# Cheese

## Tradition and basic knowledge

- *Cheese has been made in most cultures from ancient times.*
- *Cheese is a milk concentrate, the basic solids of which consist mainly of protein, actually casein, and fat. The residual liquid is called whey.*
- *As a rule of thumb, the casein and fat in the milk are concentrated approx. 10 times in production of hard and some semi-hard types of cheese.*
- *No strict definition of the concept of cheese is possible, as so many variants exist.*

- The moisture content of the cheese serves to distinguish various categories, such as hard (low-moisture), semi-hard and soft cheeses. A generally accepted classification of cheese is given in FAO/WHO Standard No. A 6.
- Each category is distinguished by a number of characteristics, such as structure (texture, body), flavour and appearance, which result from the choice of bacteria and technique employed.
- Processed cheese is a heat-treated product based on different types of cheese of varying age according to FAO/WHO Standards No. A 8 (b).
- Whey cheese is a type of cheese predominantly produced in Norway and Sweden and is defined according to FAO/WHO Standard No. A 7 as follows:

  Whey cheeses are products obtained by the concentration of whey and the moulding of concentrated whey, with or without the addition of milk and milk fat.
- Cream cheese is a soft unripened cheese briefly described in the FAO/WHO Standard C 31 as possessing a mild creamy or acid flavour and aroma typical of a milk product cultured with lactic acid and aroma-producing bacteria. It spreads and mixes readily with other foods.

# Terminology for classification of cheese

(Source: Codex Alimentarius, FAO/WHO, Standard A6)
Cheese is the fresh or ripened solid or semi-solid product in which the whey protein/casein ratio does not exceed that of milk, obtained:

**a** by coagulating (wholly or partly) the following raw materials: milk, skimmed milk, partly skimmed milk, cream, whey cream, or buttermilk, through the action of rennet or other suitable coagulating agents, and by partially draining the whey resulting from such coagulation;

or

**b** by processing techniques involving coagulation of milk and/or materials obtained from milk which give an end product which has similar physical, chemical and organoleptic characteristics as the product systemised under Classification of cheese.

## Definitions

1.1 *Cured or ripened cheese* is cheese which is not ready for consumption shortly after manufacture but which must be held for such time, at such temperature, and under such other conditions as will result in the necessary biochemical and physical changes characterising the cheese.

1.2 *Mould cured or mould ripened cheese* is a cured cheese in which the curing has been accomplished primarily by the development of characteristic mould growth throughout the interior and/or on the surface of the cheese.

1.3 *Uncured, unripened, or fresh cheese* is cheese which is ready for consumption shortly after manufacture.

## Classification of cheese

The classification shown in table 14.1 applies to all cheeses covered by this standard. However, this classification shall not preclude the designation of more specific requirements in individual cheese standards.

The biggest cheese ever made was a Cheddar cheese weighing 15 190 kg. It was produced in January 1964 by the Wisconsin Foundation to be exhibited at the World Expo in New York. It took 43 hours to produce.

In 1974 some Russians found a cheese in the permafrost of the Siberian tundra. It was at least 2 000 years old and was said to be an unrivalled delicacy.

| If the MFFB* is, % | Term I<br>The 1st phrase in the designation shall be | If the FDB** is, % | Term II<br>The 2nd phrase in the designation shall be | Term III<br>Designation according to principal curing characteristics |
|---|---|---|---|---|
| < 41 | Extra hard | > 60 | High fat | 1. Cured or ripened |
| 49 – 56 | Hard | 45 – 60 | Full fat |    a. mainly surface |
| 54 – 63 | Semi-hard | 25 – 45 | Medium fat |    b. mainly interior |
| 61 – 69 | Semi-soft | 10 – 25 | Low fat | 2. Mould cured or ripened |
| > 67 | Soft | < 10 | Skim |    a. mainly surface |
| | | | |    b. mainly interior |
| | | | | 3. Uncured or unripened*** |

\*     MFFB equals percentage moisture on fat-free basis, i.e.

$$\frac{\text{Weight of moisture in the cheese}}{\text{Total weight of cheese – weight of fat in cheese}} \times 100$$

\*\*   FDB equals percentage fat on dry basis, i.e.

$$\frac{\text{Fat content of the cheese}}{\text{Total weight of cheese – weight of fat in cheese}} \times 100$$

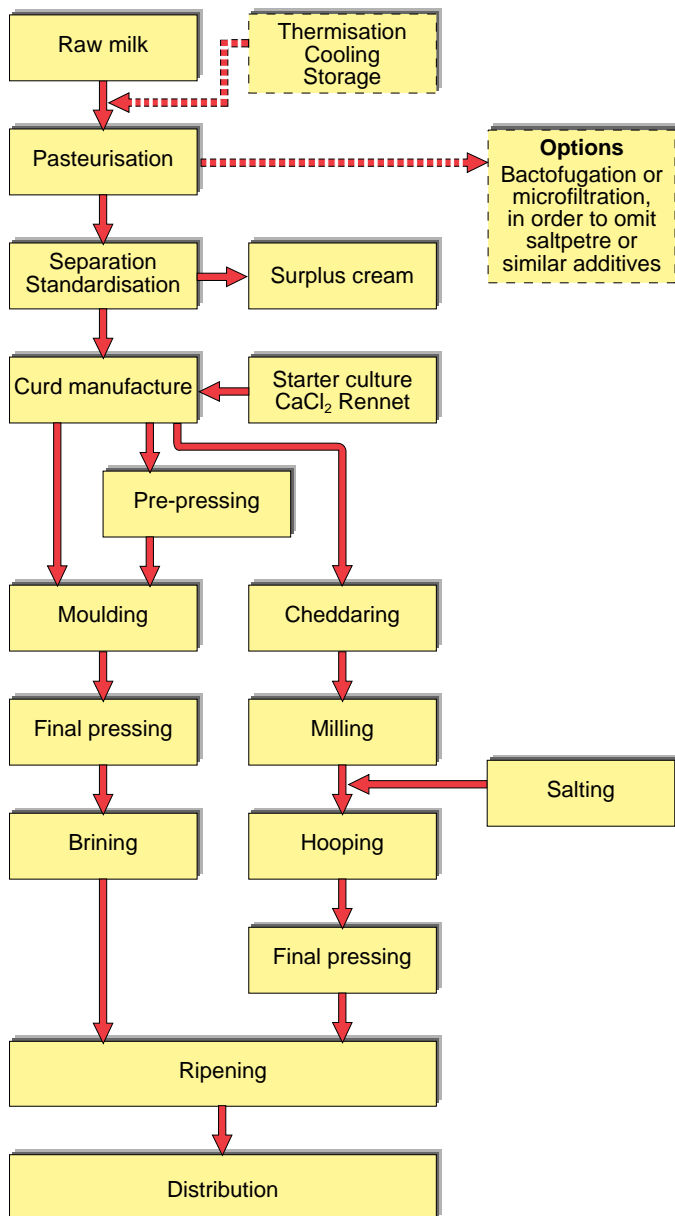\*\*\*  Milk intended for this type of cheese *to be pasteurised*.

Examples:

| Type | Origin | FDB | MFFB | Term 1 |
|---|---|---|---|---|
| Parmesan | I | 35+ | ≈ 40% | Extra hard |
| Grana | I | 35+ | ≈ 41% | Extra hard |
| Emmenthal | CH | 45+ | ≈ 52% | Hard |
| Gruyère | F | 45+ | ≈ 52.5% | Hard |
| Cheddar | UK | 50+ | ≈ 5% | Hard/Semi-hard |
| Gouda | NL | 45+ | ≈ 57% | Semi-hard |
| Tilsiter | D | 45+ | ≈ 57% | Semi-hard |
| Havarti | DK | 45+ | ≈ 59% | Semi-hard |
| Blue cheese | DK, F, S etc. | 50+ | ≈ 61% | Semi-hard/Semi-soft |
| Brie | F | 45+ | ≈ 68% | Semi-soft |
| Cottage cheese | USA | >10 | < 69% | Soft |

# Cheese production – general procedures for hard and semi-hard cheese

Cheesemaking involves a number of main stages which are common to most types of cheese. There are also other modes of treatment which are specific to certain varieties. The main stages for production of hard and semi-hard cheese are illustrated schematically on the block chart in figure 14.1.

The cheese milk is pretreated, possibly preripened after addition of a bacteria culture appropriate to the type of cheese, and mixed with rennet. The enzyme activity of the rennet causes the milk to coagulate to a solid gel known as coagulum. This is cut with special cutting tools into small cubes of the desired size – in the first place to facilitate expulsion of whey. During the rest of the curdmaking process the bacteria grow and form lactic acid, and the curd grains are subjected to mechanical treatment with stirring tools, while at the same time the curd is heated according to a preset programme. The combined effect of these three actions – growth of bacteria, mechanical treatment and heat treatment – results in syneresis, i.e. separa-

**Fig. 14.1** *Process flow in production of hard and semi-hard cheese.*

In the flow chart:

Raw milk → Thermisation / Cooling / Storage (option)

Pasteurisation → **Options** Bactofugation or microfiltration, in order to omit saltpetre or similar additives

Separation Standardisation → Surplus cream

Curd manufacture ← Starter culture CaCl$_2$ Rennet

Pre-pressing

Moulding / Cheddaring

Final pressing / Milling

Brining / Hooping ← Salting

Final pressing

Ripening

Distribution

············ = **Options**

## Cheese milk

- Fat standardisation
  - Fat relative to SNF (Casein) = F/SNF (Casein)

- Pasteurisation
  - 70-72°C/15-20 s (not always employed)
  - Cooling to about 30°C = renneting temperature

Options
- Mechanical reduction of bacteria:
  - Bactofugation
  - Microfiltration

## From milk to cheese

- In the cheese vat
  - Conditioning of cheese milk
    - Additives:
      – Calcium chloride
      – Saltpetre, if permitted by law
      – Starter bacteria, appropriate to type of cheese
      – Rennet as coagulant
- Coagulum
  - Cutting into grains (curd)
  - Heating, scalding, directly or indirectly, depending on type of cheese
  - Collection of curd for pre-pressing and/or final moulding/pressing, and if required
  - brine salting
  or for cheddar cheese
  - Cheddaring followed by milling, salting, hooping, and pressing
- Formed, pressed, and salted cheese to ripening room storage for required time

tion of whey from the curd grains. The finished curd is placed in cheese moulds of metal, wood or plastic, which determine the shape of the finished cheese.

The cheese is pressed, either by its own weight or more commonly by applying pressure to the moulds. Treatment during curdmaking and pressing determines the characteristics of the cheese.

The process flow chart in figure 14.1 also shows salting and storage. Finally, the cheese is coated, wrapped or packed.

# Milk treatment prior to cheesemaking

The suitability of milk as a raw material for cheese production depends largely on conditions at the dairy farm. Quite apart from the general demand for strict hygienic conditions, *milk from sick cows or animals undergoing*

*treatment with antibiotics must not be used for cheesemaking*, *or any other milk product.*

Feeding animals on badly prepared silage can adversely affect the quality of several varieties of cheese.

## Milk collection

With the classical method of milk reception, i.e. delivery of milk in churns to the dairy in the course of a few hours in the morning of all milk needed for the day's production, the milk was treated almost immediately after being weighed in. The fat content was then standardised in conjunction with separation and pasteurisation and, after regenerative cooling to renneting temperature, the milk was pumped to the cheesemaking vats.

The practice of collecting milk from farms at intervals of *two or even three days* is becoming more and more widespread. This means that especially stringent demands must be made on the way the milk is treated by the producers as well as on the tanker drivers, who should have the authority to refuse to accept milk that is even slightly affected and/or impaired by off-flavours. *Bovine mastitis* is a common disease that causes the cow pain as well as drastically affecting the composition of the milk; farmers must discard such milk, or at least not send it to the dairy.

## Heat treatment and mechanical reduction of bacteria.

### Thermisation

When collection of milk on alternate days was introduced, cheese producers who had to use such milk noticed that the quality of the cheese frequently deteriorated. This tendency was particularly noticeable when the milk had to be stored a further day after reception, even when it was chillled to 4°C in conjunction with transfer from road tanker to storage tank. Even longer storage times may be expected when working weeks are limited to six or even five days.

During cold storage, the milk protein and milk salts change character, which tends to impair cheesemaking properties. It has been shown that about 25 % of the calcium precipitates as phosphate after 24 hours storage at +5°C. This reduction, however, is temporary; when the milk is pasteurised, the calcium redissolves and the coagulating properties of the milk are almost completely restored. β-casein also leaves the complex casein micelle system during cold storage, which further contributes to reducing the cheesemaking properties. However, this reduction too is almost completely restored by pasteurisation.

Another and equally important phenomenon is that the microflora introduced into the milk by recontamination – especially *Pseudomonas spp* – will adapt to the low temperature at which their enzymes, proteinases and lipases, will decompose protein and fat respectively. The result of such action is a "bitter" flavour emanating from decomposition of the β-casein that has left the casein micelle during low-temperature storage.

The proteolytic and lipolytic enzymes formed by *Pseudomonas* may also co-operate to penetrate the membranes of the fat globules. This symbiotic

Thermisation
Moderate heat treatment at 65°C for 15 s which is often given to cheese milk.

**Fig. 14.2** *Reception arrangements for cheese milk.*
1   *Air eliminator*
2   *Filter*
3   *Milk meter*
4   *Intermediate storage tank*
5   *Thermisation and cooling or cooling only*
6   *Silo tank*

──────  *Milk*
──────  *Heating medium*
──────  *Cooling medium*
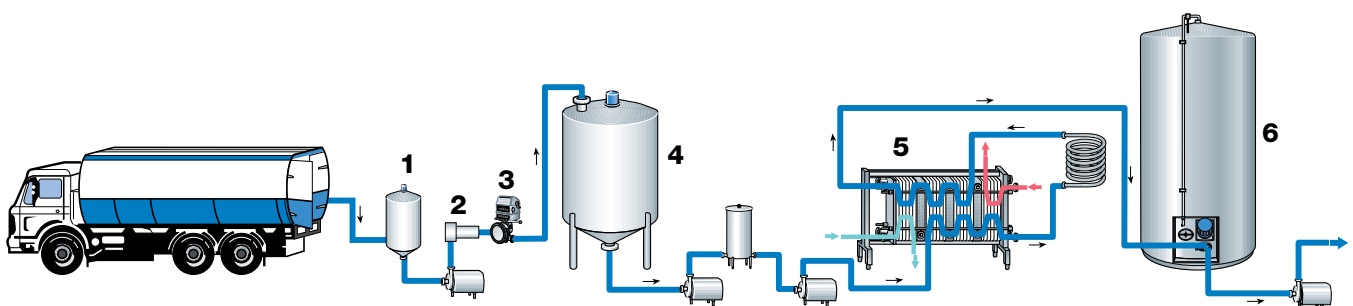
co-operation leads to liberation of fatty acids, especially the lower ones, by lipase action, giving the milk a rancid flavour.

So if milk that is already at least 24 – 48 hours old cannot be processed within about 12 hours after arrival to the dairy, it is advisable to chill it to about +4°C or, even better, to *thermise* it.

Thermisation means moderate heat treatment, 65°C for 15 seconds, followed by cooling to +4°C after which the milk is still phospatase positive. This technique was basically introduced for the purpose of arresting growth of psychotrophic flora when milk was stored for a further 12 – 48 hours after arrival at the dairy. As mentioned in chapter 1, the "critical age" of raw milk kept at +4°C normally falls between 48 and 72 hours after milking. See also figure 1.13, in chapter 1. Figure 14.2 shows the arrangement of a milk reception station.

## *Pasteurisation*

Before the actual cheesemaking begins, the milk usually undergoes pretreatment designed to create optimum conditions for production.

Milk intended for types of cheese which require more than one month for ripening need not nessesarily be pasteurised, but usually is.

From table 14.1 we can see that milk intended for unripened cheese (fresh cheese) must be pasteurised. This implies that cheese milk for types needing a ripening period of at least one month need not be pasteurised.

Whey used for fodder must however be pasteurised to prevent it from spreading bovine diseases. However, if the cheese milk is pasteurised it is not necessary to pasteurise the whey separately.

Milk intended for original Emmenthal, Parmesan and Grana, some extra hard types of cheese, must not be heated to more than 40°C, to avoid affecting flavour, aroma and whey expulsion. Milk intended for these types of cheese normally comes from selected dairy farms with frequent veterinary inspection of the herds.

Although cheese made from unpasteurised milk is considered to have a better flavour and aroma, most producers (except makers of the extra hard types) pasteurise the milk because its quality is seldom so dependable that they are willing to take the risk of not pasteurising it.

Pasteurisation must be sufficient to kill bacteria capable of affecting the quality of the cheese, e.g. *Coliforms,* which can cause early "blowing" and a disagreeable taste.

Regular HTST pasteurisation at 72 – 73°C for 15 – 20 seconds is therefore most commonly applied.

However, spore-forming micro-organisms in the spore state survive pasteurisation and can cause serious problems during the ripening process. One example is *Clostridium tyrobutyricum*, which forms butyric acid and large volumes of hydrogen gas by fermenting lactic acid. This gas destroys the texture of the cheese completely, not to mention the fact that butyric acid is unsavoury.

More intense heat treatment would reduce that particular risk, but would also seriously impair the general cheesemaking properties of the milk. Other means of reducing thermotolerant bacteria are therefore used.

Traditionally, certain *chemicals* have been added to cheese milk prior to production to prevent "blowing" and development of the unpleasant flavour caused by heat-resistant spore-forming bacteria (principally *Clostridium tyrobutyricum*). The most commonly used chemical is sodium nitrate ($NaNO_3$), but at production of Emmenthal cheese, hydrogen peroxide ($H_2O_2$) is also used. However, as the use of chemicals has been widely criticised, mechanical means of reducing the number of unwanted micro-organisms have been adopted, particularly in countries where the use of chemical inhibitors is banned.

Regular HTST pasteurisation at 72 – 73°C for 15 – 20 seconds is most commonly applied.

# Mechanical reduction of bacteria

## Bactofugation

As was discussed in chapter 6.2, bactofugation is a process in which a specially designed hermetic centrifuge, the Bactofuge®, is used to separate bacteria, and especially the spores formed by specific bacteria strains, from milk.

Bactofugation has proved to be an efficient way of reducing the number of spores in milk, since their specific gravity is higher than that of milk.

Bactofugation normally separates the milk into a fraction which is more or less free from bacteria and a concentrate (bactofugate) which contains both spores and bacteria in general and amounts up to 3 % of the feed to the Bactofuge.

Bactofugation of milk is always a part of milk pretreatment. In applications where quality milk for cheese and powder production is the objective, the Bactofuge is installed in series with the centifugal separator, either downstream or upstream of it.

When the quality of the surplus cream produced by direct in-line fat standardisation is an important consideration, the Bactofuge should be installed upstream of the separator. By doing so the cream quality will be improved as the load of spores of aerobic sporeformers such as *Bacillus cereus* will be reduced.

The same temperature is often chosen for bactofugation as for separation, i.e. 55 – 65°C or typically 60 – 63°C.

There are two types of Bactofuge:
- The *two-phase* Bactofuge
- The *one-phase* Bactofuge

The two-phase Bactofuge has two outlets at the top:
- one for continuous discharge of the heavy phase (bactofugate) via a special top disc, and
- one for the bacteria-reduced phase.

The *one-phase* Bactofuge has only one outlet at the top of the bowl, for bacteria-reduced milk; the bactofugate is collected in the sludge space of the bowl and discharged at preset intervals through ports in the bowl body.

These two types make it possible to choose various combinations of equipment to optimise the bacteriological status of milk used for both cheesemaking and other purposes.

In this context it may also be mentioned that whey, if intended for production of whey protein concentrate as an ingredient in infant formulae, should be bactofuged after recovery of fines and fat.

### Process alternatives

There are about ten possible ways to configure a bactofugation plant; three examples are given here:
1. Two-phase Bactofuge with continuous discharge of bactofugate
2. One-phase Bactofuge with intermittent discharge of bactofugate
3. Double bactofugation, with two one-phase Bactofuges in series.

### 1. Two-phase Bactofuge with continuous discharge of bactofugate

This concept, shown in figure 14.3, works under airtight conditions and

*Fig.14.3 Bactofugation with continuous discharge and sterilisation of the bactofugate.*
1. *Pasteuriser*
2. *Centrifugal separator*
3. *Automatic standardisation system*
4. *Two-phase Bactofuge*
5. *Infusion steriliser*

*Milk*
*Cream*
*Bactofugate*
*Steam*
*Heating medium*
*Cooling medium*
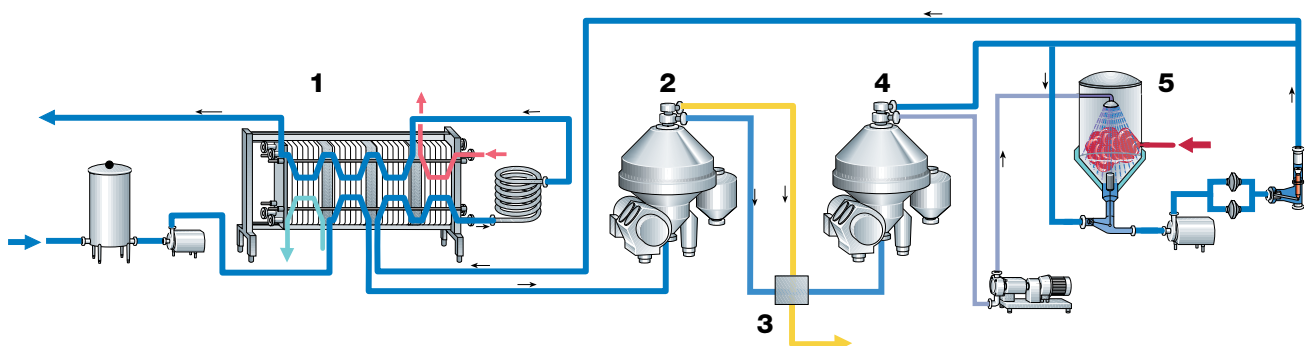
produces a continuous flow of air-free bacteria concentrate (bactofugate) as the heavy phase. This phase, comprising up to 3 % of the feed flow (adjusted by an external lobe-rotor pump with variable speed control) is often sterilised and remixed with the main flow. The steriliser is of infusion type, and a sterilisation temperature of approx. 130°C for a few seconds is sufficient to inactivate spores of *Clostridia* micro-organisms. The hot bactofugate leaving the steriliser is mixed with about half the volume of the bactofuged milk to lower the temperature before it is reintroduced into the rest of the bactofuged flow. Following mixing, the milk is routed to the pasteuriser to be pasteurised at 72°C for 15 seconds, followed by regenerative and final cooling to renneting temperature.

The Bactofuge with continuous discharge of bactofugate is used in applications where
– remixing of sterilised bactofugate is possible,
– there is an alternative use for the bactofugate in a product where the heat treatment is strong enough to inactivate the micro-organisms.
Nominal hourly capacities are 15 000 l and 25 000 l (two sizes of centrifuge), which empirically achieve at least 98% reduction of anaerobic spores.

## 2. One-phase Bactofuge with intermittent discharge of bactofugate

To achieve the same reduction effect as mentioned above, nominal capacities of 15 000 l/h and 25 000 l/h are likewise recommended. The bactofugate from a one-phase Bactofuge is discharged intermittently through ports in the bowl body at preset intervals of 15 – 20 minutes, which means that the bactofugate will be rather concentrated and thus also low in volume, 0.15 – 0.2% of the feed. When the bactofugate is to be re-introduced into the cheese milk, it must be sterilised. This is illustrated in figure 14.4, which also shows that before being pumped to the infusion steriliser the concen-
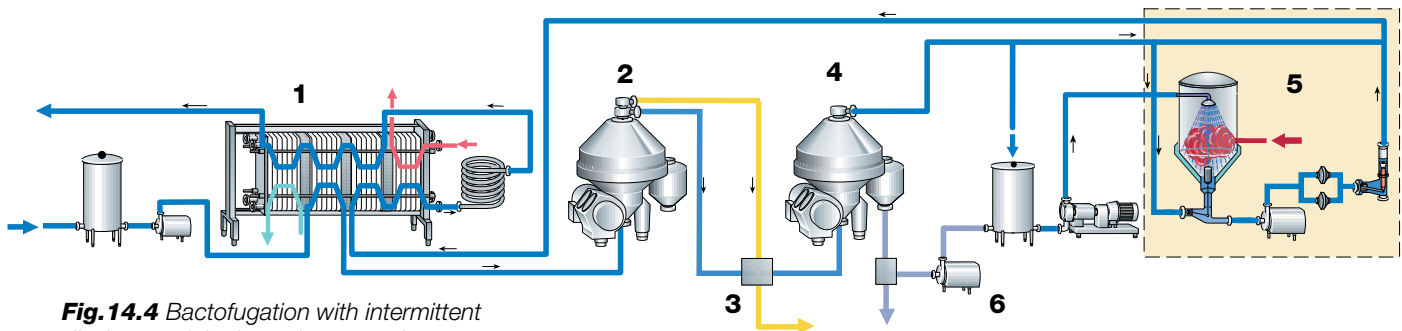


**Fig.14.4** *Bactofugation with intermittent discharge of the bactofugate and optional steriliser.*
1 *Pasteuriser*
2 *Centrifugal separator*
3 *Automatic standardisation system*
4 *One-phase Bactofuge*
5 *Infusion steriliser*
6 *Discharge pump*

| | |
|---|---|
| ▬▬▬ | *Milk* |
| ▬▬▬ | *Cream* |
| ▬▬▬ | *Bactofugate* |
| ▬▬▬ | *Steam* |
| ▬▬▬ | *Heating medium* |
| ▬▬▬ | *Cooling medium* |

trate is diluted with bactofuged milk, some 1.8 % of the feed, to obtain a sufficient volume for proper sterilisation. Start and stop of the discharge pump (6) is linked to the operation mode of the discharge system of the Bactofuge.

As it leaves the steriliser the hot bactofugate is cooled by admixture of bactofugated milk, about 50 % of the basic feed.

Where legislation does not permit reuse of the bactofugate, it can be discharged to the drain or collected in a tank for products to be sent to a destruction plant.

## 3. Double bactofugation with two one-phase Bactofuges in series.

Bactofuging milk once is not always sufficient, particularly at high spore loads in the milk. With double bactofugation, reduction of *Clostridia* spores reaches more than 99%. Figure 14.5 illustrates a plant with two one-phase Bactofuges in series serving one sterilising unit.

What was said above about treatment of the bactofugate applies here too.

Double bactofugation is sufficient in most cases to produce cheese without addition of bacteria-inhibiting chemicals. During periods when *very* high loads of spore-formers are expected, small amounts of chemicals, 2.5 – 5 g per 100 l of milk, may however be used for safety if legally allowed.
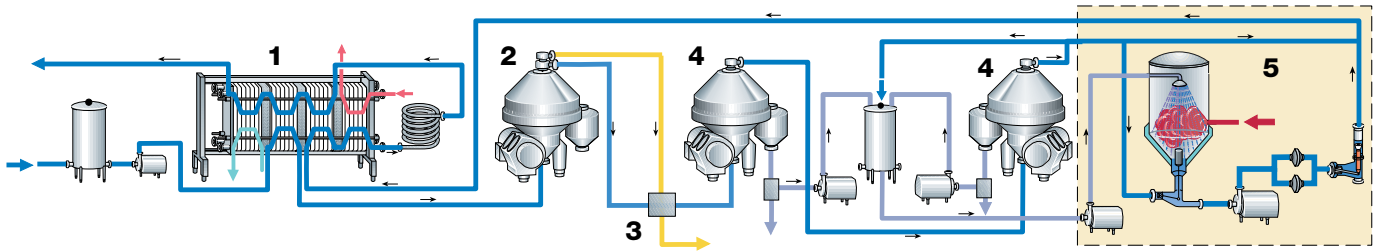
Without any mechanical means of reducing spores it is normal to add some 15 – 20 g of sodium nitrate per 100 l of milk to inhibit their growth, but with *single* bactofugation and a high load of spores in milk, 2.5 – 5 g per 100 l of milk will prevent the remaining spores from growing.

## Microfiltration

It has been known for a long time that a membrane filter with a pore size of approximatly 0.2 micron can filter bacteria from a water solution.

In microfiltration of milk, the problem is that most of the fat globules and some of the proteins are as large as, or larger than, the bacteria. This results in the filter fouling very quickly when membranes of such a small pore size are chosen. It is thus the skimmilk phase that passes through the filter, while the cream needed for standardisation of the fat content is sterilised, typically together with the bacteria concentrate obtained by simultaneous microfiltration. The principle of microfiltration is discussed in Chapter 6.4, Membrane filters.

In practice, membranes of a pore size of 0.8 to 1.4 micron are chosen to lower the concentration of protein. In addition, the protein forms a dynamic membrane that contributes to the retention of micro-organisms.
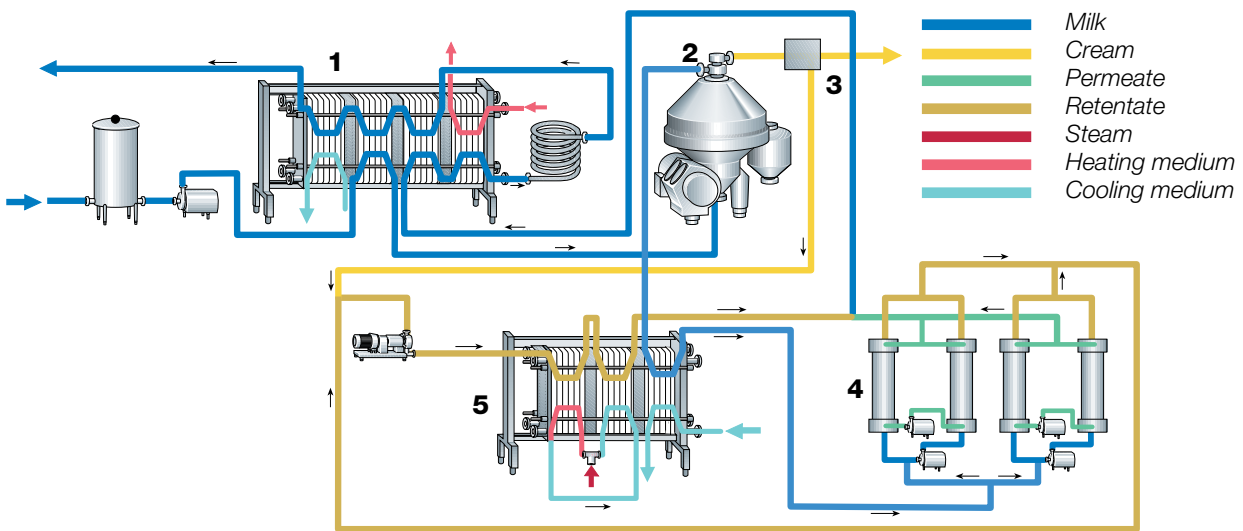
The microfiltration concept includes an indirect sterilisation unit for combined sterilisation of an adequate volume of cream for fat standardisation and of retentate from the filtration unit.

Figure 14.6 shows a milk treatment plant with microfiltration. The microfiltration plant is provided with two loops working in parallel. Each loop can handle up to 5 000 l/h of skimmilk, which means that this plant has a throughput capacity of approximately 10 000 l/h. Capacity can thus be increased by adding loops.

The raw milk entering the plant is preheated to a suitable separation temperature, typically about 60 – 63°C, at which it is separated into skimmilk and cream. A preset amount of cream, enough to obtain the desired fat

*Fig.14.5* Double bactofugation with optional steriliser.
1  Pasteuriser
2  Centrifugal separator
3  Automatic standardisation system
4  One-phase Bactofuge
5  Infusion steriliser, option

| | |
|---|---|
| ▬▬▬ | Milk |
| ▬▬▬ | Cream |
| ▬▬▬ | Bactofugate |
| ▬▬▬ | Steam |
| ▬▬▬ | Heating medium |
| ▬▬▬ | Cooling medium |

*Fig.14.6* Milk treatment including double-loop microfilter and sterilisation of bacteria concentrate together with the cream needed for fat standardistion of the cheese milk.
1  Pasteuriser
2  Centrifugal separator
3  Automatic standardisation system
4  Double-loop microfiltration plant
5  Sterilisation plant

| | |
|---|---|
| ▬▬▬ | Milk |
| ▬▬▬ | Cream |
| ▬▬▬ | Permeate |
| ▬▬▬ | Retentate |
| ▬▬▬ | Steam |
| ▬▬▬ | Heating medium |
| ▬▬▬ | Cooling medium |

content in the cheese milk, is routed by a standardisation device to the sterilisation plant.

In the meantime the skimmilk is piped to a separate cooling section in the sterilising plant to be cooled to 50°C, the normal microfiltration temperature, before entering the filtration plant.

The flow of milk is divided into two equal flows, each of which enters a loop where it is fractionated into a bacteria-rich concentrate (retentate), comprising about 5% of the flow, and a bacteria-reduced phase (permeate).

The retentates from both loops are then united and mixed with the cream intended for standardisation before entering the steriliser. Following sterilisation at 120 – 130°C for a few seconds, the mixture is cooled to about 70°C before being remixed with the permeate. Subsequently the total flow is pasteurised at 70 – 72°C for about 15 seconds and cooled to renneting temperature, typically 30°C.

Due to the high bacteria-reducing efficiency, microfiltration allows production of hard and semi-hard cheese *without* any need for chemicals to inhibit growth of *Clostridia* spores.

## Standardisation

Types of cheese are often classified according to fat on dry basis, FDB. The fat content of the cheesemilk must therefore be adjusted accordingly. For this reason the protein and fat contents of the raw milk should be measured throughout the year and the ratio between them standardised to the required value. Figure 14.7 shows an example of how the fat and protein content of milk can vary during one year (average figures from measurements in Sweden over a 5-year period, 1966 to 1971).

Standardisation can be accomplished either by in-line remixing after the separator (see Chapter 6.2, Automatic in-line standardisation systems), or for example by mixing whole milk and skimmilk in tanks followed by pasteurisation.
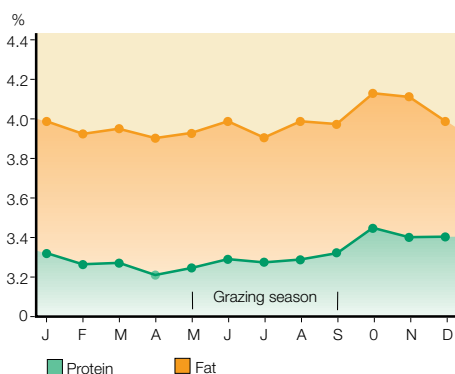
## Additives in cheesemilk

The essential additives in the cheesemaking process are the starter culture and the rennet. Under certain conditions it may also be necessary to supply other components such as calcium chloride ($CaCl_2$) and saltpetre ($KNO_3$ or $NaNO_3$). An enzyme, *Lysozyme,* has also been introduced as a substitute for saltpetre as an inhibitor of *Clostridia* organisms. An interesting approach for improving cheesemaking properties is the introduction of carbon dioxide ($CO_2$) into the cheese milk.

### Starter

The starter culture is a very important factor in cheesemaking; it performs several duties.

Two principal types of culture are used in cheesemaking:
– *mesophilic* cultures with a temperature optimum between 20 and 40°C and
– *thermophilic* cultures which develop at up to 45°C.

The most frequently used cultures are *mixed strain* cultures, in which two or more strains of both mesophilic and thermophilic bacteria exist in symbiosis, i.e. to their mutual benefit. These cultures not only produce lactic acid but also aroma components and $CO_2$. Carbon dioxide is essential to creating the cavities in round-eyed and granular types of cheese. Examples are Gouda, Manchego and Tilsiter from mesophilic cultures and Emmenthal and Gruyère from thermophilic cultures.

*Single-strain* cultures are mainly used where the object is to develop acid and contribute to protein degradation, e.g. in Cheddar and related types of cheese.

Three characteristics of starter cultures are of primary importance in cheesemaking, viz.
– ability to produce lactic acid
– ability to break down the protein and, when applicable,



*Fig. 14.7* Example of seasonal variations in milk protein and fat content. (Average figures for 1966–1971, Sweden)

The main task of the culture is to develop acid in the curd.

– ability to produce carbon dioxide ($CO_2$).

The main task of the culture is to develop acid in the curd.

When milk coagulates, bacteria cells are concentrated in the coagulum. Development of acid lowers the pH, which is important in assisting syneresis (contraction of the coagulum accompanied by elimination of whey). Furthermore, salts of calcium and phosphorus are released, which influence the consistency of the cheese and help to increase the firmness of the curd.

Another important function performed by the acid-producing bacteria is to suppress surviving bacteria from pasteurisation or recontamination bacteria which need lactose or cannot tolerate lactic acid.

Production of lactic acid stops when all the lactose in the cheese (except in soft cheeses) has been fermented. Lactic acid fermentation is normally a relatively fast process. In some types of cheese, such as Cheddar, it must be completed before the cheese is pressed, and in other types within a week.

If the starter also contains $CO_2$-forming bacteria, acidification of the curd is accompanied by production of carbon dioxide through the action of citric acid fermenting bacteria. Mixed strain cultures with the ability to develop $CO_2$ are essential for production of cheese with a texture with round holes/ eyes or irregularly shaped eyes. The evolved gas is initially dissolved in the moisture phase of the cheese; when the solution becomes saturated, the gas is released and creates the eyes.

The ripening process in hard and certain semi-hard cheeses is a combined proteolytic effect where the original enzymes of the milk and those of the bacteria in the culture, together with rennet enzyme, cause decomposition of the protein.

### Disturbances in cultures

Disturbances in the form of slow acidification or failure to produce lactic acid can sometimes occur.

One of the most common causes is the presence of *antibiotics* used to cure udder diseases.

Another possible source is the presence of *bacteriophages,* thermotolerant viruses found in the air and soil.

The detrimental action of both phenomena is discussed in Chapter 10, Cultures and starter manufacture.

A third cause of disturbance is *detergents and sterilising agents* used in the dairy. Carelessness, especially in the use of sanitisers, is a frequent cause of culture disturbances.

Disturbances in the form of slow acidification or failure to produce lactic acid can depend on:
• Antibiotics
• Bacteriophages
• Detergent residues

## Calcium chloride ($CaCl_2$)

If the milk is of poor quality for cheesemaking, the coagulum will be soft. This results in heavy losses of fines (casein) and fat as well as poor syneresis during cheesemaking.

5 – 20 grams of calcium chloride per 100 kg of milk is normally enough to achieve a constant coagulation time and result in sufficient firmness of the coagulum. Excessive addition of calcium chloride may make the coagulum so hard that it is difficult to cut.

For production of *low-fat* cheese, and if legally permitted, *disodium phosphate* ($Na_2PO_4$), usually 10 – 20 g/kg, can sometimes be added to the milk before the calcium chloride is added. This increases the elasticity of the cogulum due to formation of colloidal calcium phosphate ($Ca_3(PO_4)_2$), which will have almost the same effect as the milk fat globules entrapped in the curd.

## Carbon dioxide ($CO_2$)

Addition of $CO_2$ is one method of improving the quality of cheese milk. Carbon dioxide occurs naturally in milk, but most of it is lost in the course of processing. Adding carbon dioxide by artificial means lowers the pH of the milk: the original pH is normally reduced by 0.1 to 0.3 units. This will then result in shorter coagulation time. The effect can be utilised to obtain the same coagulation time with a smaller amount of rennet.

**Fig. 14.8** *Addition of CO$_2$ gas to cheese milk.*
1 *Gas cylinder (or a bundle of 12 cylinders or a liquid gas storage tank with vaporiser.)*
2 *Flow meter*
3 *Perforated injector pipe*
4 *Cheesemaking tank*
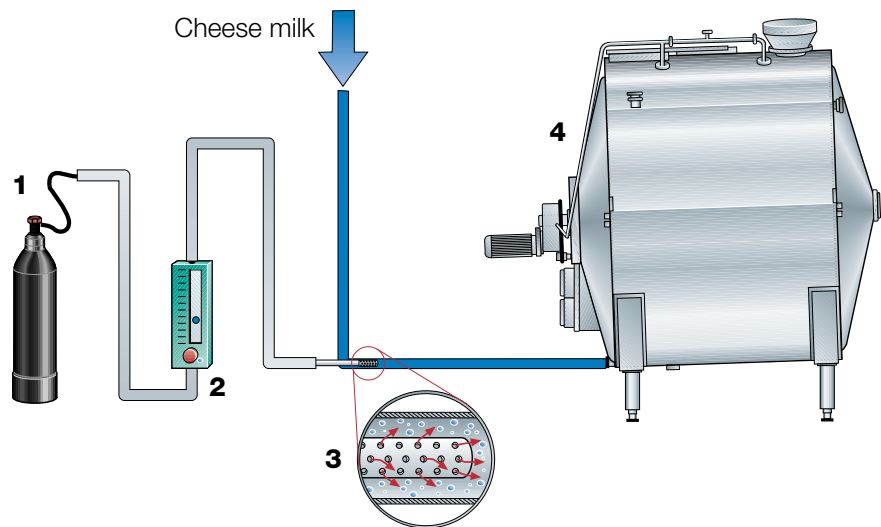
Cheese milk

The addition is made in-line in conjunction with filling of the cheese-making vat/tank as shown in figure 14.8. The rate at which the CO$_2$ gas is injected, and the time of contact with the milk before rennet admixture, must be calculated when the system is installed. Producers who use carbon dioxide admixture have reported that rennet consumption can be halved with no adverse effects.

## Saltpetre (NaNO$_3$ or KNO$_3$)

Fermentation problems may, as previously mentioned, be experienced if the cheese milk contains butyric-acid bacteria (*Clostridia)* and/or *Coliform* bacteria. Saltpetre (sodium or potassium nitrate) can be used to counteract these bacteria, but the dosage must be accurately determined with reference to the composition of the milk, the process for the type of cheese, etc., as too much saltpetre will also inhibit growth of the starter. Overdosage of saltpetre may affect the ripening of the cheese or even stop the ripening process.

Saltpetre in high doses may discolour the cheese, causing reddish streaks and an impure taste. The maximum permitted dosage is about 30 grams of saltpetre per 100 kg of milk.

In the past decade usage of saltpetre has been questioned from a medical point of view, and in some countries it is also forbidden.

If the milk is treated in a bactofuge or a microfiltration plant, the saltpetre requirement can be radically reduced or even eliminated. This is an important advantage, as an increasing number of countries are prohibiting the use of saltpetre.

## Colouring agents

The colour of cheese is to a great extent determined by the colour of the milk fat, and undergoes seasonal variations. Colours such as *carotine* and *orleana*, an anatto dye, are used to correct these seasonal variations in countries where colouring is permitted.

*Green chlorophyll* (contrast dye) is also used, for example for blue-veined cheese, to obtain a "pale" colour as a contrast to the blue mould.

## Rennet

Except for types of fresh cheese such as cottage cheese and quarg, in which the milk is clotted mainly by lactic acid, all cheese manufacture depends upon formation of curd by the action of rennet or similar enzymes.

Coagulation of casein is the fundamental process in cheesemaking. It is generally done with rennet, but other proteolytic enzymes can also be used, as well as acidification of the casein to the iso-electric point (pH 4.6 – 4.7).

The active principle in rennet is an enzyme called *chymosine,* and coagulation takes place shortly after the rennet is added to the milk. There are several theories about the mechanism of the process, and even today it is

not fully understood. However, it is evident that the process operates in several stages; it is customary to distinguish these as follows:
– Transformation of casein to paracasein under the influence of rennet
– Precipitation of paracasein in the presence of calcium ions.
The whole process is governed by the temperature, acidity, and calcium content of the milk as well as other factors. The optimum temperature for rennet is in the region of 40°C, but lower temperatures are normally used in the practice, basically to avoid excessive hardness of the coagulum.

Rennet is extracted from the stomachs of young calves and marketed in form of a solution with a strength of 1:10 000 to 1:15 000, which means that one part of rennet can coagulate 10 000 – 15 000 parts of milk in 40 minutes at 35°C. Bovine and porcine rennet are also used, often in combination with calf rennet (50:50, 30:70, etc.). Rennet in powder form is normally 10 times as strong as liquid rennet.

### Substitutes for animal rennet

About 50 years ago, investigations were started to find substitutes for animal rennet. This was done primarily in India and Israel on account of vegetarians' refusal to accept cheese made with animal rennet. In the Muslim world, the use of porcine rennet is out of the question, which is a further important reason to find adequate substitutes. Interest in substitute products has grown more widespread in recent years due to a shortage of animal rennet of good quality.

There are two main types of substitute coagulants:
– Coagulating enzymes from plants,
– Coagulating enzymes from micro-organisms.
Investigations have shown that coagulation ability is generally good with preparations made from *plant enzymes*. A disadvantage is that the cheese very often develops a bitter taste during storage.

Various types of *bacteria and moulds* have been investigated, and the coagulation enzymes produced are known under various trade names.

DNA technology has been utilised in recent times, and a DNA rennet with characteristics identical to those of calf rennet is now being thoroughly tested with a view to securing approval.

### Other enzymatic systems

Several research insitutions are working to isolate enzymatic systems that can be used to accelerate the ageing of cheese. The technique is not yet fully developed, and is therefore not commonly used.

It is however important that all such bio-systems are carefully tested and eventually approved by the relevant authorities.

# Cheesemaking modes

Cheese of various types is produced in several stages according to principles that have been worked out by years of experimentation. Each type of cheese has its specific production formula, often with a local touch.

Some basic processing alternatives are described below.

# Curd production

## Milk treatment

As was discussed above, the milk intended for most types of cheese is preferably pasteurised just before being piped into the cheese vat. Milk intended for Swiss Emmenthal cheese or Parmesan cheese is an exception to this rule.

Milk intended for cheese is not normally homogenised unless it is recombined. The basic reason is that homogenisation causes a substantial increase in water-binding ability, making it very difficult to produce semi-hard

Avoid air pick-up during filling of the cheese vat or tanks.

A

B

C

D
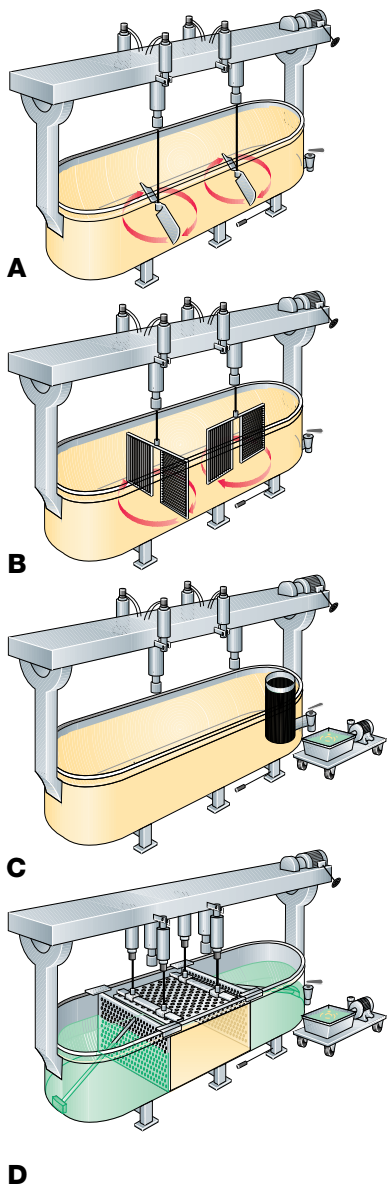
and hard types of cheese. However, in the special case of Blue and Feta cheese made from cow's milk, the fat is homogenised in the form of 15 – 20 % cream. This is done to make the product whiter and, more important, to make the milk fat more accessible to the lipolytic activity by which free fatty acids are formed; these are important ingredients in the flavour of those two types of cheese.

## Starter addition

The starter is normally added to the milk at approx. 30°C, while the cheese vat (tank) is being filled. There are two reasons for early in-line dosage of starter, viz.:

1  To achieve good and uniform distribution of the bacteria;
2  To give the bacteria time to become "acclimatised" to the "new" medium. The time needed from inoculation to start of growth, also called the pre-ripening time, is about 30 to 60 minutes.

The quantity of starter needed varies with the type of cheese. In all cheese-making, air pickup should be avoided when the milk is fed into the cheese-making vat because this would affect the quality of the coagulum and be likely to cause losses of casein in the whey.

## Additives and renneting

If necessary, calcium chloride and saltpetre are added before the rennet. Anhydrous calcium chloride salt can be used in dosages of up to 20 g/100 kg of milk. Saltpetre dosage must not exceed 30 g/100 kg of milk. In some countries dosages are limited or prohibited by law.

The rennet dosage is up to 30 ml of liquid rennet of a strength of 1:10 000 to 1:15 000 per 100 kg of milk. To facilitate distribution, the rennet may be diluted with at least double the amount of water. After rennet dosage, the milk is stirred carefully for not more than 2 – 3 minutes. It is important that the milk comes to a stillstand within another 8 – 10 minutes to avoid disturbing the coagulation process and causing loss of casein in the whey.

To further facilitate rennet distribution, automatic dosage systems are available for diluting the rennet with an adequate amount of water and sprinkling it over the surface of the milk through separate nozzles. Such systems are used primarily in large (10 000 – 20 000 l) enclosed cheese vats or tanks.

*Fig. 14.9* Conventional cheese vat with tools for cheese manufacture.
A   Vat during stirring
B   Vat during cutting
C   Vat during whey drainage
D   Vat during pressing
1   Jacketed cheese vat with beam and drive motor for tools
2   Stirring tool
3   Cutting tool
4   Strainer to be placed inside the vat at the outlet
5   Whey pump on a trolley with a shallow container
6   Pre-pressing plates for round-eyed cheese production
7   Support for tools
8   Hydraulic cylinders for pre-pressing equipment
9   Cheese knife
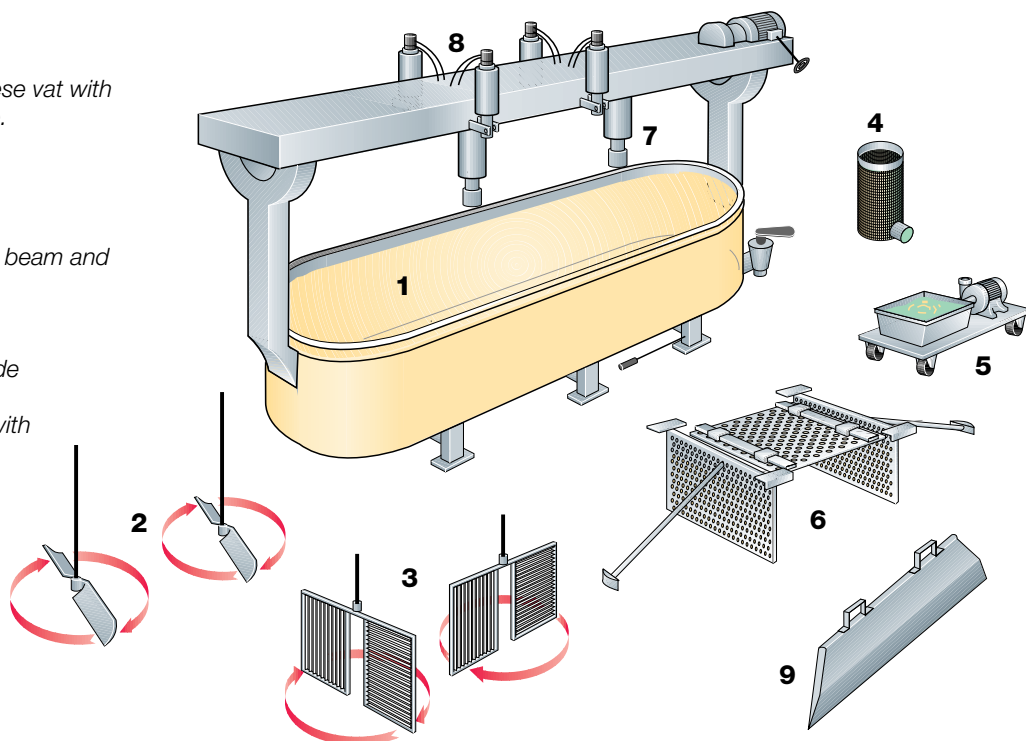
## Cutting the coagulum

The renneting or coagulation time is typically about 30 minutes. Before the coagulum is cut, a simple test is normally carried out to establish its whey-eliminating quality. Typically, a knife is stuck into the clotted milk surface and then drawn slowly upwards until proper breaking occurs. The curd may be considered ready for cutting as soon as a glass-like splitting flaw can be observed.

Cutting gently breaks the curd up into grains with a size of 3 – 15 mm depending on the type of cheese. The finer the cut, the lower the moisture content in the resulting cheese.

The cutting tools can be designed in different ways. Figure 14.9 shows a conventional open cheese vat equipped with exchangeable pairs of tools for stirring and cutting.



*Fig. 14.10* Horizontal enclosed cheese tank with combined stirring and cutting tools and hoisted whey drainage system.
1   Combined cutting and stirring tools
2   Strainer for whey drainage
3   Frequency-controlled motor drive
4   Jacket for heating
5   Manhole
6   CIP nozzle
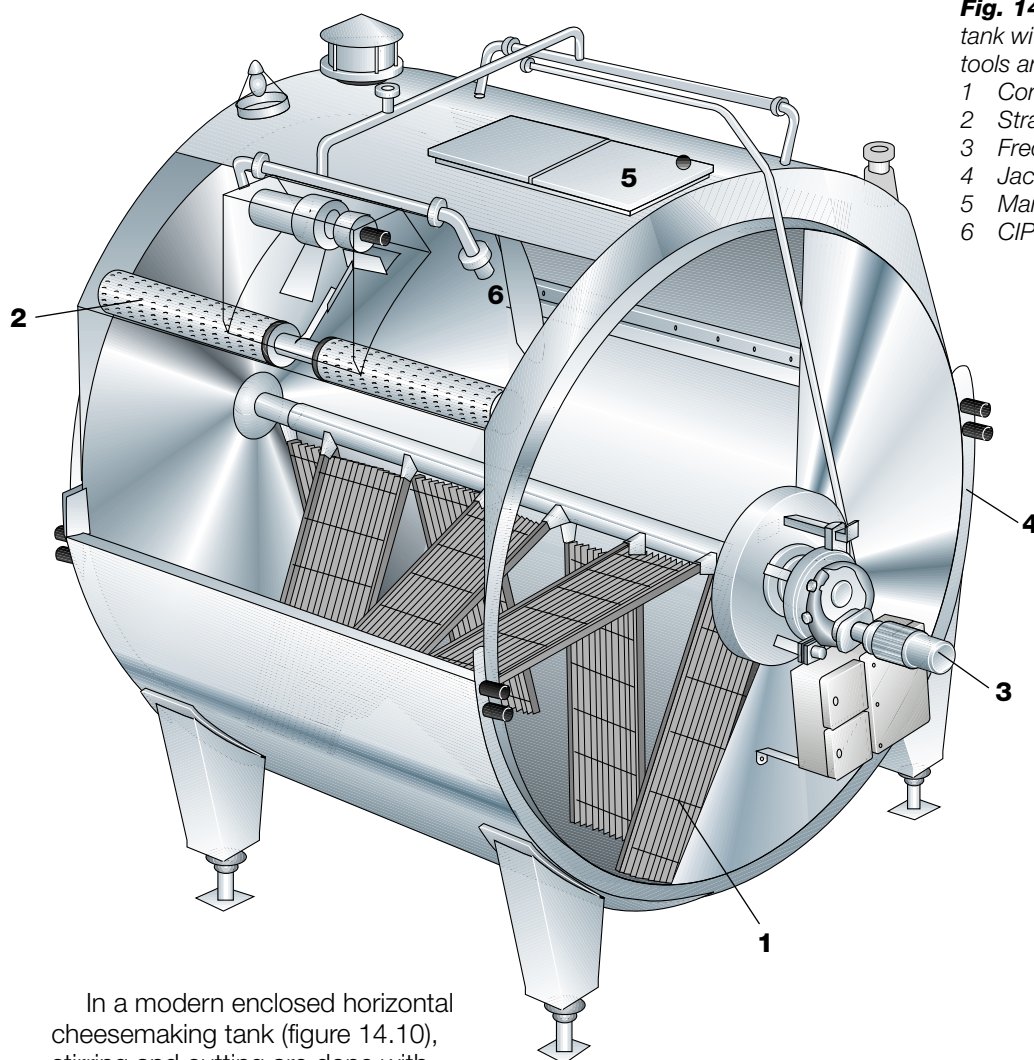
In a modern enclosed horizontal cheesemaking tank (figure 14.10), stirring and cutting are done with tools welded to a horizontal shaft powered by a drive unit with freqency converter. The dual-purpose tools cut or stir depending on the direction of rotation; the coagulum is cut by razor-sharp radial stainless steel knives with the heels rounded to give gentle and effective mixing of the curd.

In addition, the cheese vat can be provided with an automatically opera-ted whey strainer, spray nozzles for proper distribution of coagulant (rennet) and spray nozzles to be connected to a cleaning-in-place (CIP) system.

## Pre-stirring

Immediately after cutting, the curd grains are very sensitive to mechanical treatment, for which reason the stirring has to be gentle. It must however be fast enough to keep the grains suspended in the whey. Sedimentation of
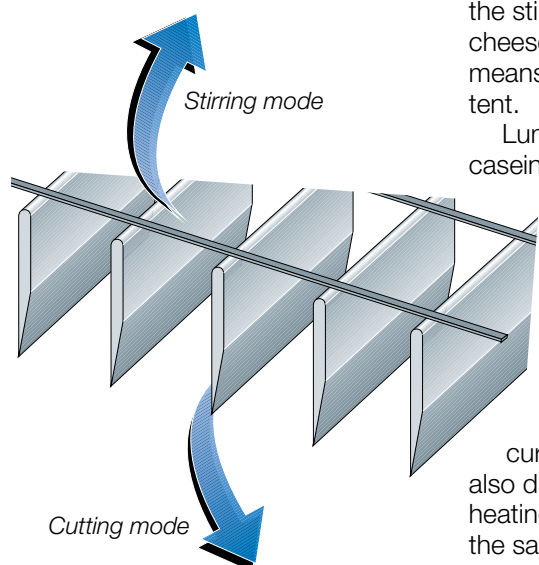
*Stirring mode*

*Cutting mode*

**Fig. 14.11** *Cross-section of the combined cutting and stirring tool blade with sharp cutting edge and blunt stirring edge.*

curd in the bottom of the vat causes formation of lumps. This puts strain on the stirring mechanism, which must be very strong. The curd of low fat cheese has a strong tendency to sink to the bottom of the vat, which means that the stirring must be more intense than for curd of high fat content.

Lumps may influence the texture of the cheese as well as causing loss of casein in whey.

The mechanical treatment of the curd and the continued production of lactic acid by bacteria help to expel whey from the grains.

## Pre-drainage of whey

For some types of cheese, such as Gouda and Edam, it is desirable to rid the grains of relatively large quantities of whey so that heat can be supplied by direct addition of hot water to the mixture of curd and whey, which also lowers the lactose content. Some producers also drain off whey to reduce the energy consumption needed for indirect heating of the curd. For each individual type of cheese it is important that the same amount of whey – normally 35%, sometimes as much as 50% of the batch volume - is drained off every time.

In a conventional vat, whey drainage is simply arranged as shown in figure 14.9 C.

Figure 14.10 shows the whey drainage system in an enclosed, fully mechanised cheese tank. A longitudinal slotted tubular strainer is suspended from a stainless steel cable connected to an outside hoist drive. The strainer is connected to the whey suction pipe via a swivel union and then through the tank wall to the external suction connection. A level electrode attached to the strainer controls the hoist motor, keeping the strainer just below the liquid level throughout the whey drainage period. A signal to start is given automatically. A predetermined quantity of whey can be drawn off, which is controlled via a pulse indicator from the hoist motor. Safety switches indicate the upper and lower positions of the strainer.

The whey should always be drawn off at a high capacity, say within 5 – 6 minutes, as stirring is normally stopped while drainage is in progress and lumps may be formed in the meantime. Drainage of whey therefore takes place at intervals, normally during the second part of the pre-stirring period and after heating.

## Heating/cooking/scalding

Heat treatment is required during cheesemaking to regulate the size and acidification of the curd. The growth of acid-producing bacteria is limited by heat, which is thus used to regulate production of lactic acid. Apart from the bacteriological effect, the heat also promotes contraction of the curd accompanied by expulsion of whey (syneresis).

Depending on the type of cheese, heating can be done in the following ways:
- By steam in the vat/tank jacket only.
- By steam in the jacket in combination with addition of hot water to the curd/whey mixture.
- By hot water addition to the curd/whey mixture only.

The time and temperature programme for heating is determined by the method of heating and the type of cheese. Heating to temperatures above 40°C, sometimes also called cooking, normally takes place in two stages. At 37 – 38°C the activity of the mesophilic lactic acid bacteria is retarded, and heating is interrupted to check the acidity, after which heating continues to the desired final temperature. Above 44°C the mesophilic bacteria are totally deactivated, and they are killed if held at 52°C between 10 and 20 minutes.

Heating beyond 44°C is typically called *scalding*. Some types of cheese, such as Emmenthal, Gruyère, Parmesan and Grana, are scalded at temperatures as high as 50 – 56°C. Only the most heat-resistant lactic-acid-producing bacteria survive this treatment. One that does so is *Propionibacteri-*

*um Freudenreichii ssp. Shermanii*, which is very important to the formation of the character of Emmenthal cheese.

## Final stirring

The sensitivity of the curd grains decreases as heating and stirring proceed. More whey is exuded from the grains during the final stirring period, primarily due to the continuous development of lactic acid but also by the mechanical effect of stirring.

The duration of final stirring depends on the desired acidity and moisture content in the cheese.

# Final removal of whey and principles of curd handling

As soon as the required acidity and firmness of the curd have been attained – and checked by the producer – the residual whey is removed from the curd in various ways.

## Cheese with granular texture

One way is to withdraw whey direct from the cheese vat; this is used mainly with manually operated open cheese vats. After whey drainage the curd is scooped into moulds. The resulting cheese acquires a texture with *irregular holes or eyes*, also called a *granular texture*, figure 14.12. The holes are primarily formed by the carbon dioxide gas typically evolved by LD starter cultures (*Sc. cremoris/lactis, L. cremoris* and *Sc. diacetylactis*). If curd grains are exposed to air before being collected and pressed, they do not fuse completely; a large number of tiny air pockets remain in the interior of the cheese. The carbon dioxide formed and released during the ripening period fills and gradually enlarges these pockets. The holes formed in this way are irregular in shape.

Whey can also be drained by pumping the curd/whey mixture across a vibrating or rotating strainer, figure 14.13, where the grains are separated from the whey and discharged direct into moulds. The resulting cheese has a *granular* texture.

## Round-eyed cheese

Gas-producing bacteria, generally of the same types as mentioned above, are also used in production of *round-eyed* cheese, figure 14.14, but the procedure is somewhat different.

According to older methods, e.g. for production of Emmenthal cheese, the curd was collected in cheese cloths while still in the whey and then transferred to a large mould on a combined drainage and pressing table. This avoided exposure of the curd to air prior to collection and pressing, which is an important factor in obtaining the correct texture in that type of cheese.

Studies of the formation of round holes/eyes have shown that when curd grains are collected below the surface of the whey, the curd contains microscopic cavities. Starter bacteria accumulate in these tiny whey-filled cavities. The gas formed when they start growing initially dissolves in the liquid, but as bacteria growth continues, local supersaturation occurs which results in the formation of small holes. Later, after gas production has stopped due to lack of substrate, e.g. citric acid, diffusion becomes the most important process. This enlarges some of the holes which are already relatively large, while the smallest holes disappear. Enlargement of bigger holes at the expense of the smaller ones is a consequence of the laws of surface tension, which state that it takes less gas pressure to enlarge a large hole than a small one. The course of events is illustrated in figure 14.15. At the same time some $CO_2$ escapes from the cheese.

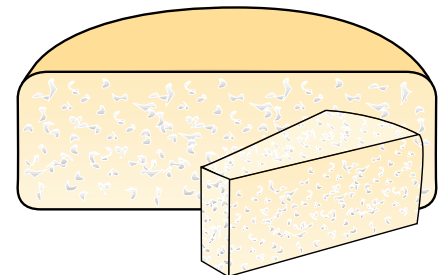In manually operated oblong or rectangular cheese vats, the curd can be
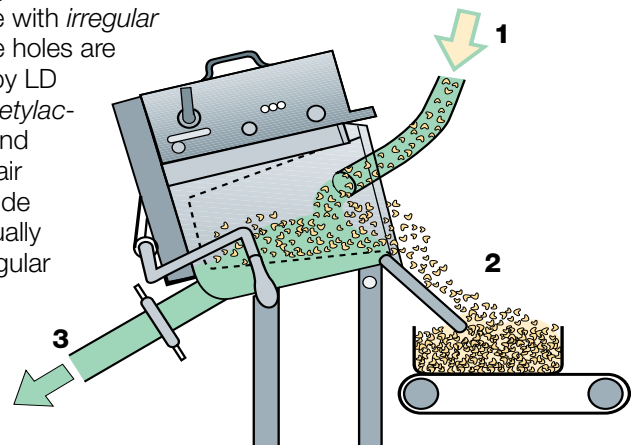
**Fig. 14.12** *Cheese with granular texture.*

**Fig. 14.13** Curd and whey are separated in a rotating strainer.
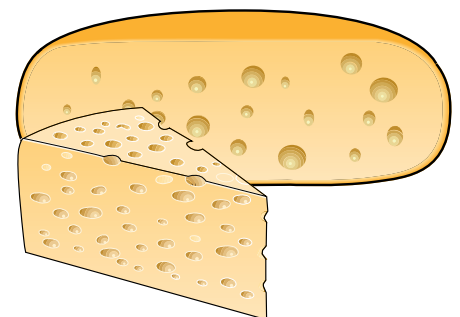1   *Curd/whey mixture*
2   *Drained curd*
3   *Whey outlet*

**Fig. 14.14** *Cheese with round eyes.*

Formation of carbon dioxide ($CO_2$)

Saturation of the curd with $CO_2$

Diffusion of $CO_2$
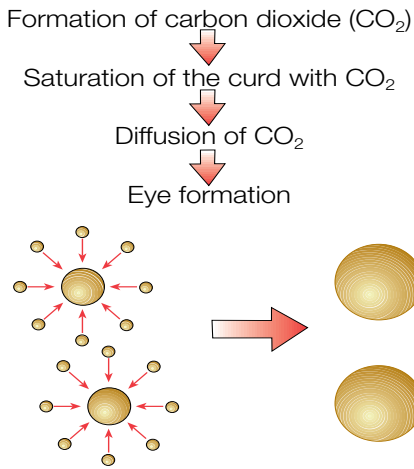
Eye formation



**Fig 14.15** *Development of gas in cheese and eye formation. (By courtesy of dr. H. Burling, R&D dept. SMR, Lund, Sweden.)*

pushed together while still immersed in whey into a compartment temporarily constructed of loose perforated plates and loose stays. The curd is levelled and a perforated pressing plate is placed on the curd bed. Two beams on top of this plate distribute the pressure applied by the hydraulic or pneumatic pressing unit. The system is illustrated in figure 14.9 D. During the pressing or rather pre-pressing period, which usually lasts some 20 – 30 minutes, free whey is discharged until the level of the curd bed level is reached. The remaining free whey is released while the pressing utensils are removed and the curd is cut by hand into blocks to fit the moulds.

## Pre-pressing vats

More often, however, pre-pressing takes place in separate vats to which a certain amount of whey has first been pumped. The remaining curd/whey mixture is then transferred to the vat by either gravity or a lobe rotor pump in such a way as to minimise exposure of the curd to air.

Figure 14.16 shows a pre-pressing system used for fairly large batch volumes, about 1 000 kg of curd or more.

The curd is supplied from the vat or tank by gravity or a lobe rotor pump and distributed by a manifold with special nozzles or by a special distribution and levelling device. Where a manifold is used, the curd must be manually levelled with rakes.

The whey is separated from the curd grains by
• a woven plastic belt,
   • a stainless steel perforated plate under the lid, and
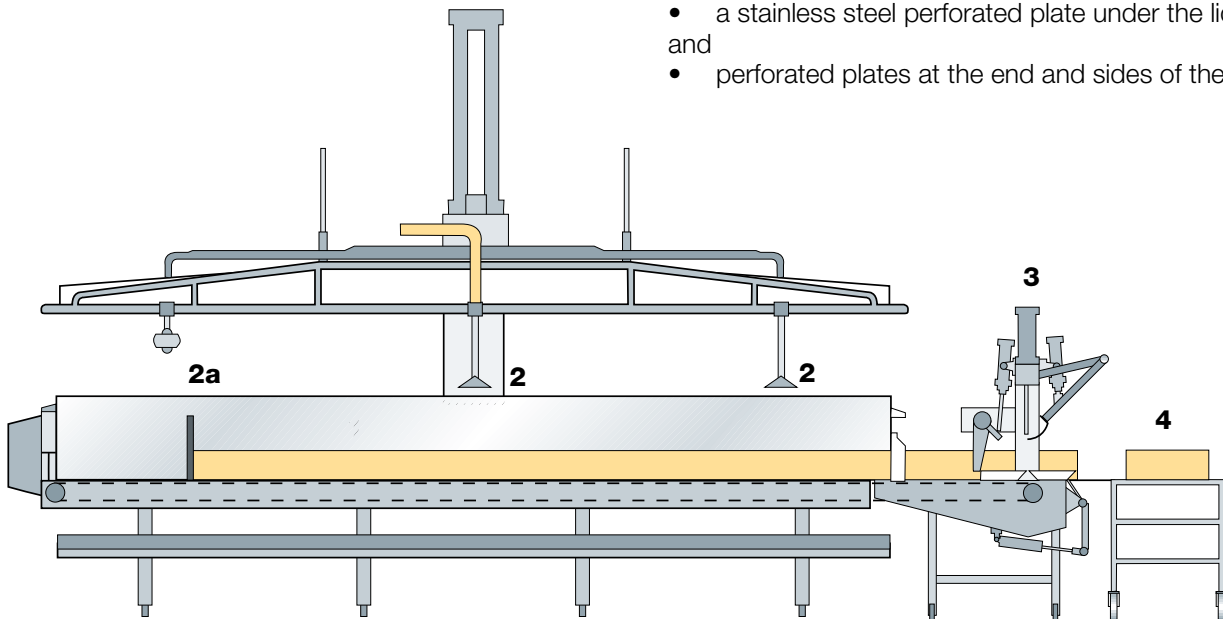   • perforated plates at the end and sides of the vat.



**Fig. 14.16** *Mechanically operated pre-pressing vat with unloading and cutting device.*
1   *Pre-pressing vat (can also be used for complete pressing)*
2   *Curd distributors, replaceable by CIP nozzles (2a)*
3   *Unloading device, stationary or mobile*
4   *Conveyor*

The lid is operated by one or two pneumatic cylinders, which are calculated to apply a pressure of about 20 g/cm$^2$ of the block surface. When the vat is used for complete pressing the pressure on the surface should be at least 10 times higher. The woven plastic bottom belt also acts as a conveyor on which the pre-pressed cheese block is transported towards the front end after the gate has been manually opened. Before the pre-press vat is emptied, a mobile unloading device with vertical knives and a guillotine for cross-cutting is placed in front of it. The spacing between the vertical knives is adjustable. (It is also possible to have a stationary unloading device serving just one vat.) The unloading appliance is also equipped for pulling out the belt, which is wound on to a cylinder located in the bottom.

The cut blocks can now be moulded manually or, more often, automatically conveyed to a mechanised moulding device.

## Continuous pre-pressing system

A more advanced system is the continuous pre-pressing, block cutting and moulding machine, the Casomatic, shown in figure 14.17. The working principle is that the curd/whey mixture, normally in a ratio of 1:3.5 – 4, is

introduced at the top of the cylindrical, square or rectangular column, the bottom of which is closed by a movable knife. The whey drains from the curd through perforated sections of the column and passes an interceptor before entering a whey collecting buffer tank from which it is pumped to a storage tank. The level of whey in the column is controlled by level electrodes; as soon as the lowermost electrode is the only one wet, whey is pumped from the interceptor into the column to prevent the curd being exposed to air.

After a preset time, usually 20 – 30 minutes, the curd at the bottom of the column has been pressed to the required firmness by its own weight. The height of the cheese column is chosen so that a pressure of about 20 g/cm$^2$ prevails at a level about 10 cm above the movable bottom plate (knife), i.e. almost the same pressure as in a pre-pressing vat. The height of the curd column is about 2.2 m and the overall unit height is up to 5.5 m. The knife is then withdrawn and the column of curd descends a preset distance. As soon as it stops the knife returns to its original position, cutting off the bottom piece as it does so. The piece is then removed from the machine and placed in a mould on a conveyor belt located underneath. The mould then proceeds to final pressing.

A standard column can handle about 600 kg of curd per hour and make cheeses of 10 – 20 kg. Cheeses of 1 kg and more can also be obtained by adding a special cutting tool at the exit of the machine and matching multi-moulds to receive the cut pieces.

Large capacities can be obtained by linking a number of pre-pressing columns together.

The Casomatic is equipped with spray nozzles at strategic points which enable the machine to be thoroughly cleaned after connection to a cleaning-in-place (CIP) system.

A processing line with continous pre-pressing is shown in figure 14.36.

## Closed texture cheese

Closed texture types of cheese, of which Cheddar is a typical example, are normally made with starter cultures containing bacteria that do not evolve gas – typically single-strain lactic-acid-producing bacteria like *Sc. cremonis* and *Sc. lactis*.

The specific processing technique may however result in formation of cavities called mechanical holes, as shown in figure 14.18. While the holes in granular and round-eyed cheeses have a characteristically shiny appearance, mechanical holes have rough inner surfaces.

When the titrated acidity of the whey has reached about 0.2 – 0.22% lactic acid (about 2 hours after renneting), the whey is drained off and the curd is subjected to a special form of treatment called *cheddaring.*

After all whey has been discharged, the curd is left for continued acidification and matting. During this period, typically 2 – 2.5 hours, the curd is formed into blocks which are turned upside down and stacked. When the titrated acidity of the exuded whey has fallen to approx. 0.75 – 0.85% lactic acid, the blocks are milled into "chips", which are dry-salted before being hooped (moulds for Cheddar cheese are called hoops). The cheddaring process is illustrated in figure 14.19.
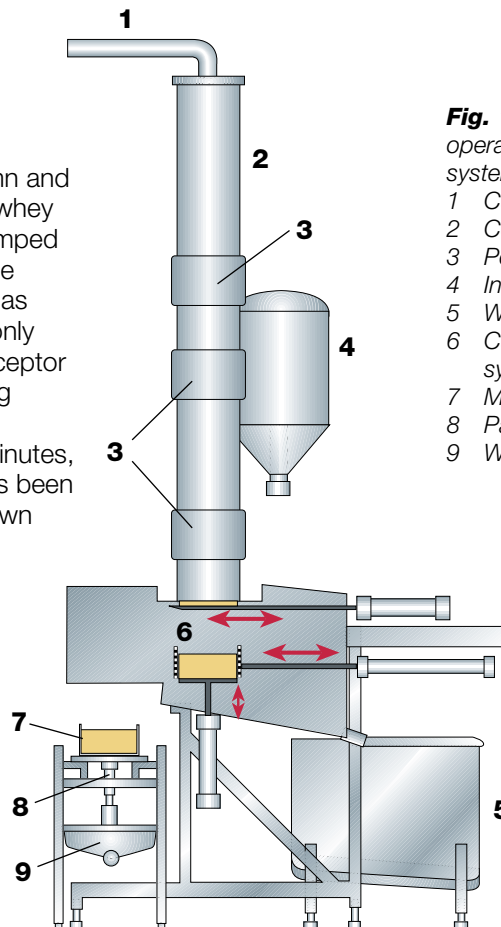


*Fig. 14.17* Casomatic, an intermittently operating continuous pre-pressing system, supplemented with mould filler.
1 Curd/whey mixture inlet
2 Column with sight glass (not shown)
3 Perforated whey discharge
4 Interceptor
5 Whey balance tank
6 Cutting and cheese discharge system
7 Mould
8 Pawl conveyor
9 Whey collecting chute



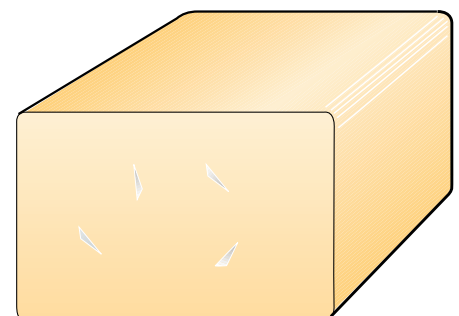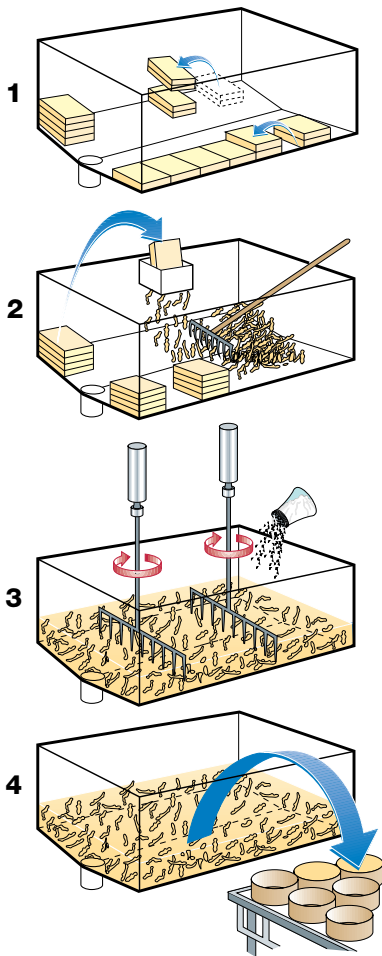*Fig. 14.18* Closed texture cheese with typical mechanical holes.

## Mechanised cheddaring machine

A highly advanced mechanised cheddaring machine, the Alfomatic, is also available, and the principle is shown in figure 14.20. These machines have capacities ranging from 1 to 8 tonnes of cheese per hour. The most common version of the machine is equipped with four conveyors, individually driven at preset and adjustable speeds and mounted above each other in a stainless steel frame. The curd/whey mixture is uniformly distributed on a special drainage screen where most of the whey is removed. The curd then falls on to the first conveyor, which is perforated and has stirrers for further whey drainage. Guide rails control the width of the curd mat on each conveyor.

The second conveyor allows the curd to begin matting and fusing. It is then transferred to a third conveyor where the mat is inverted and cheddaring takes place.

At the end of the third conveyor the curd is milled to chips of uniform size which fall on to the fourth conveyor. In machines for stirred curd types (Colby cheese) additional stirrers can be added on conveyors 2 and 3 to facilitate constant agitation, preventing fusing of the curd granules. In this case the chip mill is also by-passed.

The last conveyor is for salting. Initially dry salt is delivered to the curd, which is then stirred for efficient mixing. The curd is then fed into an auger flight hopper from which it is drawn up to a Block Former or conveyed to a hooping unit.

The first conveyor can also be equipped with a wash-water system for production of the aforementioned Colby cheese.

A machine with two or three conveyors suffices for production of cheeses of the *Pasta Filata* family (Mozzarella, Kashkaval etc.), where cheddaring is a part of the processing technique but where the milled chips are not normally salted before cooking and stretching.

A three-conveyor design is illustrated in figure 14.21, which shows that the curd is stirred only while on the first conveyor.

The machine, regardless of the number of conveyors, is equipped with spray nozzles for connection to a CIP system to ensure thorough cleaning and sanitation. A cladding of detachable stainless steel panels further contributes to hygiene.
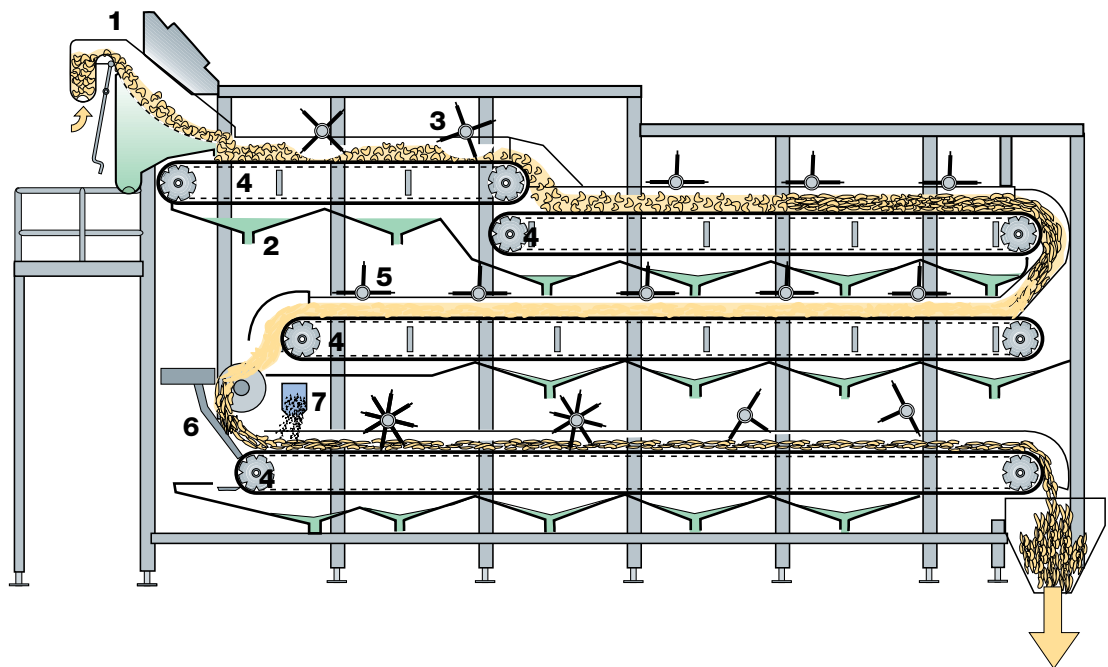


**Fig. 14.19** *Process steps in making Cheddar-type cheese.*
1 *Cheddaring*
2 *Milling of chips*
3 *Stirring the salted chips*
4 *Putting the chips into hoops*



**Fig.14.20** *Continuous system for de-wheying, cheddaring, milling, and salting curd intended for Cheddar cheese.*

1 *Whey strainer (screen)*
2 *Whey sump*
3 *Agitator*
4 *Conveyors with variable-speed drive*
5 *Agitators (optional) for production of stirred curd Cheddar*
6 *Chip mill*
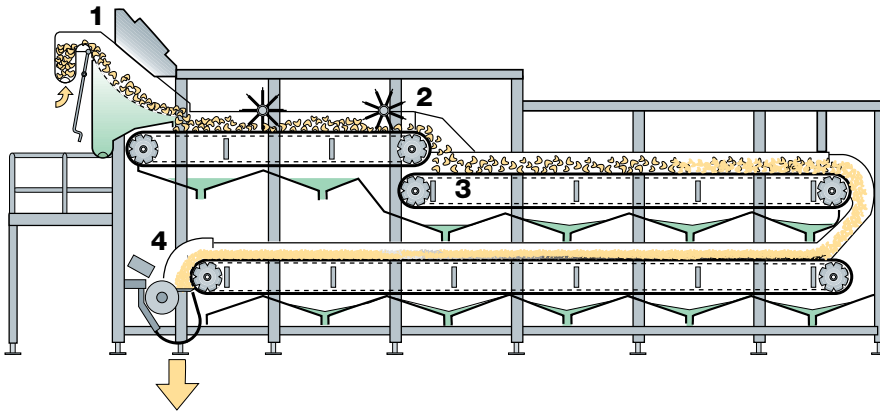7 *Dry salting system*

**Fig. 14.21** *Continuous cheddaring machine with three conveyors, suitable for Mozzarella cheese.*
*1 Whey screen*
*2 Stirrer*
*3 Conveyor*
*4 Chip mill*

# Final treatment of curd

As previously mentioned, the curd can be treated in various ways after all the free whey has been removed. It can be:
1  transferred direct to moulds (granular cheeses),
2  pre-pressed into a block and cut into pieces of suitable size for placing in moulds (round-eyed cheeses),
   or
3  sent to cheddaring, the last phase of which includes milling into chips which can be dry-salted and either hooped or, if intended for Pasta Filata types of cheese, transferred unsalted to a cooking-stretching machine.

## Pressing

After having been moulded or hooped the curd is subjected to final pressing, the purpose of which is fourfold:
• to assist final whey expulsion,
• to provide texture,
• to shape the cheese,
• to provide a rind on cheeses with long ripening periods.
The rate of pressing and pressure applied are adapted to each particular type of cheese. Pressing should be gradual at first, because initial high pressure compresses the surface layer and can lock moisture into pockets in the body of the cheese.

The pressure applied to the cheese should be calculated per unit area and not per cheese, as individual cheses may vary in size. Example: 300 g/$cm^2$.

Manually operated vertical and horizontal presses are available for *small-scale* cheese production. Pneumatic or hydraulic pressing systems simplify regulation of the required pressure. Figure 14.22 shows a vertical press. A more sophisticated solution is to equip the pressing system with a timer, signalling the operator to change pressure according to a predetermined programme.

Various systems are available for *large-scale* production.



**Fig. 14.22** *Vertical pressing unit with pneumatically operated pressing plates.*

### Trolley table pressing

Trolley table pressing systems are frequently used in semi-mechanised cheese production plants. They comprise
• a trolley table,
• moulds to be loaded on the table,
• a tunnel press with as many pressing cylinders as the number of moulds loaded on the table.

### Autofeed tunnel press

Autofeed tunnel presses are recommended for cases where highly mechanised systems for pressing of cheese are required. Arriving on a conveyor system, the filled moulds are automatically fed into an Autofeed tunnel press in rows of 3 to 5 by a pneumatic pushing device. The rows of moulds in the press are transported by push bars and slide across a stainless steel floor.
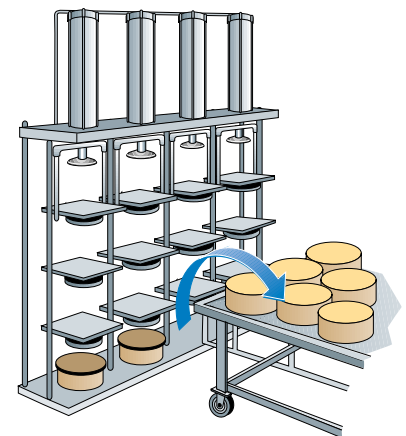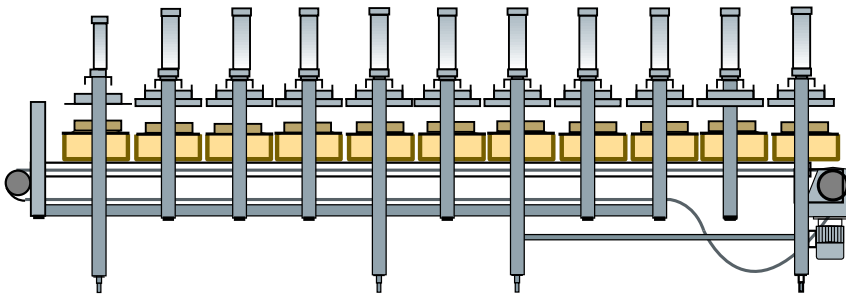
**Fig. 14.23** Conveyor press.

When the press has been filled, all air cylinders (one per mould) are connected to a common air supply line.

The pressure and intervals between increases of pressure, as well as the total pressing time, are automatically controlled from a separate panel. An Autofeed tunnel press system is designed for simultaneous loading and unloading, which allows optimum utilisation of the press.

## Conveyor press

A Conveyor press, figure 14.23, is recommended in cases where the time between pre-pressing and final pressing needs to be minimised. Both Conveyor and Autofeed presses are normally equipped with CIP systems.

## The Block Former system

A critical problem for Cheddar cheese producers has long been that of producing well-formed uniform blocks. The Block Former, utilising a basically simple system of vacuum treatment and gravity feed, solves this problem. The milled and salted chips are drawn by vacuum to the top of a tower, as illustrated in figure 14.24. The tower is filled, and the curd begins to fuse into a continous columnar mass. Vacuum is applied to the column throughout the program to deliver a uniform product, free from whey and air, at the base of the machine. Regular blocks of identical size, typically weighing about 18 – 20 kg, are automatically guillotined, ejected, and bagged ready for conveying to the vacuum sealing unit which is integral with the production line. No subsequent pressing is needed.

A tower is designed with a nominal capacity of 680 kg/h of curd which takes about 30 minutes to pass through the tower; one block is produced every 1.5 minutes. The height of the curd column itself is about 5 metres, and the overall height required for a tower is some 8 metres. High capacities can be achieved by linking towers together.

CIP manifolds at the tops of the towers assure good cleaning and sanitising results.
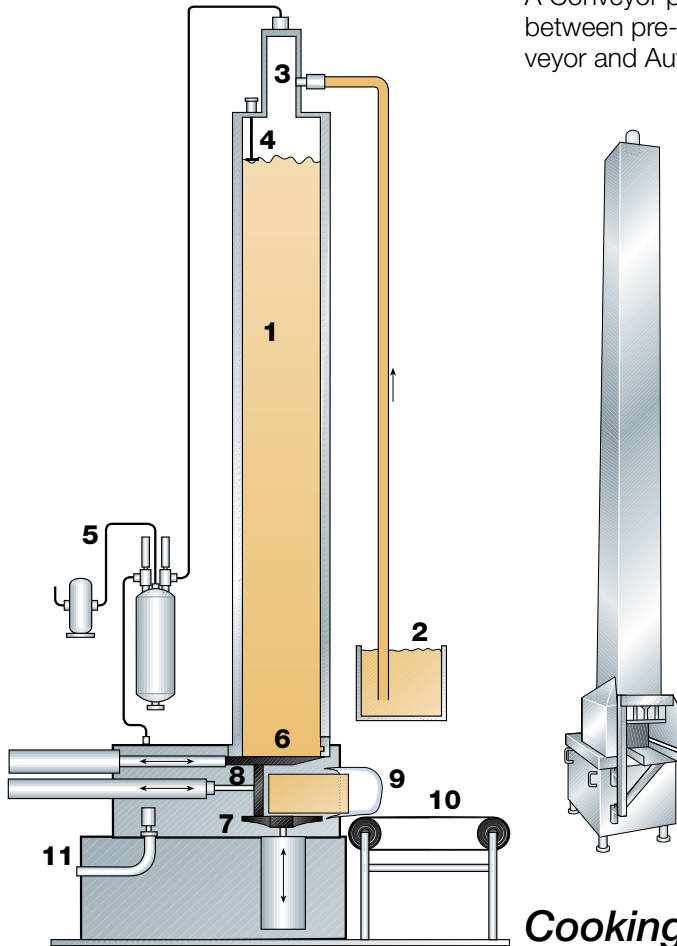


**Fig. 14.24** Block former system for Cheddar-type cheese.Principle and exterior (right).
1  Column
2  Curd feed
3  Cyclone
4  Level sensor
5  Vacuum unit
6  Combined bottom plate and guillotine
7  Elevator platform
8  Ejector
9  Barrier bag
10 Conveyor to vacuum sealing
11 Whey drainage

# Cooking and stretching of Pasta Filata types of cheese

Pasta Filata (plastic curd) cheese is characterised by an "elastic" string curd obtained by cooking and stretching cheddared curd. The "spun curd" cheeses – Provolone, Mozzarella, and Caciocavallo – originate from southern Italy. Nowadays Pasta Filata cheese is produced not only in Italy but also in several other countries. The Kashkaval cheese produced in several East European countries is also a type of Pasta Filata cheese.

After cheddaring and milling, at an acidity of approx. 0.7 – 0.8% lactic acid in the whey (31 – 35.5°SH), the chips are conveyed or shovelled into a steel mixing bowl or container or into a sanitary dough-mixing machine filled with hot water at 82 – 85°C, and the pieces are worked until they are smooth, elastic, and free from lumps. The mixing water is normally saved and separated with the whey to conserve fat.

Stretching and mixing must be thorough. "Marbling" in the finished product may be asociated with incomplete mixing, too low a water temperature, low-acidity curd, or a combination of these defects.

Continuous cooking and stretching machines are used in large-scale

production. Figure 14.25 shows a Cooker-Stretcher. The speed of the counterrotating augers is variable so that an optimal working mode can be achieved. The temperature and level of cooking water are continuously controlled. The cheddared curd is continuously transferred into the hopper or cyclone of the machine, depending on the method of feeding – screw conveyor or blowing.

In production of Kashkaval cheese the cooker may contain brine with 5 –6% salt instead of water. Warm brine, however, is very corrosive, so the container, augers and all other equipment coming in contact with the brine must be made of special material to be long-lasting.

## Moulding

As Pasta Filata cheese often occurs in various shapes – ball, pear, sausage, etc. – it is difficult to describe the process of moulding. However, automatic moulding machines are available for square or rectangular types, normally pizza cheese. Such a moulder typically comprises counterrotating augers and a revolving mould-filling system, as illustrated in figure 14.26.

The plastic curd enters the moulds at a temperature of 65 – 70°C. To stabilise the shape of the cheese and facilitate emptying the moulds, the moulded cheese must be cooled. To shorten the cooling/hardening period, a *hardening tunnel* must be incorporated in a complete Pasta Filata line.

A production line for Mozzarella types of cheese is illustrated in figure 14.38.

*Fig. 14.25 Continuous operating Cooker-Stretcher for Pasta Filata types of cheese.*
1 Feed hopper
2 Container for temperature-controlled hot water
3 Two counterrotating augers
4 Screw conveyor

# Salting

In cheese, as in a great many foods, salt normally functions as a condiment. But salt has other important effects, such as retarding starter activity and bacterial processes associated with cheese ripening. Application of salt to the curd causes more moisture to be expelled, both through an osmotic effect and a salting effect on the proteins. The osmotic pressure can be likened to the creation of suction on the surface of the curd, causing moisture to be drawn out.

With few exceptions, the salt content of cheese is 0.5 – 2%. Blue cheese and white pickled cheese variants (Feta, Domiati, etc.), however, normally have a salt content of 3 – 7%.

The exchange of calcium for sodium in paracaseinate that results from salting also has a favourable influence on the consistency of the cheese, which becomes smoother. In general, the curd is exposed to salt at a pH of 5.3 – 5.6 i.e. approx. 5 – 6 hours after the addition of a vital starter, provided the milk does not contain bacteria-inhibiting substances.

## Salting modes

### Dry salting

Dry salting can be done either manually or mechanically. Salt is applied manually from a bucket or similar container containing an adequate (weighed) quantity that is spread as evenly as possible over the curd after all whey has been discharged. For complete distribution, the curd may be stirred for 5 – 10 minutes.

There are various ways to distribute salt over the curd mechanically. One is the same as is used for dosage of salt on cheddar chips during the final stage of passage through a continous cheddaring machine.

Another is a partial salting system used in production of Pasta Filata cheese (Mozzarella), illustrated in figure 14.27. The dry salter is installed between the cooker-stretcher and moulder. With this arrangement the normal brining time of 8 hours can be reduced to some 2 hours and less area is needed for brining.
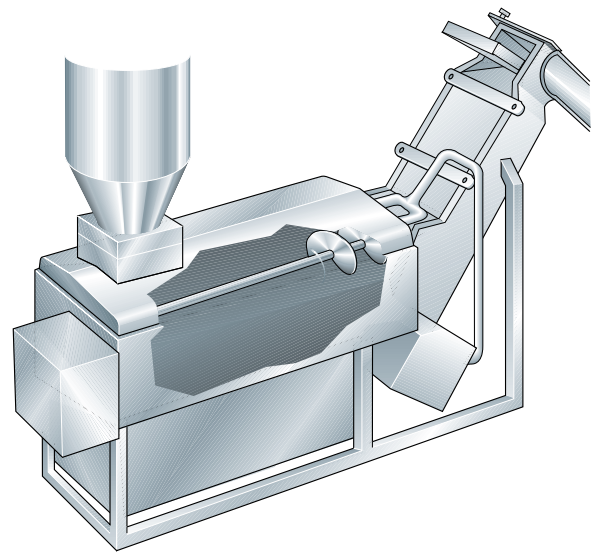
*Fig. 14.26 Moulding machine for pizza cheese*
1 Hopper
2 Counterrotating augers
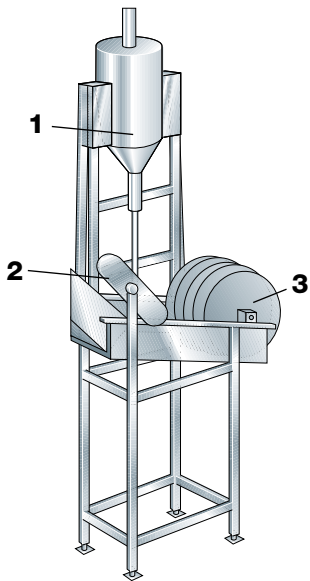3 Revolving and stationary moulds
4 Mould

**Fig. 14.27** *Dry salter for Pasta Filata.*
1  *Salt container*
2  *Level control for cheese mat*
3  *Grooving tool*

## Brine salting

*Brine salting systems* of various designs are available, from fairly simple ones to technically very advanced ones. Still, the most commonly used system is to place the cheese in a container with brine. The containers should be placed in a cool room at about 12 – 14°C. Figure 14.28 shows a practical manually operated system.

A variety of systems based on shallow brining or containers for racks are available for *large-scale production* of brine-salted cheese.

### Shallow or surface brining

In a shallow brining system, the cheese is floated into compartments where brining in one layer takes place. To keep the surface wet, the cheese is dipped below the surface at intervals by a roller on the rim of each compartment. The dipping procedure can be programmed. Figure 14.29 shows the principle of a shallow brining system.
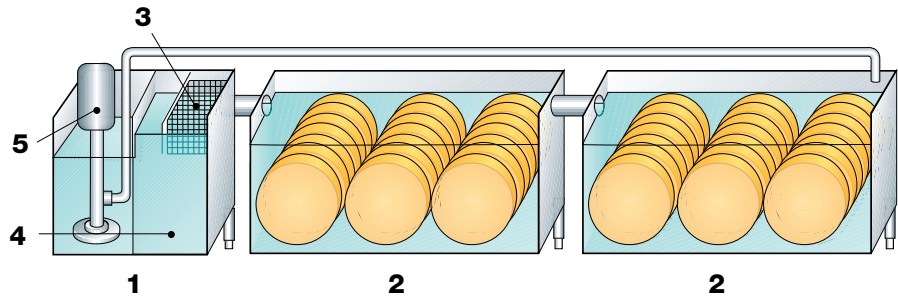


**Fig. 14.28** *Brine bath system with containers and brine circulation equipment.*
1  *Salt dissolving container*
2  *Brining containers*
3  *Strainer*
4  *Dissolution of salt*
5  *Pump for circulation of brine*

**Fig. 14.29** *Surface brining system.*
1  *Inlet conveyor with sliding plate*
2  *Regulating screen*
3  *Inlet door with regulating screen and guiding door*
4  *Surface brining department*
5  *Outlet door*
6  *Twin agitator with sieve*
7  *Brine level control with pump*
8  *Pump*
9  *Plate heat exchanger*
10 *Automatic salt dosing unit (including salt concentration measurement)*
11 *Discharge conveyor with gutter*
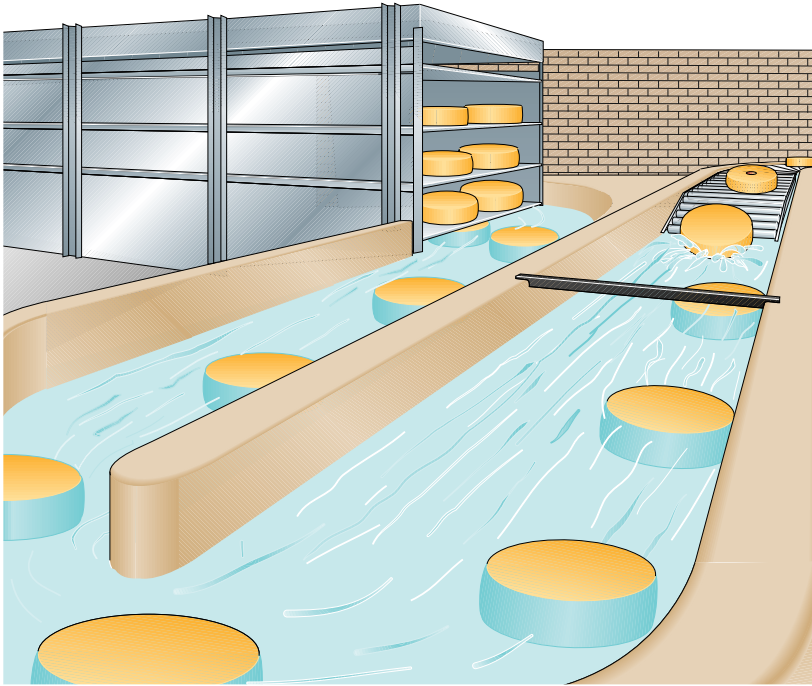12 *Brine suction device*
13 *Service area*

▬▬▬▬  *Brine*
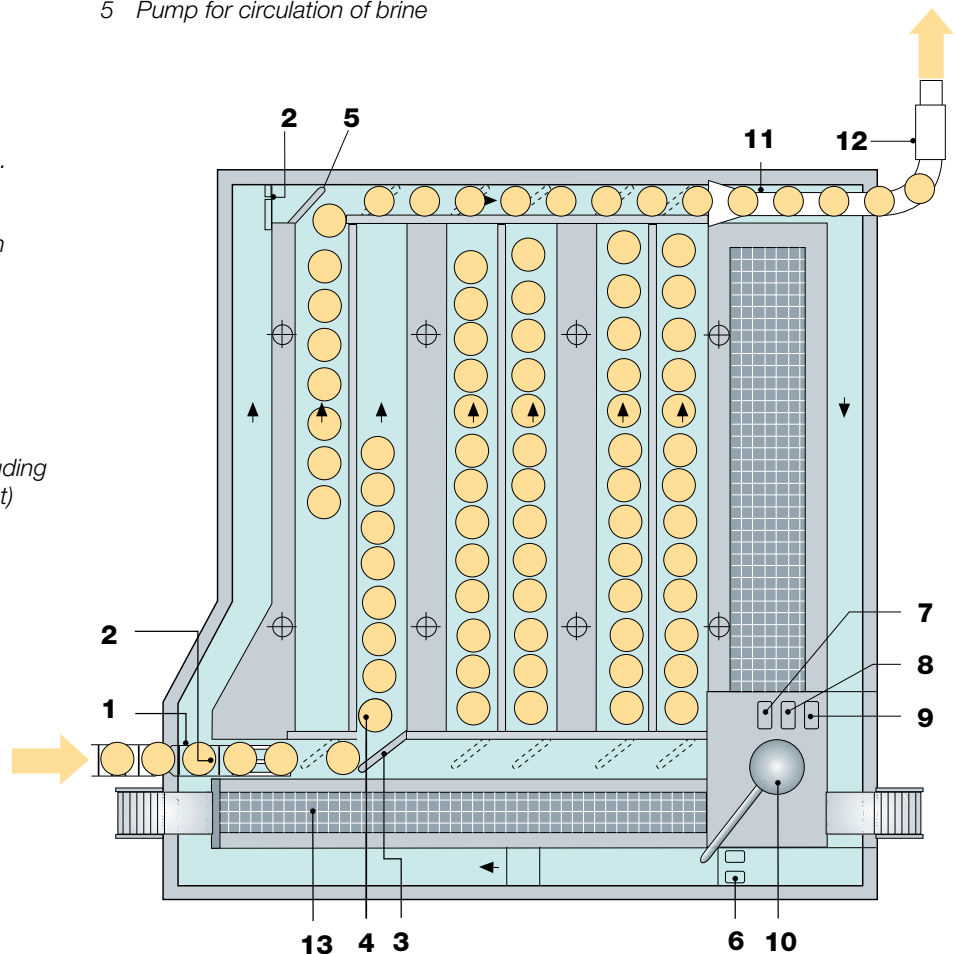
*Fig. 14.30* Deep brining system. The cage,
10 x 1.1 m with 10 layers, holds one shift's
production.

### Deep brining
The deep brining system with hoisted cages is based on the same principle.
The cages are dimensioned to hold maybe one shift's production, and one
cage occupies one compartment, which is 2.5 – 3 m deep.

To achieve uniform brining time (first in, first out), the loaded cage is
emptied when half the time has elapsed and the cheese is directed to an
empty cage. Otherwise it would be a matter of first in, last out, with several
hours' difference in brining time between the first and last cheeses loaded.
The deep brining system should therefore always be designed with an extra
compartment provided with an empty cage. Figure 14.30 shows the cage in
a deep brining system.

### Rack brining system
Another deep brining
system is based on racks
capable of holding the full
output of cheese from
one vat. All operations –
filling the racks, placing
them in the brine solution,
hoisting the racks out of
the brine and guiding
them to an unloading
station – can be com-
pletely automated. The
principle of a rack brining
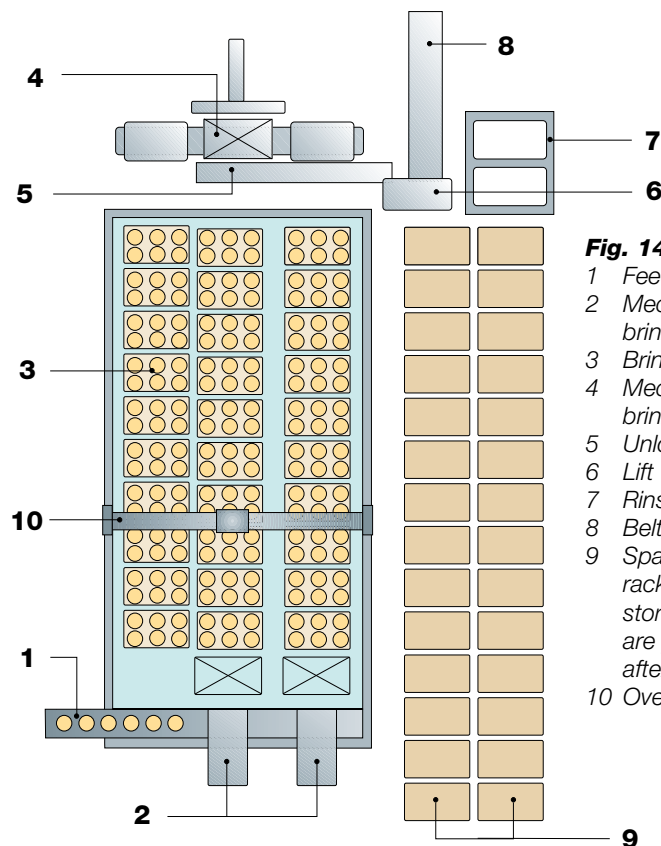system is shown in figure
14.31.



*Fig. 14.31* Rack brining system.
1   Feed conveyor
2   Mechanical loading station for
    brining racks
3   Brining racks
4   Mechanical unloading station for
    brining racks
5   Unloading conveyor
6   Lift
7   Rinsing bath
8   Belt conveyor
9   Space for empty racks and spare
    racks. Empty racks can also be
    stored in the brine. If the cheeses
    are packed/treated immediately
    after brining, this area is not needed.
10  Overhead travelling crane

## Some notes about the preparation of brine

The difference in osmotic pressure between brine and cheese causes some moisture with its dissolved components, whey proteins, lactic acid and minerals to be expelled from the cheese in exchange for sodium chloride. In the preparation of brine it is important that this is taken into consideration. Besides dissolving salt to the desired concentration, the pH should be adjusted to 5.2 – 5.3, e.g. with edible hydrochloric acid, which must be free from heavy metals and arsenic. Lactic acid can of course be used, as can other "harmless" acids.

Calcium in the form of calcium chloride ($CaCl_2$) should also be added to give a calcium content of 0.1 – 0.2%. Table 14.2 can serve as guide for preparation of brine.

## Salt penetration in cheese

The following brief description, based on Report No. 22 from Statens Mejeriforsøg, Hillerød, Denmark, gives an idea of what happens when cheese is salted:

Cheese curd is criss-crossed by capillaries; approx. 10 000 capillaries per $cm^2$ have been found. There are several factors that can affect the permeability of the capillaries and the ability of the salt solution to flow through them, but not all such factors are affected by changes in technique. This applies for example to the fat content. As the fat globules block the structure, salt penetration will take longer time in a cheese of high fat content than in one of a low fat content.

The pH at the time of salting has considerable influence on the rate of salt absorption. More salt can be absorbed at low pH than at higher pH. However, at low pH, <5.0, the consistency of the cheese is hard and brittle. At high pH, >5.6, the consistency becomes elastic.

The importance of the pH of the cheese at the time of brining has been described by the research team at the Danish Hillerød Institution:

Some parts of the calcium are more loosely bound to the casein, and at salting the loosely bound calcium is exchanged for sodium by ion exchange. Depending on the quantity of loosely bound calcium, this determines the consistency of the cheese.

This loosely bound calcium is also sensitive to the presence of hydronium ions ($H^+$). The more $H^+$ ions, the more calcium ($Ca^{++}$) ions will leave the casein complex, and $H^+$ will take the place of calcium. At salting, $H^+$ is *not* exchanged for the $Na^+$ (sodium) of the salt. This means:

**1** At high pH (6.0 – 5.8) there is more calcium in the casein. Consequently more sodium will be bound to the casein complex, and the cheese will be softer; it may even lose its shape during ripening.

**2** At pH 5.2 – 5.4 – 5.6 there may be enough $Ca^{++}$ and $H^+$ ions in the casein complex to bind enough $Na^+$ to the casein. The resulting consistency will be good.

**3** At low pH (< 5.2), too many $H^+$ ions may be included; as the $Na^+$ ions cannot be exchanged for the $H^+$ ions, the consistency will be hard and brittle.

Conclusion: it is important that cheese has a pH of about 5.4 before being brine salted.

Temperature also influences the rate of salt absorption and thus the loss of moisture. The higher the temperature, the higher the rate of absorption.

The higher the salt concentration of the brine, the more salt will be absorbed. At low salt concentrations, <16 %, the casein swells and the surface will be smeary, slimy as result of the casein being redissolved.

Salt concentrations of up to 18 – 23 % are often used at 10 – 14°C. The time of salting depends on:
• the salt content typical of the type of cheese
• the size of the cheese – the larger it is, the longer it takes
• the salt content and temperature of the brine.

## Brine treatment

In addition to readjusting the concentration of salt, the microbiological status of the brine must be kept under control, as various quality defects may arise. Certain salt-tolerant micro-organisms can decompose protein, giving a slimy surface; others can cause formation of pigments and discolour the surface. The risk of microbiological disturbances from the brine is greatest when weak brine solutions, <16%, are used.

Pasteurisation is sometimes employed.
• The brining system should then be so designed that pasteurised and unpasteurised brine are not mixed.
• Brine is corrosive, so non-corroding heat exchanger materials such as titanium must be used; these materials, however, are expensive.

*Table 14.3*

*Salt content in different types of cheese*

|                    | % salt       |
| ------------------ | ------------ |
| Cottage cheese     | 0.25 – 1.0   |
| Emmenthal          | 0.4 – 1.2    |
| Gouda              | 1.5 – 2.2    |
| Cheddar            | 1.75 – 1.95  |
| Limburger          | 2.5 – 3.5    |
| Feta               | 3.5 – 7.0    |
| Gorgonzola         | 3.5 – 5.5    |
| Other blue cheeses | 3.5 – 7.0    |

• Pasteurisation upsets the salt balance of the brine and cause precipitation of calcium phosphate; some of this will stick to the plates and some will settle to the bottom of the brining container as sludge.

Addition of chemicals is also employed. Sodium hypochlorite, sodium or potassium sorbate, or delvocide (pimaricine) are some of the chemicals used with variable results. The use of chemicals must of course comply with current legislation.

Other ways to reduce or stop microbiological activity are:
• passing the brine through UV light, provided that the brine
  – has been filtered, and
  – will not be mixed with untreated brine after the treatment.
• microfiltration, with the same reservations as above.

Table 14.3 lists the salt percentages in some types of cheese.

# Ripening and storage of cheese

## Ripening (curing)

After curdling all cheese, apart from fresh cheese, goes through a whole series of processes of a microbiological, biochemical and physical nature. These changes affect both the lactose, the protein and the fat and constitute a ripening cycle which varies widely between hard, medium-soft and soft cheeses. Considerable differences occur even within these groups.

### Lactose decomposition

The techniques which have been devised for making different kinds of cheese are always directed towards controlling and regulating the growth and activity of lactic acid bacteria. In this way it is possible to influence simultaneously both the degree and the speed of fermentation of lactose. It has been stated previously that in the cheddaring process, the lactose is already fermented before the curd is hooped. As far as the other kinds of cheese are concerned, lactose fermentation ought to be controlled in such a way that most of the decomposition takes place during the pressing of the cheese and, at latest, during the first week or possibly the first two weeks of storage.

The lactic acid which is produced is neutralised to a great extent in the cheese by the buffering components of milk, most of which have been included in the coagulum. Lactic acid is thus present in the form of lactates in the completed cheese. At a later stage, the lactates provide a suitable substrate for the *propionic acid bacteria* which are an important part of the microbiological flora of Emmenthal, Gruyère and similar types of cheese. Besides propionic acid and acetic acid, considerable amounts of carbon dioxide are formed, which are the direct cause of the formation of the large round eyes in the above-mentioned types of cheese.

The lactates can also be broken down by *butyric acid bacteria*, if the conditions are otherwise favourable for this fermentation, in which case hydrogen is evolved in addition to certain volatile fatty acids and carbon dioxide. This faulty fermentation arises at a late stage, and the hydrogen can actually cause the cheese to burst.

The starter cultures normally used in the production of the majority of hard and medium-soft kinds of cheese not only cause the lactose to ferment, but also have the ability to attack the citric acid in the cheese simultaneously, thus producing the carbon dioxide that contributes to formation of both round and granular eyes.

Fermentation of lactose is caused by the lactase enzyme present in lactic acid bacteria.

### Protein decomposition

The ripening of cheese, especially hard cheese, is characterised first and foremost by the decomposition of protein. The degree of protein decomposition affects the quality of the cheese to a very considerable extent, most of all its consistency and taste. The decomposition of protein is brought about by the enzyme systems of
- rennet
- micro-organisms
- plasmin, an enzyme that is part of the fibrinolytical system.

The only effect of rennet is to break down the paracasein molecule into polypeptides. This first attack by the rennet, however, makes possible a considerably quicker decomposition of the casein through the action of bacterial enzymes than would be the case if these enzymes had to attack the casein molecule directly. In cheese with high cooking temperatures, scalded cheeses like Emmenthal and Parmesan, plasmin activity plays a role in this first attack.

In medium-soft cheeses like Tilsiter and Limburger, two ripening processes proceed parallel to each other, viz. the normal ripening process of hard rennet cheese and the ripening process in the smear which is formed

Faulty fermentation can cause the cheese to burst.

on the surface. In the latter process, protein decomposition proceeds further until finally ammonia is produced as a result of the strong proteolytic action of the smear bacteria.

## Storage

The purpose of storage is to create the external conditions which are necessary to control the ripening cycle of the cheese as far as possible. For every type of cheese, a specific combination of temperature and relative humidity must be maintained in the different storage rooms during the various stages of ripening.

### Storage conditions

Different types of cheese require different temperatures and relative humidities (RH) in the storage rooms.

The climatic conditions are of great importance to the rate of ripening, loss of weight, rind formation and development of the surface flora (in Tilsiter, Romadur and others) - in other words to the total nature or characteristic of the cheese.

**Cheeses with rinds**, most commonly hard and semi-hard types, can be provided with a plastic emulsion or paraffin or wax coating.

**Rindless cheese** is covered with plastic film or a shrinkable plastic bag.

Covering the cheese has a dual purpose:
1 to prevent excessive water loss,
2 to protect the surface from infection and dirt.

The four examples below will give some idea of the variety of storage conditions for different kinds of cheese.

**1** Cheeses of the *Cheddar* family are often ripened at low temperatures, 4 – 8°C, and a RH lower than 80%, as they are normally wrapped in a plastic film or bag and packed in cartons or wooden cases before being transported to the store. The ripening time may vary from a few months up to 8 – 10 months to satisfy the preferences of various consumers.

**2** Other types of cheese like *Emmenthal* may need to be stored in a "green" cheese room at 8 – 12°C for some 3 – 4 weeks followed by storage in a "fementing" room at 22 – 25°C for some 6 – 7 weeks. After that the cheese is stored for several months in a ripening store at 8 – 12°C. The relative humidity in all rooms is normally 85 – 90 %.

**3** Smear-treated types of cheese – *Tilsiter, Havarti* and others – are typically stored in a fermenting room for some 2 weeks at 14 – 16°C and a RH of about 90%, during which time the surface is smeared with a special cultured smear mixed with a salt solution. Once the desired layer of smear has developed, the cheese is normally transferred to the ripening room at a temperature of 10 – 12°C and a RH of 90 % for a further 2 – 3 weeks. Eventually, after the smear is washed off and cheese is wrapped in aluminium foil, it is transferred to a cold store, 6 – 10°C and about 70 – 75% RH, where it remains until distributed.

**4** Other hard and semi-hard types of cheese, *Gouda* and similar, may first be stored for a couple of weeks in a "green" cheese room at 10 – 12°C and a RH of some 75 %. After that a ripening period of about 3 – 4 weeks may
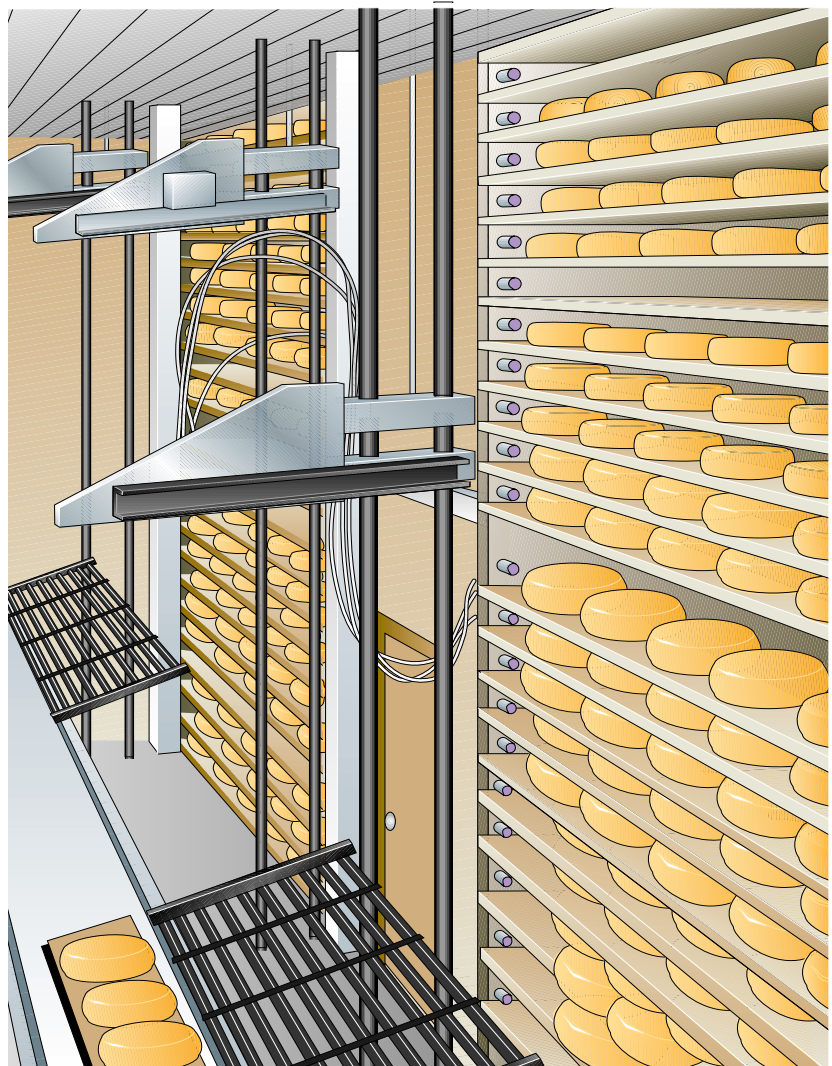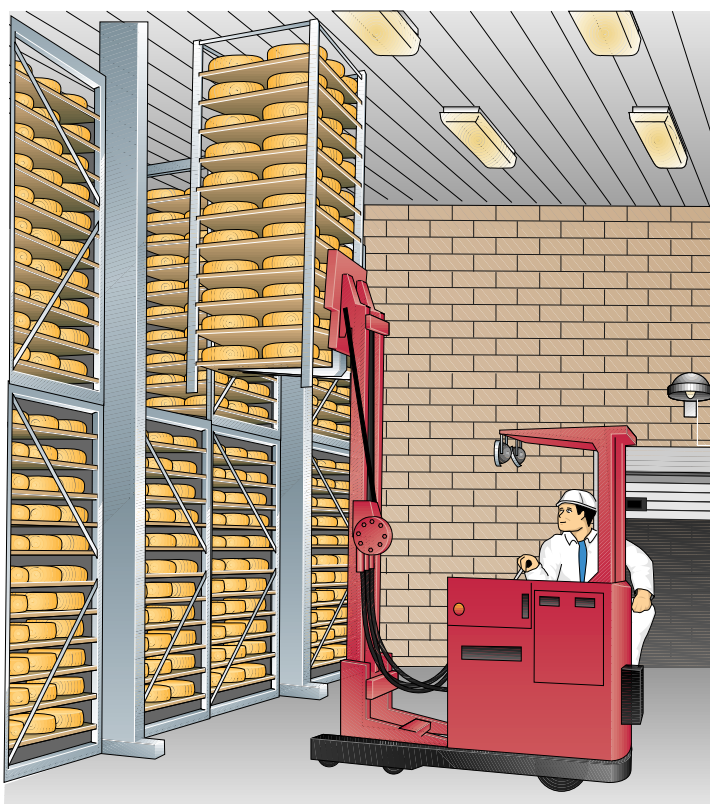


*Fig. 14.32* Mechanised cheese storage. Humidified air is blown through the plastic nozzles at each layer of cheese.

**Fig. 14.33** *Cheese storage using pallets.*

follow at 12 – 18°C and 75 – 80% RH. Finally the cheese is transferred to a storage room at about 10 – 12°C and a relative humidity of about 75%, where the final characteristics are developed.

The values given for temperatures and relative humidities, RH, are approximate and vary for different sorts of cheese within the same group. The humidity figures are not relevant to film-wrapped or bagged ripened cheese.

## *Methods of air conditioning*

A complete air conditioning system is normally required to maintain the necessary humidity and temperature conditions in a cheese ripening store, because humidity has to be removed from the cheese, which is difficult if the outside air has a high humidity. The incoming air must be dehumidified by refrigeration, which is followed by controlled rehumidification and heating to the required conditions.

It may also be difficult to distribute air humidity equally to all parts of the storeroom.

Distribution ducts for the air may be of some help, but they are difficult to keep free from mould contamination. The ducts must therefore be designed to allow cleaning and disinfection.

## *Storage layout and space requirements*

The layout depends on the type of cheese. Installing *permanent cheese racks* in the store has been the conventional solution for both hard and semi-hard cheeses. The capacity of a store for cheeses weighing about 8 – 10 kg with ten racks above each other is approximately 300 – 350 kg/m$^2$. Gangways between the racks are 0.6 m wide and the main corridor in the middle of the store is usually 1.50 – 1.80 m wide. *Mounting the racks on wheels or hanging them from overhead rails* eliminates the need for gangways between racks. They can be put close to each other and need only be moved when the cheese are handled. This system increases the capacity of the store by 30 – 40%, but the cost of the store and building remains at the same level because of the higher cost of this type of rack.

*Pallet racks or containers* are a widely used system. Pallets or pallet containers can also be put on special wheeled pallets running on rails. This method also permits compact storage. Figure 14.32 shows a mechanised cheese store. Located on a wooden shelf holding 5 cheeses, the shelf is conveyed into the green cheese storage and then into a specially designed elevator – not shown on the picture – which lowers or lifts the shelf to a preset level and pushes it into the storage. Figure 14.33 shows a ripening store based on pallets.

**Cheese ripened in film** is packed in cardboard boxes and piled on pallets for the later part of the storage period. This means that the cheese can be stored compactly. The pallets cannot be stacked on top of each other, but pallet racks can be used. The load per unit area must however be taken into consideration if this method is adopted, as the weight will far exceed the normal load allowed in old buildings.

The container system increases the storage capacity considerably as compared with permanent racks.

However, *there are companies which specialise in storage systems* of various degrees of sophistication; anything from traditional racks up to and including computerised systems. They can also advise about optimum air conditioning for the various systems.

The load per unit area must be taken into consideration if the pallet rack method is adopted, as the weight will far exceed the normal load allowed in old buildings.

# Processing lines for hard and semi-hard cheese

The following part of this chapter will only describe some examples of processing lines for some typical types of cheeses.

## Hard types of cheese

### Processing line for Emmenthal cheese

Milk intended for Emmenthal cheese is normally not pasteurised, but the fat content is standardised. At periods when high loads of bacteria spores occur, the milk may also be treated in a Bactofugation or Microfiltration plant for mechanical reduction of spores, before which it should be heated to 50 – 63°C.

After pre-treatment, including addition of necessary ingredients, curd production can start. A preliminary flowchart for production of rindless Emmenthal cheese is illustrated in figure 14.34.

Once the curd is satisfactorily acidified and firm enough, part of the whey is drained from the cheese vat and routed into the press vat (2). When an adequate amount of whey has been transferred, the curd/whey mixture is pumped into the press vat via three distributors. Following the curd/whey transfer and manual levelling of the curd (combined mechanical distribution and levelling systems are also avaible), the press lid is lowered. Surplus whey is simultaneously drained off.

Application of programmed pressures for preset times continues for 10 – 20 hours, depending on lactic acid development.

After pressing the cheese bed is cut into blocks of suitable size by being conveyed through the unloading device, which is provided with vertical knives for lengthwise cutting and a guillotine for crosswise cutting.
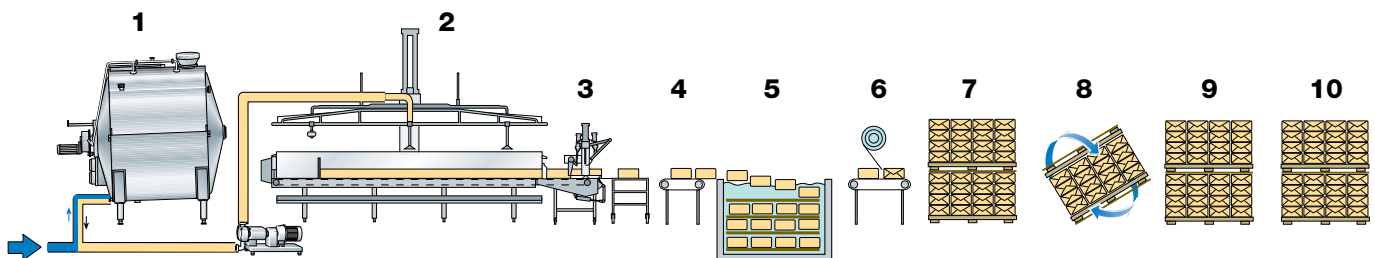


**Fig. 14.34** Flowchart for mechanised production of rindless Emmenthal cheese.

| | |
|---|---|
| 1 Cheese vat | 6 Wrapping in film and cartoning |
| 2 Press vat for total pressing of the curd | 7 Palletised cheeses in green cheese store |
| 3 Unloading and cutting device | 8 Turning the cheese |
| 4 Conveyor | 9 Fermenting store |
| 5 Brining | 10 Ripening store |

—— Milk
—— Curd/cheese

Cutting the curd bed into blocks exposes new surfaces without "skin". Sometimes these are sealed before brining in order to achieve uniform penetration of the brine. This is done by pressing with a hot Teflon-clad iron.

As Emmenthal cheeses are normally large, 30 kg up to more than 50kg, the brining period will vary and may last for up to 7 days.

Following brining, rindless cheese is typically wrapped in film and packed in cartons or big containers before being transferred to the storerooms. Turning the cheese during storage is recommended to obtain a better shape and more uniform eye formation. Palletised turning can be done with specially designed lifting trucks.

## Processing line for Cheddar cheese

Cheddar cheese and similar types are the most widely produced in the world.

Cheddar cheese generally has a moisture on fat-free basis (MFFB) of 55%, which means it can be classified as hard cheese although it is on the verge of semi-hard types. The principle of a highly mechanised production line is shown in figure 14.35.

The curd is normally manufactured from fat-standardised and pasteurised milk. At an acidity of about 0.2 % lactic acid (l.a.), after some 2 to 2.5 hours' production, the curd-whey mixture is pumped from the cheese vat into the continuous cheddaring machine (2). Pre-drawing of whey is not normally practised.

To maintain a continuous feed, a calculated number of cheese vats is scheduled for emptying in sequence at regular intervals, say every 20 minutes.

After a cheddaring period of about 2.5 hours including milling and dry salting of the chips at an acidity of approx. 0.6% l.a., the chips are blown to a block forming machine (3). An adequate number of block formers must be available to maintain continuity.

The exit of each block former is manually provided with a plastic bag into which the cut-out block is pushed. The bagged block is then conveyed to a vacuum sealing machine (4). Following sealing the cheese is weighed (5) en
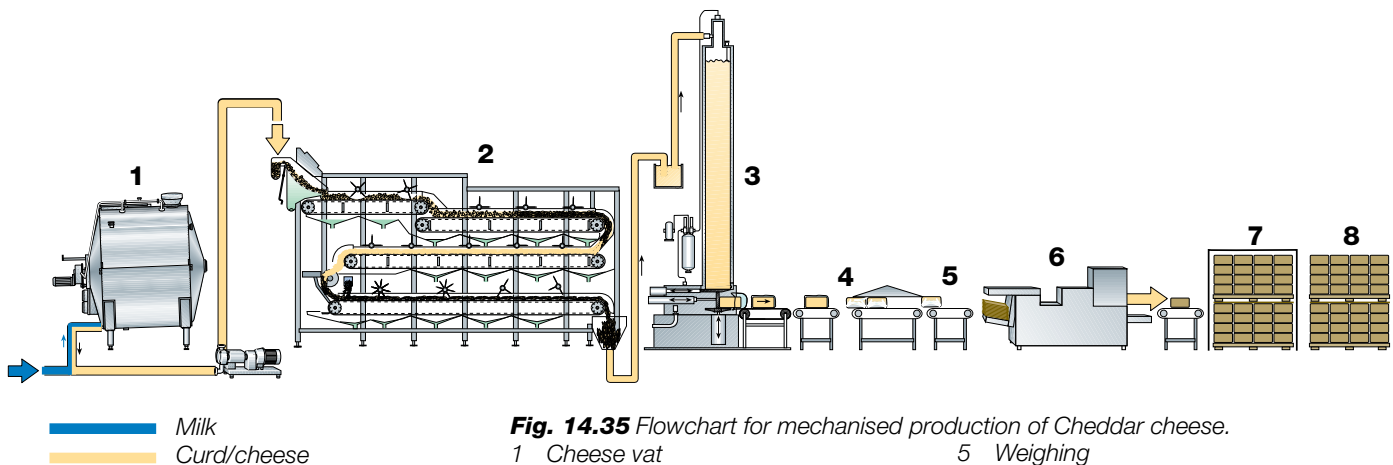


Milk
Curd/cheese

**Fig. 14.35** Flowchart for mechanised production of Cheddar cheese.

| | | | |
|---|---|---|---|
| 1 | Cheese vat | 5 | Weighing |
| 2 | Cheddaring machine | 6 | Carton packer |
| 3 | Block former and bagger | 7 | Palletiser |
| 4 | Vacuum sealing | 8 | Ripening store |

route to a machine (6) where it is covered by a carton, which is then conveyed to a palletiser (7). The filled pallet is finally trucked into the ripening store, where the cheese is held from 4 to 12 months at a temperature of 4 – 8°C.

# Semi-hard types of cheese

## Processing line for Gouda cheese

Gouda is probably the best-known representative of typical *round-eyed* cheeses. A Gouda processing line is illustrated in figure 14.36.

Fat-standardised pasteurised milk is transformed into curd and whey in the usual manner in about 2 hours. Normally, part or sometimes all of the heating is done by direct addition of hot (50 – 60°C) water in an amount equal to 10 – 20% of the original volume of milk. To make this possible, some 20 – 30% of whey must first be drained off.

After completion of curd production and further drainage of whey to a curd/whey ratio of 1:3.5 – 4.0, the contents of the cheese vat are emptied

into a buffer tank (2) provided with an agitator for proper distribution of the curd in the whey. The tank is also jacketed to enable the curd to be chilled to 1 – 2°C with cold or ice water, which may be necessary during certain periods for reduction of the activity of the culture.

The whey/curd mixture is pumped from the filled buffer tank into one or more pre-pressing columns (3). At the very start of pre-pressing, however, the column is first filled with whey, normally the "second" whey from the very first cheese vat to be emptied, so that the subsequent curd will not be exposed to air when it enters the column.

For continuous operation a suitable number of cheese vats is operated in sequence and emptied at regular intervals of about 20 – 30 minutes.

Following pre-pressing, a guillotine system at the bottom of each column cuts out a block of predetermined size, after which the block is pushed out of the machine. Normally the blocks are fed by gravity into clean moulds conveyed from the washing machine and stationed underneath the columns. A fully mechanised system also comprises:
- mechanical lidding (4) of the moulds
- transfer of moulds to conveyor or tunnel presses with pre-programmed pressures and pressing times (5)
- filling and emptying of the presses
- transport of moulds via a de-lidding station (6), a mould turning device (7), a mould emptying system (8) and a weighing scale (9) to an advanced brining system (10).

The moulds and lids are separately conveyed to a combined mould and lid washing machine (12) before being re-used.

After brining the cheese is stored in a green cheese store for about 10 days at 10 – 12°C, after which storage continues in a ripening store at 12 – 15°C for some 2 – 12 months.
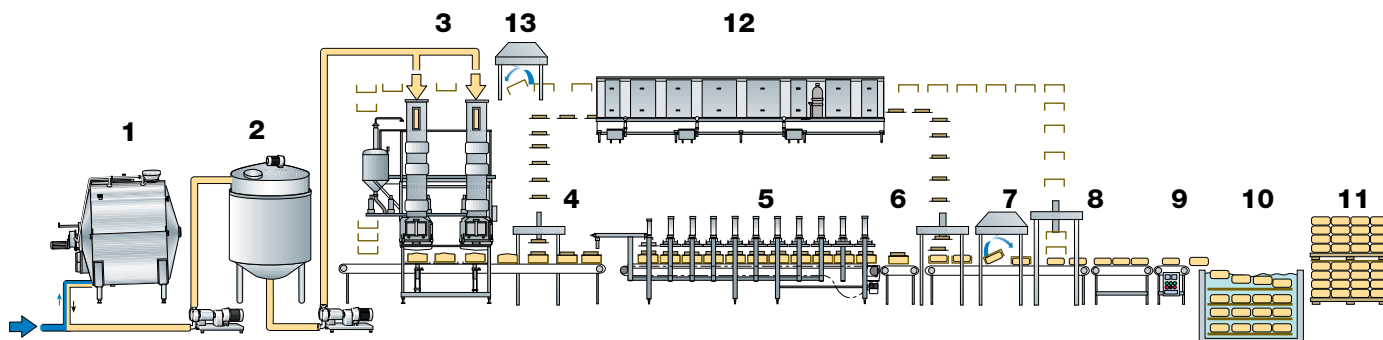


**Fig. 14.36** *Flowchart for mechanised production for Gouda cheese.*

| | |
|---|---|
| Milk | |
| Curd/cheese | |

*1  Cheese vat*
*2  Buffer tank*
*3  Casomatic pre-pressing machine*
*4  Lidding*
*5  Conveyor press*
*6  De-lidding*
*7  Mould turning*

*8  Mould emptying*
*9  Weighing*
*10 Brining*
*11 Ripening store*
*12 Mould and lid washing*
*13 Mould turning*

## Processing line for Tilsiter cheese

Tilsiter has been chosen as a representative of *granular* textured cheese. The principle of a mechanised production line is shown in figure 14.37.

Milk pretreatment and curd production are similar to those of Gouda cheese. The first basic difference is that when the pre-pressing columns are filled, the curd and whey are separated just before the curd enters the column. This is done in a rotating strainer (4) located on top of the column. Otherwise the production scheme is much the same as for Gouda cheese.

After brining, however, Tilsiter cheese undergoes special treatment involving smearing of the surface with a bacteria culture in a 5% salt solution to give it its specific flavor. Tilsiter cheese is therefore first stored in a fer-
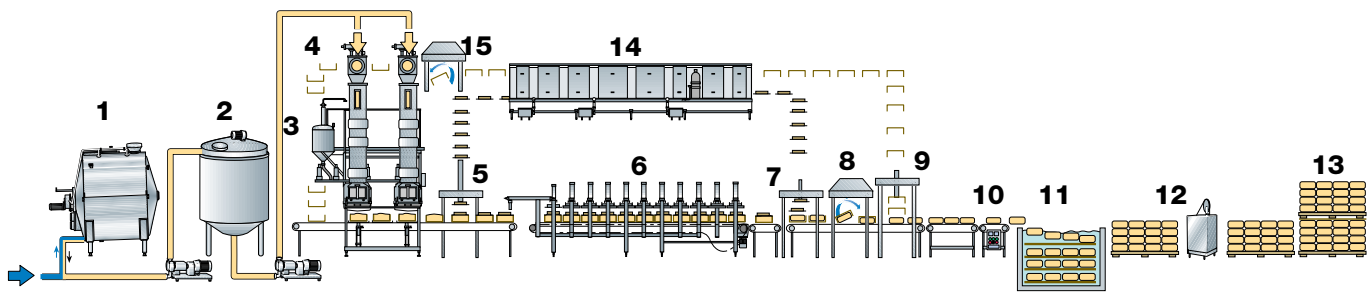
Fig. 14.37 *Flowchart for mechanised production of Tilsiter cheese.*

| | | | |
|---|---|---|---|
| 1 | Cheese vat | 9 | Mould emptying |
| 2 | Buffer tank | 10 | Weighing |
| 3 | Casomatic pre-pressing machine | 11 | Brining |
| 4 | Rotating strainer | 12 | Fermenting store with smearing machine |
| 5 | Lidding | 13 | Ripening store |
| 6 | Conveyor press | 14 | Mould and lid washing |
| 7 | De-lidding | 15 | Mould turning |
| 8 | Mould turning | | |

Milk
Curd/cheese

menting room with a high relative humidity (90 – 95%) and a temperature of about 14 – 16°C. The smearing procedure is either manual or partly mechanised, and the smeared cheese is stored for about 10 – 12 days.

Following the period of surface treatment the cheese is forwarded to ripening storage at 10 – 12°C, often after having passed a washing machine. The time in this store is some 2 – 3 weeks.

In conjunction with dispatch from the ripening store the Tilsiter cheese may be washed and wrapped in aluminium foil before being transferred to cold store at 6 – 10°C.

## Processing line for Mozzarella cheese

"Formaggio a pasta filata" is the Italian name for types of cheese which in English are called Pasta Filata cheese, characterised by an "elastic" string curd, e.g. Mozzarella and Provolone.

The typical Mozzarella cheese is originally and still based on buffalo milk deriving from the buffalos bred in central Italy. Mozzarella is also produced from a mixture of buffalo and cow milk, but nowadays most commonly from cow milk alone. Mozzarella is also called pizza cheese in some countries.

Production of Mozzarella typically involves :
• curd production in the usual manner,
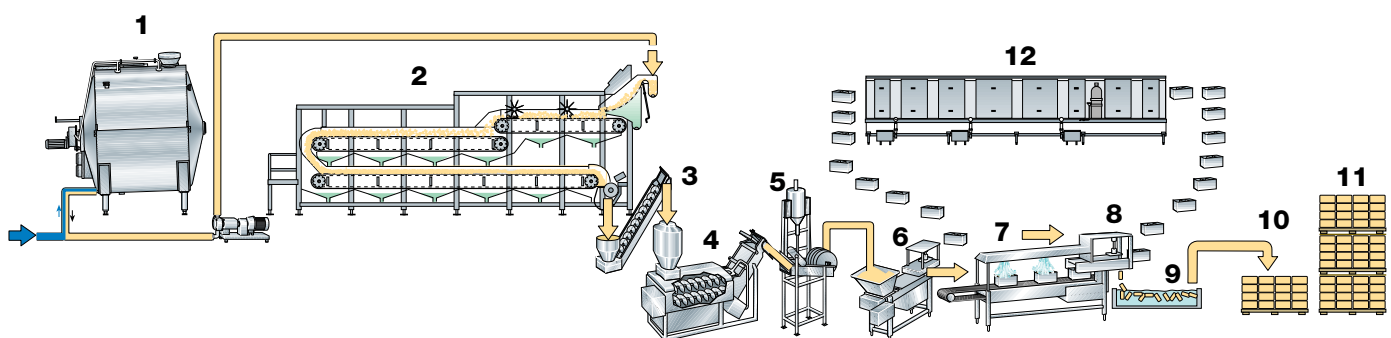


Milk
Curd/cheese

Fig. 14.38 *Flowchart for mechanised production of Mozzarella cheese.*

| | | | |
|---|---|---|---|
| 1 | Cheese vat | 7 | Hardening tunnel |
| 2 | Cheddaring machine | 8 | De-moulding |
| 3 | Screw conveyor | 9 | Brining |
| 4 | Cooker/stretcher | 10 | Palletising |
| 5 | Dry salting | 11 | Store |
| 6 | Multi-moulding | 12 | Mould washing |

- "cheddaring", including chip milling but not salting,
- cooking and stretching to obtain the elastic, stringy character,
- forming, hardening and brining,
- packaging, e.g. in plastic bags together with some brine,
- short storage before dispatch.

Figure 14.38 illustrates the principle of a mechanised production line.

Fat-standardised pasteurised milk is converted to curd in the usual way. After that, the curd and whey are pumped to a mechnical cheddaring machine (2) of a somewhat simpler type than that used for Cheddar cheese production, where the curd is matted and milled into chips. The matting and milling process takes about 2 – 2.5 hours.

After cheddaring the chips are transported by a screw conveyer (3) into the receiver of a cooker-stretcher (4). The plasticised curd is then continuously extruded to the moulding machine (6), en route to which it may be dry-salted (5) to shorten the brining time from normally about 8 hours to about 2 hours.

The curd is worked into the (multi-)mould, which then is conveyed through a hardening tunnel where the cheese is cooled from 65 – 70°C to 40 – 50°C by spraying chilled water over the moulds. At the end of the tunnel the moulds pass a de-moulding device (8). The cheese falls into the gently flowing, cold (8 – 10°C) brine bath and the empty moulds (11) are conveyed to a washing machine (12) from which they are returned to the filling machine.

The cheese may be bagged and packed in cartons before being loaded on a pallet which is then trucked to a store.

# Semi-hard, semi-soft and soft types of cheese

Sometimes it is difficult to classify a type of cheese as distinctly semi-hard or semi-soft, and as semi-soft or soft, as some types occur in intermediate forms. The Tilsiter types are typical representatives of the former intermediate forms, as are also Blue or Blue-veined types of cheese, while Brie types may represent the latter.

The following brief descriptions refer to methods of production of:
- Blue (veined) cheese, representative of *semi-hard and semi-soft* types of cheese with inside mould formation by *Penicillium roqueforti*.
- Camembert cheese, representative of *semi-soft/soft* types of cheese with outside surface mould formation by *Pencillium camemberti* and *Penicillium candidum*.
- Cottage cheese and Quarg as representatives of *soft* fresh cheese.

# Semi-hard and semi-soft cheese

## Blue veined cheese

The prototype of blue veined cheese is Roquefort, which originates from the community of Roquefort in the Aveyron Departement in France.

Roquefort cheese is produced from sheep milk; if any other kind of milk is used in the production of a similar type of cheese, it *must not* be called Roquefort cheese. Blue veined cheese is the generic name for cheeses which develop an interior blue-green mould.

To imitate the characteristic flavour of Roquefort cheese as closely as possible, cheese milk from cows should be partially homogenised, i.e. standardised by mixing skimmilk with homogenised cream of about 20% fat. The reason is that fat which has been exposed to homogenisation is more sensitive to the influence of the lipolytic enzymes emanating from the inoculated *Penicillium roqueforti* mould.

After fat standardisation the milk is normally paseturised at about 70°C, cooled to 31 – 32°C and fed to the cheese vat. After addition of an ordinary
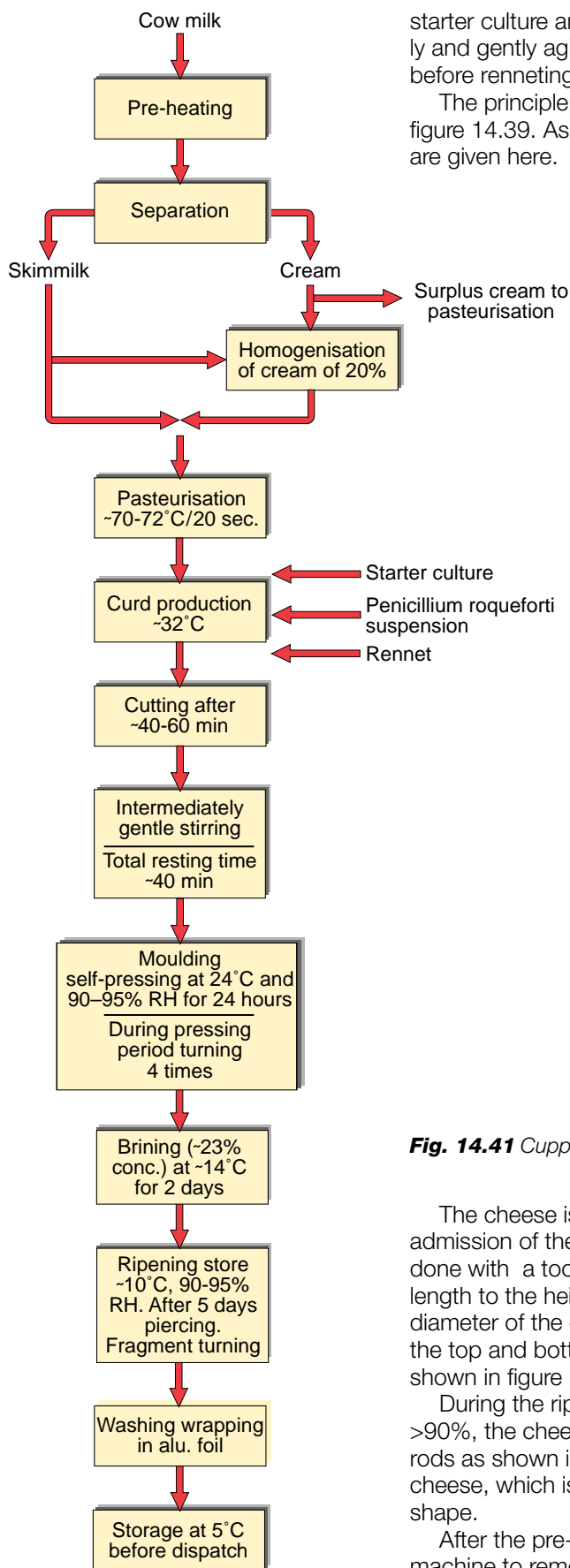
Cow milk

Pre-heating

Separation

Skimmilk          Cream

Surplus cream to
pasteurisation

Homogenisation
of cream of 20%

Pasteurisation
~70-72°C/20 sec.

Curd production
~32°C

← Starter culture
← Penicillium roqueforti
  suspension
← Rennet

Cutting after
~40-60 min

Intermediately
gentle stirring

Total resting time
~40 min

Moulding
self-pressing at 24°C and
90–95% RH for 24 hours

During pressing
period turning
4 times

Brining (~23%
conc.) at ~14°C
for 2 days

Ripening store
~10°C, 90-95%
RH. After 5 days
piercing.
Fragment turning

Washing wrapping
in alu. foil

Storage at 5°C
before dispatch

**Fig. 14.39** *Principle of production of Blue cheese.*

starter culture and a spore suspension of *P. roqueforti*, the milk is thoroughly and gently agitated to obtain good distribution of the micro-organisms before renneting.

The principle of blue cheese production is shown in a block chart in figure 14.39. As this block chart is self-explanatory, only short comments are given here.
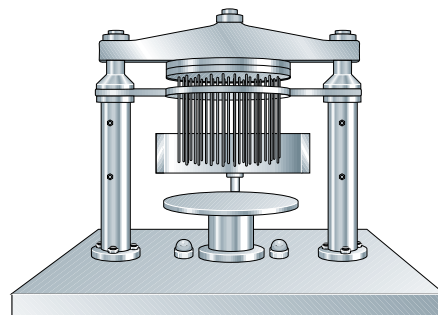


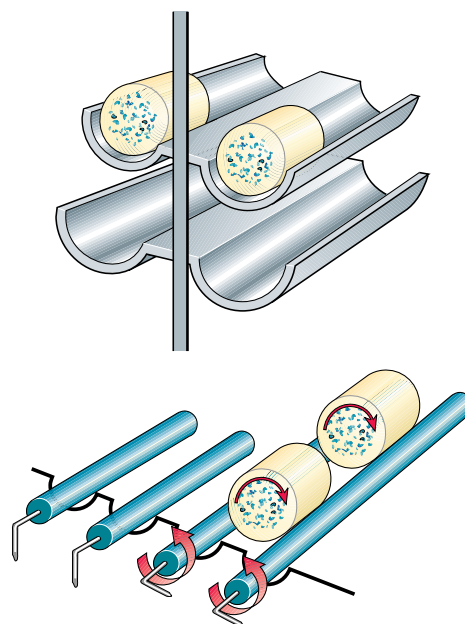**Fig. 14.40** *Pinching machine for piercing blue cheese.*



**Fig. 14.41** *Cupped shelves and pivoted rods for storage of blue cheese.*

The cheese is pierced after about 5 days in the ripening store to facilitate admission of the oxygen needed for the growth of the mould. Piercing is done with a tool with needles about 2 mm in diameter and roughly equal in length to the height of the cheese. The number of needles depends on the diameter of the cylindrical cheese, which is often pierced alternately through the top and bottom to avoid the risk of its cracking. A piercing machine is shown in figure 14.40.

During the ripening period of 5 to 8 weeks at 9 – 12°C and a RH of >90%, the cheese rests on edge, normally on cupped shelves or on pivoted rods as shown in figure 14.41. The latter system facilitates turning of the cheese, which is done frequently to maintain the cylindrical shape.

After the pre-ripening period the cheese is passed through a washing machine to remove the smear that normally develops at the high RH in the store, and mould as well. After washing the cheese is usually wrapped in aluminium foil or plastic film before being transferred to storage at about 5°C, from which it is dispatched to a retail store after a couple of days.

# Semi-soft/soft cheese

## Camembert cheese

Camembert may serve as the characteristic type of cheese covered by white mould from *Penicillum camemberti* and *Penicillium candidum*. Brie is another representative.

The cheesemaking procedure is broadly the same as for Blue veined cheese.

The cheeses are however small and flat. Self-pressing in the moulds proceeds for about 15 – 20 hours, during which time the cheeses should be turned about four times. The cheese is then brined for 1 – 1.5 hours in saturated brine (about 25% salt).

After salting the cheeses are placed on stainless steel string racks, as shown in figure 14.42, or trays. The racks are stacked as much as 15 – 20 high, and then trucked into a storeroom at 18°C and 75 – 80 % RH where they are dried for two days. Then the cheese is trucked to ripening storage at 12 – 13°C and 90% RH.

The cheeses are frequently turned during the ripening period. When the white mould is sufficiently developed, normally after 10 to 12 days, the cheese is packed in aluminium foil and often put in a box before being transferred to a cold store where it is held at 2 – 4°C pending distribution to retailers.
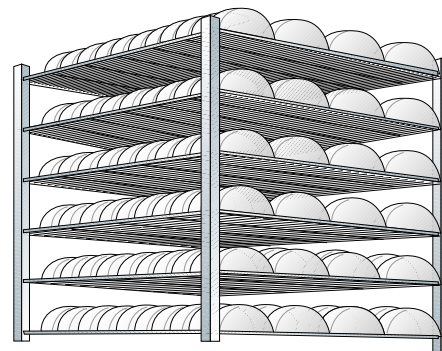


**Fig. 14.42** *String racks for white mould cheese.*

# Soft cheese

## Cottage cheese

Cottage cheese is a creamed fresh curd, low in acidity as it is thoroughly washed during manufacture.

The producer of Cottage cheese can choose between three ways to make a product of identical character, viz.
• long-set method
• medium-set method
• short-set method
The basic differences between these methods are summarised in table 14.4.

Irrespective of mode, after cutting the curd is left undisturbed for 15 to 35 minutes. At cutting the cheesemaker normally makes another choice, viz. whether to produce small curd, medium sized curd or large curd Cottage cheese, which is a matter of the fineness of the grains obtained at cutting.

Following the resting period and stirring, the curd is cooked – usually by indirect heating – for 1 – 3 hours until a temperature of 47 to 56°C is reached.

**Table 14.4**

*Processing data for different modes of production of Cottage cheese*

| Process stage | Long-set | Medium-set | Short-set |
|---|---|---|---|
| Time before cutting | 14 – 16 hours | 8 hours | 5 hours |
| Temp. of milk set | 22 ° C | 26,5°C | 32 °C |
| Starter addition | 0.5 % | 3 % | 5 % |
| Rennet (strength 1:10$^4$) | 2 ppm | 2 ppm | 2 ppm |

When the complete Cottage cheese production process takes place in the same vat, a certain volume of whey is drained off to make room for a corresponding volume of washing and cooling water.

When the same vat is used for the complete production, the curd is normally washed with three batches of water at temperatures of 30, 16 and 4°C respectively. Thorough washing dilutes the lactose and lactic acid, and further acid production and shrinkage are stopped by cooling the curd to about 4 – 5°C. The total time for washing, including intermediate whey-water drainage periods, is about 3 hours.

After all the water has been drained off, pasteurised (80 – 90°C) cream at 4°C containing a small amount of salt, known as dressing, is added and thoroughly worked in. "Ordinary" Cottage cheese contains approximately 79% moisture, 16% milk-solids-non-fat (MSNF), 4% fat and 1% salt.

Finally the Cottage cheese is packed in containers and stored at 4 – 5°C before being distributed to retail shops.

The description shows that Cottage cheese can be produced in a single vat. Special washing and creaming systems have however been developed to rationalise production, especially the washing of the curd and the dressing. The principle of a rationally functioning Cottage cheese production line is illustrated in figure 14.43.
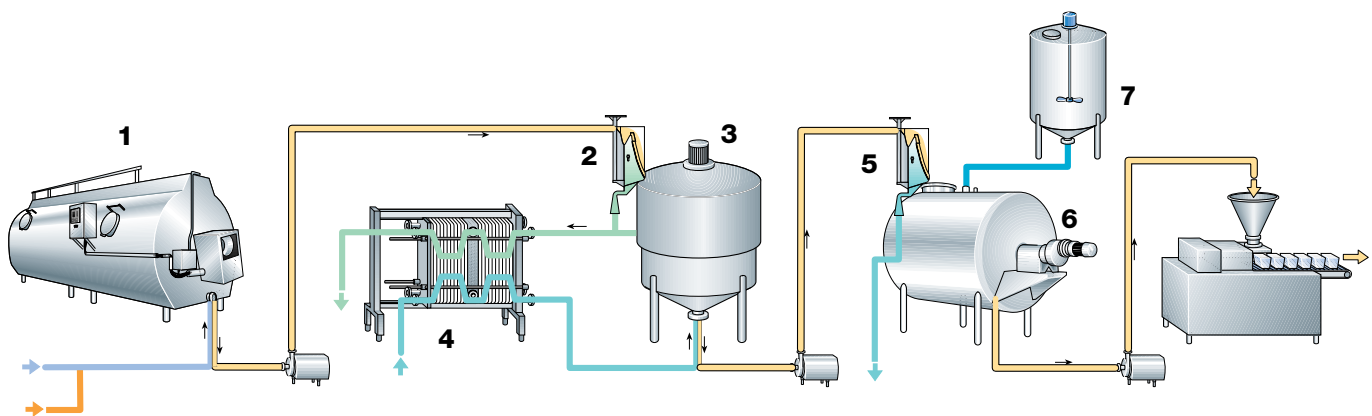


**Fig. 14.43** *Flowchart for mechanised production of Cottage cheese.*

Curd
Skimmilk
Starter
Whey
Wash water
Dressing

1 Cheese vat
2 Whey strainer
3 Cooling and washing tank
4 Plate heat exchanger

5 Water drainer
6 Creamer
7 Dressing tank
8 Filling machine

From the enclosed curd producing vat (1), which serves among other things to protect the milk from airborne infection during the long (16 – 20 hours) or relatively short (5 hours) coagulation period, the whey-curd mixture is pumped via a static whey strainer (2) to a cooling/washing (CW) tank (3).

While the whey is passed to a collection tank, the curd falls into the CW tank with a certain level of fresh water. Even before all the curd from the cheese vat has been transferred to the CW tank, fresh water is pumped in through the bottom inlet. At a certain level in the tank there is an outlet for the surplus liquid, which passes an inner, perforated part so that the curd is retained. After some minutes, when the surplus liquid is more or less free from whey, the inflow of water is stopped and the water is circulated through a plate heat exchanger (4), where the temperature is gradually lowered to 3 – 4°C. The whole cooling and washing procedure takes about 30 – 60 minutes, filling and emptying of the CW tank not included.

After washing and cooling the curd is pumped via a drainer (5) to a creamer (6) designed for mixing the curd and cream dressing. Finally the creamed Cottage cheese is packed in containers.

# Quarg

Quarg is defined as "a sour skimmilk curd cheese usually consumed unripened".

Quarg is often mixed with cream, and sometimes also with fruit and seasonings. The standard of the product varies in different countries and the dry matter in non-fat Quarg may vary between 14 and 24%.

When the Quarg separator was first introduced, the milk was pasteurised at approx. 73°C before fermentation and separation. This is called the traditional method.

Nowadays it is more common to use high-temperature long-time pasteurisation of the skimmilk, 85 – 95°C for 5 – 15 minutes, and further heat treatment of the acidified milk before separation. The latter method is called thermisation, and temperatures between 56 and 60°C for up to 3 minutes are recommended. This, together with high-temperature pasteurisation of the skimmilk, contributes to better yield.

A Quarg production line is illustrated in figure 14.44.

After pasteurisation and cooling to 25 – 28°C, the milk is routed into a tank (1) to which a bacteria culture, typically containing *Streptococcus lactis/cremoris* bacteria, is also added, often together with a small amount of rennet, normally one-tenth of what is used in ordinary cheese production or about 2 ml liquid rennet per 100 kg milk. This is done to obtain a firmer coagulum.
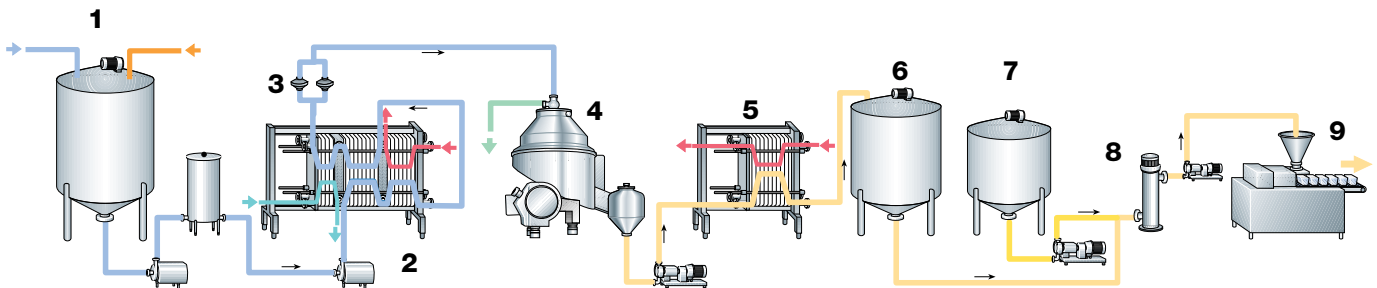


**Fig. 14.44** Flowchart for mechanised production of Quarg

1  Ripening tank
2  Plate heat exchanger for thermisation
3  Filter system
4  Quarg separator
5  Plate heat exchanger

6  Intermediate tank
7  Cream tank
8  Dynamic mixer
9  Filling machine

—— Curd
—— Skimmilk
—— Culture
—— Cooling medium
—— Heating medium
—— Whey
—— Cream

A coagulum forms after about 16 hours at pH 4.5 – 4.7. After the coagulum has been stirred, Quarg production starts with thermisation (2) and cooling to 37°C. The next step is centrifugal separation (4). The Quarg leaves the machine through nozzles at the periphery of the bowl and is discharged into a cyclone from which it is forwarded by a positive displacement pump via a plate cooler (5) into a buffer tank (6). The whey is collected from the separator outlet.

The final cooling temperature depends on the total solids content, and in fact on the protein content. At a dry matter content of 16 – 19%, the reachable temperature is 8 – 10°C. When the DM is 19 – 20%, the Quarg should only be cooled to 11 – 12°C.

Tubular coolers are also used, but they are uneconomical for small production volumes because the losses of product expressed as a percentage of the feed are high, owing to the large hold-up volume of the tubular cooler.

The cooled product is normally collected in a buffer tank before being packed.

If the Quarg is creamed, an adequate volume of sweet or cultured cream is added to the flow and subsequently mixed in a dynamic mixing unit (8) before the product goes to the packaging machine (9).

Sometimes there is a demand for a long-life Quarg product. The process includes heat treatment of the product to inactivate all micro-organisms.

Suitable stabilisers must be added in the buffer tank and thoroughly distributed by agitation. They are needed to stabilise the protein system prior to the final heating, which is performed in a plate, tubular or scraped surface heat exchanger.

The Quarg processing line outlined here can also handle production of strained yoghurt or Labneh, as well as being a part of a cream cheese processing line.

# Ultrafiltration (UF) in cheese manufacture

Ultrafiltration is used in three ways in cheesemaking :
- Preconcentration to low concentration, using a concentration factor (CF) of 1.5 – 2.0 to standardise the protein to fat relation, is followed by conventional cheesemaking in traditional equipment.
- Moderate concentration (CF = 3 – 5) and subsequent cheesemaking in a modified cheese process including some whey drainage. The equipment differs considerably from traditional equipment.
- Concentration to the final DM content of the cheese, at which the milk is first treated by UF (CF = 6 – 8) to obtain a DM content of about 35%, followed by vacuum treatment to reach the typical DM content of the cheese in question.

The first two methods can be used for the manufacture of several types of cheese, while the third makes it possible to manufacture completely new types of cheese.

With the concentration factor (CF) of 3 – 5, the increase of the firmness of the curd results in demands on reinforcement or even a special design of the cutting and stirring tools. Traditional cutting tools are capable of handling curd with a protein content of up to approximately 7%, which limits the CF to about 2.

New types of curdmaking machines have been developed to meet the demands made by CFs of 3 – 5,  one of which is illustrated in figure 14.45.

The curdmaking machine consists of dosing pumps (1), a valve unit (3), static mixers (2), a set of coagulation pipes (4) and a cutting unit (5).

From the dosing pumps the mixture of retentate, rennet and starter is distributed to the coagulation pipes. A standard machine of this type has four spiral-wound coagulation pipes which are protected by a layer of insulation and a stainless steel wall. The insulation is needed to maintain the correct renneting temperature.

The retentate, rennet and starter are metered into the plant by the pumps and mixed thoroughly before entering pipe 1. While the mixture is left for coagulation, pipe 2 is filled and subsequently pipes 3 and 4. The content of pipe 1 is coagulated and ready for discharge when pipe 4 is



**Fig. 14.45** *Principle of a curdmaking machine.*
1   *Dosage pumps for:*
    *a.   retentate*
    *b.   starter*
    *c.   rennet solution*
2   *Static mixer*
3   *Valves*
4   *Coagulator*
5   *Curd cutting unit*

Curd
Retentate
Culture
Rennet
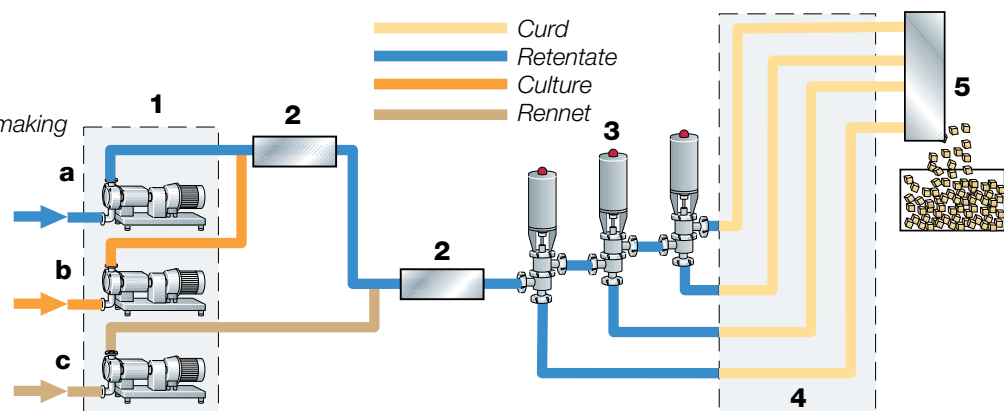
filled. The proper coagulation time in the pipes is controlled by the speed of the dosing pump.

The coagulation pipes end in the cutting unit, which consists of sets of stationary knives and a rotating knife, figure 14.46. The curd "sausage" is pressed through the stationary knives to form cheese strips. In the following stage the curd strips are cut by the rotating knife to form cubes, which are forwarded to the subsequent equipment. They are then subjected to the treatment necessary for the type of cheese which is being manufactured.

# Cheesemaking using UF and curdmaking machine

Both round-eyed, granular and close-textured cheeses can be manufactured by using UF in combination with a curdmaking machine of the type described. The downstream equipment after the curdmaking machine is specific to each type of cheese. A production line for Tilsiter-type cheese is outlined in figure 14.47.

The pretreatment of the milk is the same as in traditional production, for example pasteurisation at 72°C for 15 seconds. For some types of cheese the milk is acidified to pH 6.0 – 6.3. The milk is concentrated to CF = 3 – 5 in the UF unit, i.e. to a total solids content of 25 – 40%. Lactose can be washed away with water during UF. In this way the lactose content of the curd can be regulated and the pH controlled. This is necessary in cheese where the pH should not drop below 5.1.
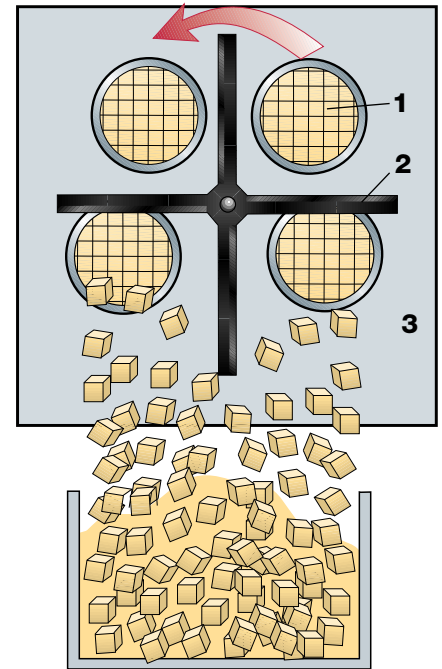


*Fig. 14.46* Cutting unit on a curdmaking machine.
1   Ends of pipes with stationary horizontal and vertical knives
2   Rotating knife
3   Frame

*Fig. 14.47* Flowchart for production of Tilsiter cheese utilising ultrafiltration and a curdmaking machine.

| | | | |
|---|---|---|---|
| 1 Milk tank | 4 After-treatment of retentate incl. pasteurisation | 7 Static mixers | 11 Whey drainage and turning |
| 2 Pre-treatment, incl. thermisation | 5 Mixing tank | 8 Curdmaking machine | 12 Mould emptying |
| 3 Ultrafiltration module | 6 Dosing pump | 9 Curd cutting unit | 13 Brining |
| | | 10 Mould filling | 14 Ripening store |



Milk/retentate
Permeate
Additives
Culture
Rennet
Curd
Heating medium
Cooling medium
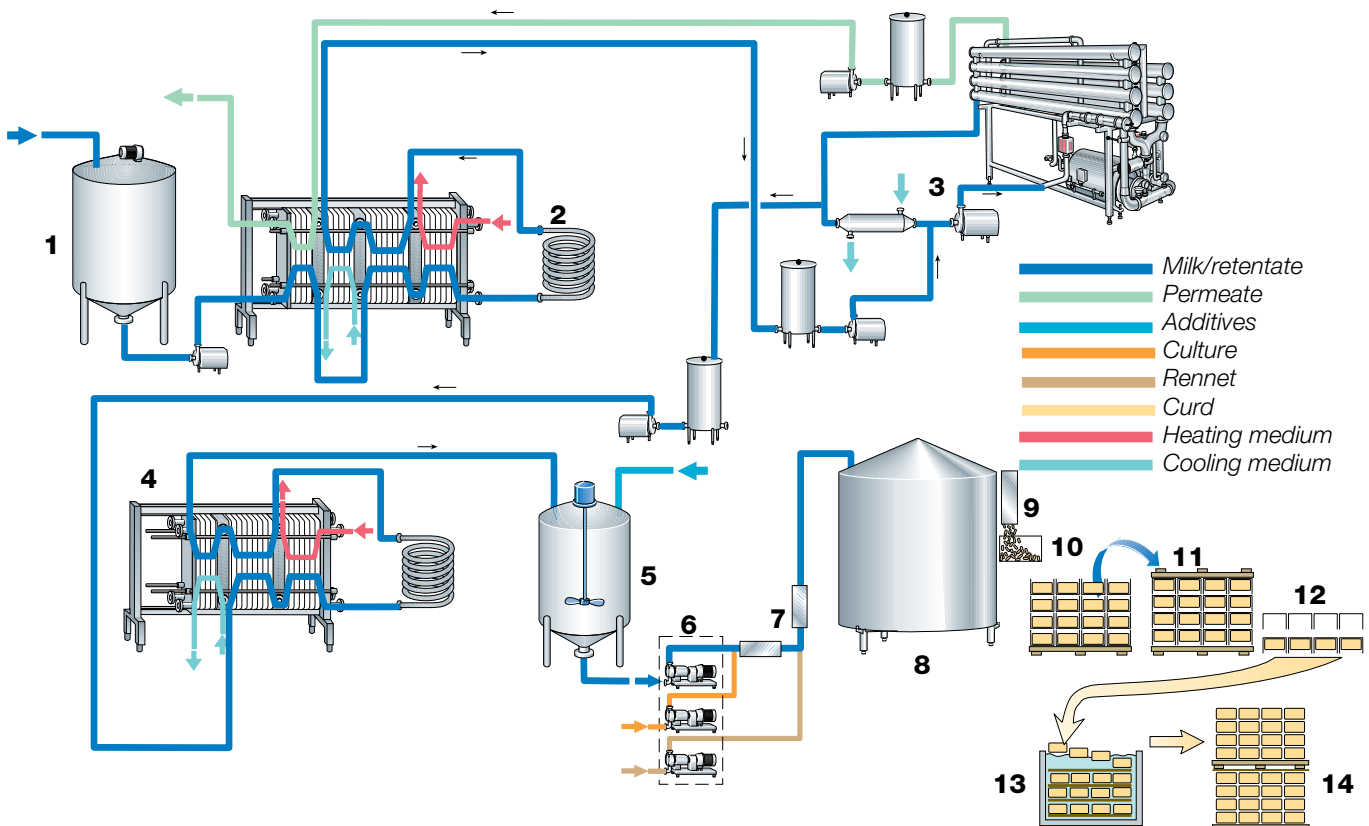
The permeate contains only lactose, some minerals and non-protein components.

The retentate is cooled to renneting temperature, 20 – 38°C depending on the type of cheese. The retentate passes through the curdmaking machine (8). It is discharged in the form of cheese cubes (9) into a moulding system (10). During the gravity pressing period the cheese is turned several times. Eventually the cheese may be mechanically pressed for a short time – 10 to 15 minutes – before being de-moulded.

Normally the cheese is brine salted to aquire a salt content of 1.6 – 1.8%, which for a 4 kg cheese submerged in a 20 – 23% salt bath at 10 – 12°C will take approximately 30 hours.

When salted the cheese is transferred to storage at 16°C and a relative humidity of 90%. Surface treatment, and further treatment as well, are similar to that previously described for traditionally produced Tilsiter cheese.

## New trends

Concentration of cheese milk in a UF plant designed for a CF of 6 – 8, followed by further concentration by vacuum treatment of the retentate (concentrate) to the same DM content as that of the cheese, offers new opportunities to rationalise production. Such methods also strongly limit losses of fat and proteins.
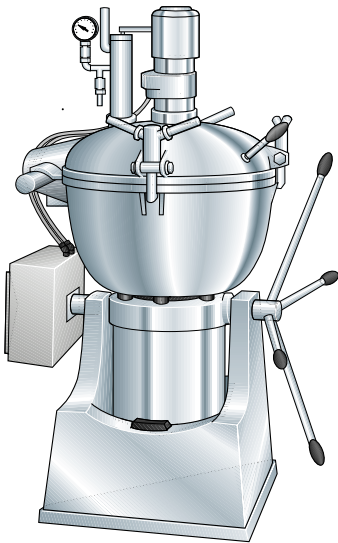


**Fig. 14.48** *Cooker for processed cheese.*

# Processed cheese

Processed cheese is made by further processing of finished cheese, usually a blend of hard rennet varieties with different aromas and degrees of maturity. There are two types of this cheese:
- Cheese blocks with a firm consistency, high acidity and relatively low moisture content.
- Cheese spreads with a soft consistency, low acidity and high moisture content.

Various flavourings can be added. Varieties with a smoked flavour can also be included under this heading.

Processed cheese usually contains 30 or 45% fat, counted on total solids, though leaner and fatter varieties are also made. The composition in other respects depends entirely on the moisture content and the raw materials used in the manufacture.

Cheese for processing is of the same quality as cheese for direct consumption. Cheese with defects regarding surface, colour, texture, size and shape, as well as cheese with a limited shelf life, can also be used for processing, as can fermented cheese where the fermentation has been caused for example by coliform bacteria, provided that it is free from off-flavours. Butyric-acid fermented cheese can cause problems, as the bacteria may cause fermentation in the processed cheese.

High-quality processed cheese can only be produced from high-quality raw materials.



**Fig. 14.49** *Cooker, open and tilted for emptying.*

## Manufacture

The manufacturing process begins with scraping and washing the cheese, which is then ground. In large factories the shredded cheese is melted continuously and in smaller plants it is transferred to cookers, of which there are several types, one of which is shown in figures 14.48 and 14.49.

Firstly water, salt and emulsifier/stabiliser are mixed into the cheese. The mixture is heated to 70 – 95°C, or even higher (depending on the type of processed cheese), in steam-jacketed cookers and by direct steam injection to speed up the cooking time, 4 – 5 min. for block cheese and 10 – 15 min. for spreads. It is kept constantly agitated during heating to avoid scorching. The process usually takes place under vacuum, which offers advantages from the point of view of heating and emulsification. It removes undesirable odours and flavours and makes it easier to regulate
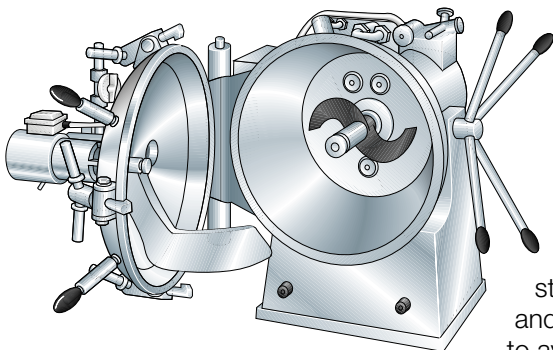
the moisture content. The capacity of a batch cooker is about 75 kg.

The pH of processed cheese should be 5.6 – 5.9 for spreads and 5.4 – 5.6 for types to be sliced. Variations in the pH of the raw material are adjusted by mixing cheese of different pH and adding emulsifiers/stabilisers to adjust the pH. The emulsifiers/stabilisers also bind calcium. This is necessary to stabilise the cheese so that it will not release moisture or fat.

The processed cheese is then discharged from the cooker into a stainless steel container which is transported to the packing station and emptied into the feed hoppers of the packing machines. The latter are usually fully automatic and can produce packages of different weights and shapes.

Normally the cheese is hot-packed at cooking temperature.

The spreadable type of processed cheese should be cooled as rapidly as possible and should therefore pass through a cooling tunnel after packing. Rapid cooling improves the spreading properties.

The cheese block on the other hand should be slowly cooled. After moulding the cheese is left at ambient temperature.