DAIRY INGREDIENTS for FOOD PROCESSING

Ramesh C. Chandan and Arun Kilara
Editors

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Dairy Ingredients for Food Processing
Dairy Ingredients for Food Processing

Edited by
Ramesh C. Chandan
Arun Kilara
# Contents

*Contributors* vii  
*Preface* xi  

1. Dairy Ingredients for Food Processing: An Overview  
   *Ramesh C. Chandan*  
   3  

2. Chemical, Physical, and Functional Characteristics of Dairy Ingredients  
   *Stephanie R. Pritchard and Kasipathy Kailasapathy*  
   35  

3. Microbiological Aspects of Dairy Ingredients  
   *Michael Rowe and John Donaghy*  
   59  

4. Processing Principles of Dairy Ingredients  
   *Arun Kilara*  
   103  

5. Concentrated Fluid Milk Ingredients  
   *Nana Y. Farkye and Shakeel ur-Rehman*  
   123  

6. Dry Milk Ingredients  
   *Mary Ann Augustin and Phillip Terence Clarke*  
   141  

7. Casein, Caseinates, and Milk Protein Concentrates  
   *Mary Ann Augustin, Christine M. Oliver, and Yacine Hemar*  
   161  

8. Whey-based Ingredients  
   *Lee M. Huffman and Lilian de Barros Ferreira*  
   179  

9. Butter and Butter Products  
   *Anna M. Fearon*  
   199  

10. Principles of Cheese Technology  
    *Ramesh C. Chandan and Rohit Kapoor*  
    225  

11. Manufacturing Outlines and Applications of Selected Cheese Varieties  
    *Ramesh C. Chandan and Rohit Kapoor*  
    267  

12. Enzyme-modified Dairy Ingredients  
    *Arun Kilara and Ramesh C. Chandan*  
    317  

13. Fermented Dairy Ingredients  
    *Junus Salampessy and Kasipathy Kailasapathy*  
    335
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Author(s)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.</td>
<td>Functional Ingredients from Dairy Fermentations</td>
<td>Ebenezer R. Vedamuthu</td>
<td>357</td>
</tr>
<tr>
<td>15.</td>
<td>Dairy-based Ingredients: Regulatory Aspects</td>
<td>Dilip A. Patel</td>
<td>375</td>
</tr>
<tr>
<td>16.</td>
<td>Nutritive and Health Attributes of Dairy Ingredients</td>
<td>Ramesh C. Chandan</td>
<td>387</td>
</tr>
<tr>
<td>17.</td>
<td>Dairy Ingredients in Dairy Food Processing</td>
<td>Tonya C. Schoenfuss and Ramesh C. Chandan</td>
<td>421</td>
</tr>
<tr>
<td>18.</td>
<td>Dairy Ingredients in Bakery, Snacks, Sauces, Dressings, Processed Meats, and Functional Foods</td>
<td>Ramesh C. Chandan</td>
<td>473</td>
</tr>
<tr>
<td>19.</td>
<td>Dairy Ingredients in Chocolate and Confectionery Products</td>
<td>Jorge Bouzas and Steven Hess</td>
<td>501</td>
</tr>
<tr>
<td>20.</td>
<td>Dairy Ingredients in Infant and Adult Nutrition Products</td>
<td>Jeffrey Baxter, Steven Dimler, and Nagendra Rangavajala</td>
<td>515</td>
</tr>
</tbody>
</table>

*Index* 533
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Preface

Dairy Ingredients for Food Processing includes advances in technology of major dairy ingredients and their uses in the processing of important food products. The objective of this book is to provide an updated applied reference book for professionals engaged in management, research and development, quality assurance, and manufacturing operations in the food industry. It is a single source that provides basic and practical information to understand and work with dairy-based ingredients. The book is designed to present the topics in a convenient, easy-to-follow format. The intended audience consists of technical personnel in the food industry as well as students and teachers in food science at the university level.

Dairy Ingredients for Food Processing gives a comprehensive description of various dairy ingredients commonly used in food processing operations. The editorial team has assembled 25 authors from the United States, Australia, New Zealand, and the United Kingdom to write the chapters. These contributors represent diverse expertise from academia, industry, and government research institutions. The editors intended to ensure current practical information and scientific accuracy to provide potential reference value to all engaged in the product development, processing, and quality assurance disciplines of the food industry. This book is not meant to be a treatise on the subject but presents the basic and applied information in a single source. The authors have presented the topics in a concise, easily understandable style to enhance usefulness of the book.

Information is conveniently grouped to include basic technology associated with the manufacture of dairy ingredients, especially the parameters that affect their performance and functionality in food systems. The applications of commonly available dairy ingredients in the manufacture of food products such as dairy foods, bakery products, processed cheese, processed meat, chocolate as well as confectionery products, functional foods, and infant and adult nutritional products are covered in some detail. Information is conveniently grouped under 20 chapters by multiple authors to provide an international perspective.

The individuality of the authors’ contributions has been protected by the editors to provide both diversity of information and the focus of the authors. The editors have included minor duplication of some material in certain chapters to give readers another perspective on the subject and to maintain continuity and flow of thought of the respective authors. For the convenience of readers, some basic information has been derived from the previously published book Dairy Processing and Quality Assurance (Wiley-Blackwell, 2008).

Chapter 1 provides an overview of the technology of dairy ingredients, and serves as a refresher on the subject. Chapter 2 is devoted to chemical, physical, and functional characteristics of dairy ingredients. The microbiological aspects are given in Chapter 3. To facilitate understanding of the origin of dairy ingredients, the principles of dairy processing are summarized in Chapter 4.
Information on concentrated fluid milk ingredients is discussed in Chapter 5. Dry milk ingredients are described in Chapter 6. Other ingredients including casein, caseinates, and milk protein concentrates are dealt with in Chapter 7. Whey-based ingredients are discussed in Chapter 8. Butter and butter products are found in Chapter 9. Natural and process cheese technology and applications are given in Chapters 10 and 11. Enzyme-modified dairy ingredients are discussed in Chapter 12 and fermented dairy ingredients are presented in Chapter 13.

Dairy fermentations have given the food industry novel and natural preservatives for public health safety and extended shelf life of foods. Furthermore, several functional food ingredients have been developed for the food industry from dairy fermentation technologies, which have been described in Chapter 14. The regulatory aspects of dairy ingredients are presented in Chapter 15, whereas their nutritive and health attributes are given in Chapter 16. The use of dairy ingredients in major dairy manufacturing operations is presented in Chapter 17. The applications of dairy ingredients in bakery, snacks, sauces, dressings, processed meats, and functional foods are discussed in Chapter 18. The applications of dairy ingredients in chocolate and confectionery products are presented in Chapter 19, and their use in infant and adult nutritional products is discussed in Chapter 20.

The authors have attempted to support the origin, properties, and functional characteristics of dairy ingredients as well as their applications in the processing of major food products with sound scientific, technological, and engineering principles. The reader should notice a slant toward practical aspects as well.

It is hoped that the contemporary and experience-based information given in Dairy Ingredients for Food Processing will appeal to all the professionals in the food industry, including manufacturers of dairy ingredients. In addition, it is hoped that the book will be a useful resource for members of academia engaged in teaching and research in food science areas, regulatory personnel, food equipment manufacturers, and technical specialists engaged in the manufacture of dairy and food products.

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Dairy Ingredients for Food Processing
Chapter 1

Dairy Ingredients for Food Processing: An Overview

Ramesh C. Chandan

Introduction

Dairy ingredients are important players in the formulation of many food products. The addition of familiar dairy ingredients, widely recognized by the consumer as “natural,” enhances the odds of success of packaged foods in the marketplace. They generally deliver a consumer-friendly label on the package.

Dairy ingredients are derived from fluid milk in the form of cream, butter, condensed milk, dry milk, cheese, and whey products (Olson and Aryana, 2008, Sodini and Tong, 2006). They provide desirable functionality to foods, such as delivery of key nutrients, water management, fat-holding capacity, emulsification capability, viscosity creation, gel formation, and foam generation. In addition, dairy-based ingredients in liquid, concentrated, or dry form confer desirable attributes of texture and flavor to dairy foods, frozen desserts, puddings, processed meat, cereal products, chocolate confections, infant formulas, and an array of dietetic as well as geriatric drinks and bars. In conventional bakery items, dairy ingredients are used in enriched breads, croissants, milk bread, cakes, cookies, and pastries. Figure 1.1 demonstrates the relationship of milk to major dairy ingredients used for food processing.

Dairy ingredients contribute several critical characteristics associated with a food product. Caseinates impart emulsifying and stabilizing ability. Whey protein concentrates and isolates give gelling properties and furnish high-quality protein (Kilara, 2008). Similarly, milk protein concentrates provide a base of dietetic products. High-heat nonfat dry milk is reputed to impart water-absorption capacity to baked goods. Lactose-containing dairy ingredients are responsible for desirable brown crust in bread and other bakery items. Enzyme-modified butter and cheese flavor concentrates are used in food products for butter and cheese carry-over. Dairy ingredients are important tools for a food developer to create certain desirable attributes in foods. An understanding of the functional properties of dairy ingredients allows food technologists to use their potential contributions to meet consumer expectations.

Consumer trends, especially in functional foods (Chandan and Shah, 2007) as well as fast and convenience foods, are shaping the development of new products in the marketplace. More recently, market opportunities have been leveraged in nutraceutical beverages for use as tools for weight management, meal replacement, and geriatric nutritional needs using fluid skim milk, nonfat dry milk, milk protein concentrate, and whey protein concentrate. In addition, coffee-based drinks have provided the consumer with a variety of nutritional and functional drinks.
Supplements. A new trend involves development of functional ingredients from whey, colostrum, and bioactive peptides from milk proteins, which possess distinct health-promoting attributes (Chandan 2007a and b). Other ingredients are specific metabolites concentrated in fermented milk or whey by the activity of specific dairy cultures. The dried fermented ingredients derived from fermented bases contain active metabolites that are used as natural preservatives to extend shelf life and safety of foods. The enzyme-

Figure 1.1. Relationship of dairy ingredients to milk.

In the arena of industrial ingredients, dairy plants fabricate convenient, custom-made mixes for food plants for processing of foods. Such practice is currently undertaken for the production of yogurt, ice cream, and confectionery products (Chandan and O’Reill, 2006a; Kilara and Chandan, 2008). Novel ingredients have been developed by applying membrane technology to fractionate milk and whey to enhance their performance in food products. Such ingredients furnish milk protein, milk fat, or milk minerals in food supplements. A new trend involves development of functional ingredients from whey, colostrum, and bioactive peptides from milk proteins, which possess distinct health-promoting attributes (Chandan 2007a and b). Other ingredients are specific metabolites concentrated in fermented milk or whey by the activity of specific dairy cultures. The dried fermented ingredients derived from fermented bases contain active metabolites that are used as natural preservatives to extend shelf life and safety of foods. The enzyme-
modified cheeses are cheese flavor concentrates that are widely used in the production of cheese powders, cheese sauces, and process cheese, and in the preparation of fillings for cookies and crackers.

**Milk and Dairy Processing**

Fluid milk is a basic ingredient in dairy foods, including frozen and refrigerated desserts (Kilara and Chandan, 2008; Chandan and Kilara, 2008). Many dairy-derived ingredients for use in food processing owe their origin to milk, which is comprised of water and milk solids. Milk solids are comprised of milk fat and milk-solids-not-fat. Figure 1.2 illustrates the gross composition of milk, showing major constituents. The composition of whole milk solids and nonfat solids is shown in Table 1.1.

Accordingly, incorporation of dairy ingredients in a food adds these constituents to the overall food composition and allows a food developer to leverage their functionality and other attributes in food product development. Chemical, physical, and functional properties of milk are discussed in Chapter 2.

**Variations in Milk Composition**

It is important to recognize that milk composition varies depending on the breed of the cow, intervals and 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 (Chandan, 2007a; Kailasapathy, 2008). The variations in major constituents of milk, namely fat, protein, lactose, and minerals, are more noticeable in milk from individual cows. In general, these variations tend to average out and display an interesting pattern in commercial milk used by processors. Nevertheless, the seasonal variations in

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**Table 1.1.** Proximate composition of whole milk solids and skim milk solids.

<table>
<thead>
<tr>
<th>Component</th>
<th>Whole milk solids</th>
<th>Skim milk/ nonfat solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat, %</td>
<td>29.36</td>
<td>1.08</td>
</tr>
<tr>
<td>Protein, casein, %</td>
<td>22.22</td>
<td>31.18</td>
</tr>
<tr>
<td>Whey protein, %</td>
<td>4.76</td>
<td>7.53</td>
</tr>
<tr>
<td>Lactose, %</td>
<td>38.10</td>
<td>52.15</td>
</tr>
<tr>
<td>Ash (minerals), %</td>
<td>5.56</td>
<td>8.06</td>
</tr>
</tbody>
</table>

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**Figure 1.2.** Gross composition of pooled raw milk.
Accordingly, homogenized milk and cream appear whiter than non-homogenized counterparts. After the precipitation of casein and fat by the addition of a dilute acid or rennet, whey separates out. The whey possesses a green-yellow color due to the pigment riboflavin. The depth of color varies with the amount of fat remaining in the whey. Lack of fat globules gives skim milk a blue tinge. Physiological disturbances in the cow also make the milk bluer.

Cow’s milk contains the pigments carotene and xanthophylls, which tend to impart 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 of milk is critical to its consumer quality criterion. Flavor is an organoleptic property in which 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 the chloride ion varies from 0.06% to 0.12%. Saltiness can be organoleptically detected in samples containing chloride ions exceeding 0.12% and it becomes marked in samples containing 0.15%. The characteristic rich flavor of dairy products may be attributed 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 toward “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 for 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 of acetone bodies into milk 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 just one minute after 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 sour, bitter, and rancid. Raw milk received at the plant should not exhibit any off-flavors. Certain minor volatile flavor may volatilized off by dairy processing procedures. Various off-flavors and their origins are summarized in Table 1.2.

Table 1.2. Origins and causes of off-flavors in milk and dairy ingredients.

<table>
<thead>
<tr>
<th>Origin</th>
<th>Off-flavor</th>
<th>Description</th>
<th>Potential causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical/biochemical</td>
<td>Rancid, lipolytic</td>
<td>Soapy, bitter, unclean, blue-cheese-like aroma, strong, foul, lingering aftertaste</td>
<td>Raw milk homogenization, delay in pasteurization after homogenization, raw milk mixed with pasteurized milk</td>
</tr>
<tr>
<td></td>
<td>Oxidized, light-induced</td>
<td>Feather, tallow, burnt, medicinal, chemical taste</td>
<td>Milk exposed to UV light (sunlight/fluorescent light in dairy cabinet)</td>
</tr>
<tr>
<td>Microbiological</td>
<td>Malty</td>
<td>Grapenut flavor, burnt, caramel</td>
<td>Equipment not properly sanitized, milk not cooled promptly to less than 10°C/50°F</td>
</tr>
<tr>
<td></td>
<td>Acid/sour</td>
<td>Tingling/peeling sensation on tongue</td>
<td>Milk stored warm for prolonged period</td>
</tr>
</tbody>
</table>
|                            | Fermented/fruity   | Odor reminiscent of sauerkraut, vinegar, apple, pineapple, and other fruits | - Old, refrigerated pasteurized milk
|                            | Bitter/unclean     | Persistent bitter, unpleasant, musty, stale, dirty, spoiled taste | Dirty utensils and equipment, temperature abuse                                     |
| Absorbed during milk       | Feed               | Aromatic, onion, garlic, clover, reminiscent of feed      | Feeding cows 0.5 to 3 hours before milking                                          |
| production                 | Barn-like          | Aroma of poorly maintained barn, unclean aftertaste       | Poor barn ventilation and accumulated aromatic odors in barn                       |
|                            | Cow-like           | Reminiscent of cow breath odor; unpleasant medicinal, chemical aftertaste | Cows afflicted with ketosis/acetonemia                                              |
| Processing induced         | Cooked             | Scorched, sulfur-like, caramelized, sweet flavor          | Pasteurization time and temperatures exceeding normal parameters, heat-sterilized milk |
|                            | Flat               | Lacking full flavor, no flavor                            | Low total solids content, watered milk                                              |
|                            | Foreign            | Flavor and aroma not typical of milk                       | Contamination with cleaning and sanitary chemicals                                  |

Adapted from Chandan (1997, 2007a)
Chapter 1

Raw Milk Quality Specifications

It is essential to set up stringent specifications for quality maintenance for purchasing milk. The specifications involve several parameters as discussed below.

**Standard plate count (SPC)** is a measure of the total bacteria count, and measures the overall microbiological quality of milk. High SPC can cause reduced shelf life of the finished product and off flavors from enzyme activity and elevated acidity.

Per Pasteurized Milk Ordinance (USDHHS PMO, 2003), the U.S. Federal Grade A Standards allow a maximum of 100,000 CFU/ml for an individual producer and 300,000 CFU in commingled milk. However, some states differ. For example, for an individual producer, the Idaho standard is 80,000 CFU/ml maximum and the California standard is 50,000 CFU/ml maximum. It is recommended to set the standard at 50,000 CFU/ml.

**Coliform bacteria count** is a measure of milk sanitation. High coliform counts reflect poor milking practices and unsatisfactory cleanliness of the dairy operation. Occasionally, coliform count may indicate sick cows in smaller herds. Coliform count is an indicator that food poisoning organisms may be present. There are no federal standards for coliform counts in raw milk, but California has a standard for coliform (750 CFU/ml maximum). A recommended standard is 500 CFU/ml.

**Laboratory pasteurized count (LPC)** is a measure of heat-stable bacteria that may survive pasteurization. It is performed by heat-treating laboratory samples to simulate batch pasteurization at 62.8°C (145°F) for 30 minutes and enumerating the bacteria that survive using the SPC method. High LPC results indicate potential contamination from soil and dirty equipment at the dairy. High LPC causes reduced shelf life of finished products. *Bacillus cereus* is a common soil microorganism that can survive pasteurization, resulting in a high LPC. There are no federal standards for LPC. However, the California standard for LPC is 750 CFU/ml maximum. A recommended standard is 500 CFU/ml.

**Preliminary incubation (PI) count** is a measure of bacteria that will grow in refrigerated conditions. The test requires holding the sample at 10°C (50°F) for 18 hours followed by a SPC test. PI type of bacteria are destroyed by pasteurization but can still result in lower quality milk due to enzymatic activity on the protein. High PIs (3- to 4-fold higher than SPCs) are generally associated with inadequate cleaning and sanitizing of either the milking system or cows and/or poor milk cooling.

There are no federal standards for PI counts in raw milk. Because the type of bacteria and the initial count of the SPC may vary, it is not possible to set a numerical standard for this test. A recommended standard is less than two times the SPC count.

**Somatic cell count (SCC)** is a measure of the white blood cells in the milk. It is used as an indicator of herd health. High SCCs are undesirable because the yield of all cultured products is proportionally reduced, the flavor becomes salty, development of oxidation increases, and it usually relates to higher SPC. Staphylococci and streptococci are heat-tolerant bacteria that normally cause mastitis. Coliform bacteria, which are easily killed by heat, may cause mastitis. The PMO standards allow individual milk not to exceed 750,000 cells/ml. State standards vary. For example, the California standard is 600,000 cells/ml maximum. A recommended standard is 500,000 cells/ml.

**Titratable acidity (TA)** is a measure of the lactic acid content of milk. High bacteria counts produce elevated lactic acid levels as the bacteria ferment lactose. The normal range of TA in fresh milk is 0.13% to 0.16%. Elevated temperatures for an extended time allow the bacteria to grow and generate a higher TA value. Lower values
Dairy Ingredients for Food Processing: An Overview

may indicate the presence of chemicals in the milk. A recommended standard is 0.13% to 0.17% TA.

**Temperature** According to the PMO standard, the temperature of milk must never exceed 7°C (45°F). A recommended standard is 5°C (40°F) or less.

**Flavor** is an important indicator of quality, as stated earlier. The milk should be fresh and clean with a creamy appearance. Elevated bacteria counts can produce off-flavors (for example, acid, bitter). Feed flavors may vary from sweet to bitter and indicate the last items in a cow’s diet, such as poor feed, weeds, onion, or silage. Elevated somatic cell counts make milk taste salty and watery. Water in the milk gives it a watery taste. Dirty, “barny,” and “cowy” flavors occur from sanitation conditions and air quality at the dairy farm. Oxidized or rancid flavors occur from equipment operation and handling.

There are no federal standards for flavor. All receiving plants should flavor milk for defects before accepting it.

A recommended standard is that no off-flavor exists.

**Appearance** is not a measured criterion but for indications of quality it is as important as flavor. There are no federal standards for appearance. Most receiving plants must note any color or debris defect in the milk before accepting it. A recommended standard is “White, clean, no debris, and filter screen of 2 or less (sediment test).”

**Antibiotics and other drugs** may not be present in milk. All raw milk must conform to the PMO Grade A regulations (Frye, 2006). To be considered organic, no milk can be used from a cow that has been treated with antibiotics without a 12-month holding period following treatment. For conventional milk, a treated cow will be withheld from the milking herd for about 5 days.

**Added water** is an adulteration. Testing the freezing point of milk using a cyroscope indicates if abnormal amounts of water exist in the load. In most states it is illegal to have a freezing point above −0.530°C Hortvet scale. A recommended standard should be −0.530°C Hortvet or less.

**Sediment** is measured by drawing 1 pint of sample through a cotton disk and assigning a grade of 1 (good) to 4 (bad) to the filter. A grade of 1 or 2 is acceptable. A processor also may monitor for sediment by screening the entire load through a 3-inch mesh filter at the receiving line. There are no federal standards. Most receiving plants should require a filter grade of 1 or 2, although a 3 may be accepted.

A recommended standard is “No excessive material in a 3-inch sani-guide filter.”

**Fat and milk-solids-not-fat (MSNF)** have FDA standards of identity for milk of 3.25% fat and 8.25% MSNF. This is the recommended standard.

In the recent past, major advances in dairy processing have resulted in improvement in safety and quality of products. In particular, ultra-pasteurization techniques and aseptic packaging systems have presented the industrial user with extended and long shelf-life products.

**Basic Steps in Milk Processing**

It is beneficial for food developers and processors to know the basic steps involved in dairy processing. A detailed description of basic dairy processing is given in Chapter 4. Milk production, transportation, and processing are regulated by Grade A Pasteurized Milk Ordinance (USDHHS PMO, 2003; Frye and Kilara, 2006). Chapter 15 of this book deals with the regulatory aspects of dairy-based ingredients. Figure 1.3 shows the journey of milk from the farm to supermarket, including processing at the milk plant.

**Bulk Milk Handling and Storage**

The handling and storage of bulk milk are key components of good quality milk. Dairy
farms produce sanitary raw milk under the supervision of U.S. Public Health Services (Pasteurized Milk Ordinance). The regulations help in the movement of assured quality milk across interstate lines.

Today, virtually all the raw milk at the plant is delivered in tank trucks. Unloading of milk involves agitation of the truck, inspection for the presence of off-flavors, collection of a representative sample, and connection of 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, and finishing with a chlorine/iodine sanitizing treatment. A clean-in-place line

![Figure 1.3. The journey of milk from farm to market.](image-url)
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 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°C to 4.4°C (35°F to 40°F). The maximum bacterial count at this stage is 300,000 CFU/ml, as opposed to the maximum of 100,000 CFU/ml allowed at the farm. The higher count is justified because pumping breaks the clumps of bacteria, which gives higher counts and provides more opportunity for contamination of milk as it comes in contact with more equipment during handling and transfer. Also, the longer storage time adds more bacterial numbers. The 3-A sanitary standards are followed for equipment design (Frye, 2006). Chapter 3 deals with the microbiological aspects of milk and dairy ingredients.

Separation

The purpose of the separation step is to separate milk into cream and skim milk. All incoming raw milk is passed through the separator, which is essentially a high-speed centrifuge. This equipment separates milk into lighter cream fraction and heavier skim milk fraction. A separator of adequate bowl capacity collects all the “slime” material containing heavy casein particles, leukocytes, larger bacteria, body cells from cows’ udders, dust and dirt particles, and hair. Homogenized milk develops sediment upon storage if this particulate fraction of raw milk is not removed. 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 or low-fat milk) and cream. Skim milk should normally contain 0.01% fat or less. A standardization valve on the separator permits the operator to obtain separated milk of a predetermined fat content. Increased back pressure on the cream discharge port increases the 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 100% of 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, denatured whey proteins complex with casein, and no precipitation is observed in milk. In contrast to milk, whey that lacks casein, and heat treatment at 75°C to 80°C (167°F to 176°F) results in precipitation of the whey proteins.

From a consumer standpoint, heat treatment of milk generates several sensory changes (cooked flavor) depending on the intensity of heat. In general, pasteurized milk possesses the most acceptable flavor. Ultra-pasteurized milk and ultra-high-temperature (UHT) milk exhibit a slightly cooked flavor. Sterilized milk and evaporated milk possess a pronounced cooked flavor and off-color.

The U.S. Food and Drug Administration (PMO) has defined pasteurization time and
temperature for various products. The process is regulated to assure public health. Milk is pasteurized using plate heat exchangers with a regeneration system. The process of pasteurization involves heating every particle of milk or milk product in properly designed and operated equipment to a prescribed temperature and holding it continuously at or above that temperature for at least the corresponding specified time. Minimum time-temperature requirements for pasteurization are based on thermal death time studies on the most resistant pathogen that might be transmitted through milk. Table 1.3 gives the various time-temperature requirements for legal pasteurization of dairy products.

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

**Homogenization**

Homogenization reduces the size of fat globules of milk by pumping milk at high pressure through a small orifice, called a valve. The device for size reduction, the homogenizer, 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 less than 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 a new membrane formed from milk proteins. Thus, the presence of a minimum value of 0.2 g of casein/g fat is desirable 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 a single-stage homogenizer. It works well with low-fat products or in products in which high viscosity is desired, as in cream and sour cream manufacture. On the other hand, homogenizers that reduce 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. 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 a whiter color and fuller body and flavor characteristics. Homogenization leads to better viscosity and stability by fully dispersing stabilizers and other ingredients in ice cream, cultured products, and other formulated dairy products.

**Cooling, Packaging, and Storage**

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 warehouses for distribution.

**Fluid Milk Products**

Commercial milk is available in various milk fat contents. The approximate composition of fluid milk products is shown in Table 1.4. The
Table 1.3. Minimum time-temperature requirements for legal pasteurization in dairy operations.

<table>
<thead>
<tr>
<th>Process</th>
<th>Milk: whole, low fat, skim/nonfat</th>
<th>Milk products with increased viscosity, added sweetener, or fat content 10% or more</th>
<th>Egg nog, frozen dessert mixes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vat (batch)</td>
<td>30 minutes at 63°C (145°F)</td>
<td>30 minutes at 66°C (150°F)</td>
<td>30 minutes at 69°C (155°F)</td>
</tr>
<tr>
<td>High temperature short time</td>
<td>15 seconds at 72°C (161°F)</td>
<td>15 seconds at 75°C (166°F)</td>
<td>25 seconds at 80°C (175°F)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 seconds at 83°C (180°F)</td>
<td>15 seconds at 83°C (180°F)</td>
</tr>
<tr>
<td>Higher heat</td>
<td>1 second at 89°C (191°F)</td>
<td>1 second at 89°C (191°F)</td>
<td>1 second at 89°C (191°F)</td>
</tr>
<tr>
<td>Shorter time</td>
<td>0.5 second at 90°C (194°F)</td>
<td>0.5 second at 90°C (194°F)</td>
<td>0.5 second at 90°C (194°F)</td>
</tr>
<tr>
<td></td>
<td>0.1 second at 94°C (201°F)</td>
<td>0.1 second at 94°C (201°F)</td>
<td>0.1 second at 94°C (201°F)</td>
</tr>
<tr>
<td></td>
<td>0.05 second at 96°C (204°F)</td>
<td>0.05 second at 96°C (204°F)</td>
<td>0.05 second at 96°C (204°F)</td>
</tr>
<tr>
<td></td>
<td>0.01 second at 100°C (212°F)</td>
<td>0.01 second at 100°C (212°F)</td>
<td>0.01 second at 100°C (212°F)</td>
</tr>
<tr>
<td>Ultra pasteurized</td>
<td>2 seconds at 138°C (280.4°F)</td>
<td>2 seconds at 138°C (280.4°F)</td>
<td>2 seconds at 138°C (280.4°F)</td>
</tr>
<tr>
<td>Ultra-high temperature (UHT), aseptic</td>
<td>Comply with low acid canned food regulations (21CFR 113)</td>
<td>Comply with low acid canned food regulations (21CFR 113)</td>
<td>Comply with low acid canned food regulations (21CFR 113)</td>
</tr>
</tbody>
</table>

Adapted from Chandan (1997), Partridge (2008), USHHS FDA (2003)
been demonstrated that the shelf life is 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 to achieve the maximum shelf life of milk.

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

Fluid 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

<table>
<thead>
<tr>
<th>Table 1.4. Typical composition of fluid dairy ingredients.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairy Ingredient</td>
</tr>
<tr>
<td>Whole milk</td>
</tr>
<tr>
<td>Skim milk</td>
</tr>
<tr>
<td>Half and half</td>
</tr>
<tr>
<td>Light cream</td>
</tr>
<tr>
<td>Light whipping cream</td>
</tr>
<tr>
<td>Heavy whipping cream</td>
</tr>
<tr>
<td>Plastic cream</td>
</tr>
<tr>
<td>Fluid UF* whole milk</td>
</tr>
<tr>
<td>Fluid UF* skim milk</td>
</tr>
<tr>
<td>Fluid UF* skim milk, diafiltered</td>
</tr>
</tbody>
</table>

*UF, ultra-filtered
Adapted from Chandan (1997), Chandan and O’Reilly (2006a)
Fat-rich Products

Butter

The manufacture of butter and spreads is discussed in another publication (Fearon and Golding, 2008) and in Chapter 9 of this book. Butter is a concentrated form of milk fat, containing at least 80% fat. It can be converted to shelf-stable products such as butter oil, anhydrous milk fat, and ghee. Table 1.5 shows the approximate composition of butter and its products.

Figure 1.5 is flow-sheet diagram for the manufacture of butter, butter oil, and certain dry milk products. The diagram also displays interrelationships between these products.
Table 1.5. Typical composition of milk fat concentrates.

<table>
<thead>
<tr>
<th>Product</th>
<th>% Water</th>
<th>% Fat</th>
<th>% Protein</th>
<th>% Lactose</th>
<th>% Ash</th>
<th>Added ingredient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butter</td>
<td>16.5</td>
<td>80.5</td>
<td>0.6</td>
<td>0.4</td>
<td>2.5</td>
<td>0–2.3% salt</td>
</tr>
<tr>
<td>Anhydrous milk fat</td>
<td>0.1</td>
<td>99.8</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Butter oil</td>
<td>0.3</td>
<td>99.6</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ghee</td>
<td>&lt;0.5</td>
<td>99–99.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Adapted from Chandan (1997), Aneja et al. (2002)

Figure 1.5. Flow sheet diagram for butter, butter oil, dry buttermilk, nonfat dry milk, and dry whole milk.