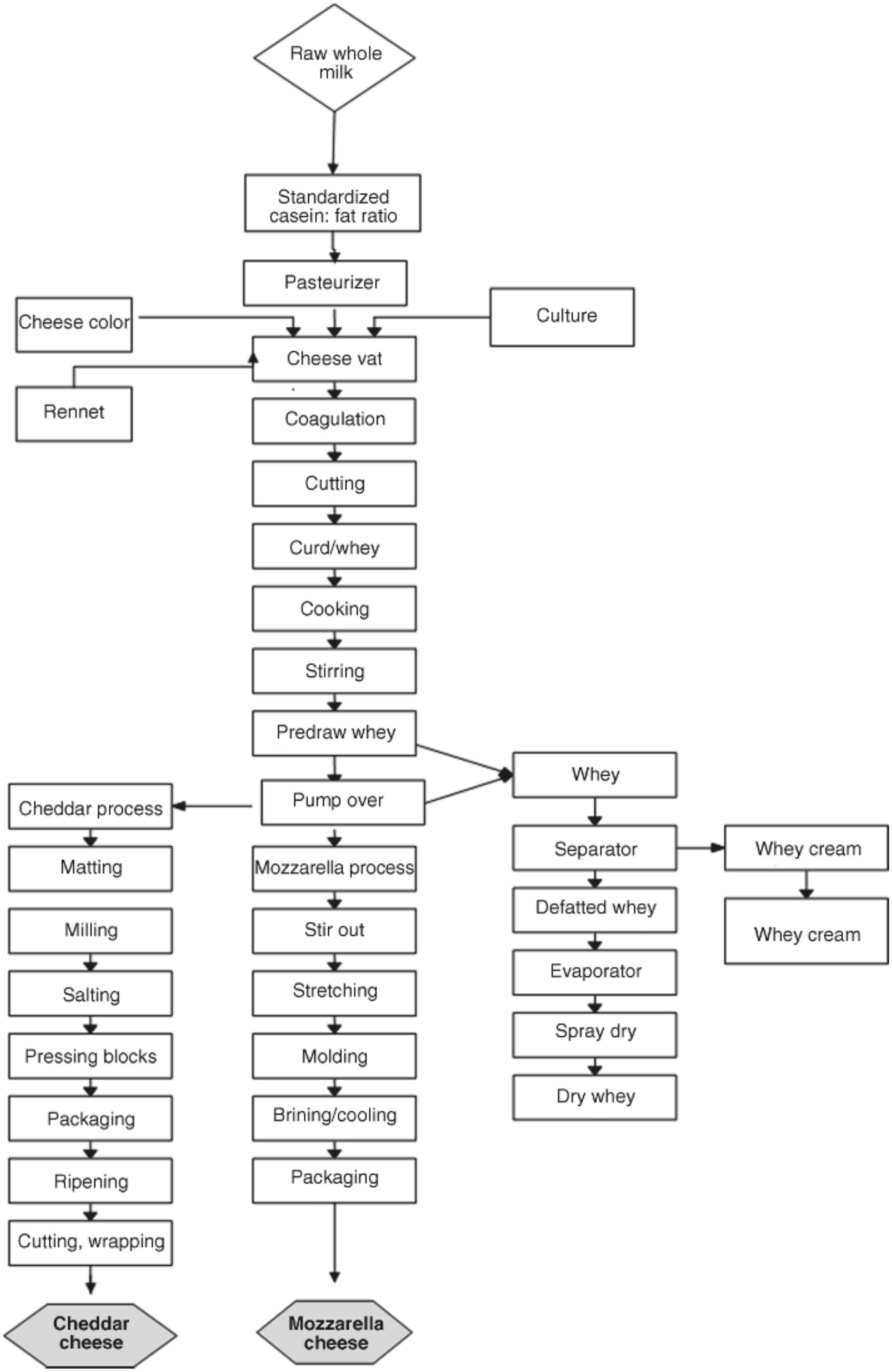

Figure 1.11. An outline of natural cheese manufacture.

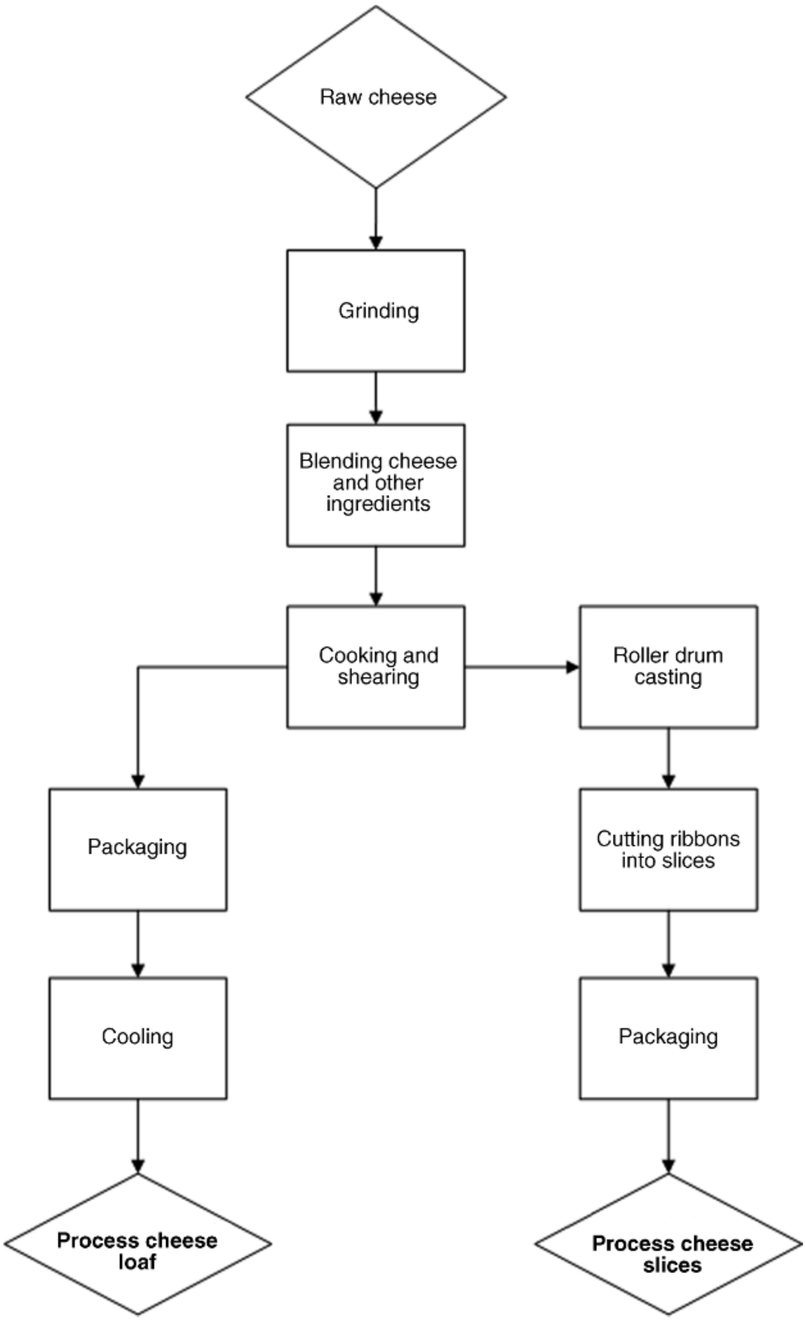

Figure 1.12. A manufacturing outline of processed cheese products.

flavored with seasonings, smoke, pimento, jalapeno, salami, pepperoni, etc. Moisture content is 44% maximum and fat in dry matter is 41% minimum.

Pasteurized Process Cheese Spread

Pasteurized process cheese spread contains even higher moisture and lower fat than process cheese food. It is more spreadable than cheese food. It may contain meat, vegetables, pimento, pineapple, or may be flavored with blue cheese, onion, etc. Its uses include snacks, deviled eggs, noodle casserole, meat balls, hot vegetables, sandwiches, sauces, and dressings.

It is similar to process cheese food, but is spreadable at 21 °C (69.8 °F). It has a moisture content of 44–60% and fat content is not less than 20%. It may contain optional dairy ingredients, emulsifying agents, and gums (<0.5%). Acids may be added to get pH to not less than 4.0. Sweetening agents may be used (sugar, dextrose, corn sugars). Sorbic acid (<0.2%) may be used a preservative.

Cold Pack Cheese (Club Cheese)

Cold pack cheese (club cheese) is a cold blend of American cheese or Swiss cheese and may be smoke flavored. It spreads easily and is used as an appetizer, snack, or dessert. The product involves blending without heating various cheeses. Only cheese from pasteurized milk is used. Its moisture content is the same as individual cheese; the fat content in dry matter is not less than 47% in most cheese except Swiss (not less than 43%) and Gruyere (not less than 45%). Cold pack cheese may contain acids to standardize pH to not below 4.5. Sorbic acid (<0.3%) can be used as preservative.

Cold Pack Cheese Food

Cold pack cheese food is prepared by comminuting and mixing (without heating) cheeses and other ingredients like cream, milk, skim, buttermilk, whey solids, and anhydrous milk fat. Acids may be added to pH not <4.5. Sweetening agents (sugar, corn solids) may also be used. Sorbic acid (0.3%) may be used as a preservative. Guar gum or xanthan gum may be used (0.5%). Moisture content cannot exceed 44% and fat content is not less than 23%. It may be smoke flavored. It is more spreadable than cold pack cheese. Its uses are the same as for cold pack cheese.

Cheese Powders

Spray-dried cheese powders are widely used as seasonings and flavorings in grain-based snacks. They are produced by macerating cheese, dispersing in water at 35–40% solids concentration, adding emulsifying salts, homogenizing, and spray drying. Foam spray drying is considered to give a superior flavored product with larger particle size. In addition to cheese, dry milk, whey, vegetable oils, salt, enzyme-modified cheese concentrate, color, and seasonings may also be incorporated in the ingredient.

Cheese powders can be packed in nitrogen atmosphere to give a longer storage life. Hard Italian cheese (namely, Parmesan) is dried after grating in tray or belt dryers in which dry hot air is circulated to reduce moisture to less than 6%. After cooling, the cheese is ground and packaged.

Enzyme-Modified Cheeses

(EMC's) are cheese flavor concentrates obtained by treating raw cheese curd with specific lipases and proteases along with fermentation with a cheese culture (Kilara and Chandan, 2011). It takes 1–3 days to develop flavor concentration of 10- to 20-fold as compared to ripened cheeses. Cheese paste is then heat treated to stop the biochemical reactions, and cooled. The EMC may be purchased as a paste or it may be blended with whey and dried as a spray-dried powder. It offers significant savings as a substitute of aged cheese in cheese flavored crackers and other bakery items. Also, it is an economical ingredient in process cheese manufacture.

Cheese Sauces

They are aseptically processed slurries and canned for convenient use as a dip or as a sauce on nachos, potatoes, etc. Typically, ingredients used are Cheddar cheese, skim milk, whey, buttermilk, vegetable oil, starch, sodium phosphate, salt, caseinate, citrate, color, lactic acid, stabilizers, emulsifier, and seasonings (Chandan, 1997).

WHEY PRODUCTS

Whey, the greenish-yellow liquid produced from the manufacture of cheese, contains about half of the solids of whole milk. Its composition depends largely on the variety of cheese being made. These solids are valuable additions to the functional properties of various foods, as

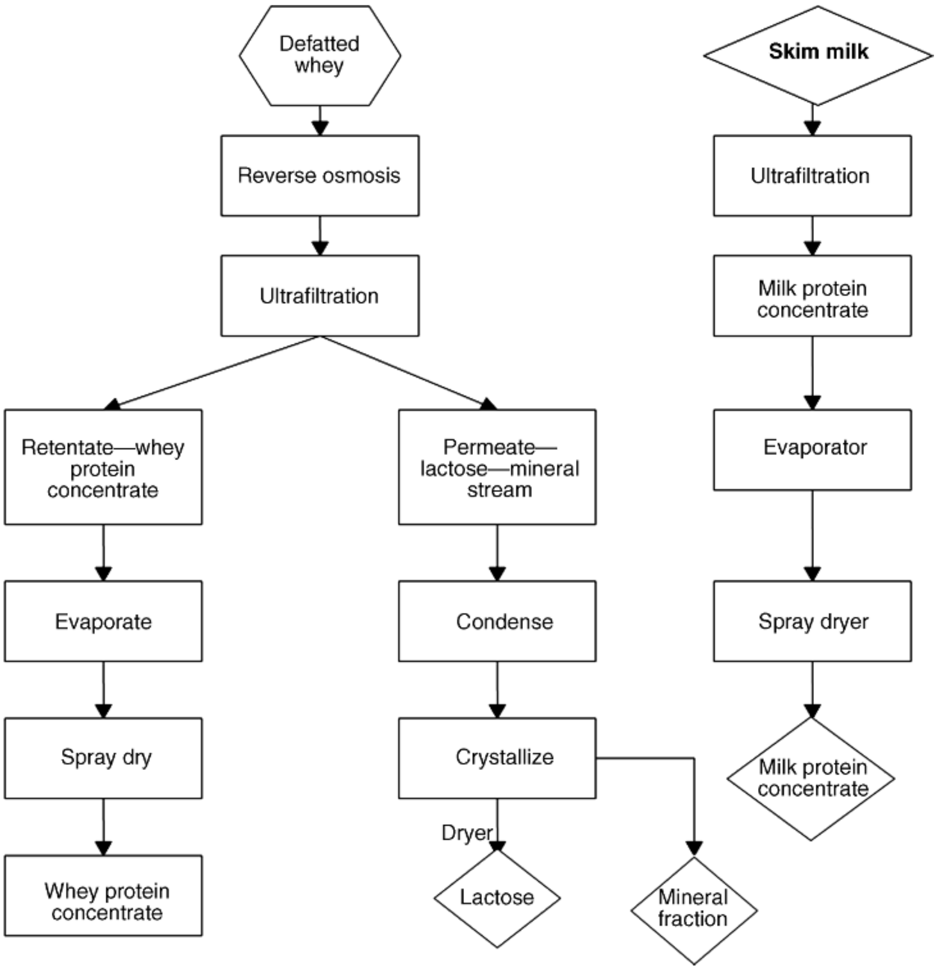

Figure 1.13. A flow sheet diagram for whey processing.

well as a source of valuable nutrients. The techniques of concentration, drying, and reverse osmosis recover all of the whey solids. Crystallization, ion exchange, and membrane systems such as ultrafiltration and electrodialysis effect fractionating whey into concentrates of protein, minerals, and lactose. These technologies are used for manufacturing important dry whey and fractionated whey ingredients for food processing (Huffman and Ferreira, 2011).

Figure 1.13 shows an outline for the manufacture of whey products and milk protein concentrate.

The proximate composition of dry whey, whey products, caseinates, and milk protein concentrates is shown in Table 1.9.

Dry Sweet Whey

Dry sweet whey is produced by drying of defatted fresh whey obtained from the manufacture of Cheddar, Swiss, and other cheeses. It contains all the constituents except water in the same relative proportion as in liquid whey.

Table 1.9. Proximate Composition of Dry Whey and Other Dairy Products

Product	Water (%)	Fat (%)	Protein (%)	Lactose (%)	Ash (%)
Dry sweet whey	4.5	1.1	12.9	73.5	8.0
Reduced lactose whey	4.0	2.5	22.0	55.0	16.5
Demineralized whey	4.0	2.2	13.0	76.8	4.0
Dry acid whey	4.3	1.0	12.3	71.3	11.1
Whey protein concentrate (34% protein)	3.5	4.0	34.5	51.0	7.0
Whey protein concentrate (50% protein)	3.5	4.0	50.5	36.0	6.0
Whey protein concentrate (80% protein)	3.5	6.0	80.5	5.0	5.0
Whey protein isolate	3.5	0.5	93.0	1.0	2.0
Acid casein	9.0	1.0	88.0	0.1	1.9
Rennet casein	11.0	1.0	85.0	0.1	2.9
Calcium caseinate	4.6	1.1	90.5	0.1	3.7
Sodium caseinate	4.6	1.1	90.4	0.1	3.8
Milk protein concentrate 75	5.5	1.5	75.0	19.5	7.5
Food grade lactose	0.5	0.1	0.1	99.1	0.2
Dairy minerals concentrate	10.0	1.0	8.0	1.0	80.0

Source: Adapted from Chandan (1997), Chandan and O'Rell (2013), Augustin and Clarke 2011, and Augustin et al. (2011).

Dry acid whey is similar to dry sweet whey but is produced by drying of fresh whey obtained from Cottage, Greek yogurt, and Ricotta cheese manufacture.

Spray drying of condensed whey converts sweet whey into a stable, nonhygroscopic, and noncaking product. In this process, high solids whey concentrate is spray dried to a free moisture content of 12–14%, causing lactose to take on a molecule of water and become crystallized. This causes whey solids to convert from a sticky, syrupy-like material into a damp powder with good flow characteristics. For drying acid cottage cheese whey, a commercial dryer combines spray drying, with through-flow continuous bed drying. The concentrate is spray dried in the hot air chamber to 12–15% moisture. The particles fall to a continuous, porous, stainless-steel belt where lactose undergoes rapid crystallization. Crystallization of lactose before final drying is necessary for drying acid whey. A belt conveys the product to another chamber where the whey is further dried by dehumidified air that moves through the porous bed.

Dry sweet whey is widely used in bakery products, dry mixes, process cheese foods and spreads, frozen desserts, sauces, meat emulsions, confections, soups, gravies, snack foods, and beverages. Dry acid whey has an additional functional attribute of providing acid flavor in certain foods and it imparts desirable textural properties to bakery items.

Fractionated Whey Products

Membrane technology is used for partial concentration (reverse osmosis), fractionation of solutes (lactose, minerals) from macromolecules like proteins, fat globules, colloidal particles, (ultrafiltration) and demineralization (ion-exchange, electro-dialysis) of whey, its fractions and milk. These processes produce highly functional ingredients and are commonly used in whey concentration and fractionation. The two are pressure-activated processes that separate components on the basis of molecular size and shape. Reverse osmosis is the process in which virtually all species except water are rejected by the membrane. The osmotic pressure of the feed stream in such a system often will be quite high. Consequently, to achieve adequate water flux rates through the membrane, such systems often use hydrostatic operating pressures of 5883.6 Kg/cm^2 (600 psi) or greater. Ultrafiltration refers to the process in which the membrane is permeable to relatively low molecular weight solutes and solvent (permeate), but is impermeable to higher molecular weight materials (retentate). The permeability and selectivity characteristics of these membranes can be controlled during the fabrication process so that they will retain only molecules above a certain molecular weight. Thus, ultrafiltration is essentially a fractionating process, while reverse osmosis is effectively a concentrating process.

One advantage of ultrafiltration over other processes is that by varying the amounts of permeate removed, a wide variety of protein concentrates, ranging up to 60% protein, can be obtained. Higher levels can be obtained by simultaneously adding fresh water and further concentrating by ultrafiltration. The permeate is used for manufacture of milk sugar, lactose, by condensing and crystallization. Lactose crystals are harvested and dried in a tumble dryer.

Reduced Lactose Whey

Reduced lactose whey is produced from whey by partial crystallizing out lactose and recovery of mother liquor by centrifugation. Lactose content of the dry product is 60% or less.

Reduced Minerals Whey

Reduced minerals whey is produced from whey by selective removal of a portion of minerals. Ash content of the dry product is 7% or less. Demineralization processes have helped in the development in an array of whey products. Excessive mineral content makes whey distasteful, and they can have an adverse effect on the physical properties of some foods. The two most widely used demineralization processes for whey are ion exchange and electrodialysis.

In the ion-exchange process, whey is passed through two containers, which are filled with special synthetic resins, which have the ability to exchange ions. In the first container, the special synthetic resins exchange hydrogen ions for cations in the whey. Here, the positive ions of the salt are captured and acid is formed by the release of hydrogen ions. The whey is then passed over the anion exchanger where hydroxyl ions are exchanged for negative ions of the salt, and water is formed. When the mobile ions of the resins are completely replaced by other ions, the resin must be regenerated for further use. This is done by passing an acid (hydrochloric) solution through the cationic exchanger, and a basic solution (sodium chloride) through the anionic exchanger.

Electrodialysis, a combination of electrolysis and dialysis, is the separation of electrolytes, under the influence an electric potential through semipermeable membranes. The driving force is an electric field between the anode (positively charged) and the cathode (negatively charged). Between the anode and the cathode, a number of ion-selective membranes are placed which are permeable only to anions or cations. Every other membrane has a positive charge repelling positive ions and allowing negative ions to pass, and in between there is a negatively charged membrane doing just the opposite.

In principle, whey is pumped through every second space between two membranes, and a solution of sodium chloride (cleaning solution) is pumped through the compartments between the whey streams. The ions move from the whey stream into the cleaning solution where they are retained, because they cannot move any further. The cleaning solution contains minerals, acid, some lactose, and small nitrogenous molecules. The membranes are cleaned chemically. Protein molecules remain in the fluid while the minerals are removed. The process results in a protein concentrate.

Lactose

Lactose is crystallized from condensed whey or from permeate (50–60%, solids) obtained by ultrafiltration fractionation of milk or whey. The supersaturated solution is cooled under specific conditions to crystallize lactose. Lactose crystals are harvested and washed to remove the mother liquor and dried. Crude lactose obtained this way contains approximately 98% lactose. Edible and USP grades are produced from crude lactose by protein precipitation, decolorization with activated carbon and subsequent demineralization. Lactose is further refined by recrystallization, followed by spray drying.

Whey Protein Concentrates and Isolates

Whey protein concentrates are products derived from whey by removal of minerals and lactose. The process of protein concentration utilizes ultrafiltration, electrodialysis, and ion-exchange technologies. On dry basis, the protein concentrate contains a minimum of 25% protein. Whey protein isolate contains at least 92% protein.

Whey protein concentrate of 34% protein is commonly used as a stabilizer in yogurt, bakery mixes, dietetic foods, infant foods, and confections. Its water binding, fat-like mouthfeel, and gelation property is particularly useful in these products. Whey protein concentrate of 50% or 80% protein offers distinct functional attributes. It is especially suited for use in nutritional drinks, soups, bakery, meat, dietary foods, and protein fortified beverages. It gives clear suspensions over a wide pH range and has a bland flavor. Some applications require undenatured ingredients to maximize water-binding capacity during food processing. It is also available in gel-forming version.

Chapter 15 of this book gives details of various aspects of whey and whey products.

Other Dry Milk Products

In this category are products such as casein, caseinates, and milk protein concentrates.

Casein and Caseinates

Casein represents products obtained from pasteurized skim milk by precipitation of casein fraction of milk protein using an acid, followed by drying. This gives acid casein. Casein derived from the action of rennet (chymosin) is called rennet casein. Micellar casein is also commercially available. They all have distinctive functional characteristics (Augustin et al., 2011).

Caseinates are derived from casein by treatment with a suitable alkali. Casein is basically insoluble in water, whereas caseinates are easily dispersible. Acid casein is produced by precipitation of skim milk with hydrochloric acid, sulfuric acid, acetic acid, or lactic acid at pH 4.6. Acid casein is neutralized to pH 6.7 with sodium hydroxide for the production of sodium caseinate. Similarly, potassium hydroxide and calcium hydroxide yield potassium and calcium caseinates, respectively.

Milk Protein Concentrate

Milk protein concentrate is obtained by ultrafiltration of skim milk and subsequent spray drying. Protein content varies according to the application in dairy products. An outline for the manufacture of milk protein concentrate is also shown in Fig. 1.13.

REFRIGERATED DAIRY DESSERTS/SNACKS

This category includes puddings, custards, cheese cake, and other products sold in refrigerated form. They are discussed in Chapter 17.

ICE CREAM AND FROZEN DESSERTS

Ice cream is a food produced by freezing, while stirring, a pasteurized mix consisting of ingredients defined by Food and Drug regulations. Ice cream is a frozen blend of air, water, milk fat, milk solids-not-fat, sweeteners, stabilizers, emulsifiers, flavorings such as fruits, nuts and chocolate chips, and coloring materials. Regular ice cream must contain at least 10% fat before the addition of bulky flavors and must weigh at least 4.5 pounds/gallon. There are other products in frozen desserts category (Kilara and Chandan, 2007, 2013a). Frozen custard or French ice cream must contain at least 10% milk fat and 1.4% egg yolk solids. Sherbet contains 1–2% milk fat, higher sweetener level than ice cream and must weigh not less than 6 pounds/gallon. Sherbet is commonly flavored with fruit and fruit juices. Sorbet and water ice resemble sherbet but contains no dairy ingredients. Frozen yogurt is made of milk/skim milk, nonfat dry milk/condensed milk, cream, yogurt, sweeteners and corn syrup solids, stabilizers emulsifiers, and flavorings.

All frozen dessert mixes are formulated, processed, and extruded through ice cream freezers to deliver desirable consumer attributes of flavor, texture, and shelf life.

Frozen desserts may be labeled as low fat or nonfat depending on their fat contribution per serving of ½ cup (65–70 g). Products containing no more than 3 g fat/serving are classified as low fat. Nonfat products contribute less than 0.5 g fat/serving. Reduced fat products provide less than 25% lower fat than reference product.

Dairy ingredients constitute 50–55% of the total solids of ice cream and related frozen desserts. Choice of dairy ingredients and formulation of an ice cream mix are determined by the regulatory standards, desired quality of the frozen dessert, marketing strategy, consumer demand, relative prices, and availability of the ingredients in a given locality.

The milk products constitute the most important ingredients because they furnish the basic ingredients for a good quality ice cream. Variables related to dairy ingredients exert a profound influence on flavor, body, and texture of the frozen product. The nature and intensity of overall ice cream flavor is a function of the flavor quality of individual constituents and subsequent processing treatment accorded the ice cream mix. Flavor defects in the ingredients cannot be alleviated during ice cream making. Actually, flavor problems could be compounded as a consequence of negligent processing procedures.

The body or consistency of ice cream is related to mechanical strength of the mix and its resistance to melting. Heat shock resistance is dependent on the nature and concentration of stabilizer–emulsifier system

Table 1.10. Typical Formulation of Ice Cream Mix and Sherbet Mix

Component	Economy Ice Cream	Regular Ice Cream	Premium Ice Cream	Super Premium Ice Cream	Low-Fat Ice Cream	Sherbet
Milk fat (%)	10.1	10–12	12	16–18	3	1.5
Nonfat milk solids (%)	7.5	7.5–10	9	9–10.5	13	3.5
Whey solids (%)	2.5	0–2.5	0–2	0	0	
Sucrose (%)	0	6–12	7–8	15.5	9	23
55 DE* high fructose corn syrup (%)	7.6–9.0	0–6	4–5	0	0	0
36 DE* corn syrup solids (%)	9–11.4	6	9	0	9	7
Stabilizer (%)	0.3	0.25	0.35	0–0.12	0.6	0.3
Emulsifier (%)	0.1	0.1	0.25	0.1	0.2	0.1
Total solids (%)	37–40	38–40	40.50	40–42	34.8	35.4

Source: Adapted from Kilara and Chandan (2007).
*DE: dextrose equivalent.

used. The texture of ice cream depends upon the size, shape, number, and arrangement of air cells, fat globules, ice crystals, and ratio of frozen and liquid water in ice cream.

An important variable related to foam formation as a result of aeration of ice cream mix during freezing process is called overrun. Overrun is the volume of ice cream obtained over and above the volume of mix used. For instance, if the volume of ice cream is double of the ice cream mix, the overrun is 100%.

Mellorine is similar to ice cream except that it contains no milk fat, which is substituted with vegetable fat in the formulation.

Table 1.10 shows typical formulation for ice cream and frozen dessert mixes.

For the manufacture of ice cream and frozen desserts, the liquid ingredients are blended in a processing vat. The dry ingredients are added to the liquid blend through a powder funnel or high shear mixing equipment. The mix is pasteurized at 79.4 °C (175 °F) for 25 seconds and homogenized at 57.2–62.8 °C (135–145 °F) at 2000 psi, first stage and 500 psi, second stage. The mix is then cooled to less than 4.4 °C (40 °F) and extruded through an ice cream freezer at −6 °C (−21.1 °F). It is packaged and hardened at −30 to −35 °C (−22 to −31 °F).

Soft Frozen Dairy Products

These products constitute soft-serve ice cream, which is served immediately from the ice cream freezer. Milk shakes also belong to this category. These products are generally lower in fat than their hard-pack counterparts. Fat substitutes based on starch, pectin, and whey proteins along with gums, cellulose gel, microcrystalline cellulose, maltodextrin, sodium caseinate, etc., provide body and texture to the product. Serum solids content varies from 10 to 16% and the total solids vary from 30 to 35%. In comparison with hard ice cream, soft frozen desserts contain higher serum solids and lower sweetener level. The draw temperature is also lower −6.7 to −7.8 °C (18–20 °F) for soft serve products.

Chapter 16 describes in detail the manufacture of ice cream and frozen desserts.

NUTRIENT PROFILES OF DAIRY FOODS

Milk and milk products are composed of unique nutrients providing complete nutritional needs of the neonate. Most nutrition experts recognize milk and milk products as vital constituents of a balanced diet for humans of all ages. Chapter 18 of this book is dedicated to the nutrition and health aspects associated with milk and dairy foods.

Tables 1.11–1.13 show nutrient profiles relative to fluid milk and cream products, yogurt, buttermilk, sour cream, butter, and certain cheeses.

The contribution of crucial nutrients is corroborated by the data shown in the Tables 1.11–1.13. Among other

Table 1.11. Typical Nutrient Profile (per 100 g) of Fluid Milk and Cream Products

Nutrient	Nonfat/Fat Free/ Skim Milk with Added Vitamins A and D	Low-Fat Milk, 1% Fat with Added Vitamins A and D	Reduced Fat Milk, 2% with Added Vitamins A and D	Chocolate Whole Milk, with Added Vitamins A and D	Half and Half, 10.5% Fat	Light/Coffee Cream, 18% Fat	Whipping Cream, Heavy, 36% Fat
National Nutrient Data No.	01085	01082	01079	01102	01049	01050	01053
Moisture (%)	90.84	89.92	89.21	82.30	80.57	73.75	57.71
Calories (kcal)	34	42	50	83	130	195	345
Protein (g)	3.37	3.37	3.30	3.17	2.96	2.70	2.05
Total fat (g)	0.08	0.97	1.98	3.39	11.50	19.31	37.00
Saturated fatty acids (g)	0.056	0.633	1.257	2.104	7.158	12.020	23.032
Monounsaturated fatty acids (g)	0.022	0.277	0.560	0.990	3.321	5.577	10.686
Polyunsaturated fatty acid (g)	0.003	0.035	0.073	0.124	0.427	0.717	1.374
Cholesterol (mg)	2	5	8	12	37	66	137
Carbohydrate (g)	4.96	4.99	4.80	10.34	4.30	3.66	2.79
Total dietary fiber (g)	0	0	0	0	0	0	0
Calcium (mg)	122	125	120	112	105	96	65
Iron (mg)	0.03	0.03	0.02	0.24	0.07	0.04	0.03
Potassium (g)	156	150	140	167	130	122	75
Sodium (mg)	42	44	47	60	41	40	38
Vitamin A (IU)	204	196	190	98	354	656	1470
Thiamin (mg)	0.045	0.020	0.039	0.037	0.035	0.032	0.022
Riboflavin (mg)	0.182	0.185	0.185	0.162	0.149	0.148	0.110
Niacin (mg)	0.094	0.093	0.092	0.125	0.078	0.057	0.039
Ascorbic acid (mg)	0	0	0.2	0.9	0.9	0.80	0.60
Common measure	1 cup = 245 g	1 cup = 244 g	1 cup = 244 g	1 cup = 250 g	1 fl oz. = 30.2 g 1 tbsp = 15 g 1 cup = 242 g	2 tbsp = 1 fl oz. = 30 g	1 tbsp = 15 g 1 cup = 238 g = 2 cups whipped

Source: Reproduced from United States Department of Agriculture (2013).

Table 1.12. Typical Nutritional Profile of Yogurt (100 g Basis)

Nutrient	Yogurt Nonfat, Plain	Yogurt, Greek, Nonfat, Plain	Yogurt, Low-Fat, Plain	Plain, Whole Milk	Fruit-Flavored, Nonfat	Fruit-Flavored, Low-fat Vitamin D Fortified	Light, Nonfat, Vanilla
National Nutrient Data No.	01118	01256	01117	01116	43261	01216	01203
Moisture, %	85.23	85.10	85.07	87.90	75.40	75.30	74.10
Calories (kcal)	56	59	63	61	95	99	105
Protein (g)	5.73	10.19	5.25	3.47	4.40	3.98	4.86
Total fat (g)	0.18	0.39	1.55	3.25	0.20	1.15	1.41
Saturated fatty acids (g)	0.116	0.117	1.000	2.096	0.488	0.742	0.909
Monounsaturated fatty acids (g)	0.049	0.053	0.426	0.893	0.205	0.316	0.387
Polyunsaturated fatty acid (g)	0.005	0.012	0.044	0.092	0.030	0.033	0.040
Cholesterol (mg)	2	5	6	13	4	5	6
Carbohydrate (g)	7.68	3.60	7.04	4.66	19.00	18.64	18.60
Total dietary fiber (g)	0	0	0	0	0	0	0
Calcium (mg)	199	110	183	121	152	138	152
Iron (mg)	0.09	0.07	0.08	0.05	0.07	0.06	0.07
Potassium (g)	255	141	234	95	194	177	194
Sodium (mg)	77	36	70	46	58	53	58
Vitamin A (IU)	7	4	51	99	17	40	443
Thiamin (mg)	0.048	0.023	0.044	0.029	0.040	0.034	0.041
Riboflavin (mg)	0.234	0.278	0.214	0.142	0.180	0.162	0.180
Niacin (mg)	0.124	0.208	0.114	0.075	0.200	0.086	0.105
Ascorbic acid (mg)	0.9	0	0.8	0.5	0.7	0.6	0.7
Common measure	1 (6 oz) cup = 170 g 1 (8 oz) cup = 227 g	1 (6 oz) cup = 170 g	1 (4 oz) cup = 113 g 1 (6 oz)cup = 170 g 1 (8 oz) cup = 227 g	1 (4 oz) cup = 113 g 1 (6 oz) cup = 170 g 1 (8 oz) cup = 227 g	1 (4 oz) cup = 113 g 1 (6 oz) cup = 170 g 1 (8 oz) cup = 227 g	1 (4.4 oz) cup = 125 g 1 (6 oz) cup = 170 g 1 (5 oz) cup = 142 g	1 (6 oz) cup = 170 g 1 (8 oz) cup = 227 g

Source: Reproduced from United States Department of Agriculture (2013).

Table 1.13. Nutrient Profile of Some Dairy Products (100 g Basis)

Nutrient	Cultured Buttermilk, Low Fat	Sour/Cultured Cream	Butter, Salted	Cottage Cheese, Creamed 4% Fat	Cream Cheese	Cheddar Cheese	Mozzarella Cheese, Part Skim, Low Moisture
National Nutrient Data No.	01088	01056	01001	01012	01017	01009	01029
Moisture (%)	90.13	74.46	15.87	79.79	54.44	36.75	46.46
Calories (kcal)	40	193	717	98	342	403	302
Protein (g)	3.31	2.07	0.85	11.12	5.93	24.90	25.96
Total fat (g)	0.88	19.73	81.11	4.30	34.24	33.14	20.03
Saturated fatty acids (g)	0.548	11.507	51.368	1.718	19.292	21.092	10.877
Monounsaturated fatty acids (g)	0.254	5.068	21.697	0.778	8.620	9.391	4.850
Polyunsaturated fatty acid (g)	0.033	0.840	3.043	0.123	1.437	0.942	0.508
Cholesterol (mg)	4	52	215	17	110	105	54
Carbohydrate (g)	4.79	2.88	0.06	3.38	4.07	1.28	3.83
Total dietary fiber (g)	0	0	0	0	0	0	0
Calcium (mg)	116	110	24	83	98	721	731
Iron (mg)	0.05	0.17	0.02	0.07	0.38	0.68	0.25
Potassium (g)	151	141	24	104	138	98	95
Sodium (mg)	190	47	643	364	365	621	652
Vitamin A (IU)	47	576	2499	140	1343	1002	605
Thiamin (mg)	0.034	0.036	0.005	0.027	0.200	0.027	0.101
Riboflavin (mg)	0.154	0.172	0.034	0.163	0.125	0.375	0.329
Niacin (mg)	0.058	0.109	0.042	0.099	0.145	0.080	0.119
Ascorbic acid (mg)	1.0	0.9	0	0	0	0	0
Common measure	1 cup = 245 g	1 tbsp = 15 g	1 pat = 5 g, 1 tbsp = 14.2 g, 1 cup = 227 g	4 oz = 113 g, 1 cup (large curd) = 210 g, 1 cup (small curd) = 225 g	1 tbsp = 14.5 g, 1 tbsp whipped = 10 g, 1 cup = 232 g	1 cup diced = 132 g, 1 cup melted = 244 g, 1 cup shredded = 113 g	1 oz = 28.35 g, 1 cup diced = 132 g, 1 cup shredded = 113 g

Source: Reproduced from United States Department of Agriculture (2013).

vital functions, they provide significant quantities of calcium, protein, vitamins, and essential fatty acids. Furthermore, milk and dairy products are now gaining recognition as discrete functional foods or wellness foods in human diet.

Milk and dairy ingredients are now recognized for their role beyond conventional nutrition (functional attributes) in human health maintenance (Chandan, 2007b; Chandan and Shah, 2007).

QUALITY ASSURANCE

A successful dairy operation must manufacture safe and wholesome milk and dairy products. It is imperative to maximize customer satisfaction, minimize product loss, and comply with sanitary codes. The quality of the dairy product equates survival and growth of the business. Factors such as plant conditions, manufacturing practices, housekeeping, sanitary standards, personal hygiene, and work habits of employees and visitors assume critical importance in plant control of quality, product safety, personal safety, and financial integrity.

Good Manufacturing Practices

The plant must conform to good manufacturing practices as defined by the Food and Drug Administration. This regulation details various standards for floors, walls, doors and windows, lighting, ventilation, water supply, plant cleanliness, disposal of wastes, and sanitary personnel practices.

Hazard Control and Critical Control Points (HACCP)

HACCP is useful in safe manufacture of a food product. Defining critical control points helps to eliminate or control hazardous microorganisms or their toxins at any point during the entire production sequence. HACCP information is available in the USFDA publication "Pasteurized Milk Ordinance, 2011". The reader is referred to the website: http://www.cfsan.fda.gov/~ear/pmo03j-k.html#appk. Excerpts from the FDA document are given below to introduce the concept of HACCP to the readers.

HACCP is a management tool that provides a structured and scientific approach to the control of identified hazards. It is currently a voluntary program.

The HACCP concept enables those operating under and regulating under a HACCP plan to move to a preventive approach, whereby potential hazards are identified and controlled in the manufacturing environment that is prevention of product failure.

The following are the seven HACCP principles to be included in a HACCP Plan:

- Conduct a hazard analysis;
- Determine the Critical Control Points (CCPs);
- Establish critical limits;
- Establish monitoring procedures;
- Establish corrective actions;
- Establish verification procedures; and
- Establish record-keeping and documentation procedures.

Prerequisite Programs (PPs)

Prior to the implementation of a HACCP Plan, there is a requirement for dairy plants, receiving stations and transfer stations to develop, document, and implement written PPs. PPs provide the basic environment and operating conditions that are necessary for the production of safe, wholesome food. Complete, up-to-date process flow diagrams are required for all milk and milk products manufactured. Flow diagrams may be combined when processes, products, and hazards are similar.

HACCP is not a stand-alone program, but is part of a larger control system. PPs are the universal procedures used to control the conditions of the milk plant environment that contribute to the overall safety of the milk or milk product. They represent the sum of programs, practices, and procedures that must be applied to produce and distribute safe milk and milk products in a clean, sanitary environment. They differ from CCPs in that they are basic sanitation programs that reduce the potential occurrence of a milk or milk product safety hazard. Frequently, both CCPs and PPs control measures are necessary to control a food safety hazard.

HACCP may be implemented only in a facility that is constructed and operated to provide a sanitary environment. Milk plant, receiving station or transfer station premises, building construction, maintenance, and housekeeping shall be maintained in a manner sufficient to provide such an environment. These factors shall be controlled by effective milk plant, receiving station or transfer station programs or by PPs, as the milk plant, receiving station or transfer station chooses.

The following required PPs shall have a brief written description or checklist that the PPs can be audited against to ensure compliance. PPs shall include procedures that can be monitored; records that specify what is monitored; and how often it will be monitored. Each milk plant, receiving station or transfer station shall have and implement PPs that address conditions and practices before, during, and after processing. The PPs shall address safety of the water that comes into contact with milk or milk products or product-contact surfaces, including steam and ice; condition and cleanliness of equipment product-contact surface; prevention of cross-contamination from unsanitary objects and or practices to milk or milk products or product-contact surfaces, packaging material, and other food-contact surfaces, including utensils, gloves, outer garments, etc., and from raw product to processed product. Furthermore, PPs involve maintenance of hand washing, hand sanitizing, and toilet facilities; protection of milk or milk product, packaging material, and product-contact surfaces from adulteration with lubricants, fuel, pesticides, cleaning compounds, sanitizing agents, condensate, and other chemical, physical, and biological contaminants; proper labeling, storage, and use of toxic compounds; control of employee health conditions, including employee exposure to high risk situations, that could result in the microbiological contamination of milk or milk products, packaging materials, and product-contact surfaces; and, pest exclusion from the milk plant.

The milk plant, receiving station or transfer station shall monitor the conditions and practices of all required PPs with sufficient frequency to ensure conformance with those conditions and that are appropriate both to the milk plant, receiving station or transfer station and to the safety of the milk or milk product being processed. Each milk plant, receiving station or transfer station shall document the correction of those conditions and practices that are not in conformance. Devices, such as indicating and recording thermometers that are used to monitor PPs shall be calibrated to assure accuracy at a frequency determined by the milk plant, receiving station, or transfer station. Each milk plant, receiving station or transfer station shall maintain records that document the monitoring and corrections.

Hazard Analysis

Each milk plant, receiving station or transfer station shall develop, or have developed for it, a written hazard analysis to determine whether there are milk or milk product hazards that are reasonably likely to occur for each type of milk or milk product processed or handled by the milk plant, receiving station or transfer station and to identify the control measures that the milk plant, receiving station or transfer station can apply to control those hazards.

The hazard analysis shall include hazards that can be introduced both within and outside the milk plant, receiving station or transfer station environment, including hazards that can occur during handling, transportation, processing, and distribution.

A hazard that is reasonably likely to occur is one for which a prudent milk plant, receiving station or transfer station operator would establish controls because experience, illness data, scientific reports, or other information provide a basis to conclude that there is a reasonable possibility that, in the absence of these controls, the hazard will occur in the particular type of milk or milk product being processed. In evaluating what milk or milk product hazards are reasonably likely to occur, at a minimum, consideration should be given to microbiological contamination, parasites, chemical contamination, unlawful drug and pesticide residues, natural toxins, unapproved use of food or color additives, presence of undeclared ingredients that may be allergens, and physical hazards. Milk plant, receiving station or transfer station operators should evaluate product ingredients, processing procedures, packaging, storage, and intended use; facility and equipment function and design; and milk plant sanitation, including employee hygiene, to determine the potential effect of each on the safety of the finished milk or milk product for the intended consumer.

HACCP Plan

Every milk plant, receiving station or transfer station shall have and implement a written HACCP plan whenever a hazard analysis reveals one or more hazards that are reasonably likely to occur. A HACCP plan shall be specific to each location and milk or milk product. The plan may group similar types of milk and milk products together, or similar types of production methods together, if the hazards, CCPs, CLs, and procedures required to be identified and performed are essentially identical, provided that any required features of the plan that are unique to a specific milk or milk product or method are clearly delineated in the plan and are observed in practice. The HACCP plan includes complete up-to-date process flow diagrams for all milk and milk products manufactured. Flow diagrams may be combined when processes, milk and milk products, and hazards are similar. The plan requires:

All hazards that are reasonably likely to occur as identified in the hazard analysis specified above, and that must be controlled for each type of milk or milk product.

The CCPs for each of the identified hazards, including the appropriate CCPs designed to control hazards that could occur or could be introduced in the milk plant, receiving station or transfer station environment are listed. The procedures and the frequency with which they are to be performed that will be used to monitor each of the CCPs to ensure compliance with the CLs. Any corrective action plans that have been developed in accordance with the corrective action requirements and that are to be followed in response to deviations from CLs at CCPs should be included in the plan. Verification and validation procedures, and the frequency with which they are to be performed, are also included. Finally, a record keeping system that documents the monitoring of the CCPs in accordance with the record requirements must be instituted. The records shall contain the actual values and observations obtained during monitoring.

Sanitation controls may be included in the HACCP Plan. However, to the extent that they are monitored in accordance with the PPs, they need not be included in the HACCP Plan.

Corrective Actions

Whenever a deviation from a CL occurs, a milk plant, receiving station or transfer station shall take corrective action. Milk plants, receiving stations or transfer stations may develop written corrective action plans, which become a part of their HACCP plan(s). A corrective action plan that is appropriate for a particular deviation describes the steps to be taken and assigns responsibility for taking those steps, to ensure that no milk or milk product is allowed to enter commerce that is either injurious to health or is otherwise adulterated as a result of the deviation, or if such milk or milk product has entered commerce, it is expeditiously removed; and the cause of the deviation is corrected. Verification activities shall include the calibration of CCP process-monitoring instruments, verification also includes a review, including signing and dating, by an individual records that document to ensure that the records are complete and to verify that the recorded document values are within the CLs.

Validation of the HACCP Plan

Every milk plant, receiving station or transfer station shall validate that the HACCP plan is adequate to control hazards that are reasonably likely to occur. This validation shall occur at least once within 12 months after implementation and at least annually thereafter or whenever any changes in the process occur that could affect the hazard analysis or alter the HACCP plan.

Required Records

It is essential that milk plants, receiving stations, and transfer stations use consistent terminology to identify each piece of equipment, record, document, or other program throughout their written HACCP system. All records shall be retained at the milk plant, receiving station, or transfer station for perishable or refrigerated products, for at least 1 year after the date that such products were prepared, and in the case of frozen, preserved, or shelf-stable products, for two years after the date that the products were prepared or the shelf-life of the product, whichever is greater, unless longer retention time is required by other regulations.

Training and Standardization

Regulatory agency personnel responsible for the evaluation, licensing, and regulatory audits of facilities using the HACCP program will have specialized training in conducting HACCP system audits. Industry, State and Federal regulatory and listing personnel should be trained together.

HACCP Audits and Follow-up Actions

Audits shall be conducted of the milk plant, receiving station, or transfer station facility, and HACCP Program to ensure compliance with the HACCP System. The audit may be announced at the discretion of the auditor under certain circumstances, that is, initial audit, follow-up audit, new construction, pasteurizer checks, etc. When unannounced audits are conducted, the audits shall not be completed until appropriate milk plant personnel have had an opportunity to make all pertinent records available for review by the auditor.

After initial audit, the next audit is 30–45 days and at 4 months interval thereafter. Next audits are normally scheduled 6 months later. The regulatory agency has the discretion of auditing with greater frequency. In addition, compliance follow-ups are made to insure that the observed problems have been resolved.

Chapter 19 describes the sensory analysis techniques associated with quality assurance programs. Chapter 23 discusses in detail the management systems for safety and quality of milk and dairy products. Chapter 24 deals with the laboratory analysis of milk and dairy products.

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