Fermented milk products

Cheese

Perhaps no other fermented food starts with such a simple raw material and ends up with products having such an incredible diversity of color, flavor, texture, and appearance as does cheese. It is even more remarkable that milk, pale in color and bland in flavor, can be transformed into literally hundreds of different types of flavorful, colorful cheeses by manipulating just a few critical steps. How so many cheeses evolved from this simple process undoubtedly involved part trial and error, part luck, and plenty of art and skill. It is fair to assume that, until very recently, most cheese makers had only scant knowledge of science, and microbiology in particular. Now, however, it is likely that few fermented foods require such a blend of science, technology, and craftsmanship as does the making of cheese.

On a volume basis, the cheese industry is the largest of all those involved in fermented foods manufacture. Of the 75 billion Kg (165 billion pounds) of milk produced in the United States in 2001, more than one-third was used in the manufacture of 3.7 billion Kg (8.1 billion pounds) of cheese. About a fourth of that cheese was used to make various types of processed cheese. On a per capita basis, cheese consumption in the United States has increased in the past twenty-five years from 8 Kg in 1980 to nearly 14 Kg (30.1 pounds) per person per year in 2003 (of U.S. made cheese).The most popular cheeses have been the American style (e.g., Cheddar, Colby) and Italian style (e.g., Mozzarella and pizza cheese) cheeses, accounting for 41.5% and 40.6%, respectively, of all cheeses consumed in the United States (Figure 5.1). In addition, another 0.75 Kg of imported cheese is consumed per person per year. Worldwide, Greece (26 Kg per person per year), France (24 Kg per person per year), and Italy (21 Kg per person per year) are the leading consumers of cheese, with other European countries not too far behind (Figure 5.2).

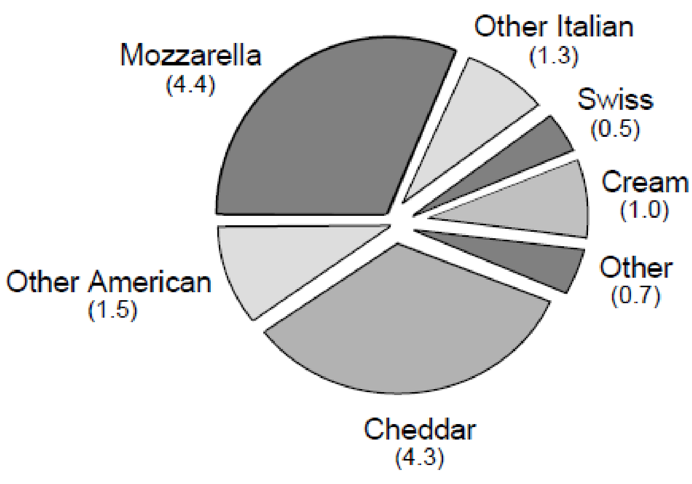

Figure 5–1. Per capita consumption (Kg per person per year) of different varieties of cheese in the United States in 2003. Adapted from USDA Economic Research Service statistics.

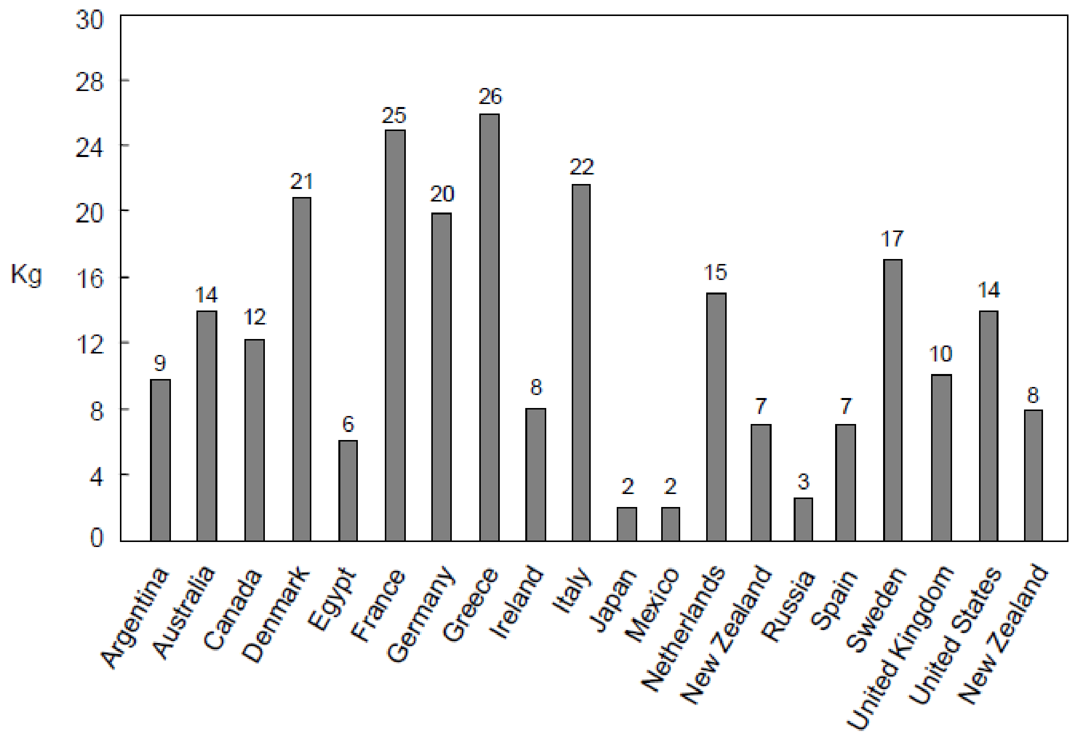

Figure 5–2. Worldwide per capita cheese consumption (Kg per person per year). Adapted from 2002 USDA and United Nations/FAO Agricultural Database statistics.

Manufacturing Principles

Like so many fermented foods, the first cheese made by human beings was almost certainly a result of an accident. Some wandering nomad, as the legend goes, filled up a pouch made from the stomach of a calf or cow with a liter or two of fresh milk. After a few hours, the milk had turned into a solid-like material, and when our would-be cheese maker gave the container a bit of a shake, a watery-like fluid quickly separated from the creamy white curd. This moderately acidic, pleasant-tasting curd and whey mixture not only had a good flavor, but it also probably had a longer shelf-life than the fresh milk from which it was made. And despite the rather crude production scheme, the product made several thousands of years ago was not much different than many of the cheeses currently produced and consumed even today. Just what happened to cause the milk to become transformed into a product with such a decidedly different appearance, texture, and flavor? To answer that question, it is first necessary to compare the composition of the starting material, milk, to that of the product, the finished cheese (Figure 5.4). Cow's milk consists of, in descending order (and in general concentrations), water (87%), lactose (5%), fat (3.5% to 4%), protein (3.2% to 3.4%), and minerals (<1%), mainly calcium. In contrast, a typical cheese, such as Cheddar cheese, contains 36% to 39% water, 30% to 32% fat, 26% to 28% protein, 2% to 2.5% salt, 1% mineral (mostly calcium), and <1% lactose. The differences should be evident—cheese contains less water and more milk solids, in the form of fat and protein, than the milk from which it was made. Thus, cheese making can simply be viewed as a concentration process, in which the water portion, or whey, is removed and the solids are concentrated. In fact, as we shall see later, most of the steps involved in cheese making are performed for the singular purpose of removing water. Doing so not only concentrates and solidifies the solid matter, but also decreases microbial and enzymatic activities such that cheese is much better preserved than milk. As noted in the previous chapter, buttermilk, yogurt, sour cream, and other cultured dairy products are different from cheese in several respects, but chief among these differences is that these products do not involve a water removal step.

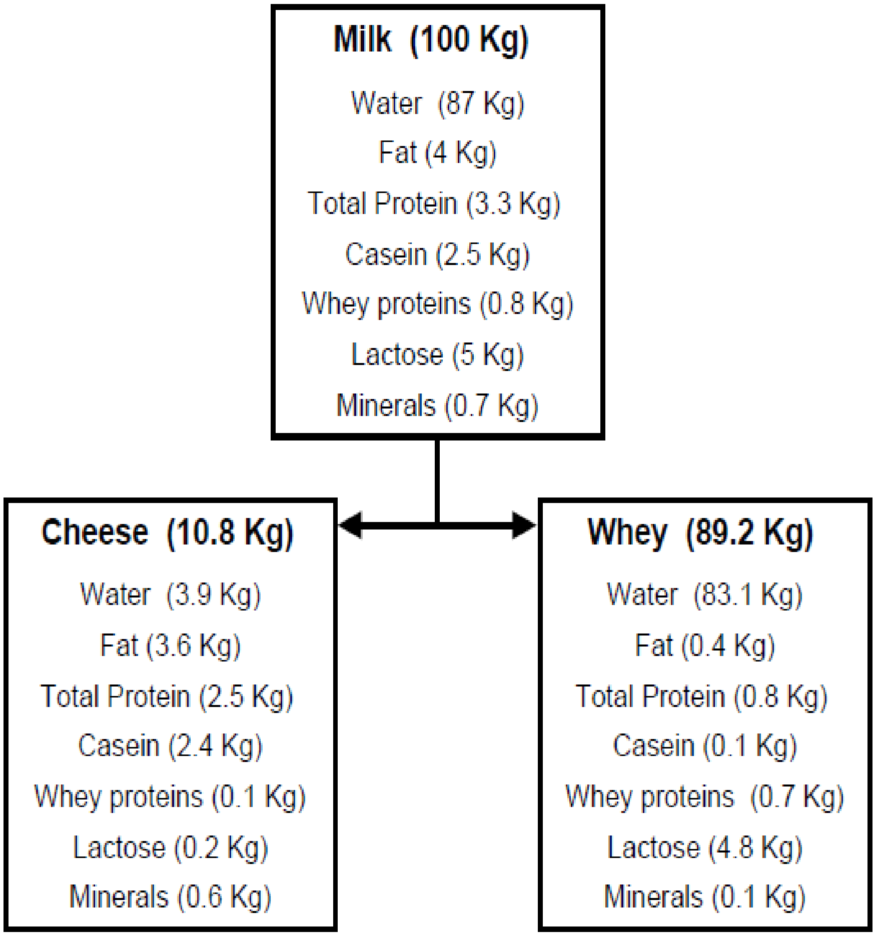

Figure 5–4. Partition of milk into cheese and whey.

General Steps in Cheese Making

On a worldwide basis, there are probably thousands of different types of cheeses produced and consumed. As Charles De Gaulle, the former French president, famously lamented, there are hundreds of different cheeses made in France alone1. Anyone who has visited a fromageri in Paris or a formaggio in Milan (or perhaps the National Cheese Emporium in England), can certainly appreciate the incredible variety of cheeses that are available. How could there be so many? Are the procedures for making cheese so complex as to allow for all the cheeses produced? In reality, the basic manufacturing steps for all cheeses are surprisingly similar. However, it is the almost unlimited number of variables that exist at each of these steps that ultimately account for the myriad number of different cheeses. Described below are the various ingredients and manufacturing steps that are used in cheese making, with an emphasis on those variables that distinguish one type of cheese from another.

Milk

As shown in Figure 5.5, the first variable starts with the milk itself. Although most cheeses are made from cow's milk, many cheeses are made using milk from other sources. For example, Feta and Chevre are ordinarily made from goat milk, Roquefort and Romano are made from sheep milk, and Mozzarella is often made from the milk of water buffaloes. These milks have dramatically different gross compositions from bovine milk; in particular, they all contain more fat (water buffalo and goat milk contain nearly twice as much). However, even the composition of cow's milk varies according to the breed of cow, the nature of the feed consumed by the cow, and even when the milk was obtained (i.e., morning versus evening). Moreover, in cheese making, not only does the gross composition affect cheese properties, but so does the specific composition of each of the milk constituents. The lipid portion of goat milk, for example, contains a higher percentage of volatile, short-chain fatty acids, such that rancid flavor notes are most evident when the triglycerides are hydrolyzed by lipases.

The fat content also has a profound influence of other properties of cheese. Fat not only contributes to the body and texture of cheese, but it also serves as substrate for important flavor-generating reactions performed by microorganisms. Also, many of the flavor constituents derived from non-lipid substrates that form during cheese ripening are soluble in the lipid phase. For example, hydrophobic peptides derived from casein hydrolysis (many of which are bitter) are found in the fat portion of the cheese. For some cheeses, the milk is standardized to give a fat content that is particular to a given cheese. In general, the minimum fat content for most cheeses is usually around 50% (on a dry basis). For example, Cheddar type cheeses are made with whole milk, containing 3.5 to 4.5% milkfat. However, other cheeses are made with milk adjusted to 3% fat (e.g., Swiss cheese) or less (part-skim Mozzarella). In part, this is because the body characteristics of certain hard cheeses, for example, Swiss and Parmesan, require less fat and a higher casein-to-fat ratio. In contrast, some cheeses are made from milk that is enriched with cream, such that the fat content of the cheese (so-called double cream cheese) will be 60% (or even 72% for triple cream cheese).

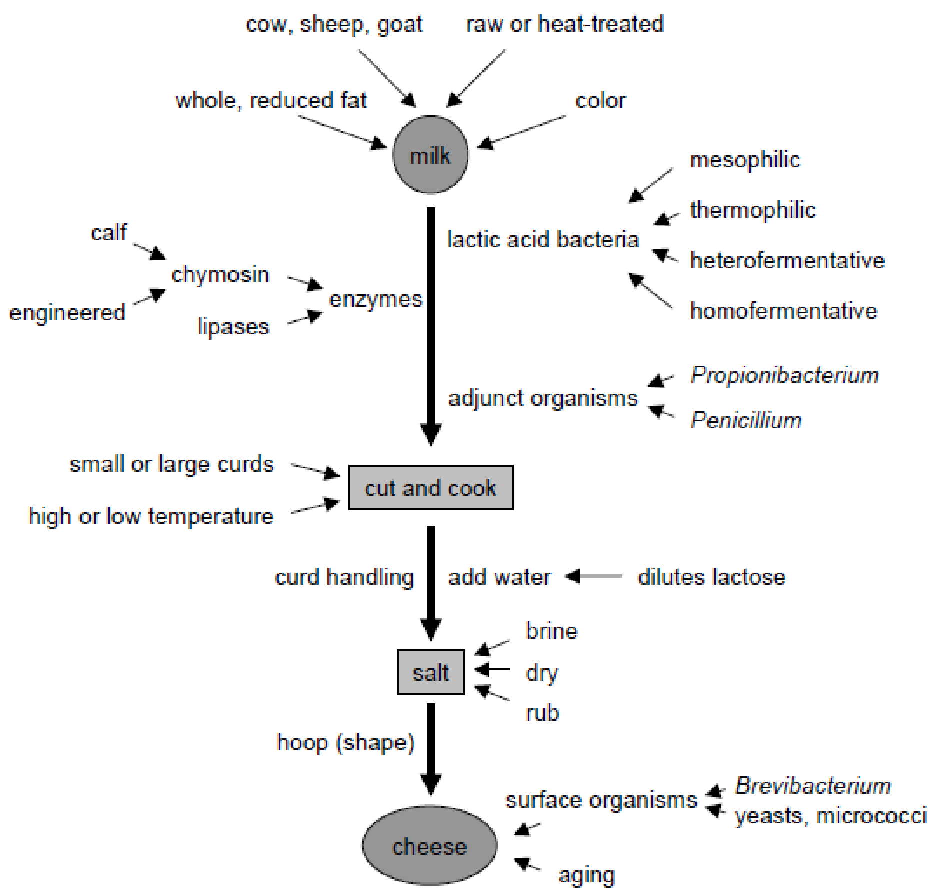

Figure 5–5. General steps for manufacture of hard cheeses.

Another key variable involves the handling of the milk, and in particular, whether the milk has been heated or not. In the United States, all unripened cheese (aged less than sixty days) must be made from pasteurized milk, whereas only aged cheese (held for more than sixty days at a temperature not less than 1.7°C) can be made from raw milk.In many other parts of the world, including France, Italy, and other major cheese-producing countries, there are no such pasteurization requirements, and even fresh cheeses can be made from raw milk (unless they are to be exported to the United States— then they must conform to U.S. requirements).

In reality, however, even cheese milk that is not pasteurized is often heat-treated to subpasteurization conditions (even for aged cheese). The reason for pasteurizing milk, regardless of how that milk is to be used, is to kill pathogenic and spoilage microorganisms. Given the concern about food safety in the United States, there has been a trend among large U.S. manufacturers to use pasteurized milk for most cheeses,even those that are aged. Pasteurization, however, not only kills pathogens and undesirable spoilage bacteria, but it also inactivates much of the endogenous microflora and enzymes ordinarily present in raw milk. Since the microflora and enzymes both contribute to the overall flavor and texture properties of the finished cheese, especially if the cheese is aged, quality differences between cheese made from raw or heattreated milk can be significant. Thus, there is now a debate between those who believe that pasteurization should be required and those who contend that pasteurization is detrimental to cheese quality. It should be emphasized, however, that whether the milk is raw or pasteurized, it should still be of high microbiological quality, free of antibiotics, and within the standards specified by government regulations. Finally, one of the most obvious ways to treat milk to distinguish one cheese from another is by the color. Milk, and the finished cheese, can be made more yellow by adding the natural coloring agent, annato, or made more white by adding bleaching-type agents. Although the color has no effect on flavor or texture, manufacturers have learned that visual appeal can have a pronounced effect on acceptability and preference. In the United States, for example, consumers from the Midwest, in general, prefer orange-colored Cheddar cheese, whereas Northeasterners favor white Cheddar.

Starter cultures

The composition of the starter culture depends on the intentions of the cheese maker. If the cheese-making procedure includes a step where the curds will be exposed to high temperatures, such as during manufacture of Swiss, Parmesan, and Mozzarella cheese, then a thermophilic lactic acid bacterial culture able to withstand those temperature must be used. If a particular flavor compound is desired, such as diacetyl in Gouda cheese, then again, the culture must contain specific organisms capable of producing those flavor compounds. In fact, culture technology has advanced now to the point where each strain present in the culture can be selected on the basis of the specific performance attributes desired by the customer. Thus, the culture can contribute to considerable variation in the finished cheese, and even modest changes in the culture composition or amount can result in dramatic differences in the cheese.

Cultures used for cheese fermentations consists of several genera and species of lactic acid bacteria. Aside from selecting a culture that gives the desired rate and extent of acid development and that produces the desired flavor and texture, the main distinction for culture selection is based on temperature. Mesophilic cultures, containing strains of *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris*, grow within a wide temperature range of about 10°C to 40°C. Growth rates at the extreme ends of this range are, however, quite low and temperatures much above the upper limit for growth are lethal. Moreover, the optimum temperature for growth of mesophilic cultures is about 28°C to 32°C (depending on the strain), which is generally very near the temperature range that the milk or cheese will be held during manufacture (i.e., when fermentation is expected to occur).

The mesophilic cultures are the workhorses of the cheese industry, and are used for the majority of cheeses. Thermophilic cultures, mainly *Lactobacillus helveticus* and *Streptococcus thermophilus,* are also widely used. They have a temperature optima around 42°C to 45°C and are able to grow at temperatures as high as 52°C. Like the mesophiles, however, temperatures just a few degrees higher than their maximum growth temperature may result in thermal inactivation. This means that when curds are heated, the temperature must not exceed that which the culture can tolerate. Otherwise, the culture will be inactivated or injured and the subsequent fermentation will either be slow or not occur. However, it should be noted that thermal effects on microorganisms obey first-order kinetics, such that inactivation or killing occurs at a logarithmic rate. Thus, even when the temperature reaches a lethal level, some cells will survive (depending on the exposure time) and be able to grow (albeit slowly), once a compatible temperature is established. Most of the strains that comprise mesophilic and thermophilic cultures are homofermentative. However, heterofermentative lactic acid bacteria may be included in mesophilic cultures that are used for particular cheeses. Specific heterofermentative species include *Leuconostoc mesenteroides* subsp. *cremoris* and *Leuconostoc lactis*. Not coincidently, these organisms also ferment citrate and produce diacetyl. Thus, cheeses such as Gouda and Edam have a buttery aroma, as well as a few small eyes, due to CO2 formation. Finally, cultures may also contain non-lactic acid bacteria for Swiss-type and surface-ripened cheeses, as well as fungal spores for mold-ripened cheeses.

Until relatively recently, bulk cultures grown in whey or milk without pH control were the dominant form in which cultures were used. Culture inoculum for Cheddar type cheeses was usually about 1% (w/w), which gave an initial cell concentration of about 5×10^6 cells per ml of milk. Other cheeses are made using more culture (e.g., Mozzarella is normally made with a 2% starter) or less culture (e.g., Swiss is made with 0.5% culture). Although these traditional bulk cultures are still used, in the past twenty years, bulk culture tanks began to be equipped with external pH control systems. This simple technology made it possible for operators to partially neutralize the medium as the cells grew, and, therefore, maintained the pH at a level that was more to the liking of the starter culture organisms.

Specialized culture media was also introduced that provided “internal” pH control. With the widespread use of these pH controls, bulk culture systems, culture viability, and cell density (i.e., cells per gram) have been significantly enhanced. Thus, less culture is necessary, perhaps half as much on a weight or volume basis. In addition, highly concentrated, direct-to-vat cultures are also now widely used. These products may contain ten or more times as many cells as traditional bulk cultures. One 500 ml can, for example, is sufficient to inoculate 10,000 L of milk (i.e., 0.005%). Despite the consistent nature of modern cultures, their activity and cell density may still be somewhat variable. Thus, it is important for cheese manufactures to adjust inoculum levels to satisfy production schedules and performance expectations. In the case of Cheddar cheese, if too much culture is added, acid development might occur too rapidly, resulting in early loss of calcium and demineralization of the cheese (discussed later). In addition, a large culture inoculum may lead to excessive production of proteolytic enzymes that can eventually affect cheese yield, flavor, and texture. In contrast, if not enough culture was added, fermentation and acid development is delayed, causing production schedule headaches as well as opportunities for spoilage or pathogenic organisms to grow.

It is important to note that, despite the availability of defined and consistent starter cultures, there are some cheeses made using more traditional starter cultures. Parmigiano Reggiano, the authentic version manufactured only in the Parma region of Italy, is made using whey as starter culture, a form of backslopping. Many of the Dutch-type cheeses (e.g., Gouda and Edam) are still made using undefined strains maintained simply as a mixed culture. Whether a pure, mixed, or undefined starter culture is used, the milk for most cheeses made with a mesophilic culture is ordinarily brought to a temperature between 30°C and 40°C (higher for cheeses made using thermophilic cultures). If early culture growth is to be encouraged, the milk may be held for a period of time within this temperature range. However, despite a mostly favorable temperature, little culture activity and little acid development normally occurs during this early stage of the process. This is because the cells either are coming out of a somewhat dormant phase (in the case of frozen or lyophilized direct-vat-set cultures), or are adapting from a rich, almost ideal bulk culture medium to a milk medium that requires induction of at least some new biochemical pathways, such as those involving protein hydrolysis and amino acid use. Depending on the culture media and culture preparation conditions, it is possible for cultures to be rather active, with relative short lag phases. In general, most cultures still experience a lag phase (that may be quite extended, especially if a cooking step is also included), before active log phase growth occurs. Although growth of the culture and production of fermentation end-products (other than lactic acid) usually does not occur until later in the cheese making process, delays due to culture inhibition can cause serious problems for the manufacturer. Large cheese factories that process a million or more Kg of milk per day require high throughput (i.e., the rate that milk is converted to finished cheese products). A bottleneck at the fermentation step may place upstream operations are on hold, disrupting production schedules and perhaps causing employees to work extra hours. Of course, if the fermentation is slow, sluggish, or fails altogether, cheese quality will be poor. There are several possible causes of starter culture inhibition. Although state and federal laws require that milk be free of antibiotics, if residues were present they could inhibit the lactic culture. However, it is now very rare that milk would contain undetected antibiotics. Milk may also contain natural immunoglobulins that bind to culture bacteria, forming clumps that eventually settle in the vat. This is particularly a problem in Cottage cheese due to the long fermentation time. Another potential inhibitor is formed via the lactoperoxidase reaction. This reaction occurs when the enzyme lactoperoxidase oxidizes thiocyanate in the presence of hydrogen peroxide to form hypothiocyanate.This reactive compound can be inhibitory to certain starter culture lactic acid bacteria. Lactoperoxidase and thiocyanate are naturally present in milk, and hydrogen peroxide can be produced by the endogenous microflora. It is also possible to activate this reaction by inoculating raw milk with hydrogen peroxide-producing lactic acid bacteria in an effort to control psychrotrophic spoilage bacteria.

Chemical agents used to sanitize cheese vats can occasionally inhibit cultures if residues are not adequately rinsed. By far, however, the main cause of culture inhibition are bacteriophages, viruses that infect bacteria—in this case, lactic acid bacteria. Their detrimental role in the cheese making process, and the means by which phage problems can be controlled.

Coagulation

In many cheese factories, chymosin is added to the milk immediately after or nearly at the same time as the culture is added. Some cheese makers allow a pre-ripening period to give the culture a brief opportunity to produce a small amount of acid and a slight lowering of the milk pH. Since chymosin is an acid protease (its optimum activity on κ-casein occurs at pH 5.5), it will be more active as milk pH decreases. The solubility of calcium also increases as the pH decreases. Thus, with pre-ripening, less chymosin can be used to give the same clot firmness. For similar reasons, it is also common to add calcium chloride to the milk to promote coagulation (and yield).

In any event, the amount of chymosin added, and the length of the setting period prior to cutting, depends on the cheese being made and the curd firmness desired. Usually, about 200 ml of single-strength chymosin per 1,000 kilograms of milk will give a suitable coagulation within about 30 minutes. For many large, automated manufacturers, the point at which the curd is sufficiently firm and ready for cutting is based strictly on the clock (but also on *a priori* knowledge of what times give the best cheese). Although specialized instruments are available for this purpose, curd firmness is more often than not determined on a subjective basis, i.e., when the operator deems it ready based on a simple cutting method.

Cutting and cooking

The coagulated mass is next cut using harp-like, wire knives that cut the curds into die-sized particles. The knives are constructed such that the curds can vary in size. Since this step is performed to enhance syneresis, the size, or more importantly, the surface area of the curd particles, has a major influence on the rate of water removal from the curd. Hard, low-moisture cheeses like Parmesan and Swiss are typically cut into kernel or wheat berry-sized curds, whereas soft, high-moisture cheeses are cut into die-sized pieces. The size of the curd also influences fat loss—more fat is retained in large curds than in small ones. Regardless of the size of the curd at cutting, the actual composition varies relatively little. The curd is constructed of a calcium-casein complex that contains entrapped fat and bacteria (including starter culture organisms), as well as water and water-soluble components including whey proteins, enzymes, vitamins, minerals, and lactose.

Syneresis begins as soon as the curds are cut, and increases during the ensuing minutes when the curds are gently stirred. The initial rate depends on the starting pH of the curd, because prior acid development greatly enhances syneresis. However, the cooking step is the primary means of enhancing syneresis. All other factors being equal, the higher the temperature and the longer the curds are cooked and stirred, the dryer will be the finished cheese. Thus, the cooking step is one of the major variables that cheese manufacturers can manipulate to produce different types of cheese.

As noted previously, the more water removed from the curd, the less lactose will be available for fermentation. Cheese manufacturers can, therefore, influence acid production and cheese pH by modulating the cooking time and temperature conditions. Whatever the cooking temperature, however, the culture must be able to withstand that temperature, or else the cells will be attenuated (or worse yet, inactivated). Furthermore, when heat is applied it must be done gradually via a step-wise progression, since too rapid heating causes the exterior of the curds to harden and actually reduce syneresis. The cooking and stirring step has so much of an effect on the finished cheese that some experienced cheese makers can tell how dry the cheese will be simply by touch and the feel of the curd. Of course, some soft cheeses, like Brie, are not cooked at all, but rather are stirred at the setting temperature. Finally, although the actual heating step usually occurs via indirect heat transfer through jacketed vats, it is also possible to inject steam directly into the whey-curd mixture.

Curd handling

Perhaps the most influential step during the cheese making process involves the means by which the curd is handled during and after the cooking and stirring steps. For many cheeses, the whey is removed when the desired acidity is reached, when the curd has been cooked for a sufficient length of time, or when it is sufficiently firm or dry. There are several means by which the curd is separated and the whey is removed. In traditional Cheddar cheese manufacture, the curds are simply pushed to the sides of the cheese vat and the whey is drained down from the center, with screens in place at the drain end to prevent curd loss. Alternatively, the curds can be collected in cheese cloth and hoisted above the whey, as in traditional Swiss cheese manufacture. In more modern, large production factories, where cheese vats must be cleaned and re-filled, curds and whey are typically pumped to draining tables or Cheddaring machines, where whey separation occurs. Similarly, the curd-whey mixture can be added directly into perforated cheese hoops, where the whey drainage step is completed.

Although there are many ways to manipulate the curd to alter the properties of the cheese, one simple twist in the separation step is worth special mention. If, during the draining step, water is added back to the curds, then so-called “sweet” or low-acid cheeses will result. This is due to lactose dilution. Since the lactose concentrations in the curd and whey are ordinarily in equilibrium, when whey is removed and replaced by water, lactose will diffuse from curd to water, leaving the curd with markedly less lactose available for subsequent fermentation by the starter culture. Thus, the initial pH of Colby, Gouda, Havarti, and Edam cheeses are generally in the range of 5.2 to 5.4. If the added water is warm (i.e., about 35°C), cooking and syneresis will continue (as is the case for Gouda, Edam, and Havarti).However, if the water is cold (about 15°C), the moisture content of the cheese may increase (e.g., Colby).This washing step is also used for Mozzarella, in part for pH control, but more so to remove lactose and galactose from the curd.

Once the curds are separated from the whey, several things begin to happen. First, the starter culture finds itself at a temperature conducive for growth, and soon the fermentation of lactose to lactic acid occurs. A subsequent decrease in curd pH and an increase in the titratable acidity (expressed as percent lactic acid) of the expressed whey is evident. The curds, almost immediately after whey is removed, mat or stick together. The matted curds, helped by piling slabs on top of one another, begin to stretch out and become plasticlike, a process known as Cheddaring. Alternatively, the dry curds can be stirred to facilitate whey removal and to lower the moisture in the finished cheese.

Salting

Salt is an essential ingredient that provides flavor, enhances syneresis, and contributes to the preservation of most cheeses. Even the simple step of salting, however, represents an important variable during cheese manufacture. Salt can be applied directly (i.e., in dry form) to the milled curds, as in the case of Cheddar, or salt can be rubbed onto the surface of hooped cheese, as in the case of some blue cheese varieties (e.g., Gorgonzola and Roquefort). Alternatively, some cheeses, such as Swiss, Mozzarella, and Parmesan, can be placed in brines. Obviously, when salting occurs via brining methods, the amount of salt that ends up in the cheese is a function of the diffusion rate into the cheese, as well as the geometry of the cheese block, the duration of brining, and brine strength. If the cheese is shaped or cut into small units and left in the brine, as with Feta cheese, salt concentrations can be very high (>3%). In contrast, large blocks or wheels of brined Swiss cheese typically contain less salt (<1%), especially in the interior sections. Brined cheeses that are then allowed to air dry develop natural rinds, due to surface dehydration.

Aging

The last step in the cheese making process has as much influence as any previous step with regard to the properties and qualities of the finished cheese. As noted in Chapter 1, it is a fine line that separates the production of a perfectly flavored, three-year old Cheddar cheese and a bitter, rancid, sour Cheddar cheese that is quickly rejected by any discerning consumer. Although the distinctly different properties of both of these two cheese are the result of microbial and enzymatic activities, there is one clear distinguishing factor. The key difference is that the gourmet cheese is produced when aging occurs under controlled conditions, whereas the rejected cheese occurs when control is absent or lost. As a general rule, any cheese that is intended for aging must be manufactured, from the very start, differently than an unaged cheese. The handling of the milk, the cheese pH, the moisture and salt content, and the water/salt ratio, in particular, all are important determinants that influence aged cheese quality.

In addition to its impact on the finished cheese, aging or ripening is also one of the most complex and most variable of all cheese making steps. This is due largely to the enzymes and microorganisms that are primarily responsible for flavor and texture changes that occur during ripening. The enzymes in cheese may occur naturally in the milk or be added directly in the form of rennet, chymosin, or lipase extracts. Enzymes are also derived from starter culture bacteria, adjunct organisms, or endogenous milkborne organisms. Furthermore, the availability of substrates and the pH and Eh conditions in the cheese influence the activity of these enzymes and the types and amounts of products that are formed. Similarly, microorganisms in cheese originate from the milk, the environment, and the starter culture. Although the temperature in aging rooms is generally low (usually around 3°C to 7°C, but sometimes much higher), and the cheese milieu is not particularly conducive for growth (as noted above), metabolism of the various substrates in cheese by intact organisms still occurs. A ripening cheese represents a rather vibrant ecosystem.

Types of Cheese

Given the hundreds of cheeses produced worldwide, it is obviously not possible to discuss each particular one. There are, however, several ways to categorize the many different types of cheese into manageable groups, based, for example, on their level of hardness (e.g., from soft to hard), moisture content, cooking temperature, or extent of aging. In the sections that follow, the manufacturing procedures for different cheeses and the role of microorganisms involved in their production will be reviewed, based on the primary properties of those cheeses and their distinguishing characteristics (Table 5–1).

Table 5.1. Properties of major cheese groups.

Cheese	Starter Culture	Other organisms	Salt	Moisture	pH
Cheddar type					
Cheddar	mesophilic[1]		1.5	37	5.5
Cheshire	mesophilic		1.7	38	4.8
Colby	mesophilic		1.5	39	5.5
Dutch type					
Gouda	mesophilic	*Leuconostoc* sp.	2.0	41	5.8
Edam	mesophilic	*Leuconostoc* sp.	2.0	42	5.7
Cheese with eyes					
Emmenthal	thermophilic[2]	*Propionibacterium*	0.7	35	5.6
Gruyere	thermophilic	*Propionibacterium*	1.1	33	5.7
Grating type					
Parmesan	thermophilic		2.6	31	5.4
Romano	thermophilic		5.5	23	5.4
Pasta filata					
Mozzarella	thermophilic		1.2	53	5.2
Provolone	thermophilic		3.0	42	5.4
Blue mold					
Roquefort[3]	mesophilic	*Penicillium roqueforti*	3.5	40	6.4
Gorgonzola	mesophilic	*Penicillium roqueforti*	2.5	45	6.2
Stilton	mesophilic	*Penicillium roqueforti*	2.3	39	6.2
External mold					
Brie[4]	mesophilic	*Penicillium camemberti*	1.6	52	6.9
Camembert[4]	mesophilic	*Penicillium camemberti*	2.5	49	6.9
Surface ripened					
Havarti	mesophilic		1.9	43	6.4
Muenster	mesophilic	*Brevibacterium linens*	1.6	42	6.4
Limburger[5]	mesophilic	*Brevibacterium linens*	2.0	45	6.8
Brined					
Feta	mesophilic		3.0	53	4.5

[1]Mesophilic cultures = *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris*
[2]Thermophilic cultures = *Streptococcus thermophilus, Lactobacillus delbrueckii* subsp. *bulgaricus*, and/or *Lactobacillus helveticus*
[3]Citrate-fermenting *Leuconostoc* or *Lactococcus* sp. may be added
[4]*Streptococcus thermophilus* may be added
[5]For Limburger and other surface-ripened cheeses, species of *Arthrobacter, Micrococcus*, and yeasts may also be present.
Data from Guinee and Fox, 2004; Marcos et al., 1981; and other sources

Acid-coagulated cheeses

In the United States, the most popular of the acid-precipitated cheeses are Cottage cheese and cream cheese. And although per capita consumption of Cottage cheese (all varieties) has declined in the past twenty years by nearly 30% (despite modest increases in lowfat versions), cream cheese per capita consumption has increased by more than 100% (from less than 0.5 Kg to more than 1 Kg per person per year). This increase in cream cheese consumption is undoubtedly due to an equal increase in the popularity of bagels and cheesecakes. The availability of flavored, whipped, and low- and reduced- fat cream cheese products has also contributed to this increase.

Other cheeses in this category, including bakers' cheese and farmers' cheese, have only a small share of the market.

Processed and Cold Pack Cheese

Although cheese is the main ingredient, processed cheese (or what many consumers mistakenly call American cheese) is not a fermented food. However, because processed cheese is so popular in the United States and there is so much confusion regarding the differences between natural cheese and processed cheese, it is worthwhile to describe the manufacture of processed cheese.

Briefly, processed cheese is made by adding emulsifying salts to natural cheese, along with water and other dairy and non-dairy ingredients. The mixture is then agitated while being heated to about 70°C or higher. The emulsification that occurs in processed cheese is different than other true food emulsions. In the case of process cheese, sodium or potassium polyphosphate and citrate emulsifying salts raise the pH and displace calcium ions from the casein complex, resulting in more soluble sodium casein. The latter contains both lipophilic and hydrophilic regions that then forms an emulsion-like mixture with the lipid portion of the cheese. After heating, the cooled mixture is then formed into slices or loaves or filled into jars or cans. The finished products have excellent functionality and convenience features. Due to the heat treatment and other inherent conditions (pH, water activity, antimycotic agents), these products also have long shelf-lives,even at ambient temperature.

The quality of the cheese used as the starting material is among the factors that influence processed cheese manufacture.A typical blend consists of 15% aged and 85% young (or current) cheese. The aged cheese provides flavor; the young cheese provides elasticity, body, and emulsifying properties. Too much of the former may cause a soft, soupy body, too much of the latter may lead to hard body and brown pigment formation. Cold pack cheese, in contrast, is made by mixing or grinding different types of natural cheese in the absence of heat. Various optional ingredients, including color, spices, and other flavoring agents, as well as antimycotic agents, can also be added. These products have excellent flavor, but typically lack the functionality of process cheeses.

Fermented Milk

Milk fermentations must undoubtedly be among the oldest of all fermented foods. Milk obtained from a domesticated cow or camel or goat, some thousands of years ago, would have been fermented within hours by endogenous lactic acid bacteria, creating a yogurt-like product. In fact, the ability to maintain milk in a fresh state before souring and curdling had occurred would have been quite some trick, especially in warm environments. Of course, fermentation and acid formation would have been a good thing since, in the absence of viable lactic acid bacteria, other bacteria, including pathogens, could have grown and caused unpleasant side effects.

Milk is particularly suitable as a fermentation substrate owing to its carbohydrate-rich, nutrient-dense composition. Fresh bovine milk contains 5% lactose and 3.3% protein and has a water activity near 1.0 and a pH of 6.6 to 6.7, perfect conditions for most microorganisms. Lactic acid bacteria are saccharolytic and fermentative, and, therefore, are ideally suited for growth in milk. In general, they will out-compete other microorganisms for lactose, and by virtue of acidification, will produce an inhospitable environment for would-be competitors. Therefore, when properly made, cultured dairy products have long shelf-lives and, although growth of acid-tolerant yeast and molds is possible, growth of pathogens rarely occurs.

Given the early recognition of the importance of milk in human nutrition and its widespread consumption around the world, it is not surprising that cultured dairy products have evolved on every continent. Their manufacture was already well established thousands of years ago. Although the manufacturing procedures, the sources of milk, and the names of these products may vary considerably, they share many common characteristics. Thus, dahi (India), laban (Egypt, Lebanon), and jugart (Turkey) are all yogurt-like products whose manufacture involves similar milk handling procedures and depends on the same thermophilic culture bacteria. Other products, in particular, kefir and koumiss, evolved from Asia, and are made using various lactose-fermenting yeasts in addition to lactic acid bacteria.

1. Curd/Dahi

Dahi (Indian curd) is well known fermented milk product consumed by large sections of the population throughout the country, either as a part of the daily diet or as a refreshing beverage. Dahi is prepared from heated milk (generally boiled milk) after inoculation with starter culture. Dahi is produced with varieties of taste varying with region-to-region and individual food habits. It is estimated that about 6.9 per cent of total milk produced in India is utilized for making dahi.

Definition of Dahi

Dahi or curd is a semi solid product, obtained from pasteurized or boiled milk by souring, using harmless lactic acid or other bacterial cultures. Dahi may contain additional cane sugar. It should have the same minimum percentage of fat and solids-not-fat as the milk from which it is prepared. Where Dahi or curd, other than skimmed milk Dahi, is sold or offered for sale without any indication of the class of milk, the standards prescribed for Dahi prepared from buffalo milk shall apply.

Dahi made from buffalo milk produces a thick bodied product because of its high SNF content. Dahi prepared from whole milk contains about 5 – 8% fat, 3.2 – 3.4% protein, 4.6 – 5.2% lactose, 0.70 – 0.72% ash, and titratable acidity 0.60–0.80 % lactic acid.

Table: FSSR (2011) and BIS specifications of Dahi

Characteristics	FSSR(2011)	BIS
Acidity % lactic acid	-	0.6 - 0.8
Total Plate count	Not more than 1000000/g	
Coliform count	10 per g max	10 per g max
Escherechia coli	Absent in 1g	
Salmonella	Absent in 25g	
Shigella	Absent in 25g	
Stephylococcus aureus	Not more than 100/g	
Yeast and Mould	100 per g max	100 per g max
Anaerobic spore	Absent in 1g	
Listeria monocytogenes	Absent in 1g	
Phosphatase test		Negative
Other requirements	It should have the same minimum percentage of fat and SNF as the milk from which it is prepared. If no standards declared then standards prescribed for dahi from buffalo milk shall apply	Dahi shall conform to the requirements of milk fat and MSNF, as laid down in FSSR, 2011

Classification of Dahi

Dahi is prepared in different varieties with region specific tastes. Dahi may be classified on the following basis.

- Dahi for consumption
- Dahi for production of desi butter
- Dahi for preparation of chakka, shrikhand and lassi
- Dahi prepared from whole milk, skim milk, standard milk, and special milk
- Dahi prepared with added sugar and fruits

Optimum acidity of normal dahi is less than 0.7% lactic acid while acidity of sour dahi is more than 0.7% lactic acid. Dahi made from buffalo milk produces a thick bodied product because of its high total solids content. It is recommended to make dahi from a milk containing 11- 13% total solids. Higher milk solids yield dahi with higher consistency and also keep the product from wheying off.

Method of Manufacture of Dahi

i. **Traditional method:** In traditional method dahi is prepared at small scale, either in the consumer's household or in the confectionary (*Halwais*) shop. Milk is heated intensively to boil for 5 to 10 min, cooled to room temperature and inoculated with previous day's curd or butter milk at the rate of 0.5 to 1.0 %. Milk is then stirred and allowed to set undisturbed for about overnight. At the confectionary shops, the method employed for preparation of dahi is more or less same except that the milk is concentrated in open pan before inoculation. Concentration of milk results in custard like consistency of dahi and keeps the product from wheying off.

ii. **Industrial Method of Dahi Making:** Organized sector produces dahi on the basis of scientific lines. Fresh, sweet, good quality milk is received, preheated to 35°- 40°C and subjected to filtration and clarification to ensure that, the milk is free from extraneous matter. The milk is standardized to 2.5 - 3.0 % fat and 10 – 12% solids not fat, preheated to 60°C and homogenized at a pressure of 175 kg/ cm2 in single stage. The milk is heated to 85° – 90°C for 15-30 minutes, cooled to 37°C and inoculated with 1 – 1.5 % of specific dahi starter culture. It is then filled in suitable packaging containers (food grade polystyrene and polypropylene cups) of the appropriate size and incubated at 37°C for suitable time. After proper setting of the dahi, the acidity of dahi reaches 0.6 to 0.7 percent and a firm curd is formed. The product mix is incubated till its pH reaches 4.4 to 4.5 and then it is cooled rapidly to less than 5°C by exposing the cups to high velocity cold air. Dahi is normally stored at 4 – 5°C. Storage area should be maintained clean and tidy to avoid any cross contamination. The flow diagram for manufacture of dahi is presented in Fig. below.

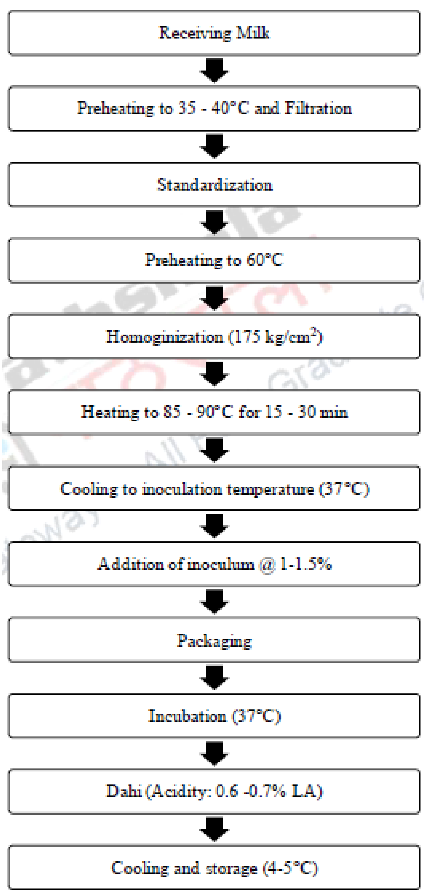

Fig. Flow sheet for manufacture of Dhai

2. Acidophilus milk

Acidophilus milk is cultured with *Lactobacillus acidophilus*, whose primary function is to produce lactic acid from lactose. Moreover, *Lactobacillus acidophilus* is considered to be a probiotic bacterium, and has been claimed to confer various nutritional and health benefits on consumers. An ability to grow in the presence of acid and bile acids enables it to survive in the intestinal tract. *Lactobacillus acidophilus* grows only slowly in milk and therefore it is essential to maintain the inoculum's activity by daily transfers of mother culture; this will help to ensure consistent results. Acidophilus milk is fermented at 38 °C with the inoculum of 2–5% active culture, until a curd forms (which usually happens after 18–24 h). The final product contains 1.5–2.0% lactic acid but no alcohol. It is cooled to 10 °C before agitation and pumped to a filler where it is filled into bottles or cartons. In some countries, doctors recommend acidophilus milk to patients with various gastrointestinal tract disorders including constipation, nonulcerative colitis, and diarrhea.

3. Bulgarian Milk

Bulgarian buttermilk, a high-acid fermented milk, is made by inoculating *Lactobacillus delbrueckii* subsp. *bulgaricus* alone (at 2% inoculum) into pasteurized whole milk and incubating at 38–42 °C for 10–12 h, until a curd forms with about 1.4% titratable acidity, which gives it a sharp acidic flavor. This product is popular only in Bulgaria.