

Chapter 2

Overview of Cheese Manufacture

Summary The objective of this chapter is to present a very brief description of the principal operations of cheese production so that the operations described in the following chapters can be seen in an overall context

Introduction

The production of all varieties of cheese involves a generally similar protocol (Fig. 2.1), various steps of which are modified to give a product with the desired characteristics. The principal general steps are

1. Selection, standardization and, in most cases, pasteurization of the milk.
2. Acidification, usually via the in situ production of lactic acid by selected bacteria.
3. Coagulation of the milk by acidification or limited proteolysis.
4. Dehydration of the coagulum to yield cheese curd, by a range of techniques, some of which are variety-specific.
5. Forming the curds into characteristic shapes.
6. For most varieties, ripening (maturation) of the curd during which the characteristic flavour and texture of the cheese develop.

The objective of this chapter is to present a very brief description of the principal operations so that the operations described in the following chapters can be seen in an overall context.

Keywords Selection and treatment of cheesemilk • Annato • Coagulation • Salting • Ripening • Processed cheese

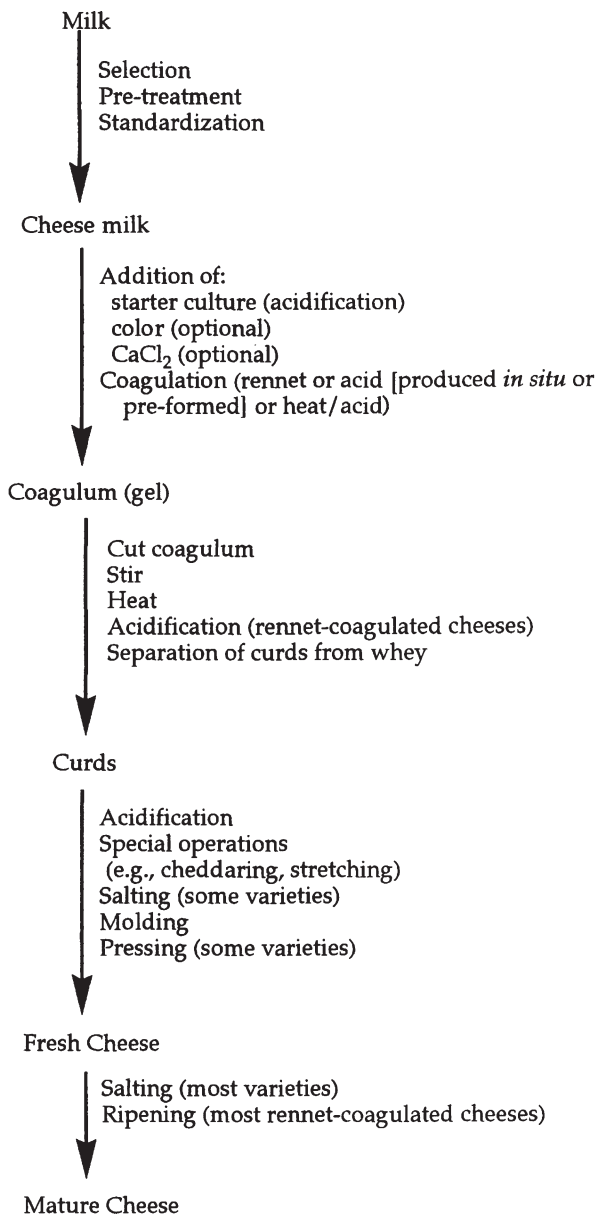


Fig. 2.1 General protocol for cheese manufacture

2.1 Selection of Milk

The composition of cheese is strongly influenced by the composition of the cheese milk, especially the content of fat, protein, calcium and pH. The constituents of milk, which are described in Chap. 4, are influenced by several factors, including species, breed, individuality, nutritional status, health and stage of lactation of the producing animal. Owing to major compositional abnormalities, milk from cows in the very early or late stages of lactation and those suffering from mastitis should be excluded. Somatic cell (leucocyte) count is a useful index of quality. Some genetic polymorphs of the milk proteins have a significant effect on cheese yield and quality and there is increasing interest in breeding for certain polymorphs. The milk should be free of chemical taints and free fatty acids, which cause off-flavours in the cheese, and antibiotics which inhibit bacterial cultures.

The milk should be of good microbiological quality, as contaminating bacteria will be concentrated in the cheese curd and may cause defects or public health problems. This subject will be discussed in Chap. 5.

2.2 Standardization of Milk Composition

Milk for cheese is subjected to a number of pre-treatments, with various objectives.

Different cheese varieties have a characteristic fat-in-dry matter content, in effect, a certain fat-to-protein ratio and this situation has legal status in the “Standards of Identity” for many cheese varieties. While the moisture content of cheese, and hence the level of fat plus protein, is determined mainly by the manufacturing protocol, the fat:protein ratio is determined mainly by the fat:casein ratio in the cheese milk. Depending on the ratio required, it can be modified by:

- removing some fat by natural creaming, as in the manufacture of Parmigiano Reggiano, or centrifugation
- adding skim milk
- adding cream
- adding micellar casein (prepared by ultrafiltration)
- adding milk powder, evaporated milk or ultrafiltration retentate. Such additions also increase the total solids content of the milk and hence cheese yield and will be discussed in Chap. 10.

Calcium plays a major role in the coagulation of milk by rennet and subsequent processing of the coagulum and hence it is common practice to add CaCl_2 (e.g., 0.01 %) to cheese milk.

The pH of milk is a critical factor in cheesemaking. The pH is inadvertently adjusted by the addition of 1.5–2 % starter culture which reduces the pH of the milk immediately by about 0.1 unit. Starter concentrates (sometimes called direct-to-vat starters), which are now used widely, have no immediate acidifying effect.

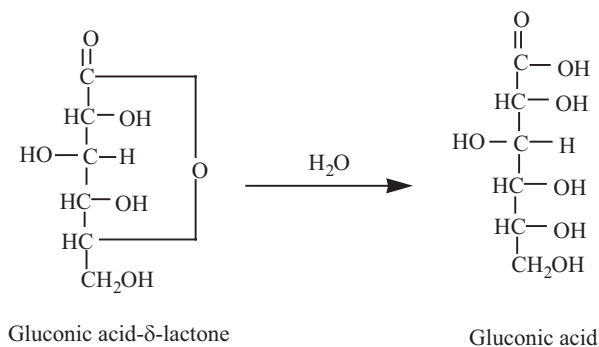
Previously, it was standard practice to add the starter to the cheese milk 30–60 min before rennet addition. During this period, the starter microorganisms began to grow and produce acid, a process referred to as “ripening”. Ripening served a number of functions:

- it allowed the starter bacteria to enter their exponential growth phase and hence to be highly active during cheesemaking; this is not necessary with modern high-quality starters.
- the lower pH was more favourable for rennet action and gel formation.

However, the practice increases the risk of bacteriophage infection of the starter as phage become distributed throughout the liquid milk but is reduced after the milk has coagulated (see Chap. 6). Although ripening is still practiced for some varieties, it has been discontinued for most varieties.

The pH of milk on reception at the dairy is higher today than it was previously owing to improved hygiene during milking and the more widespread use of refrigeration at the farm and factory. In the absence of acid production by contaminating bacteria, the pH of milk increases slightly during storage due to the loss of CO_2 to the atmosphere. The natural pH of milk is ~ 6.6 – 6.7 but varies somewhat (e.g., it increases in late lactation and during mastitic infection).

To offset these variations and to reduce the pH as an alternative to ripening, the pre-acidification of milk by 0.1–0.2 pH units is recommended, either through the use of the acidogen, gluconic acid- δ -lactone, or by limited growth of a lactic acid starter, followed by pasteurization (referred to as pre-maturation).



2.3 Heat Treatment of Milk

Traditionally, all cheese was made from raw milk, a practice which remained widespread until the 1940s. Even today, significant amounts of cheese are made in Europe from raw milk. The use of raw milk may be undesirable due to:

- Public health safety
- The presence of undesirable microorganisms which may cause defects or variability in flavour and/or texture.

When cheese was produced from fresh milk on farms or in small, local factories, the growth of contaminating microorganisms was very low but as cheese factories became larger, storage of milk for longer periods became necessary and hence the microbiological quality of the milk varied. For public health reasons, it became increasingly popular from the beginning of the twentieth century to pasteurize milk for liquid consumption. The pasteurization of cheese milk became widespread about 1940, primarily for public health reasons, but also to provide a milk supply of more uniform bacteriological quality and to improve its keeping quality. Although a considerable amount of cheese is still produced from raw milk, on both an artisanal and factory scale, especially in southern Europe (including such famous varieties as Swiss Emmental, Gruyère de Comté, Parmigiano Reggiano and Grano Padano), pasteurized milk is now generally used, especially in large factories. The flavour of cheese made from raw milk is different from and more intense than that from pasteurized because beneficial indigenous LAB, which may contribute positively to cheese flavour, are killed by pasteurization. To counteract the loss of such LAB, it is becoming increasingly common to add a culture of selected LAB (lactobacilli) to cheese milk in addition to the main acid-producing culture. Some indigenous enzymes, e.g., lipase, which may contribute positively to cheese ripening, are also inactivated by pasteurization. A sub-pasteurization temperature, eg., 68–70 °C may be used for cheese milk and a temperature >72 °C × 15 s should not be used, owing to damage to the cheesemaking properties of milk (see Chaps. 7 and 8). Aspects of pasteurization are discussed in Chap. 5.

There are four alternatives to pasteurization for reducing the number of microorganisms in milk:

- treatment with H₂O₂
- Activation of the lactoperoxidase-H₂O₂-thiocyanate system.
- Bactofugation
- Microfiltration

These processes are also discussed briefly in Chap. 5.

2.4 Cheese Colour

Colour is a very important attribute of foods and serves as an index of quality, although in some cases, this is cosmetic. The principal indigenous pigments in milk are carotenoids which are obtained from the animal's diet, especially from fresh grass and clover. The carotenoids are secondary pigments involved in photosynthesis; the structure of β-carotene is shown in Fig. 2.2. Owing to the conjugated double bond system, carotenoids absorb ultraviolet and visible light, giving them colours ranging from yellow to red. They are responsible for the

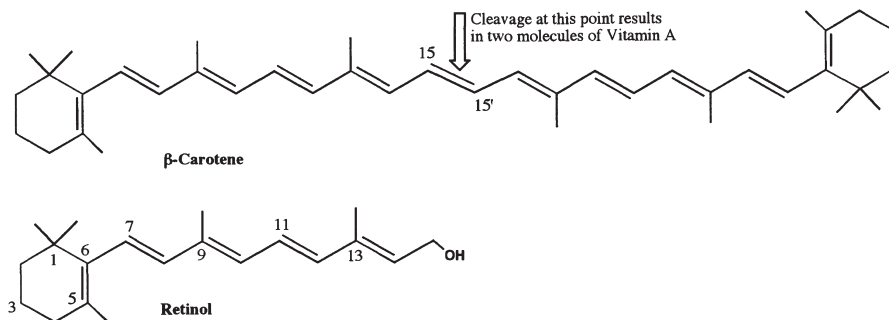


Fig. 2.2 Structures of β -carotene and retinol

colour of many foods, e.g., carrots, squashes, peppers, maize; they are also present in the leaves of plants in which their colour is masked by the green chlorophylls. Some carotenoids have pro-vitamin A activity and may be converted to retinol (vitamin A; Fig. 2.2) in the body.

Animals do not synthesize carotenoids but absorb them from plant materials in their diet. In addition to serving as pro-vitamin A, some animals store carotenoids in their tissues, which then acquire a colour, e.g., salmon, cooked lobster and egg yolk. Cattle transfer carotenoids to adipose tissue and milk but goats, sheep and buffalo do not. Therefore, bovine milk and products made therefrom are yellow to an extent dependent on the carotenoid content of the animal's diet. Products such as butter and cheese made from sheep, goat or buffalo milk are very white in comparison with their counterparts made from bovine milk. This yellowish colour may make products produced from cows' milk less acceptable than products produced from sheep's, goats' or buffalo milk in Mediterranean countries where the latter are traditional. The carotenoids in bovine milk can be bleached by treatment with H_2O_2 or benzoyl peroxide or masked by chlorophyll or titanium oxide (TiO_2), although such practices are not permitted in all countries.

At the other end of the spectrum are individuals who prefer highly coloured cheese, butter or egg yolk. Such intense colours may be obtained by adding carotenoids (synthetic or natural extracts) directly to the product or to the animal's diet. In the case of cheese and dairy products, annatto, extracted from the pericarp of the seeds of the annatto plant (*Bixa orellana*), a native of Brazil, is used most widely. Annatto contains two apocarotenoid pigments, bixin and norbixin (Fig. 2.3). By suitable modification, the annatto pigments can be made fat-soluble, for use in butter or margarine, or water-soluble for use in cheese.

Initially, annatto may have been used in cheese manufacture to give the impression of a high fat content in partially skimmed cheese but some people believe that coloured ("red") cheese tastes better than its white counterpart of equivalent quality.

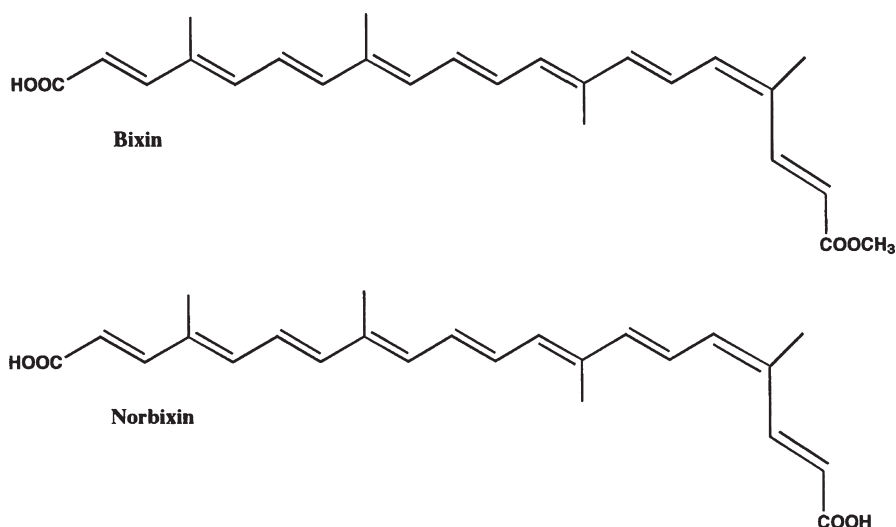


Fig. 2.3 Structures of *cis*-bixin and norbixin, the apocarotenoid pigments in annatto

2.5 Conversion of Milk to Cheese Curd

After the milk has been standardized, pasteurized or otherwise treated, it is transferred to vats (or kettles) which vary in shape (hemi-spherical, rectangular, vertical or horizontal cylindrical), may be open or closed and may range in size from a few hundred litres to 20,000–40,000 L [a selection of vats are shown in Fig 2.4]. Here, it is converted to cheese curd, a process that involves three basic operations: acidification, coagulation and dehydration.

2.5.1 Acidification

Acidification is usually achieved by the *in situ* production of lactic acid through the fermentation of the milk sugar, lactose, by lactic acid bacteria. Initially, the indigenous milk microflora was relied upon to produce acid but since this microflora is variable, the rate and extent of acidification are variable, resulting in cheese of variable quality. Cultures of lactic acid bacteria for cheesemaking were introduced commercially about 130 years ago and have been progressively improved and refined. The science and technology of starters are described in Chap. 6. The acidification of curd for some artisanal cheeses still relies on the indigenous microflora.

Direct acidification using acid (usually lactic or HCl) or acidogen (usually gluconic acid- δ -lactone) may be used as an alternative to biological acidification and is used commercially to a significant extent in the manufacture of Cottage, Quarg, Feta-type cheese from UF-concentrated milk and Mozzarella. Direct acidification is



Fig. 2.4 Examples of vats used for cheesemaking

more controllable than biological acidification and, unlike starters, is not susceptible to phage infection. However, in addition to acidification, the starter bacteria serve very important functions in cheese ripening (see Chaps. 11 and 12) and hence chemical acidification is used mainly for cheese varieties for which texture is more important than flavour.

The rate of acidification is fairly characteristic of the variety and its duration ranges from 5 to 6 h for Cheddar and Cottage to 10–12 h for Dutch and Swiss types. The rate of acidification, which depends on the amount and type of starter used and on the temperature profile of the curd, has a major effect on the texture of cheese, mainly through its solubilizing effect on colloidal calcium phosphate; this subject is discussed in Chap. 14.

Regardless of the rate of acidification, the ultimate pH of the curd for most hard cheese varieties is in the range 5.0–5.3 but it is 4.6 for the soft, acid-coagulated varieties, e.g., Cottage, Quarg and Cream, and some rennet-coagulated varieties, e.g., Camembert and Brie.

The production of acid at the appropriate rate and time is a key step in the manufacture of good quality cheese. Acid production affects several aspects of cheese manufacture, many of which will be discussed in more detail later:

- Coagulant activity during coagulation (Chap. 7).
- Denaturation and retention of the coagulant in the curd during manufacture and hence the level of residual coagulant in the curd; this influences the rate of proteolysis during ripening, and may affect cheese quality (Chaps. 8 and 12).
- Curd strength, which influences cheese yield (Chap. 10).
- Gel syneresis, which controls cheese moisture and hence regulates the growth of bacteria and the activity of enzymes in the cheese; consequently, it strongly influences the rate and pattern of ripening and the quality of the finished cheese (Chaps. 8, 12 and 15).
- The rate of acidification determines the extent of dissolution of colloidal calcium phosphate which modifies the susceptibility of the caseins to proteolysis during ripening and influences the rheological properties of the cheese, e.g., compare the texture of Emmental, Gouda, Cheddar and Cheshire cheese (see Chap. 14).
- Acidification controls the growth of many non-starter bacteria in cheese, including pathogenic, food-poisoning and gas-producing microorganisms; properly-made cheese is a very safe product from the public health viewpoint (see Chap. 19).

The level and time of salting have a major influence on pH changes in cheese. The concentration of NaCl in cheese (commonly 0.7–4 %, equivalent to 2–10 % salt in the moisture phase) is sufficient to halt the growth of starter bacteria. Some varieties, mostly of British origin, are salted by mixing dry salt with the curd toward the end of manufacture and hence the pH of curd for these varieties must be close to the ultimate value (~ pH 5.1) at salting. However, most varieties are salted by immersion in brine or by surface application of dry salt; salt diffusion in cheese moisture is a relatively slow process and thus there is ample time for the pH to decrease to ~5.0 before the salt concentration becomes inhibitory throughout the interior of the cheese. The pH of the curd for most cheese varieties, e.g., Swiss, Dutch, Tilsit, Blue, etc., is 6.2–6.5 at moulding and pressing but decreases to ~5–5.2 during or shortly after pressing and before salting. The significance of various aspects of the concentration and distribution of NaCl in cheese are discussed in Chap. 9.

In a few special cases, e.g., Domiati, a high level of NaCl (10–12 %) is added to the cheesemilk, traditionally to control the growth of the indigenous microflora. This concentration of NaCl has a major influence, not only on acid development, but also on rennet coagulation, gel strength and curd syneresis.

2.5.2 Coagulation

The essential characteristic step in the manufacture of all cheese varieties involves coagulation of the casein component of the milk protein system to form a gel which entraps the fat, if present. Coagulation may be achieved by:

- Limited proteolysis by selected proteinases (rennets);
- Acidification to ~pH 4.6;
- Acidification to a pH value >4.6 (perhaps ~5.2) in combination with heating to ~90 °C.

The majority of cheese varieties, and ~75 % of total production, are produced by rennet coagulation but some acid-coagulated varieties, e.g., Quarg, Cottage and Cream, are of major importance. The coagulation of milk by rennets or acid are discussed in Chaps. 7 and 16, respectively. Acid-heat-coagulated cheeses are of relatively minor importance and are usually produced from whey or a blend of whey and skim milk and probably evolved as a useful means for recovering the nutritionally-valuable whey proteins. Their properties are very different from those of rennet- or acid-coagulated cheeses and they are usually used as food ingredients. Important varieties are Ricotta and related varieties (indigenous to Italy), Anari (Cyprus) and Manouri (Greece) (see Chaps. 3 and 18).

A fourth, minor, group of cheeses is produced, not by coagulation, but by thermal evaporation of water from a mixture of whey and skim milk, whole milk or cream and crystallization of lactose. Varietal names include Mysost and Gjetost. These cheeses, which are almost exclusive to Norway, bear little resemblance to rennet- or acid-coagulated cheeses and probably should be classified as whey products rather than cheese, *sensu stricto*.

2.5.3 Post-Coagulation Operations

Rennet or acid-coagulated milk gels are quite stable if maintained under quiescent conditions but if cut or broken, they synerese, expelling whey. Syneresis essentially concentrates the fat and casein of milk by a factor of 6–12, depending on the variety. In the dairy industry, concentration is normally achieved through thermal evaporation of water and more recently by removing water through semi-permeable membranes. The syneresis of rennet- or acid-coagulated milk gels is thus a rather unique method for dehydration, dependent on special characteristics of the caseins.

The rate and extent of syneresis are influenced, *inter alia*, by milk composition, especially the concentrations of Ca^{2+} and casein, pH of the whey, cooking temperature, rate of stirring of the curd-whey mixture and, of course, time (see Chap. 8). The composition of the finished cheese is determined by the extent of syneresis and since this is under the control of the cheesemaker, it is here that the differentiation of the individual cheese varieties really begins, although the type and composition of the milk, the amount and type of starter and the amount and type of rennet are also significant in this regard.

A more or less unique protocol has been developed for the manufacture of each cheese variety. These protocols differ mainly with respect to the syneresis process. The protocols for the manufacture of the principal families of cheese are summarized in Chap. 3.

2.5.4 Removal of Whey, Moulding and Pressing of the Curd

When the desired degree of syneresis has been achieved and in some cases, the desired pH attained also, the curds are separated from the whey by a variety-specific method, e.g., transferring the curds-whey into perforated moulds (common for soft varieties, e.g., Camembert), allowing the curds to settle in the vat and sucking off the supernatant whey (e.g., Gouda and Emmental), scooping the curds from the vat using heavy cloths and placing them in moulds (e.g., Parmigiano Reggiano), draining the whey from the curds using perforated screens (e.g., Cheddar and Pizza cheese).

Many cheeses are made into traditional shapes and sizes, e.g., small flat cylinders (e.g., Brie and Camembert), taller cylinders, ranging in size from 5 to 40 kg (e.g., Cheddar and Parmesan), large low cylinders (e.g., Emmental), spheres (Edam). In some cases the traditional shapes have been abandoned, e.g., Cheddar and Emmental now frequently made as rectangular or square blocks.

In some cases, the size and shape of a cheese are cosmetic and traditional but the size of a cheese has important consequences for the ripening of many varieties. Surface-ripened varieties, e.g., Camembert, must be small since the surface microflora plays a critical role in ripening but are effective over only a short distance. The opposite is required for varieties in which eyes develop due to the propionic acid fermentation, e.g., Emmental, which must have a close texture and large enough to retain sufficient CO₂ for eye development. For an 80 kg Emmental cheese, 120 L of CO₂ are produced during maturation, 60 L remain dissolved in the cheese body, 40 L diffuse out of the cheese and 20 L are in the eyes.; too much CO₂ will be lost from a small or open cheese and eye formation will be poor or absent. A selection of cheese shapes is shown in Fig 2.5.

Curds for high-moisture cheeses form a congealed mass under their own weight but the curds for medium- and especially for low-moisture cheese must be pressed to form a well-matted body, e.g., Cheddar cheese is pressed at 2.7 kPa. As well as consolidating the curd mass, pressing removes some whey, e.g., for Cheddar cheese, ~1.3 % of the volume of milk used is in the press whey.

2.5.5 Special Operations

The curds or pressed cheese curd for certain varieties are subjected to specific treatments to induce a characteristic texture or physico-chemical property or to induce the growth of certain microorganisms. Examples of such varieties are Cheddar, Pasta Filata, washed-curd varieties or Blue cheeses.



Cheddar



Camembert



Blue



Edam



Emmental



Gouda



Parmigiano-reggiano



Provolone

Fig. 2.5 Examples of the shape of cheese

2.5.6 Salting

Salting is the last manufacturing operation. Salting promotes syneresis but it is not a satisfactory method for controlling the moisture content of cheese curd which is best achieved by ensuring that the degree of acidification, heating and stirring in the cheese vat are appropriate to the particular variety. Salt has several functions in cheese, which are described in Chap. 9. Although salting should be a very simple operation, quite frequently it is not performed properly, with consequent adverse effects on cheese quality.

A low level of Na is essential in the diet (the RDA in the USA and UK is 2.4 g) but an excessive intake is undesirable. Although cheese contributes relatively little NaCl, even with a high consumption of cheese (consumption of 20 kg of cheese, containing 2 % NaCl, per annum, which is at the upper level of consumption, contributes 400 g NaCl per annum, i.e., about 1.1 g NaCl or 0.7 g of sodium daily), there is a commercial incentive to reduce the level of salt in cheese. Approaches are discussed in Chap. 9.

2.5.7 Application of Ultrafiltration in Cheesemaking

Since cheese manufacture is essentially a dehydration process, it was obvious that ultrafiltration would have applications in cheese manufacture, not only for standardizing cheese milk with respect to fat to casein, but also for the preparation of a concentrate with the composition of the finished cheese, commonly referred to as “pre-cheese”. Standardization of cheese milk by adding UF concentrate (retentate) is now common but the manufacture of pre-cheese has to date been successful commercially for only certain cheese varieties, most notably UF Feta and Quarg. It seems very likely that ultrafiltration will become much more widespread in cheese manufacture, perhaps for the production of new varieties rather than modifying the process protocol for existing varieties.

2.6 Ripening

Fresh cheeses constitute a major proportion of the cheese consumed in some countries. Most of these cheeses are produced by acid coagulation and are described in Chap. 16. Although rennet-coagulated cheese varieties may be consumed at the end of manufacture and a little is (e.g., Burgos cheese), most rennet-coagulated cheeses are ripened (cured, matured) for a period ranging from ~3 weeks to >2 years; generally, the duration of ripening is inversely related to the moisture content of the cheese. Many varieties may be consumed at any of several stages of maturity, depending on the flavour preferences of consumers and economic factors.

Although curds for different cheese varieties are recognizably different at the end of manufacture (mainly as a result of compositional and textural differences arising from differences in milk composition and processing factors), the unique characteristics of the individual cheeses develop during ripening as a result of a complex set of biochemical reactions. The changes that occur during ripening, and hence the flavour, aroma and texture of the mature cheese, are largely predetermined by the manufacturing process, i.e., by composition, especially moisture, NaCl and pH, level of residual coagulant activity, the type of starter and in many cases by a secondary inoculum added to, or gaining access to, the milk or curd.

The biochemical changes that occur during ripening are caused by one or more of the following agents:

- coagulant
- indigenous milk enzymes, especially proteinase and lipase, which are particularly important in cheese made from raw milk
- starter bacteria and their enzymes
- secondary microorganisms and their enzymes
- non-starter lactic acid bacteria

The secondary microflora may arise from the indigenous microflora of milk that survive pasteurization or gain entry to the milk after pasteurization, e.g., some mesophilic *Lactobacillus* spp. especially *Lb casei* and *Lb paracasei*, and perhaps *Pediococcus* and *Micrococcus*. They may also be added as a secondary starter, e.g., citrate-positive *Lactococcus* or *Leuconostoc* spp. in Dutch-type cheese, *Propionibacterium* in Swiss cheese, *Penicillium roqueforti* in Blue varieties, *P. camemberti* in Camembert or Brie, or *Brevibacterium linens* in surface smear-ripened varieties, e.g., Tilsit and Limburger. In many cases, the characteristics of the finished cheese are dominated by the metabolic activity of these secondary microorganisms.

The primary biochemical changes involve catabolism of residual lactose and perhaps citrate, lipolysis and proteolysis but these are followed and overlapped by a host of secondary catabolic changes to the compounds produced in these primary pathways, including deamination, decarboxylation and desulphurylation of amino acids, β -oxidation of fatty acids, catabolism of lactic acid and even some synthetic reactions, e.g., esterification.

Although it is not yet possible to fully describe the biochemistry of cheese ripening, very considerable progress has been made on elucidating the primary reactions and these will be discussed in Chap. 12.

2.7 Processed Cheese Products

Depending on culinary traditions, a variable proportion of mature cheese is consumed as such, often referred to as “table cheese”. A considerable amount of natural cheese is used as an ingredient in other foods, e.g., Parmesan or Grana on pasta

products, Mozzarella on pizza, Quarg in cheesecake, Ricotta in ravioli. A third major outlet for cheese is in the production of a broad range of processed cheese products which in turn have a range of applications, especially as spreads, sandwich fillers or food ingredients. These products are discussed in Chaps. 17 and 18.

2.8 Whey and Whey Products

Only about 50 % of the solids in milk are incorporated into cheese; the remainder (90 % of the lactose, ~ 20 % of the protein and ~10 % of the fat) are present in the whey. Until recently, whey was regarded as an essentially useless by-product, to be disposed of as cheaply as possible. However, in the interest of reducing environmental pollution, but also because it is now possible to produce valuable food products from whey, whey processing has become a major facet of the total cheese industry. The principal aspects of whey processing are discussed in Chap. 22.

Fundamentals of Cheese Science

Fox, P.F.; Guinee, T.P.; Cogan, T.M.; McSweeney, P.L.H.
2017, XV, 799 p. 271 illus., 78 illus. in color., Hardcover
ISBN: 978-1-4899-7679-6