Butter Manufacture

Butter is classified

According to process:

- Sweet cream butter
- Sour cream butter

According to salt content:

- Salted
- Unsalted
- Extra salted

Definitions and Standards

Milk Fat

- the lipid components of milk, as produced by the cow, and found in commercial milk and milk-derived products, mostly comprised of triglyceride.

Butterfat

- almost synonymous with milkfat; all of the fat components in milk that are separable by churning.

Anhydrous Milkfat (AMF)

- the commercially- prepared extraction of cow's milkfat, found in bulk or concentrated form (comprised of 100% fat, but not necessarily all of the lipid components of milk).

Butteroil

- synonomous with anhydrous milkfat; (conventional terminology in the fats and oils field differentiates an oil from a fat based on whether it is liquid at room temp. or solid, but very arbitrary).

Butter

- a water-in-oil emulsion, comprised of >80% milkfat, but also containing water in the form of tiny droplets, perhaps some milk solids-not-fat, with or without salt (sweet butter); texture is a result of working/kneading during processing at appropriate temperatures, to establish fat crystalline network that results in desired smoothness (compare butter with melted and recrystallized butter); used as a spread, a cooking fat, or a baking ingredient.

The principal constituents of a normal salted butter are fat (80 - 82%), water (15.6 - 17.6%), salt (about 1.2%) as well as protein, calcium and phosphorous (about 1.2%). Butter also contains fat-soluble vitamins A, D and E.

Butter should have a uniform colour, be dense and taste clean. The water content should be dispersed in fine droplets so that the butter looks dry. The consistency should be smooth so that the butter is easy to spread and melts readily on the tongue.

Butter production

milk (free from antibiotics, disinfectants
no psychrotrophic bacteria) IV < 28 hard fat
IV ≯ 40 soft fat

↓

pre-heating 37-74°C

↓

Separation cream → Skim milk

↓

Cream (30-35% fat)

↓

Neutralization & standardization (11-13° SH)

↓

heating 65°C / 30' or 87°C - 15" peroxidase test (−)

↓

deaeration (vacuum) 62°C

↓

Cooling & ripening
amount of SC (optional) depends on

Temp-treatment

↓

Temp-treatment (SC, T°C, time)

(rapid cooling gives many small fat crystals so more liquid fat will be absorbed. If gradual cooling is applied which cause larger & fewer crystals ∴ by modification of cooling program you can regulate size)

↓

Churning 8-15°C / 30'-45'

↓

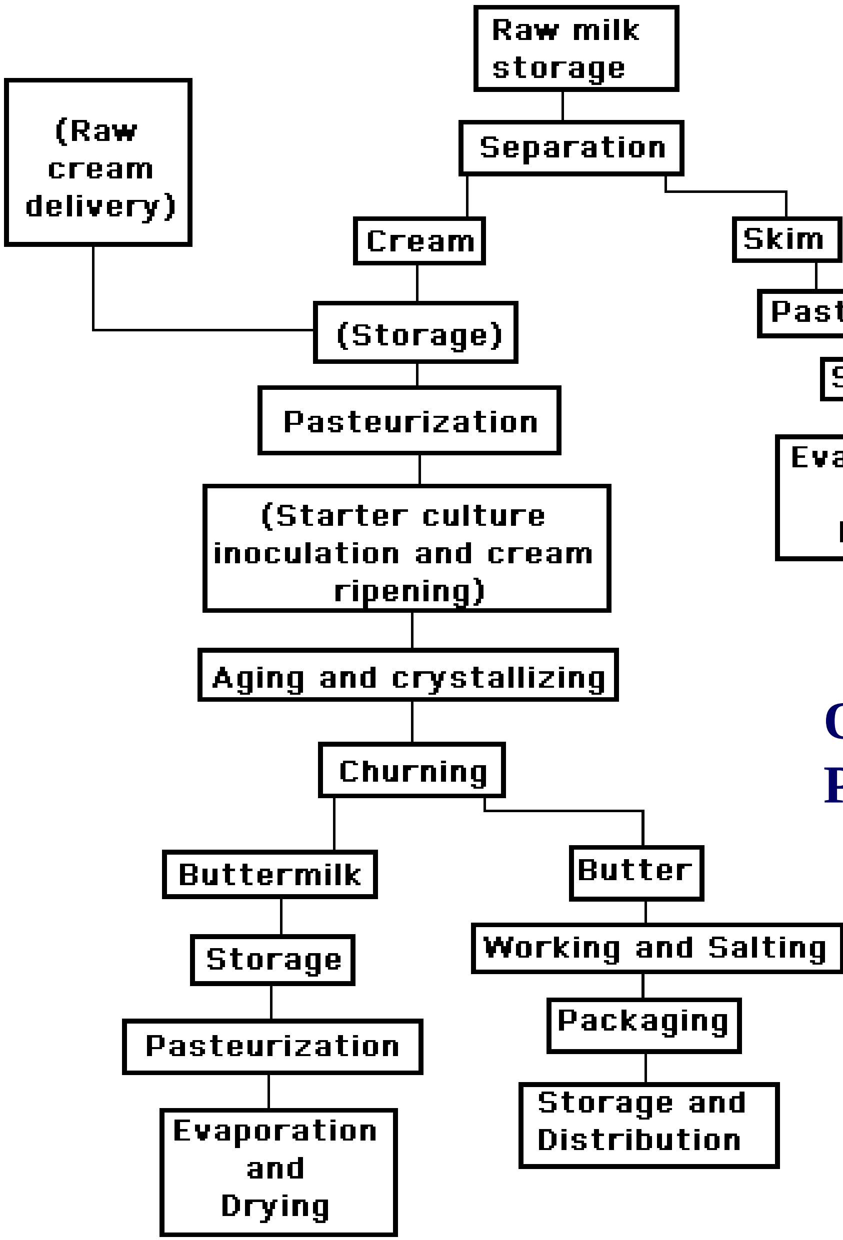
working

↓

Washing (≤ 2.5% salt

↓

working → packaging



Overview of the Buttermaking Process

Butter

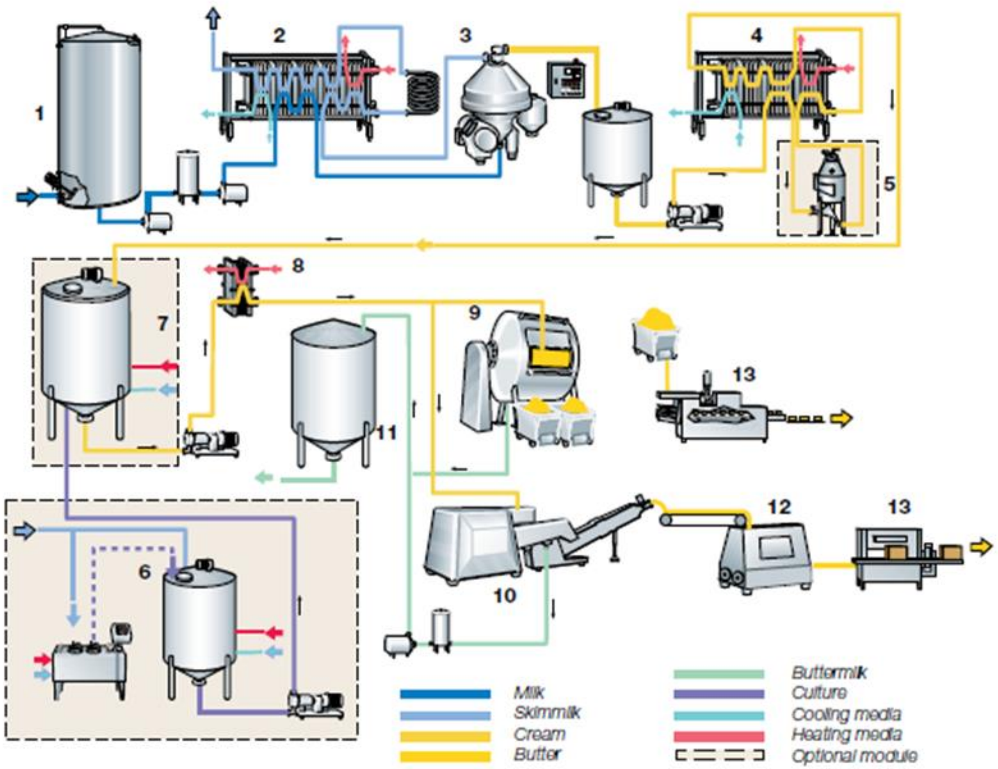


Fig. 12.2 *General process steps in batch and continuous production of cultured butter*

1 Milk reception
2 Preheating and pasteurisation of skimmilk
3 Fat separation
4 Cream pasteurisation
5 Vacuum deaeration, when used
6 Culture preparation, when used
7 Cream ripening and souring, when used
8 Temperature treatment
9 Churning/working, batch
10 Churning/working, continuous
11 Buttermilk collection
12 Butter silo with screw conveyor
13 Packaging machines

Vacuum deaeration is recommended when the cream has a very strong flavour or aroma defect, e.g. onion taste. Vacuum treatment may have an unfavourable effect on the yield and the butter consistency.

Fayway Butter Churn

500.

125.

Wooden Stomper Churn

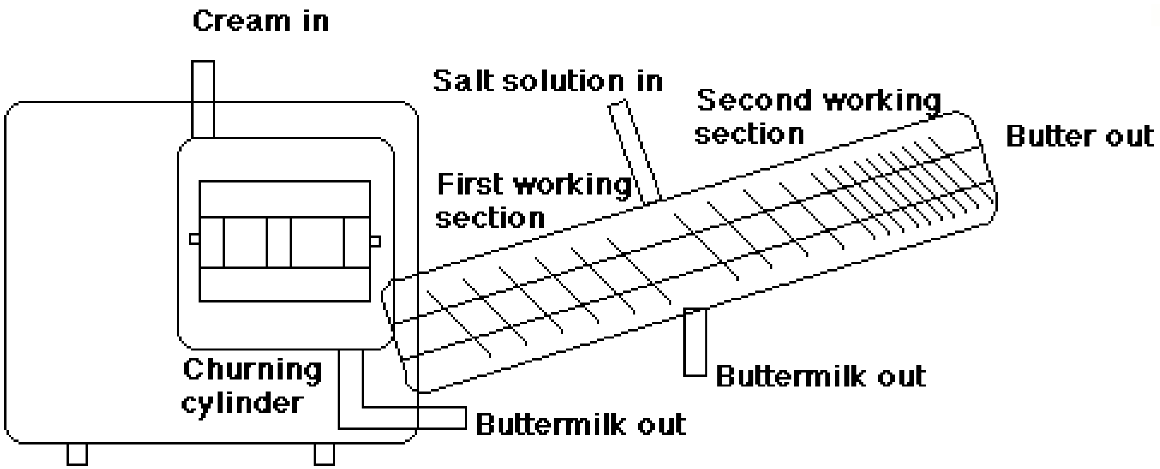
Continuous Buttermaking

There are essentially four types of buttermaking processes:

- •traditional batch churning from 25- 35% mf. cream;
- •continuous flotation churning from 30-50% mf. cream;
- •the concentration process whereby "plastic" cream at 82% mf. is separated from 35% mf. cream at 55 C and then this oil-in-water elulsion cream is inverted to a water-in-oil emulsion butter with no further draining of buttermilk;
- •the anhydrous milkfat process whereby water, SNF, and salt are emulsified into butter oil in a process very similar to margarine manufacture.

An optimum churning temperature must be determined for each type of process but is mainly dependent on the mean melting point and melting range of the lipids, i.e., 7-10°C in summer and 10 - 13°C in winter. If churning temperature is too warm or if thermal cycle permits to much liquid fat than a soft greasy texture results; if too cold or too much solid fat than butter too brittle and sticky.

Continuous Flotation Churns



Continuous Butter Churn

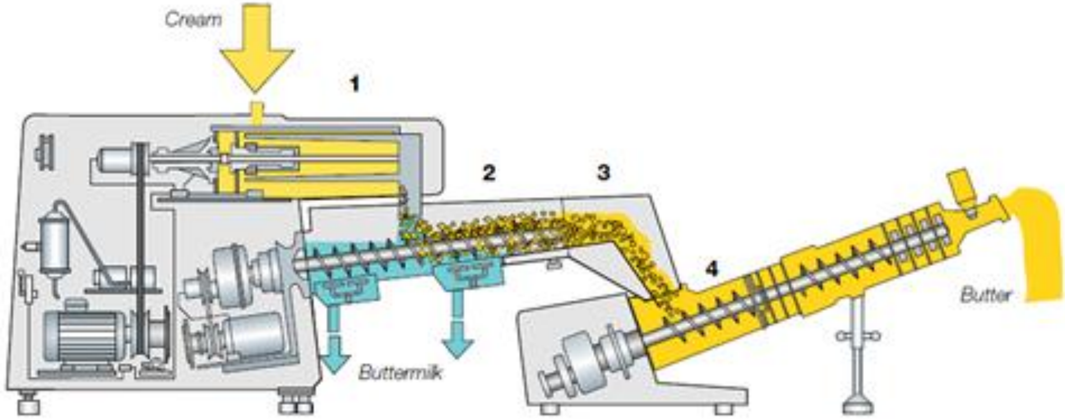


Fig. 12.6 A continuous buttermaking machine
1 Churning cylinder
2 Separation section
3 Squeeze-drying section
4 Second working section

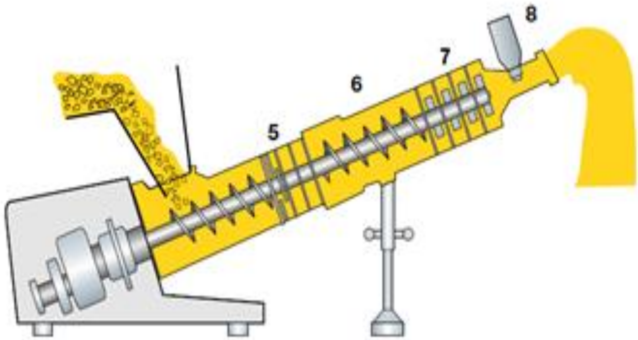


Fig. 12.7 The vacuum working section
5 Injection section
6 Vacuum working section
7 Final working stage
8 Moisture control unit

Crystallizing of the milkfat during aging

Modification of the cooling program for the cream provides possibility to regulate the size of the crystals in the fat globules and in this way influence both the magnitude and the nature of the important continuous fat phase.

Principal temperature programmes adjusted to the iodine value and recommended volumes of culture, when used.

Iodine value	Temperature programme, °C	Approx % of starter in cream
<28	8 – 21 – 20	1
28 – 29	8 – 21 – 16	2 – 3
30 – 31	8 – 20 – 13	5
32 – 24	6 – 19 – 12	5
35 – 37	6 – 17 – 11	6
38 – 39	6 – 15 – 10	7
>40	20 – 8 – 11	5

Treatment of hard fat

The program of treatment necessary to achieve this result comprises the following stages:

- rapid cooling to about 8^oC and storage for about 2 hours at this temperature;
- heating gently to 20 - 21^oC and storage at this temperature for at least 2 hours (water at 27 - 29^oC is used for heating);
- cooling to about 16^oC.

Treatment of medium-hard fat

With an increase in the iodine value, the heating temperature is accordingly reduced from 20-21^{o}C. Consequently a larger number of fat crystals will form and more liquid fat will be adsorbed than is the case with the hard fat program. For iodine values up to 39, the heating temperature can be as low as 15^{o}C.

Treatment of very soft fat

Where the iodine value is greater than 39-40 the "summer method" of treatment is used. After pasteurization the cream is cooled to 20^{o}C. If the iodine value is around 39 - 40 the cream is cooled to about 8^{o}C, and if 41 or greater to 6^{o}C. It is generally held that aging temperatures below the 20^{o}C level will give a soft butter.

Packaging

There are basically three ways of transporting butter or dairy spreads from the machine to packaging:

1. The product is discharged into a silo with a screw conveyor at the bottom. The conveyor feeds the product to the packaging machine.

2. The product is pumped direct to the packaging machine.

3. Transfer by means of trolleys filled with product. The trolleys are often fitted with screw conveyors. A combination of these methods is also possible.

Butter can be packed in bulk packs of more than 5 kg and in packets from 10 grams to 5 kg. Various types of machines are used, depending on the type of packaging. The machines are usually fully automatic, and both portioning and packaging machines can often be reset for different sizes, for example 250 g and 500 g or 10 g and 15 g.

The wrapping material must be greaseproof and impervious to light, flavouring and aromatic substances. It should also be impermeable to moisture, otherwise the surface of the butter will dry out and the outer layers become more yellow than the rest of the butter.

Butter is usually wrapped in aluminium foil. Parchment paper, once the most common wrapping material, is still used but has now been largely replaced by aluminium foil, which is much less permeable.

After wrapping, the pat or bar packets continue to a cartoning machine for packing in cardboard boxes, which are subsequently loaded on pallets and transported to the cold store.

CHEESE PRODUCTION

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 systemized 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.

Table 14.1

Classification of cheese

If the MFFB* is, %	**Term I** The 1st phrase in the designation shall be	If the FDB** is, %	**Term II** The 2nd phrase in the designation shall be	**Term III** 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.

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

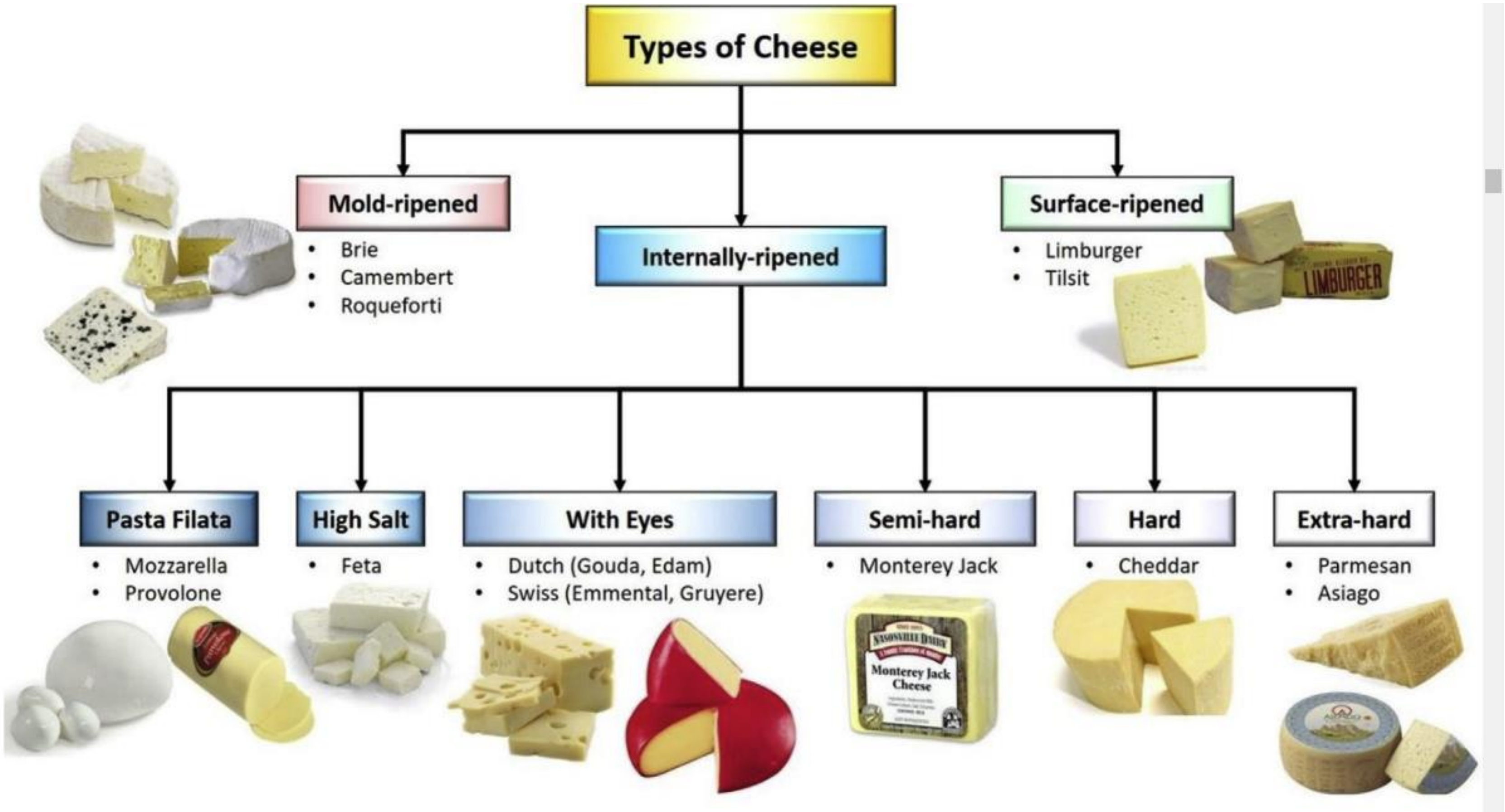
** FDB equals percentage fat on dry basis, i.e.

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

*** 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


Types of Cheese
Mold-ripened
• Brie
• Camembert
• Roqueforti
Internally-ripened
Surface-ripened
• Limburger
• Tilsit
LIMBURGER
Pasta Filata
• Mozzarella
• Provolone
High Salt
• Feta
With Eyes
• Dutch (Gouda, Edam)
• Swiss (Emmental, Gruyere)
Semi-hard
• Monterey Jack
Monterey Jack Cheese
Hard
• Cheddar
Extra-hard
• Parmesan
• Asiago

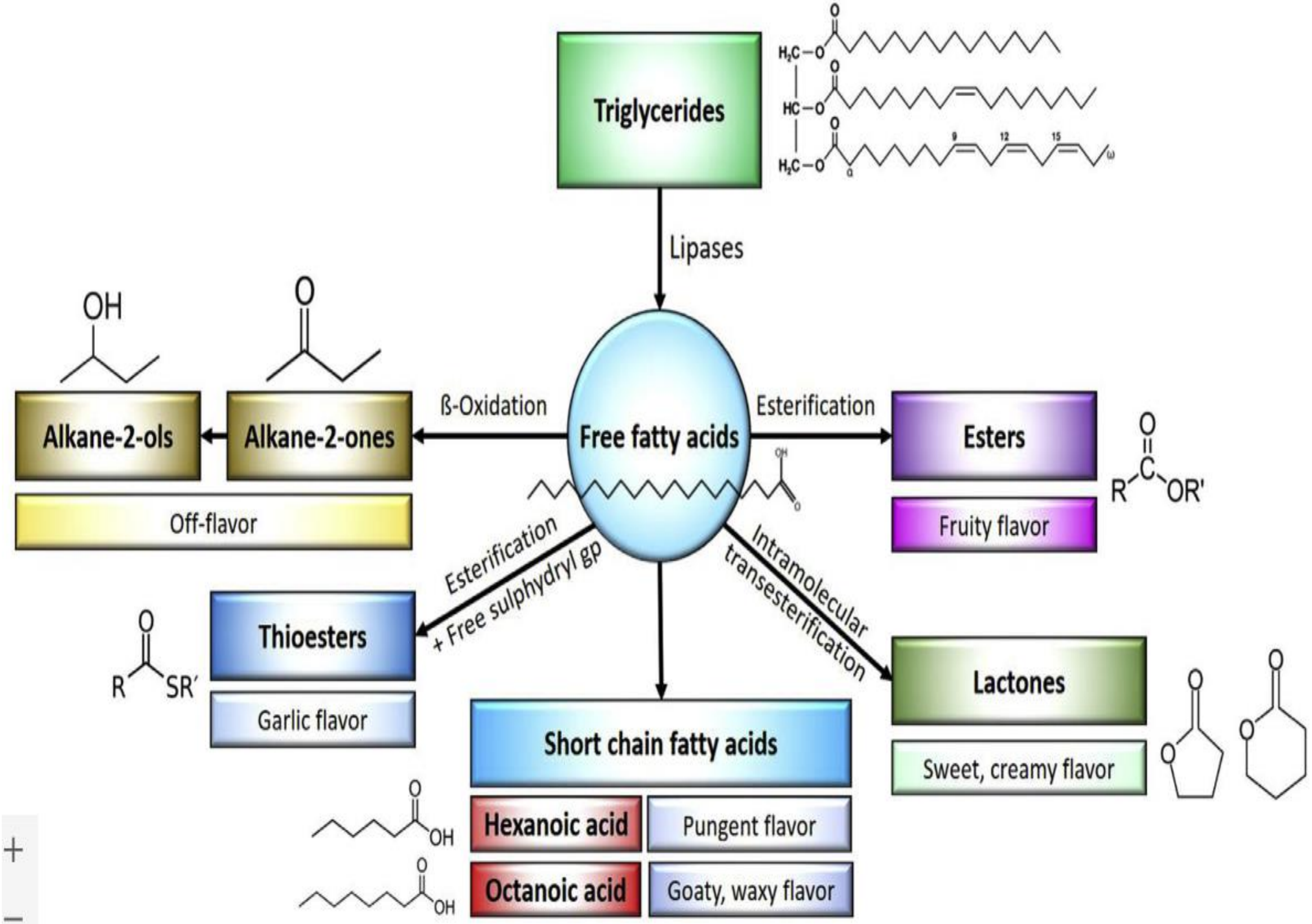
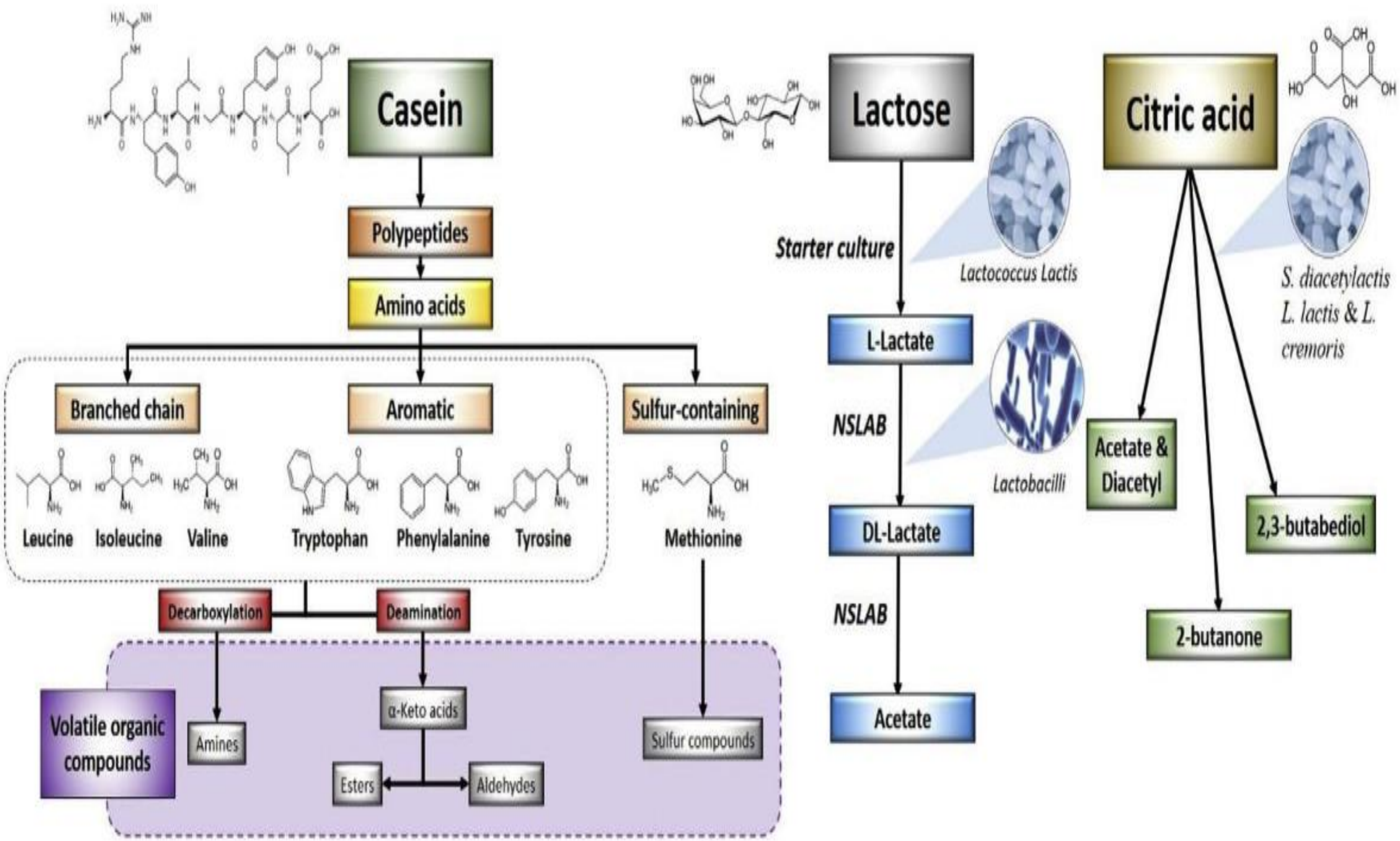


Fig. 4. Lipolytic biochemical changes leading to the development of cheese flavor and off-flavor.



ig. 2. Glycolytic and proteolytic biochemical reactions involved in the development of cheese flavor.

There are several **types of cheese**, which are grouped or classified according to criteria such as length of ageing, texture, methods of making, fat content, animal milk, country or region of origin, etc. The method most commonly and traditionally used is based on moisture content, which is then further narrowed down by fat content and curing or ripening methods. The criteria may either be used singly or in combination, but with no single method being universally used. The combination of types produces around 500 different varieties recognised by the International Dairy Federation, over 400 identified by Walter and Hargrove, over 500 by Burkhalter, and over 1,000 by Sandine and Elliker.

Ek-1: Sertlik derecesine göre peynirlerin sınıflandırılması;

Sertlik derecesine göre	(YPKN) Yağsız peynir kitlesindeki nem oranı (%)	Tolerans(%)
Ekstra sert	<49	±2
Sert	49- 57<	
yarı sert	57- 64<	
Yarı yumuşak	64-70	
Yumuşak	>70	

Ek-2: Olgunlaşma durumu ve yöntemine göre peynirlerin sınıflandırılması

Olgunlaşma		Gün olarak minimum olgunlaşma süresi	
Olgunlaşma yöntemi	**Olgunlaşma durumu**	Ağırlık>1,5 kg	Ağırlık≤1,5
	Olgunlaştırılmamış/Taze	-	
-Olgunlaştırılmış -Küflü Olgunlaştırılmış	Olgunlaştırılmış	90	45
-Salamurada Olgunlaştırılmış	Olgunlaştırılmış	90	90

Ek-3: Peynirlerin Süt Yağı Miktarına göre sınıflandırılması;

Yağlılık durumu	%, kuru maddede süt yağı
Tam yağlı	45 ≤ süt yağı
Yarım Yağlı	25≤ süt yağı < 45
Az Yağlı	10 ≤ süt yağı < 25
Yağsız	10 > süt yağı

Ek:4:Peynirlerin Kimyasal Özellikleri;

	Nem, % (m/m), en çok	**Tuz (NaCl), % (m/m), en çok**
[1]**Salamurada olgunlaştırılan peynirler**	60	3,5
[1]**Pıhtısı Haşlanmış peynirler**	45	3,0
[1]**Küfle olgunlaştırılan Peynirler**	55	3
Lor ve peynir altı suyu peynirleri	75	2,0
Taze Peynirler	84	1,5
Çeşnili taze peynirler	80	1,5
Olgunlaştırılmış Beyaz Peynir	60	3,0
Taze Beyaz Peynir	65	2,5
Kaşar Peyniri	40	3,5
Taze Kaşar Peyniri	[2]45	2,5
Eritme Peyniri	65	2,5
Tulum Peyniri	45	4,0

[1] Belirtilen değerler taze/olgunlaştırılmış beyaz peynir, kaşar peyniri, tulum peyniri, eritme peyniri, taze peynir, Lor ve peynir altı suyu peynirleri, Çeşnili taze peynirler dışında kalan peynirler için geçerlidir.

[2] Burada belirlenen değer tam yağlı taze kaşar peyniri için geçerlidir. Diğer yağlılık durumları için **Nem, % (m/m)**, en çok %50 olur.

Cheese milk

• Fat standardisation

• casein/fat ratio between 0.69-0.73 for cow's; 1 for lamb's milk

Pasteurisation

• 70-72°C/15-20 s (not always employed)

Cooling to about 30°C = renneting temperature

Mechanical reduction of bacteria:

• Bactofugation

• Microfiltration

• Additives to milk for cheese production:
– Calcium chloride
– Saltpetre, if permitted by law
– Starter bacteria, appropriate to type of cheese
– Rennet used as coagulant

After formation of Coagulum curds are cut into grains

• 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

Some important explanations given next slides;

Standardisation

Types of cheese are often classified according to fat on dry basis, FDB/TSE. The fat content of the cheese milk 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 standardized to the required value. Standardization can be accomplished either by in-line remixing after the separator, or for example by mixing whole milk and skim milk in tanks followed by pasteurization.

Additives in cheesemilk

The essential additives in the cheese-making 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 cheese making; it performs several duties.

Two principal types of culture are used in cheese making:

– *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 CO2. 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.

Three characteristics of starter cultures are of primary importance in cheesemaking,

– ability to produce lactic acid

– ability to break down the protein and, when applicable

– ability to produce carbon dioxide (CO_2).

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

Calcium chloride ($CaCl_2$)

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

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.

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.

There is a relation between strength of rennin and milk.

$$Strenght\ of\ rennin = \frac{V(2400)}{tv}$$

V is volume of milk, v is volume of rennin, t is coagulation time

Ex: if total required time for coagulation is 1.5 h and 1000 L milk is present and strength of rennin is 1/10.000, find amount of rennin.

10000=(2400)(1000)/[(2(1.5 h)/3)(v)], v=66 mL (0.066 L)

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,

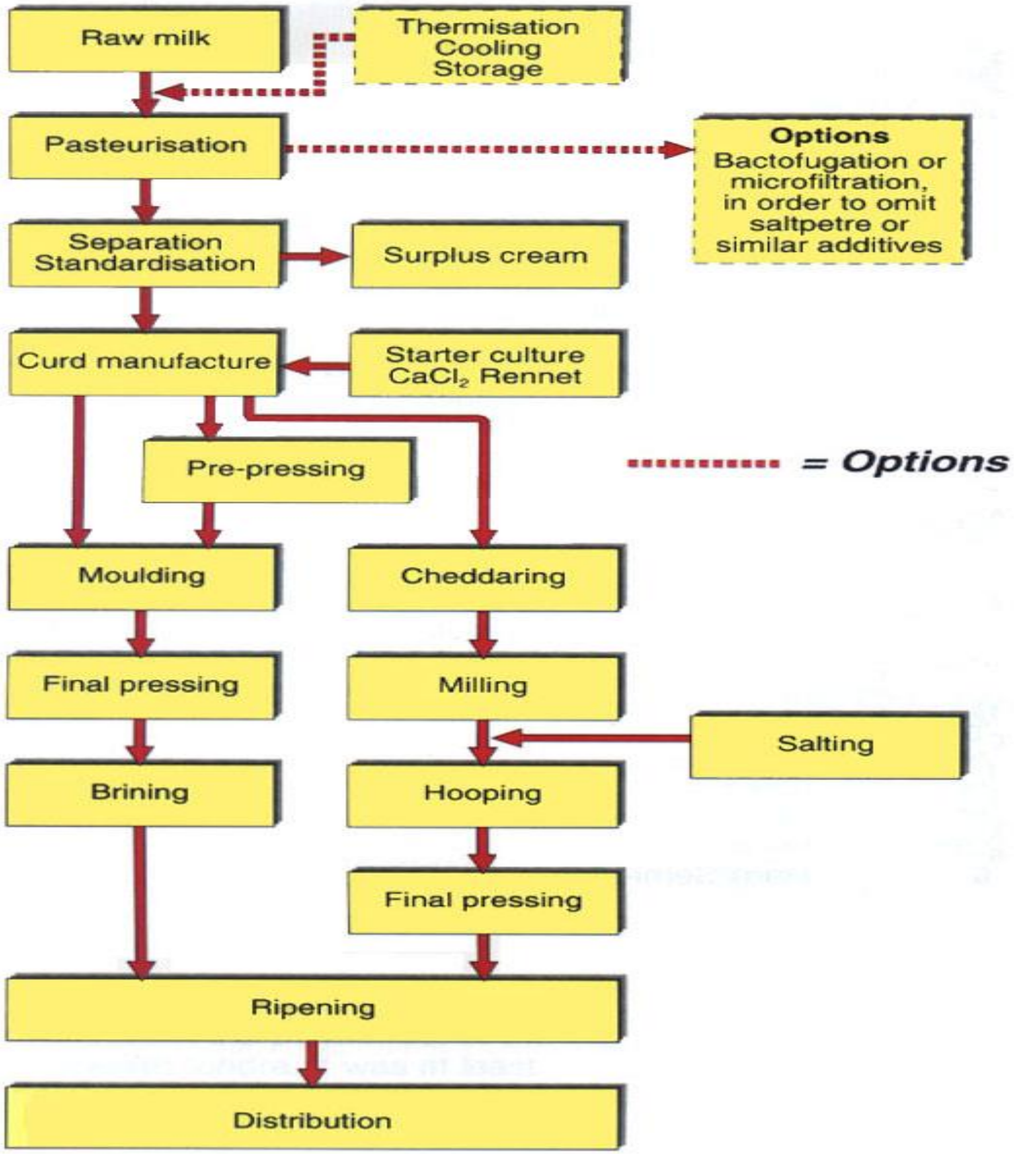
– Coagulating enzymes from micro-organisms.

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.

Cheesemaking

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



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

General cheese making

Raw milk (free from antibiotics, pesticides)

↓

thermisation, cooling, storage (if necessary)

↓

Pasteurization (70–72°C / 15–20") or bactofugation

or microfiltration

↓

Cooking to 30°C

↓

Cream ← Separation, standardization

↓

Ripening ← SC — amount & time & $T = f(S.C)$; $t \sim 30\text{–}60'$, $T \sim 30°C$

check (pH ~ 30'–90') acidity

↓

$CaCl_2$ added if necessary

↓

Inoculation ← rennet

- $\frac{30 \text{ mL rennet}}{100 \text{ kg milk}}$ (1:10000, 1:15000)
- mix for 2–3 min. diluted rennet (double) is added
- then not mix 8–10'

↓

Incubation & cutting — req. incubation ~ 1.5 h

↓

Branch 1	Branch 2
prepressing	Cheddaring
↓	↓
moulding	milling
↓	↓ ← salting
Final pressing	Hooping
↓	↓
Brining	final pressing (→ Ripening)
↓	
Ripening	
↓	
Distribution	

$$\text{strength of rennin} = \frac{V(2400)}{t \times v}$$

t = coagulation time (2/3 of total period)

V: volume of milk, v = volume of rennin

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:

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.

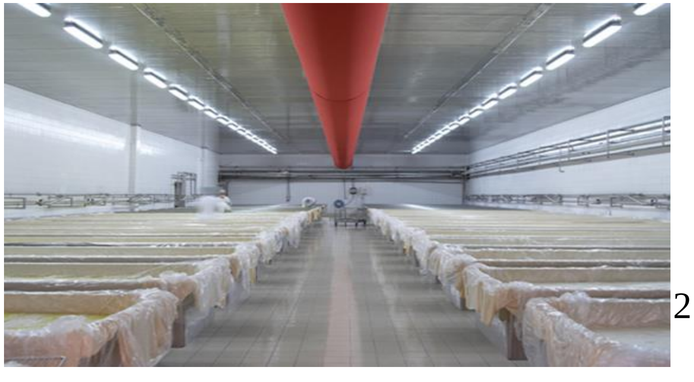
The quantity of starter needed varies with the type of cheese. In all cheesemaking, air pickup should be avoided when the milk is fed into the cheesemaking vat because this would affect the quality of the coagulum and be likely to cause losses of casein in the whey.

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 still stand 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.



Chymosin, or **rennet**, is most often used for enzyme coagulation. During the **primary stage**, rennet cleaves the Phe(105)-Met(106) linkage of kappa-casein resulting in the formation of the soluble CMP which diffuses away from the micelle and para-kappa-casein, a distinctly hydrophobic peptide that remains on the micelle. The patch or reactive site, as illustrated in the above image, that is left on the micelles after enzymatic cleavage is necessary before aggregation of the paracasein micelles can begin.

During the **secondary stage**, the micelles aggregate. This is due to the loss of steric repulsion of the kappa-casein as well as the loss of electrostatic repulsion due to the decrease in pH. As the pH approaches its isoelectric point (pH 4.6), the caseins aggregate. The casein micelles also have a strong tendency to aggregate because of hydrophobic interactions. Calcium assists coagulation by creating isoelctric conditions and by acting as a bridge between micelles. The temperature at the time of coagulation is very important to both the primary and secondary stages. With an increase in temperature up to 40° C, the rate of the rennet reaction increases. During the secondary stage, increased temperatures increase the hydrophobic reaction.

The **tertiary stage** of coagulation involves the rearrangement of micelles after a gel has formed. There is a loss of paracasein identity as the milk curd firms and syneresis begins.

Cutting the coagulum

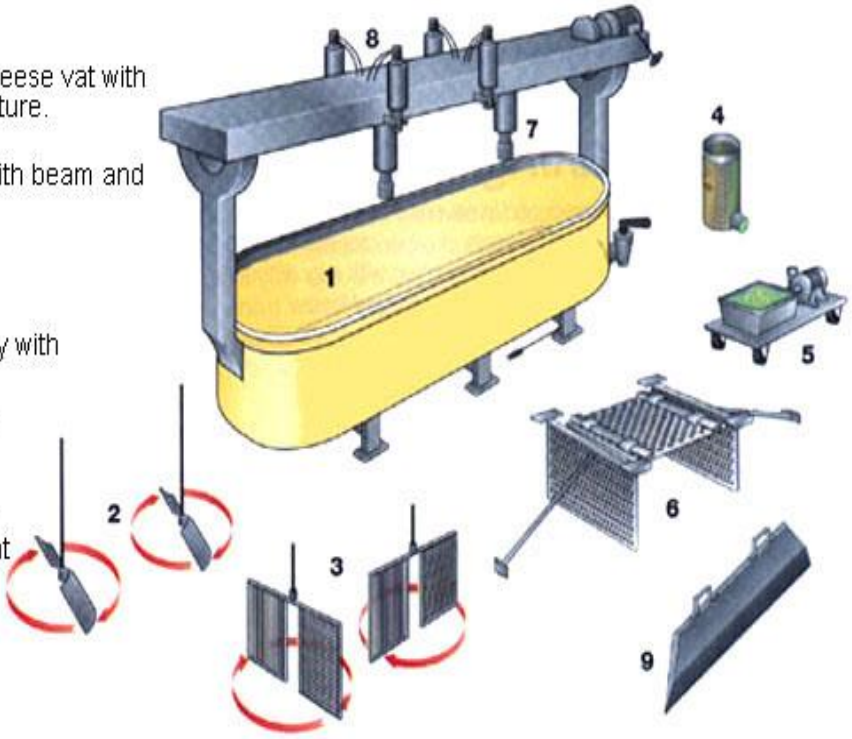
The renneting or coagulation time is typically about 30 minutes. Before the coagulum is cut, a simple test is normally carried out to establish its whey eliminating quality. Typically, a knife is stuck into the clotted milk surface and then drawn slowly upwards until proper breaking occurs. The curd 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. 14.9 Conventional cheese vat with tools for cheese manufacture.

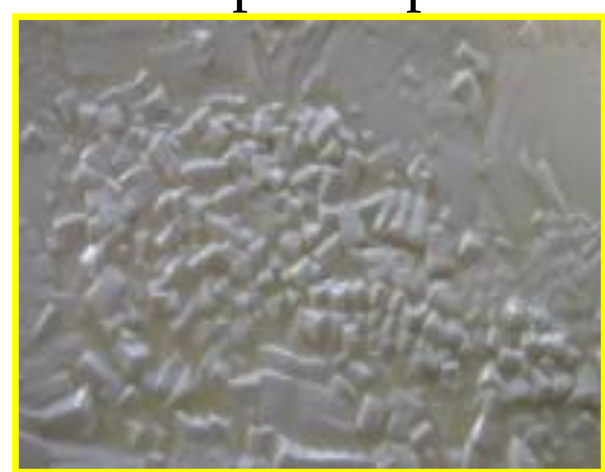
1 Jacketed cheese vat with beam and drive motor for tools
2 Stirring tool
3 Cutting tool
4 Strainer to be placed
5 Whey pump on a trolley with a shallow container
6 Pre-pressing plates for round-eyed cheese
7 Support for tools
8 Hydraulic cylinders for pre-pressing equipment
9 Cheese knife



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 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.

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 *Propionibacterium 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.

the curd is
with *irregular*
holes are
LD
ylac-
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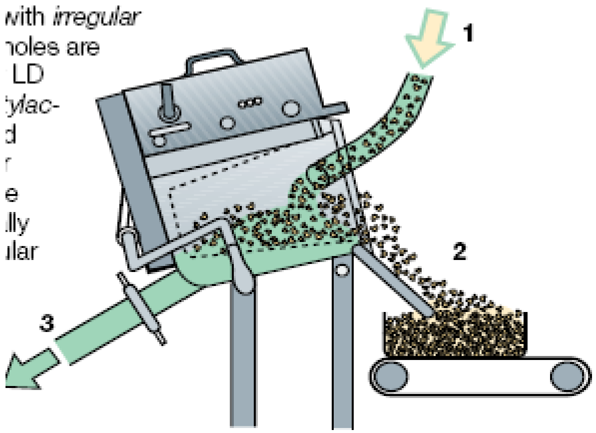


Fig. 14.13 Curd and whey are separated in a rotating strainer.
1 *Curd/whey mixture*
2 *Drained curd*
3 *Whey outlet*

ned above,
4, but the

hal cheese,
nd then
sing table.

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 CO2 escapes from the cheese.

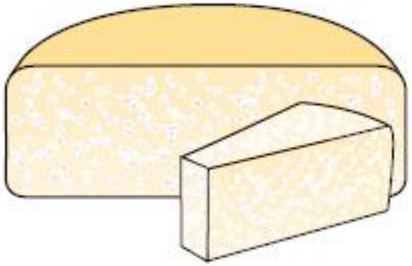


Fig. 14.12 *Cheese with granular texture.*

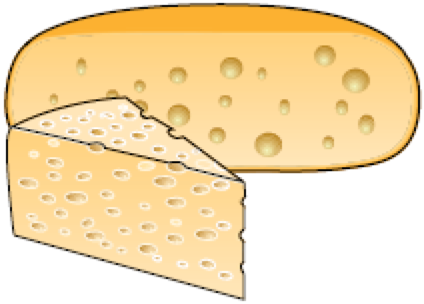


Fig. 14.14 *Cheese with round eyes.*

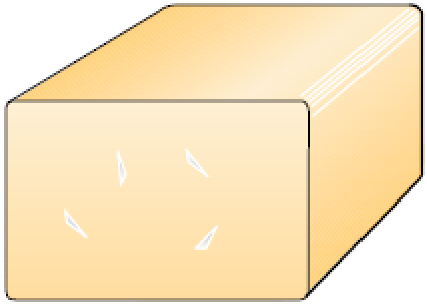


Fig. 14.18 *Closed texture cheese with typical mechanical holes.*

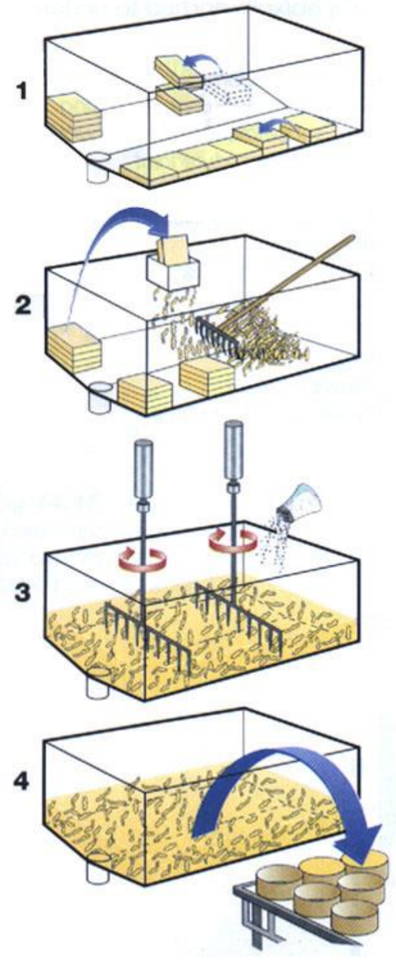


Fig. 14.19 Process steps in making Cheddar-type cheese.

1 Cheddaring
2 Milling of chips
3 Stirring the salted chips
4 Putting the chips into hoops

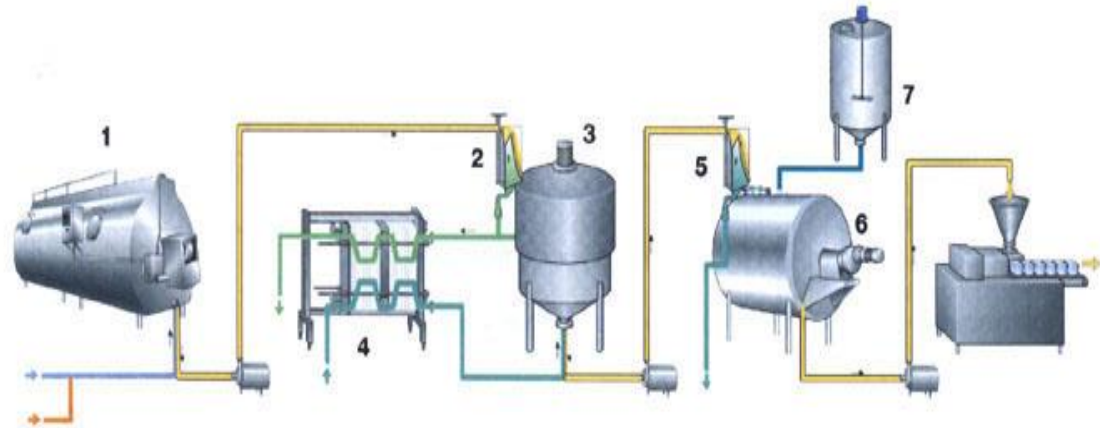


Fig 14.43 Flowchart for the mechanised production of Cottage cheese.

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

- Curd
- Skimmilk
- Starter
- Whey
- Wash water
- Dressing

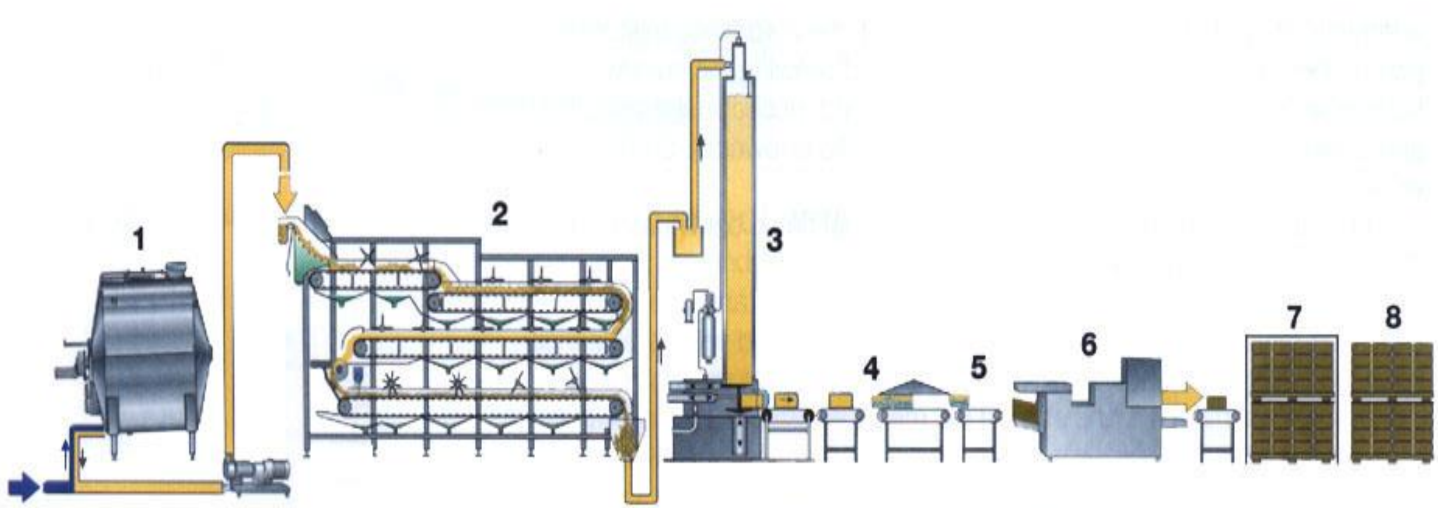


Fig. 14.35 Flowchart for mechanized production of Cheddar cheese.

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

Milk
Curd/cheese

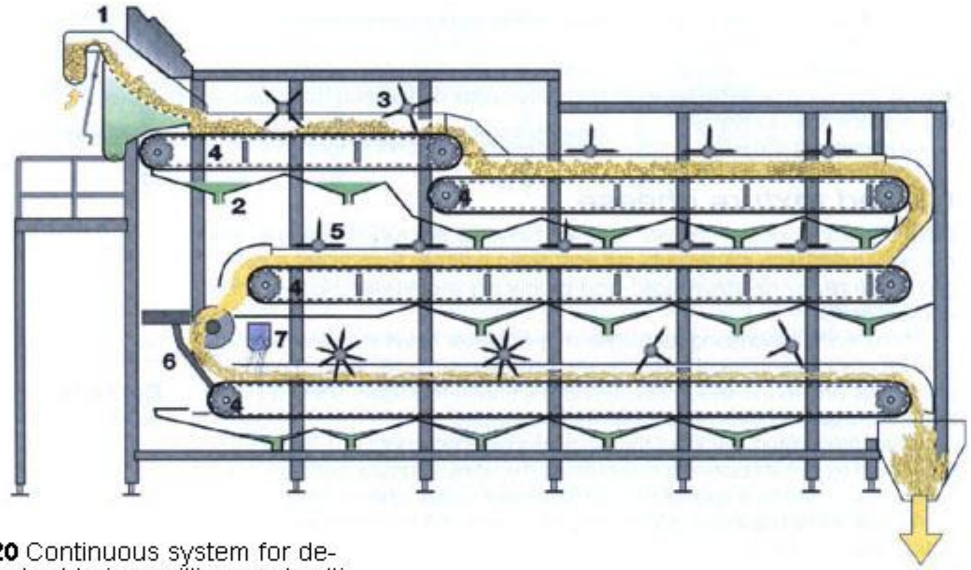
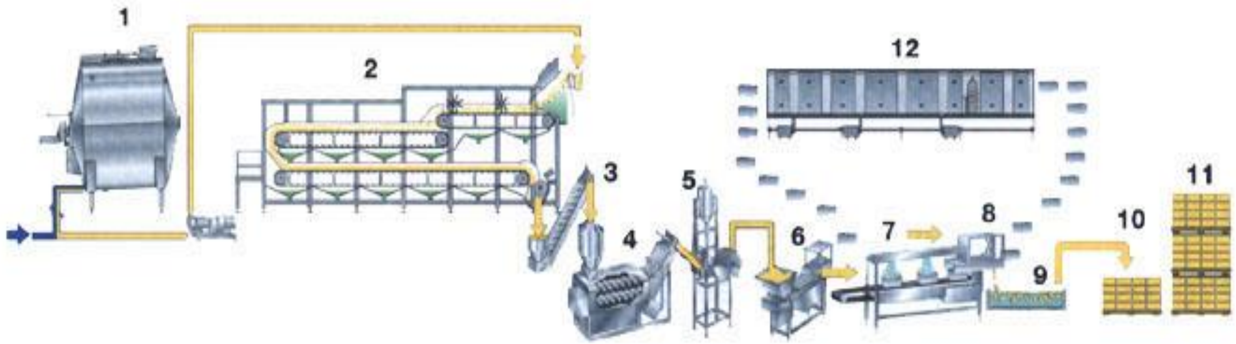


Fig. 14.20 Continuous system for de-wheying, cheddaring, milling, and salting curd intended for Cheddar cheese.

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



Milk
Curd/cheese

Fig. 14.38 Flowchart for mechanised production of Mozzarella cheese.

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

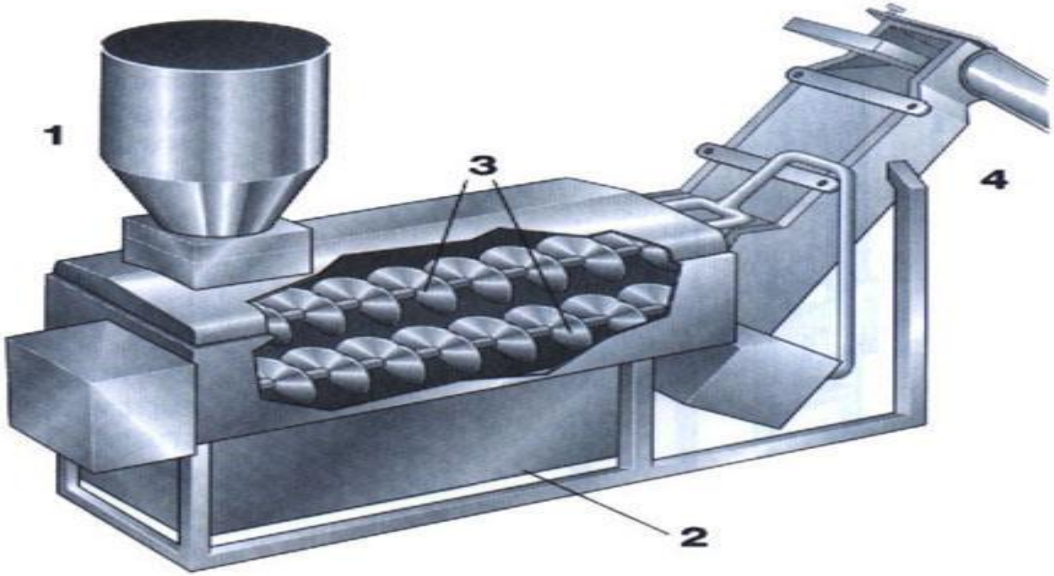
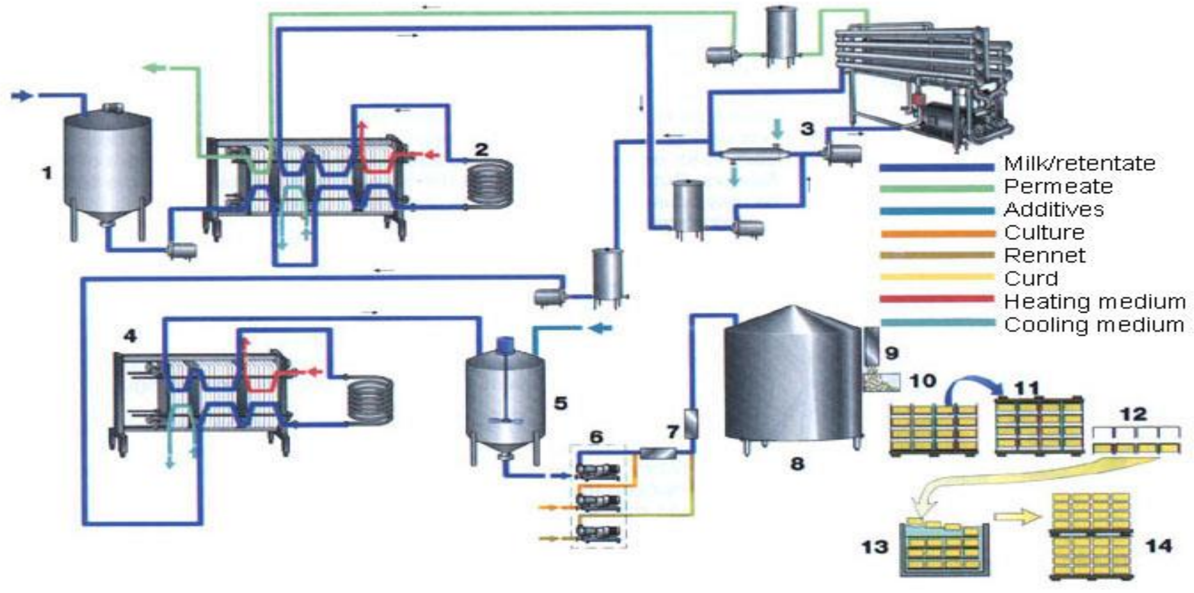


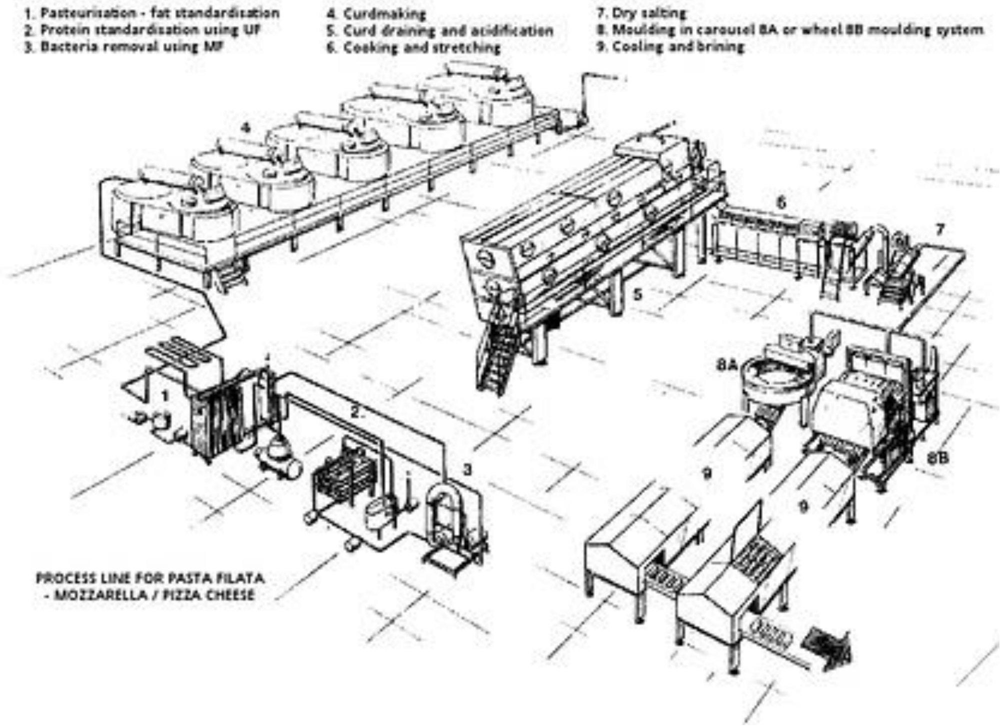
Fig. 14.25 Continuous operating Cooker-Stretcher for Pasta Filata types of cheese.

1 Feed hopper
2 Container for temperature-controlled hot water
3 Two counterrotating augers
4 Screw conveyor

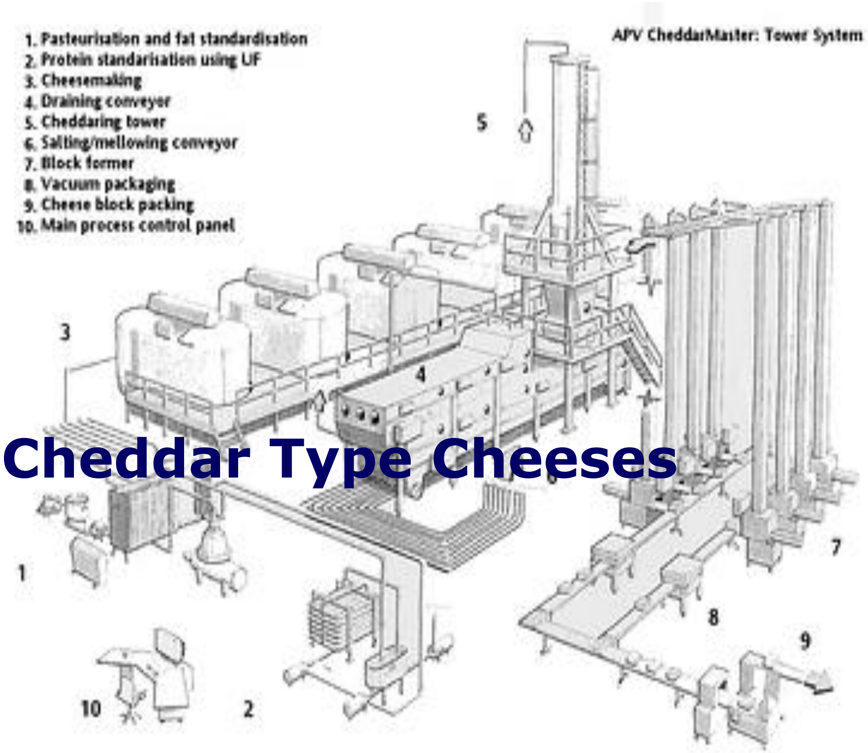
Fig. 14.47 Flowchart for production of Tilsiter cheese utilising and a curdmaking machine.

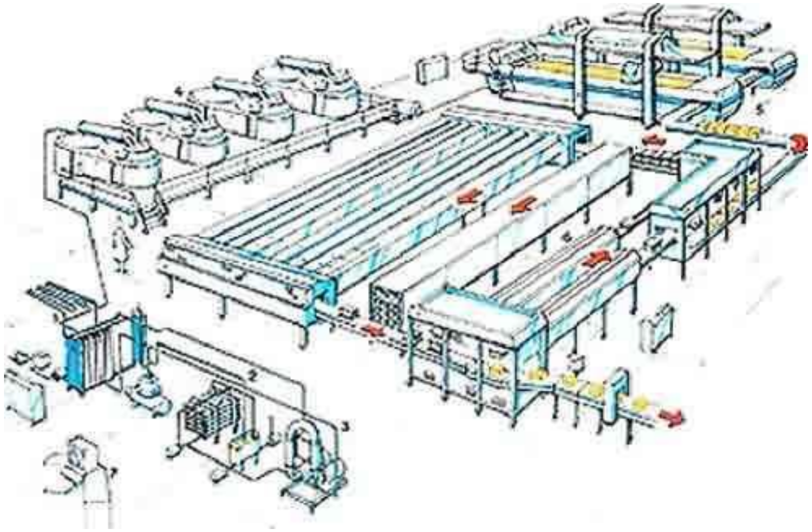
1 Milk tank
2 Pre-treatment, incl. thermisation
3 Ultrafiltration
4 After-treatment of retentate incl. pasteurisation
5 Mixing tank
6 Dosing pump
7 Static mixers
8 Curdmaking machine
9 Curd cutting unit
10 Mould filling
11 Whey drainage and turning
12 Mould emptying
13 Brining
14 Ripening store




1. Pasteurisation - fat standardisation
2. Protein standardisation using UF
3. Bacteria removal using MF
4. Curdmaking
5. Curd draining and acidification
6. Cooking and stretching
7. Dry salting
8. Moulding in carousel 8A or wheel 8B moulding system
9. Cooling and brining
PROCESS LINE FOR PASTA FILATA
- MOZZARELLA / PIZZA CHEESE

Cheddar Type Cheeses

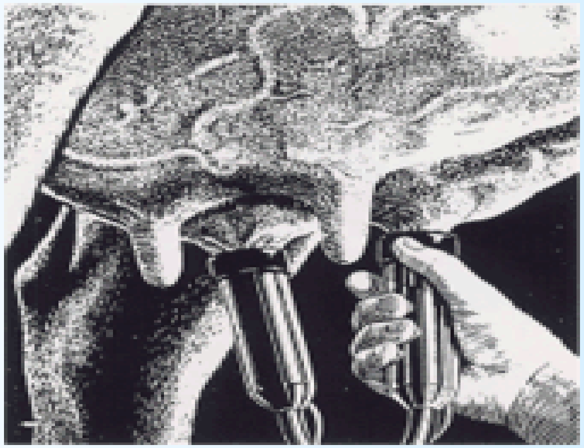




DAIRY PROCESSES

Collecting, cooling, transportation
Milking

- Hand milking
- Machine milking



Milk reception

- Churn reception
- Tanker reception
- Measuring by volume
- Measuring by weight

Chilling the incoming milk

- Milk should be chilled to (and handled) <+4°C
- Transportation using different ways:
- By insulated tankers
- In churns

All the ways, same rules

- Kept chilled
- Free from air
- Treated as gently as possible

Raw milk storage

- Agitation in silo tanks
- Tank temperature indication
- Level indication
- Low level protection
- Overflow protection
- Empty tank indication

Testing milk for quality

- Taste and smell
- Cleaning checks
- Sediment test
- Hygiene or resazurin tests
- Somatic cell count
- Bacteria count
- Protein content
- Fat content
- Freezing point

Homogenization

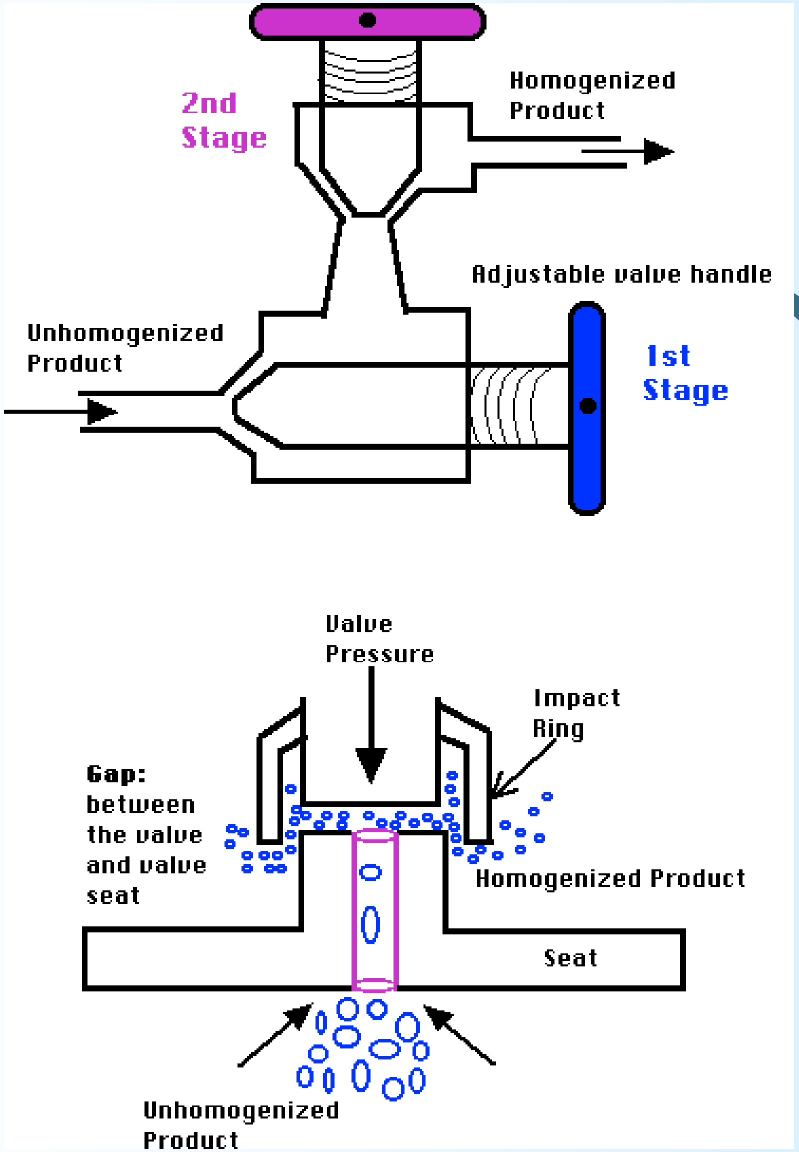
Advantages

- Smaller fat globules leading to no cream-line formation
- Whiter and more appetizing color
- Reduced sensitivity to fat oxidation
- More full-bodied, better moutfeel
- Better stability of cultured milk products

Disadvantages

- Homogenized milk cannot be efficiently separated
- Somewhat increased sensitivity to light
- Reduced heat stability (in case of one-stage)
- Milk will not be suitable for some types of cheese production

- In summary, the homogenization variables are:
  - type of valve
  - pressure
  - single or two-stage
  - fat content
  - surfactant type and content
  - viscosity
  - temperature
- Also to be considered are the droplet diameter (the smaller, the more difficult to disrupt), and the log diameter which decreases linearly with log P and levels off at high pressures.


2nd
Stage
Homogenized
Product
Adjustable valve handle
Unhomogenized
Product
1st
Stage
Valve
Pressure
Impact
Ring
Gap:
between
the valve
and valve
seat
Homogenized Product
Seat
Unhomogenized
Product

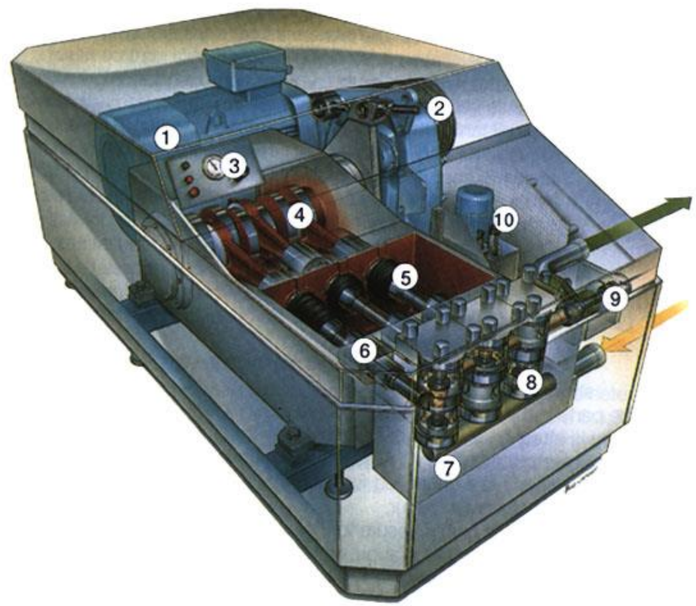
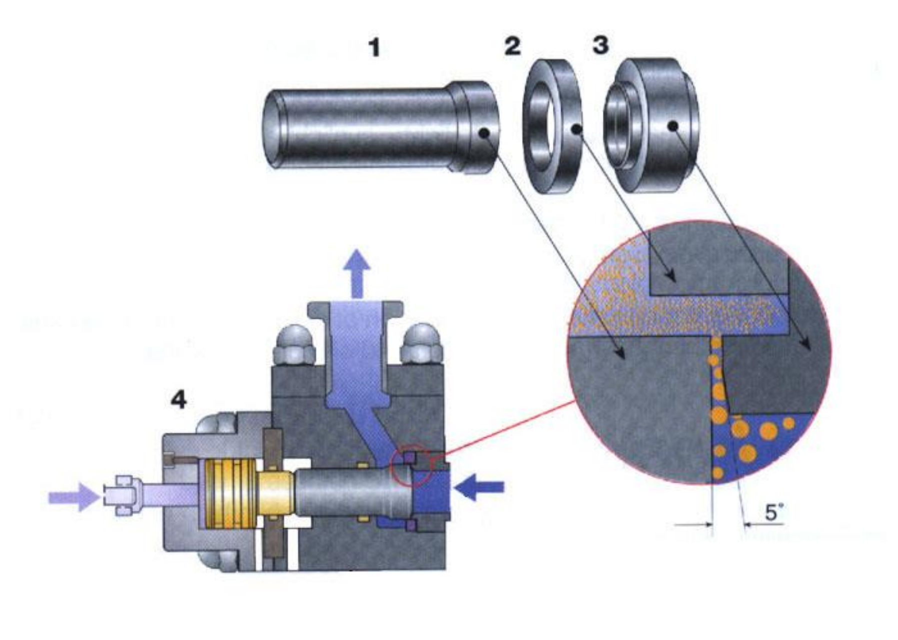


Fig. 6.3.4 The homogenizer is a large high-pressure pump with a back pressure device.

1 Main drive motor
2 V-belt transmission
3 Pressure indication
4 Crankcase
5 Piston
6 Piston seal cartridge
7 Solid stainless steel pump block
8 Valves
9 Homogenizing device
10 Hydraulic pressure setting system


1
2
3
4
5°

It is most likely that a combination of two theories, turbulence and cavitation, explains the reduction in size of the fat globules during the homogenization process.

Turbulence

Energy, dissipating in the liquid going through the homogenizer valve, generates intense turbulent eddies of the same size as the average globule diameter. Globules are thus torn apart by these eddie currents reducing their average size.

Cavitation

Considerable pressure drop with charge of velocity of fluid. Liquid cavitates because its vapor pressure is attained. Cavitation generates further eddies that would produce disruption of the fat globules. The high velocity gives liquid a high kinetic energy which is disrupted in a very short period of time. Increased pressure increases velocity. Dissipation of this energy leads to a high energy density (energy per volume and time). Resulting diameter is a function of energy density.

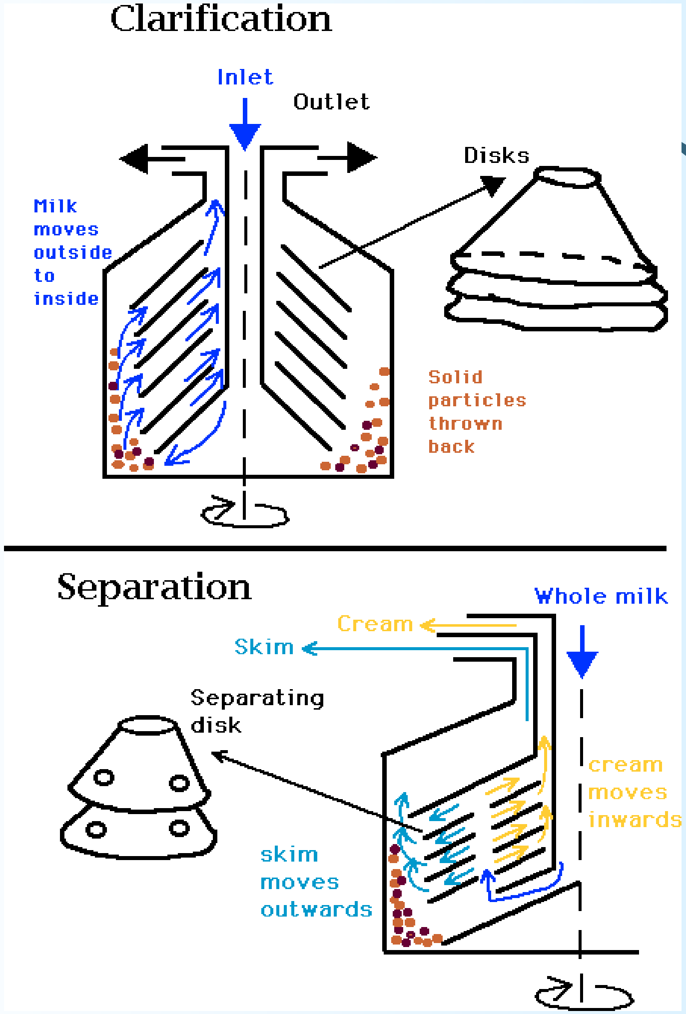
Cream Separation

According to Stok's Law the rising velocity of a particle is given by:

$$V_g = \frac{d^2(\rho_p - \rho_f)}{18\eta} g$$

where

- Vg: velocity wrt gravity
- d: particle diameter
- ρp: density of the particle
- ρf: density of the fluid
- □: velocity
- g: force of gravity


Clarification
Inlet
Outlet
Disks
Milk
moves
outside
to
inside
Solid
particles
thrown
back
Separation
Whole milk
Cream
Skim
Separating
disk
cream
moves
inwards
skim
moves
outwards

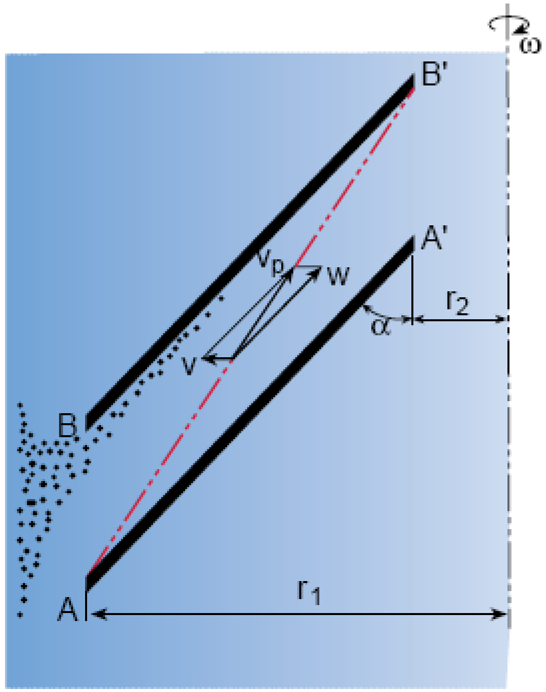


Fig. 6.2.16 *Simplified diagram of a separation channel and how a solid particle moves in the liquid during separation.*

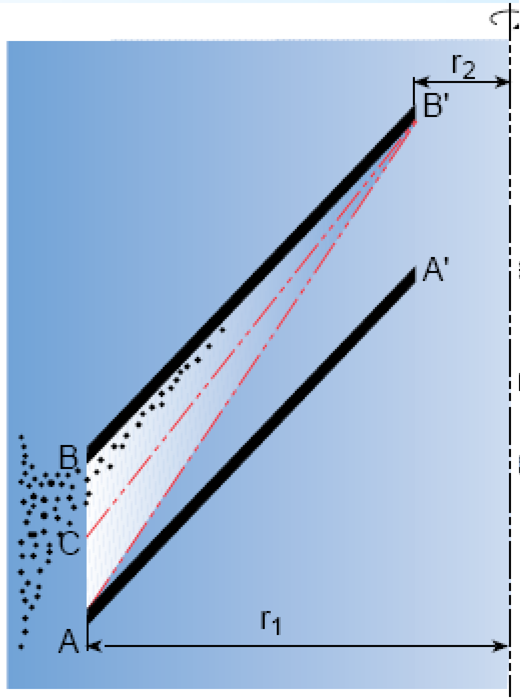


Fig. 6.2.17 *All particles larger than the limit particle will be separated if they are located in the shaded area.*

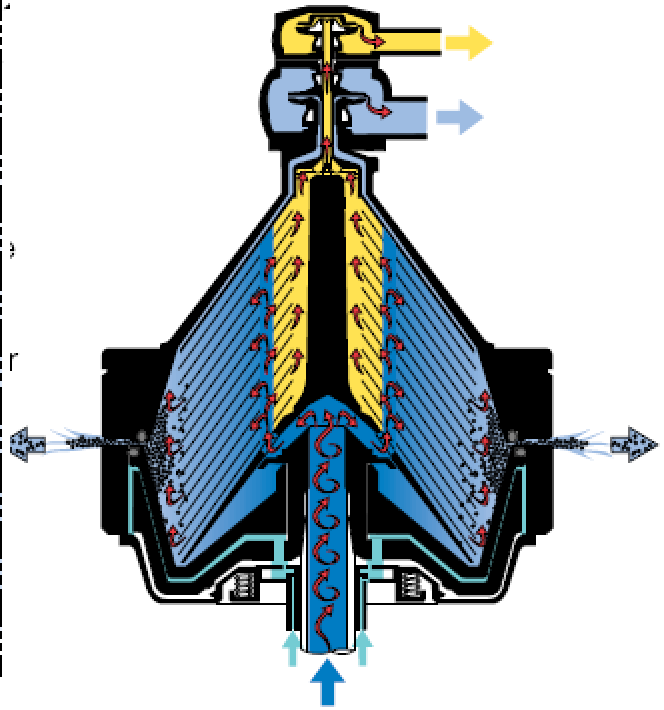


Fig. 6.2.22 *Solids ejection by short opening of the sedimentation space at the periphery of the bowl.*

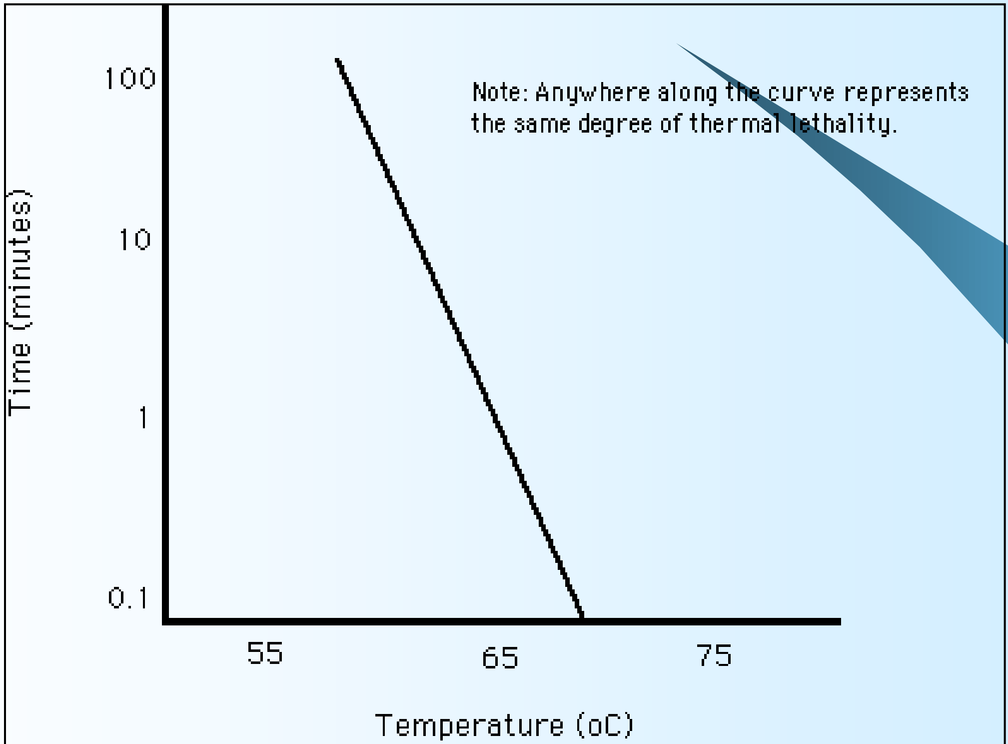
Heat treatments

- Thermisation
- Pasteurization
- Sterilization

- **Milk**:
  63° C for not less than 30 min.,
  72° C for not less than 16 sec.,
  or equivalent destruction of pathogens and the enzyme phosphatase.

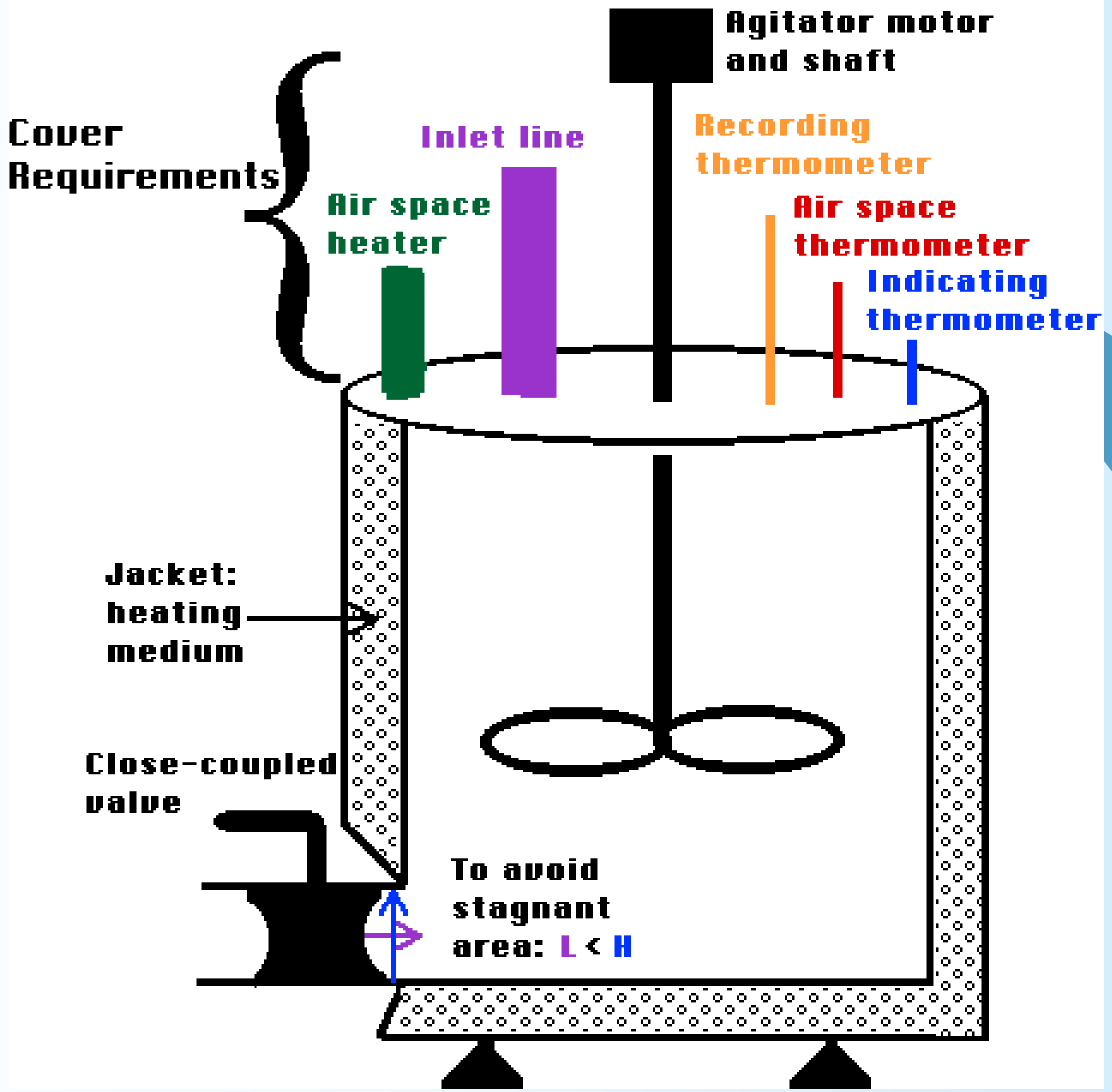
- Milk is deemed pasteurized if it tests negative for alkaline phosphatase.

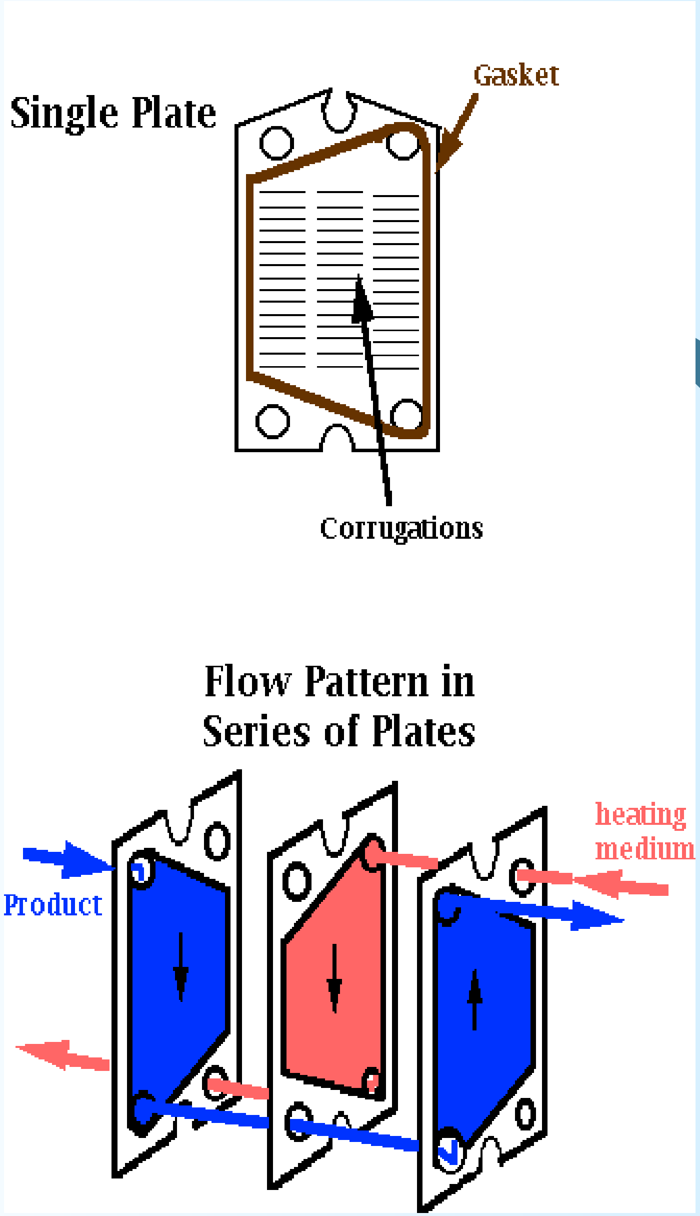
- **Frozen dairy dessert mix** (ice cream or ice milk, egg nog):
  at least 69° C for not less than 30 min;
  at least 80° C for not less than 25 sec;
  other time temperature combinations must be approved (e.g. 83° C/16 sec).
- **Milk based products-** with 10% mf or higher, or added sugar (cream, chocolate milk, etc)
  66° C/30 min, 75° C/16 sec



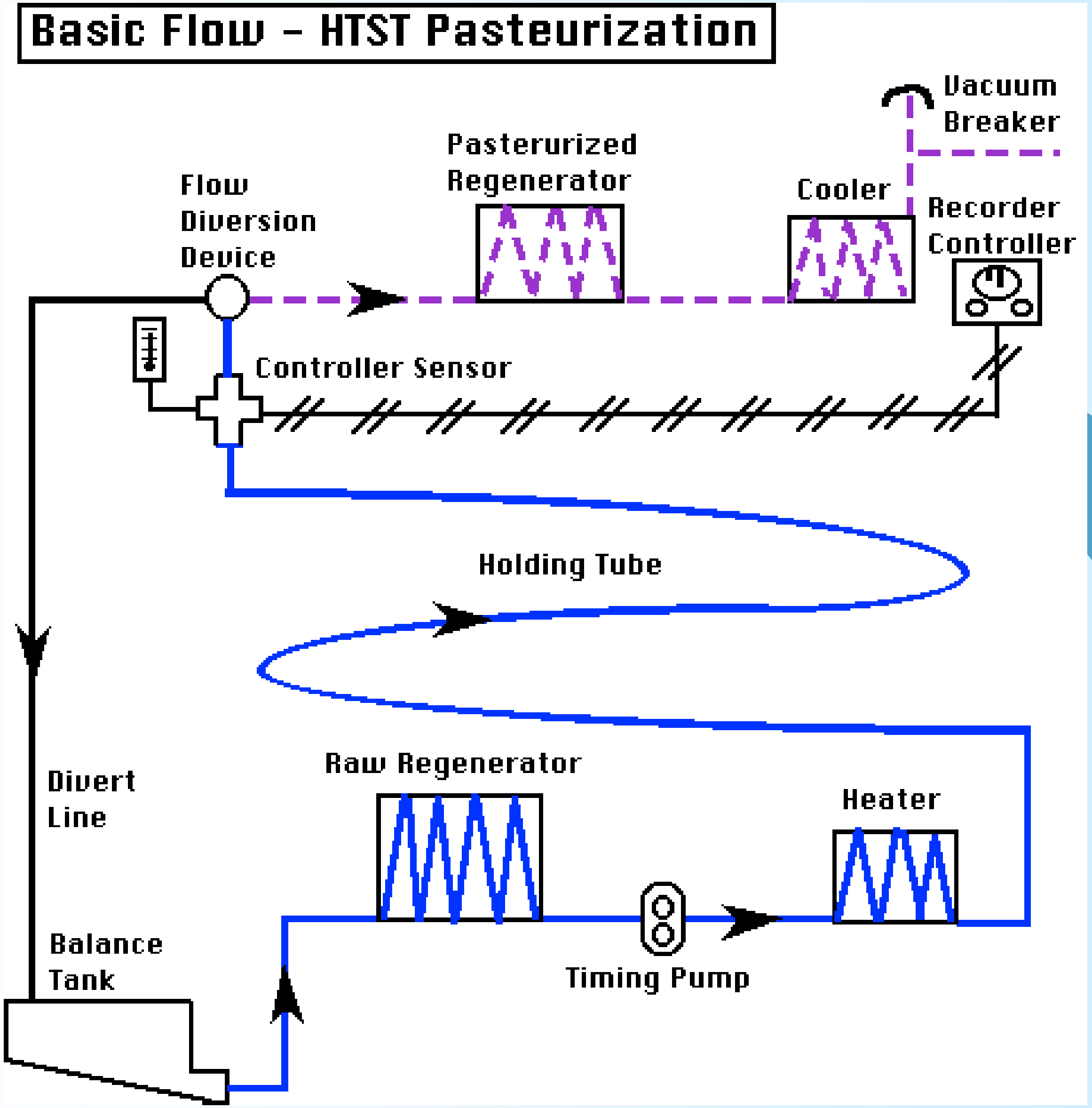
Thermal Death Time Curve for
Coxiella burnetti, z = 4oC

Batch Pasteurizer

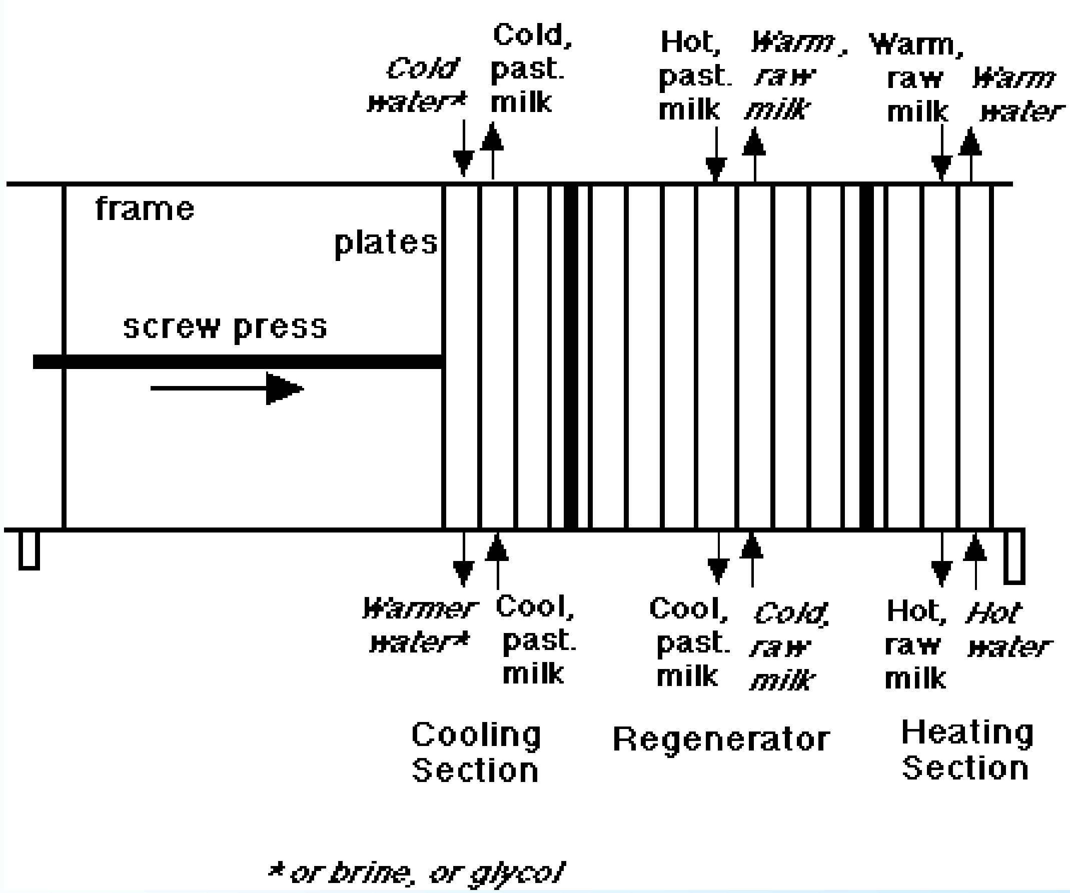



Single Plate
Gasket
Corrugations
Flow Pattern in
Series of Plates
heating
medium
Product

HTST milk pasteurization equipment and the flow of milk through it.



HTST Continuous Plate Pasteurizer



There are several other factors involved in maintaining the pressure differential:

- The balance tank overflow level must be less than the level of lowest milk passage in the regenerator
- Properly installed booster pump is all that is permitted between balance tank and raw regenerator
- No pump after pasteurized milk outlet to vacuum breaker
- There must be greater than a 12 inch vertical rise to the vacuum breaker
- The raw regenerator drains freely to balance tank at shut-down

UHT Methods

There are two principal methods of UHT treatment:

1. Direct Heating
2. Indirect Heating

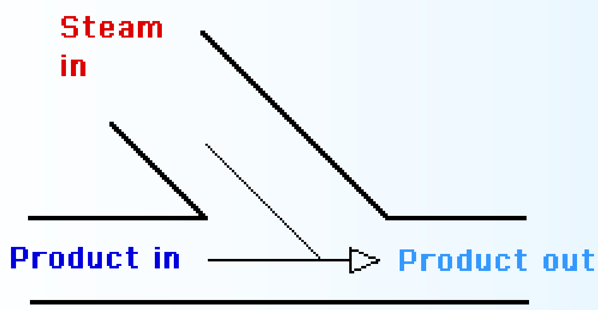
Direct heating systems

The product is heated by direct contact with steam of potable or culinary quality. The main advantage of direct heating is that the product is held at the elevated temperature for a shorter period of time. For a heat-sensitive product such as milk, this means less damage.

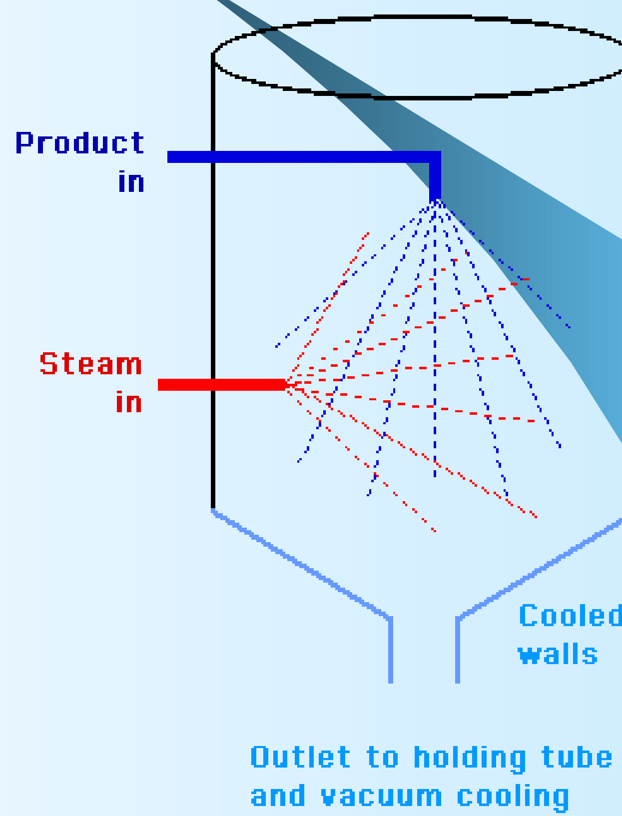
There are two methods of direct heating;

1. injection
2. infusion

INJECTION VALVE



INFUSION CHAMBER

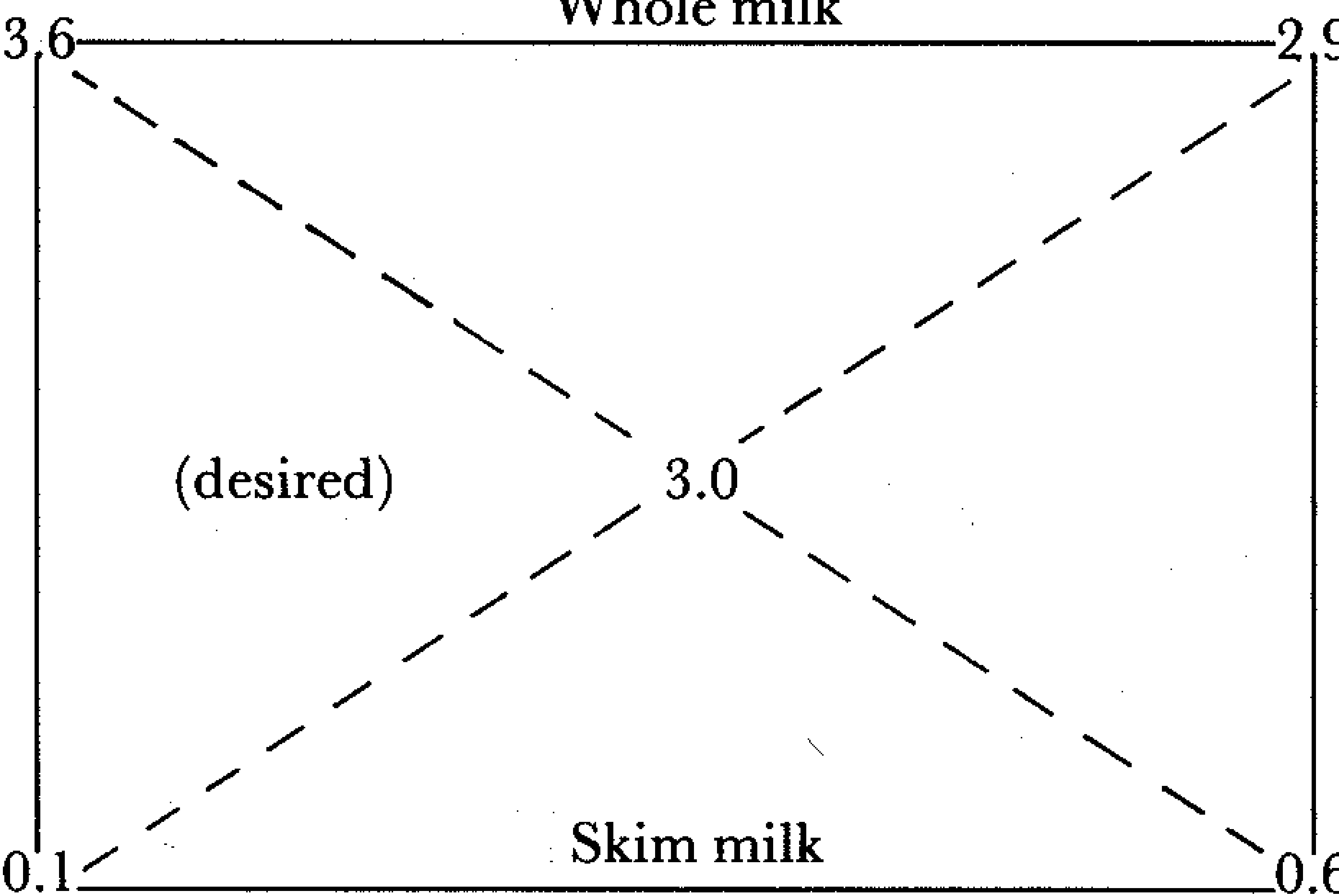


Standardization of milk & cream

The streams of skim and cream after separation must be recombined to a specified fat content. This can be done by adjusting the throttling valve of the cream outlet; if the valve is completely closed, all milk will be discharged through the skim milk outlet. As the valve is progressively opened, larger amounts of cream with diminishing fat contents are discharged from the cream outlet. With direct standardization the cream and skim are automatically remixed at the separator to provide the desired fat content

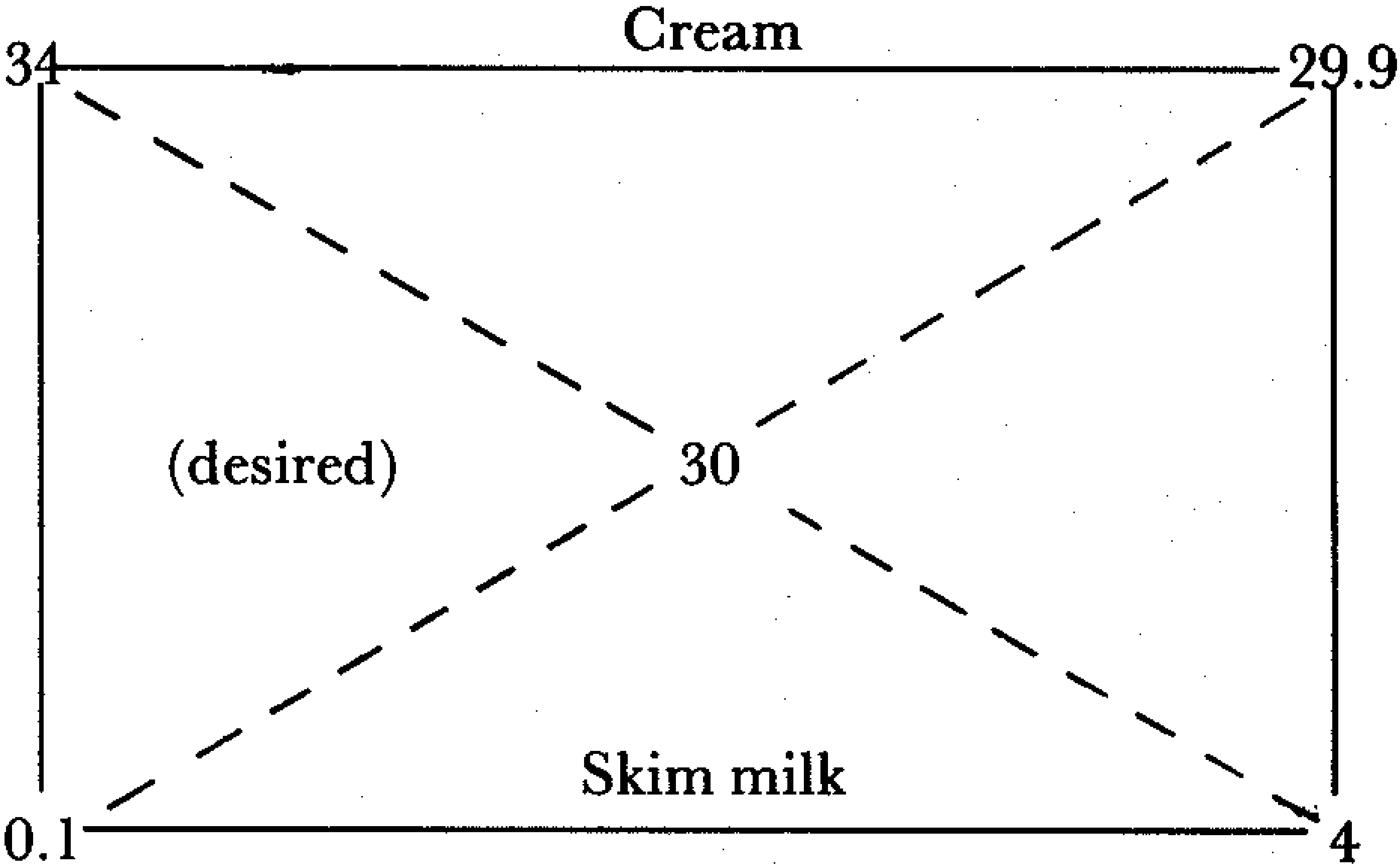
- The usual method of making standardization calculations is the Pearson's Square technique.

- To make this calculation, draw a square and write the desired fat percentage in the standardised product at its centre and write the fat percentage of the materials to be mixed on the upper and lower left-hand corners. Subtract diagonally across the square the smaller from the larger figure and place the remainders on the diagonally opposite corners. The figures on the right-hand corners indicate the ratio in which the materials should be mixed to obtain the desired fat percentage.


Whole milk
3.6
(desired)
3.0
Skim milk
0.1

the fat content of whole milk is to be reduced to 3.0%, using skim milk produced from some of the whole milk. Using Pearson's Square, it can be seen that for every 2.9 liters of whole milk, 0.6 liters of skim milk must be added.

How much skim milk containing 0.1 % fat is needed to reduce the percentage fat in 200 kg of cream from 34% to 30%?


Cream
34
29.9
(desired)
30
Skim milk
0.1
4

If 29.9 parts of cream require 4 parts of skim milk, 200 parts of cream require x parts of skim milk.

Weight of skim milk needed = x = $(200 \times 4)/29.9$ = 26.75 kg

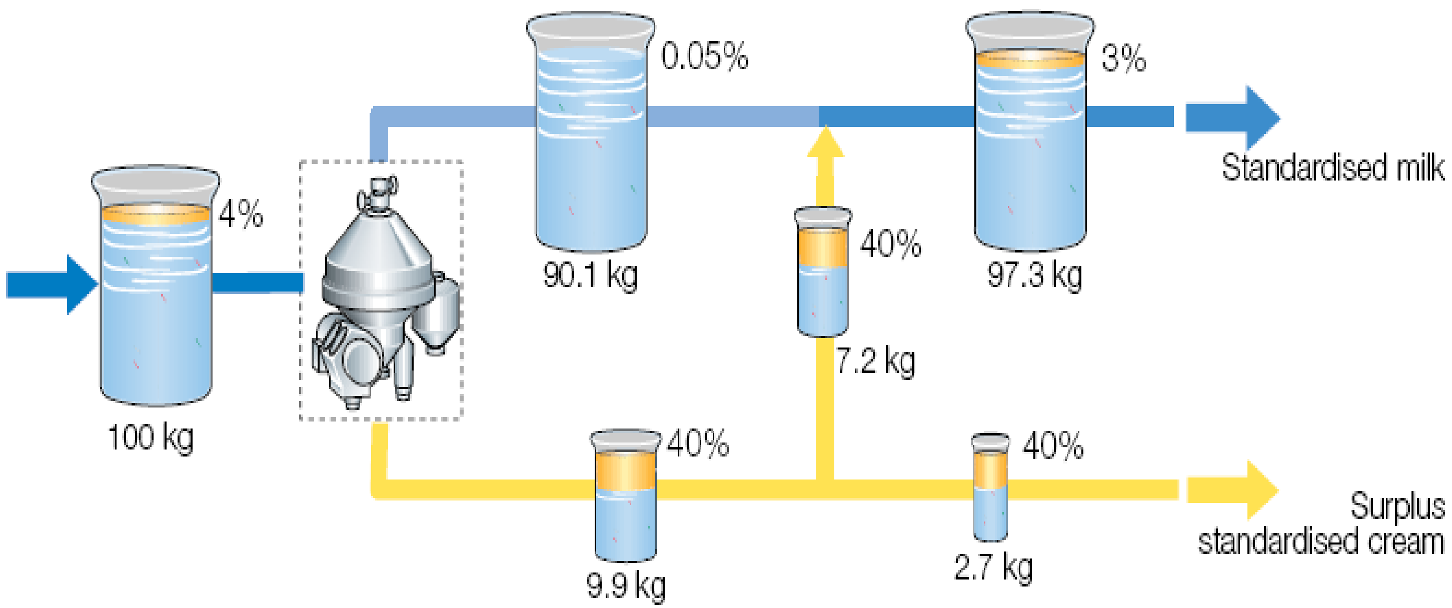
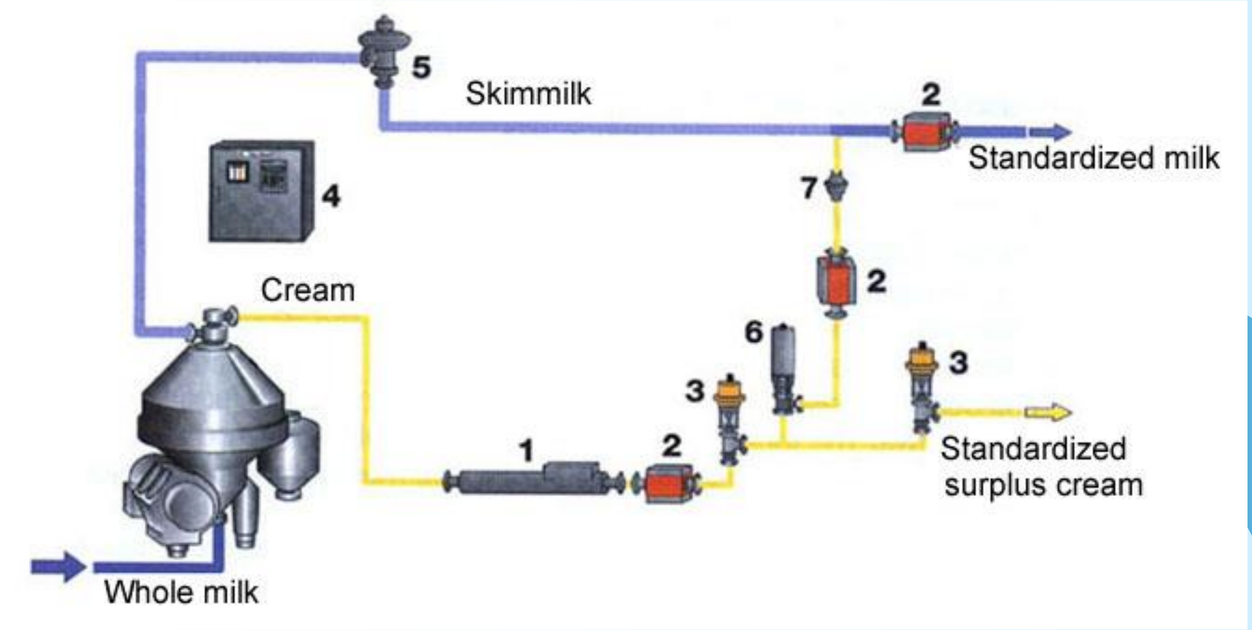
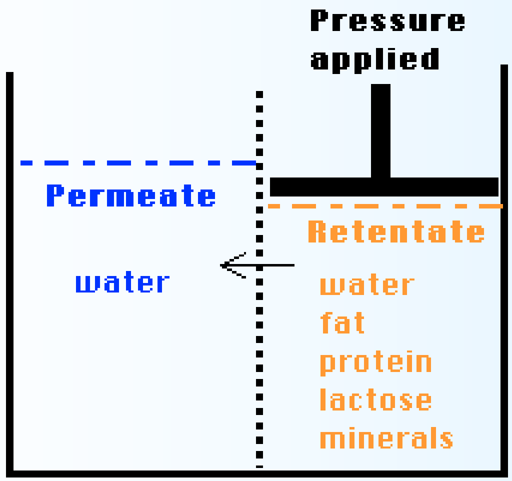


Fig. 6.2.32 *Principle of fat standardisation.*

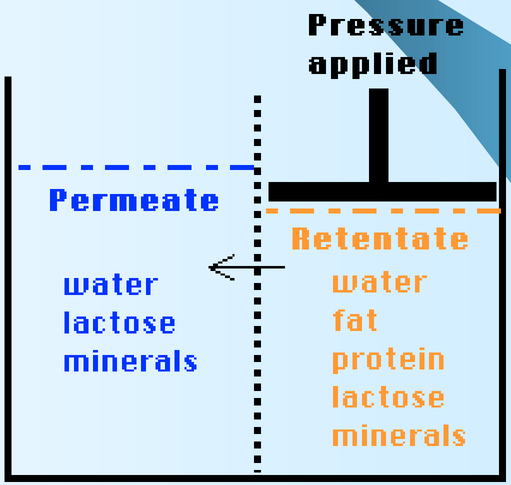

5
Skimmilk
2
Standardized milk
4
7
2
Cream
6
3
3
1
2
Standardized
surplus cream
Whole milk

Separation processes
Used
in dairy industry

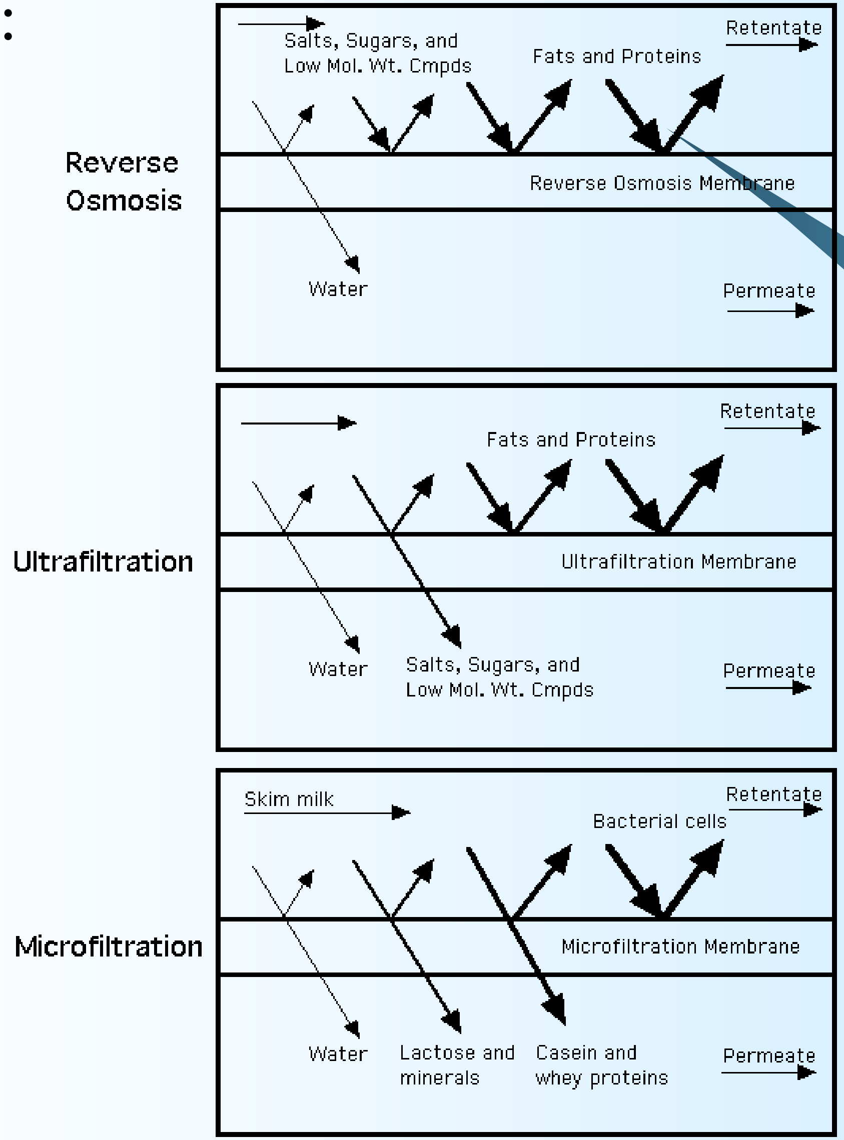
Reverse Osmosis

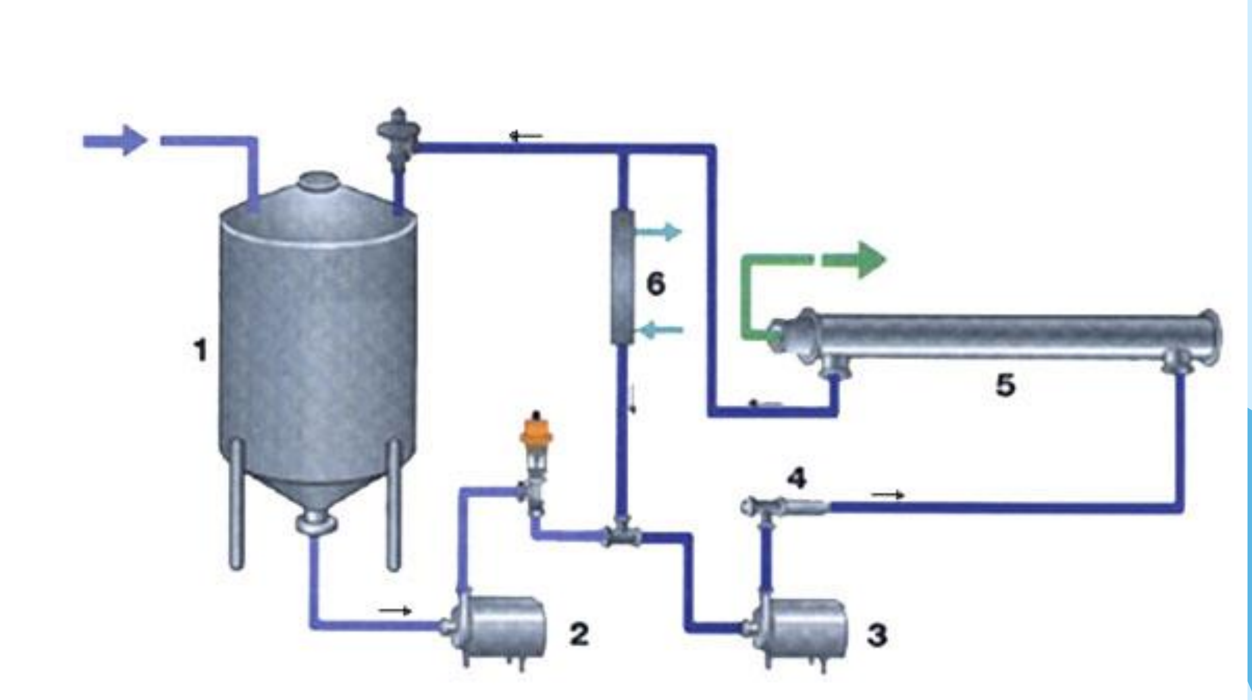


Ultrafiltration



This can be visualized with another schematic, as follows, which may be more informative:





Membrane separation plant

Reference is Dairy technology handbook

It is uncertain how long ice cream has been produced, but it probably originates from China. From very old writings it has been learned that the Chinese liked a frozen product made by mixing fruit juices with snow, what we now call water ice. This technique later spread to ancient Greece and Rome, where the wealthy, in particular, were partial to frozen desserts.

After disappearing for several centuries, ice creams in various forms reappeared in Italy in the Middle Ages, most probably as a result of Marco Polo returning to Italy in 1295 after a 16–17 year stay in China, where he had learned to appreciate a frozen dessert based on milk. From Italy ice cream spread over Europe during the seventeenth century, and long remained a luxury product for the royal courts.

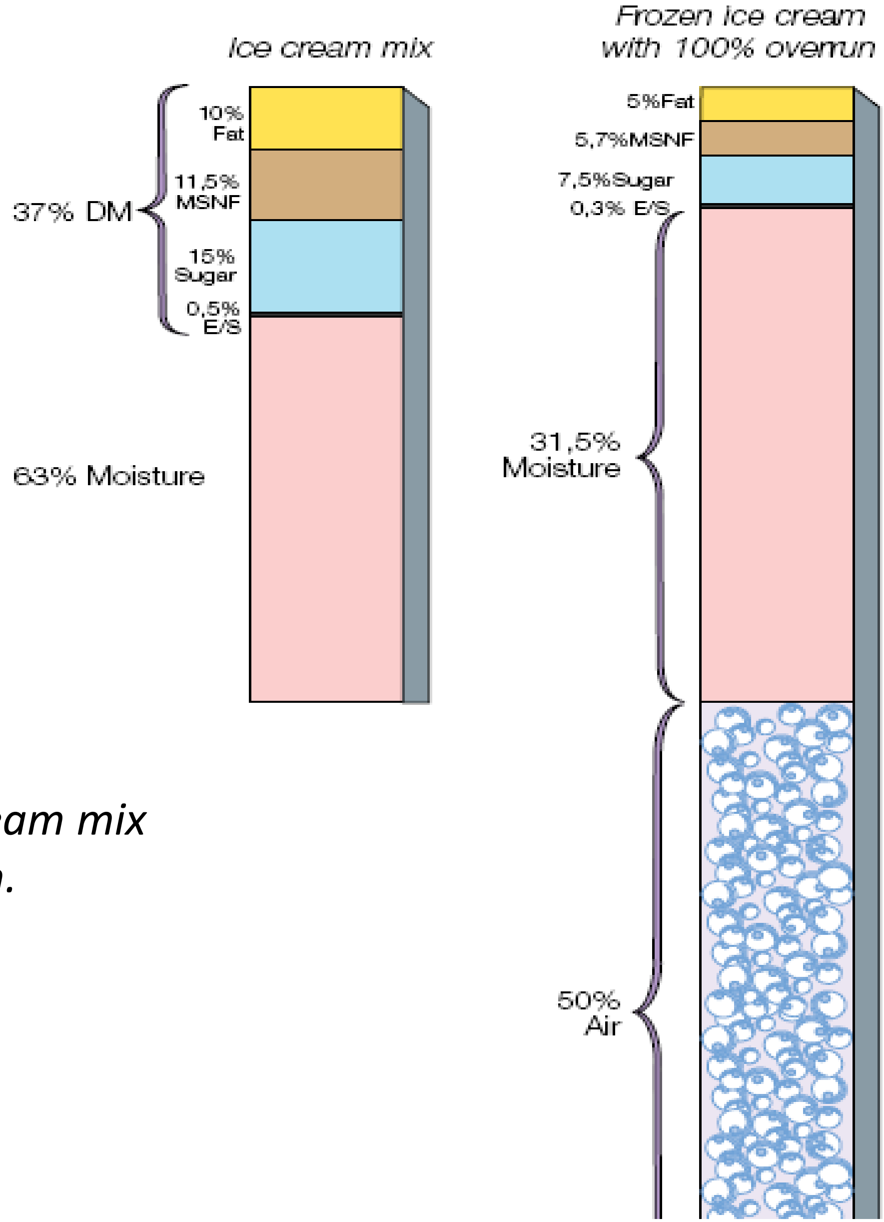
Typical ice cream formulas

Type of ice cream	Fat % wt	MSNF % wt	Sugar % wt	E/S % wt	Water % wt	Overrun % vol
Dessert ice	15	10	15	0.3	59.7	110
Ice cream	10	11	14	0.4	64.6	100
Milk ice	4	12	13	0.6	70.4	85
Sherbet	2	4	22	0.4	71.6	50
Water ice	0	0	22	0.2	77.8	0

Fat: Milk, cream, butter or vegetable fat
Water: May include flavouring or colouring matter
MSNF: Milk solids-non-fat (protein, salts, lactose)
Sugar: Liquid or solid sucrose (10% of sugar may be glucose or non-sugar sweetener)
E/S: Emulsifier and stabiliser, e.g. monoglycerides, gelatin, alginate
Overrun: Amount of air in product
Other ingredients: Egg, fruit and chocolate pieces may be added during processing.

Ice Cream Mix General Composition:

- Milkfat: >10% - 16%
- Milk solids-not-fat (SNF): 9% - 12%
- Sucrose: 10% - 14%
- Corn syrup solids: 4% - 5%
- Stabilizers: 0% - 0.4%
- Emulsifiers: 0% - 0.25%
- Water: 55% - 64%
- The SNF contains, on average, dry wt. basis, 38% protein, 54% lactose, and 8% ash (including 1.38% Ca, 1.07% P, 1.22% K, 0.7% Na).



From ice cream mix
to ice cream.

Formulation Considerations

- First of all, regulatory issues. What are the product definitions for your legal restriction? These, of course, have to be met. Next, desired Fat and Total solids (%): - Quality considerations, what kind of product are you trying to make?
- Fat:-MSNF ratio is usually determined next based on fat content.
- Sugar: Glucose-solid ratio is determined based on fat and total solids requirements, sweetness, freezing point depression, body and shelf life desired, and cost considerations.
- Stabilizer/Emulsifier considerations come last, based on the ice cream formulation, and processing and distribution factors involved in each application.

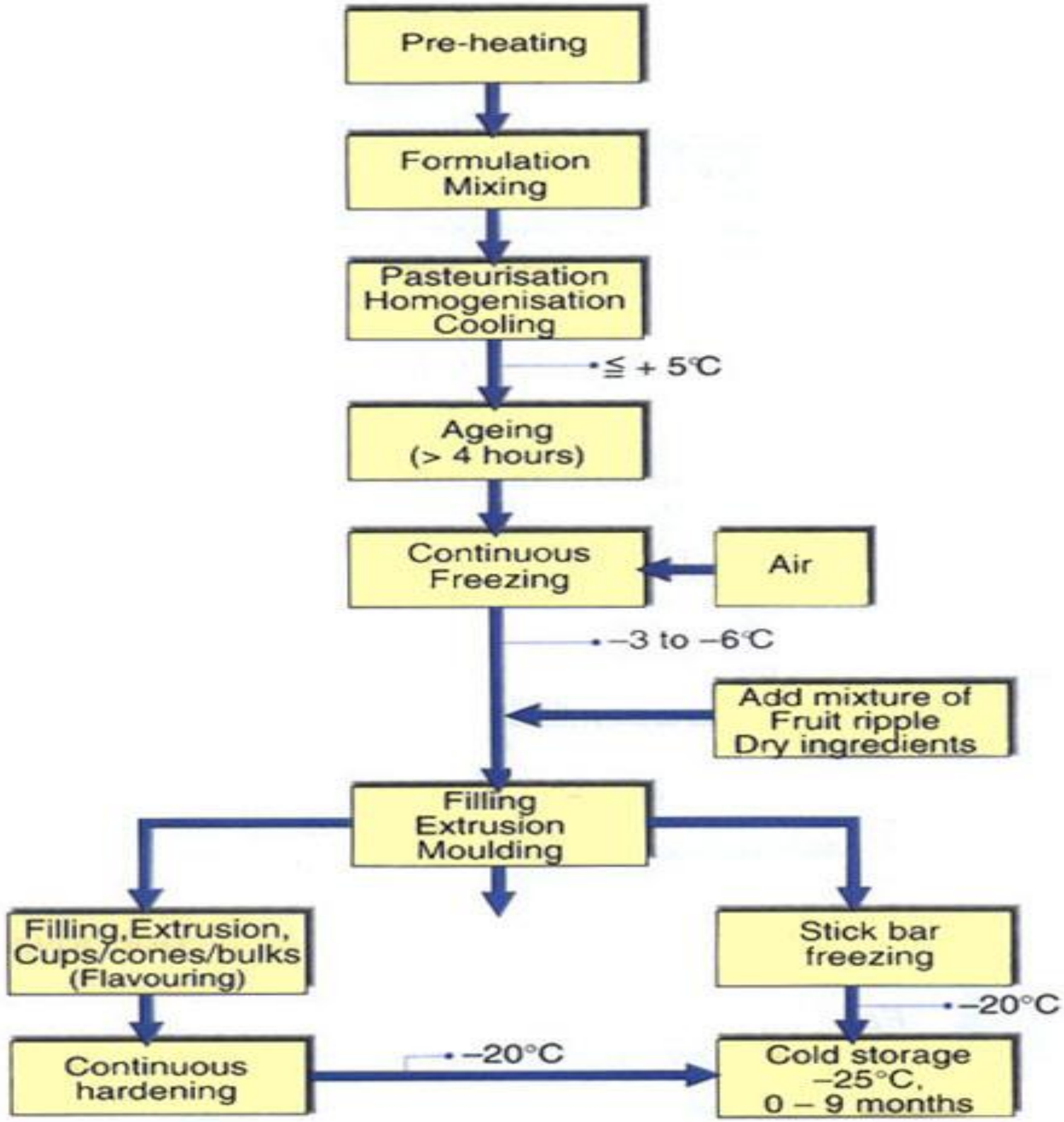
Ice cream may have the following composition:

- greater than 10% milkfat and usually between 10% and as high as 16% fat in some premium ice creams
- 9 to 12% milk solids-not-fat: this component, also known as the serum solids, contains the proteins (caseins and whey proteins) and carbohydrates (lactose) found in milk
- 12 to 16% sweeteners: usually a combination of sucrose and glucose-based corn syrup sweeteners
- 0.2 to 0.5% stabilizers and emulsifiers
- 55% to 64% water which comes from the milk or other ingredients.

These compositions are percentage by weight. Since ice cream can contain as much as half air by volume, these numbers may be reduced by as much as half if cited by volume. In terms of dietary considerations, however, the percentages by weight are more relevant.

Even the low fat products have high caloric content: Ben and Jerry's No Fat Vanilla Fudge contains 150 calories per half cup due to its high sugar content.

Fig. 19.1 The ice cream process.



Ingredients

The various ingredients are received, weighed and analyzed in the raw-material reception department, which is usually divided into one section for dry ingredients and one for liquid ingredients.

The ingredients used in ice cream production are:

- Fat
- Milk solids-non-fat (MSNF)
- Sugar/non-sugar sweetener
- Emulsifiers/stabilisers
- Flavouring agents
- Colouring agents

Fat

Fat, which makes up about 10 – 15% wt. of dairy ice cream mix, may be milk fat or vegetable fat. In the first case it may be whole milk, cream, butter or AMF. Some or all of the milk fat in ice cream may be replaced by vegetable fat in the hardened form of sunflower oil, coconut oil, soybean oil and rapeseed oil. The use of vegetable fat results in a slight difference in colour and flavour compared to milk fat. The difference is hardly noticeable if colouring and flavouring additives are used. The use of vegetable fat in ice cream is prohibited in some countries.

Milk solids-non-fat (MSNF)

Milk solids-non-fat consist of proteins, lactose and mineral salts. They are added in the form of milk powder and condensed skim milk. For best results the quantity of MSNF should always be in a certain proportion to the quantity of fat. The amount of MSNF should be 11 – 11.5% wt. for the manufacture of ice cream mix with a fat content of 10 – 12%.

MSNF has not only a high nutritional value, but also the important ability to improve the texture of the ice cream by binding and replacing water. The protein component of MSNF also significantly affects the correct distribution of air in the ice cream during the freezing process.

Sugar

Sugar is added to adjust the solids content in the ice cream and to give it the sweetness which customers prefer. The ice cream mix normally contains between 10 and 18% wt. sugar. Many factors influence the sweetening effect and product quality, and many different types of sugar can be used, such as cane and beet sugar, glucose, lactose and invert sugar (a mixture of glucose and fructose). Sweetened condensed milk is sometimes used, contributing to both the sweetening effect and the solids-non-fat content.

Ordinary sugar is sometimes dissolved in water; a concentration of 50 – 55% can be achieved at ambient temperature, and up to 70% at about 80°C. Liquid sugar is easier to handle than dry sugar. To satisfy dieters, among whom diabetics are an important category, sweeteners should be used. A sweetener has no nutritive value but tastes very sweet even in very small doses. *Note that a sweetener cannot be used* as a preservative for sweetened condensed milk.

Emulsifiers

Emulsifiers are substances which assist emulsification by reducing the surface tension of liquid products. They also help to stabilize the emulsion. Egg yolk is a well-known emulsifier, but is expensive and less effective than the most commonly used types, which are mainly non-ionic derivatives of natural fats which have been esterified to give them one or more water-soluble (hydrophilic) radicals bonded to one or more fat-soluble (lipophilic) radicals.

The emulsifiers used in ice cream manufacture can be divided into four groups: glycerin esters, sorbitol esters, sugar esters and esters of other origins. The amount added is usually 0.3 – 0.5% wt. of the ice cream mix.

Stabilizers

A stabilizer is a substance which, when dispersed in a liquid phase (water), binds a large number of water molecules. This is called hydration and means that the stabilizer forms a network which prevents the water molecules from moving freely. There are two types: protein and carbohydrate stabilizers. The protein group includes gelatin, casein, albumin and globulin.

The carbohydrate group includes marine colloids, hemicellulose and modified cellulose compounds. The stabiliser dosage is usually 0.2 – 0.4% wt. of the ice cream mix.

Flavoring

Flavoring additives are very important to the customer's choice of ice cream. The most commonly used flavors are vanilla, nougat, chocolate, strawberry and nut. These can be added at the mixing stage. If flavoring takes the form of larger pieces such as nougat, nuts, fruit or jam, it is added when the mix has been frozen.

Cocoa is widely used to give ice cream bars, cones and bricks a coating of chocolate. For this purpose the cocoa is mixed with fat – for example cocoa fat – to give the chocolate coating the correct viscosity, elasticity and consistency.

- *Coloring*
- Coloring agents are added to the mix to give the ice cream an attractive appearance and to improve the color of fruit flavoring additives. The coloring agent is usually added in the form of a concentrate. Only approved coloring agents and sterilants may be used.

- *Weighing, measuring and mixing*
- Generally speaking, all dry ingredients are weighed, whereas liquid ingredients can be either weighed or proportioned by volumetric meters. In plants with small capacities and small total volumes, dry ingredients are generally weighed and supplied to the mix tanks by hand. These tanks are designed for indirect heating and equipped with efficient agitators.
- Large-scale producers use automatic batching systems, which are often custom-built to the user's specifications. The raw materials in the tank are heated and blended to a homogenous mix, which is then pasteurized and homogenized.
- In large production plants it is common to have two mix tanks of a volume corresponding to the hourly capacity of the pasteurizer, in order to maintain a continuous flow. The dry ingredients, especially the milk powder, are generally added in a mixing unit through which water is circulated, creating an ejector effect that sucks the powder into the flow. Before returning to the tank the mix is normally heated to 50–60°C to facilitate dissolution.
- Liquid ingredients such as milk, cream, liquid sugar, etc. are metered into the mix tank.

- *Homogenization and pasteurization*

- In large-scale production the ice cream mix flows through a filter to a balance tank and is pumped from there to a plate heat exchanger where it is preheated to 73 – 75°C.
- AMF or vegetable fat can be proportioned and blended into the flow in
- an in-line mixer en route to the homogenizer. After homogenization at 14–20 MPa (140 – 200 bar), the mix is pasteurized.
- In batch production the mix, including a metered quantity of fat, is first
- pasteurized in the combined mixing and processing tank, typically at 70°C
- with a hold of 30 minutes. The mix is then passed through the homogenizer, cooled to 5°C in a plate heat exchanger and transferred to the ageing tank.
- In large-scale plants the homogenized mix is returned to the plate heat
- exchanger and pasteurized at 83 – 85°C for about 15 seconds. The pasteurized mix is then cooled to 5°C and transferred to an ageing tank.

Ageing

The mix must be aged for at least 4 hours at a temperature between 2 and 5°C with continuous gentle agitation. Ageing allows time for the stabiliser to take effect and the fat to crystallize.

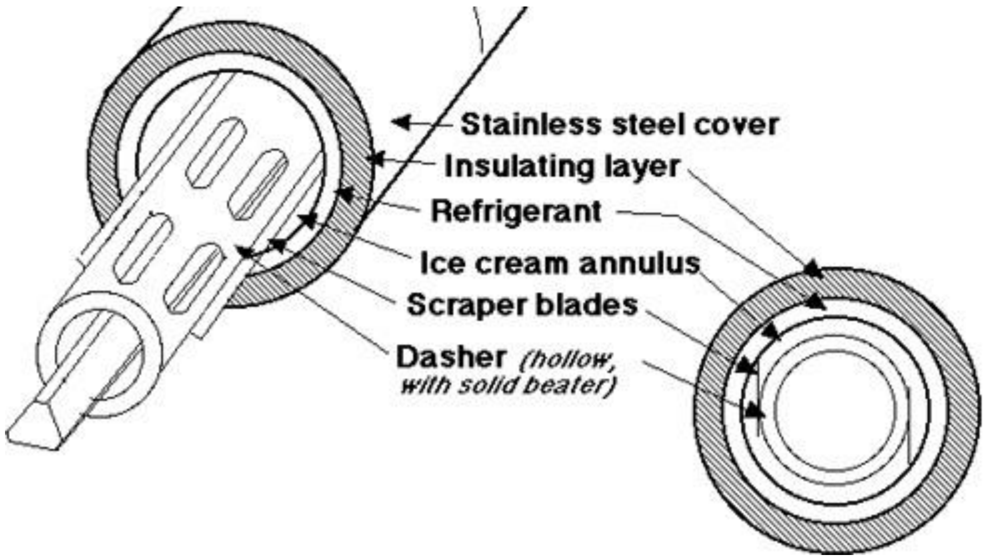
Continuous freezing

The continuous freezer has two functions:

- to whip a controlled amount of air into the mix;
- to freeze the water content in the mix to a large number of small ice crystals.

Figure on next page shows the exterior and the interior of the continuous freezer unit. The mix is pumped into a cylinder refrigerated by an ammonia jacket. The freezing process is *very rapid; this is very important for the formation* of small ice crystals. The layer of frozen mix on the cylinder wall is continuously scraped off by a rotating knife-equipped mutator inside the cylinder. From the ageing tanks the mix is passed to the continuous freezer, where air is whipped in while it is frozen to between –3°C and –6°C depending on the ice cream product. Increase in the volume by the incorporation of air in ice cream mix is called "overrun" and is normally 80 –100%, i.e. 0.8 to 1 litre of air per litre of mix. The ice cream leaving the continuous freezer has a texture similar to soft ice, and some 40% of the water content is frozen. It can therefore be pumped to the next stage in the process, which is either packing, extrusion or moulding.

Fruit ripple and dry ingredients like pieces of fruit, nuts or chocolate can be added to the ice cream immediately after the continuous freezer. This is done by connecting a ripple pump or an ingredient feeder unit to the ice cream line.



continuous freezer

Packing, extrusion and moulding

Packing in cups, cones and containers

Ice cream is packed in cups, cones and containers (1 to 6 litres) in a rotary or in-line filling machine. These can be filled with various flavors, and the products may be decorated with nuts, fruits and chocolate. The packs arelidded before leaving the machine, after which they are passed through a hardening tunnel where final freezing down to –20°C takes place. Before or after hardening the products can be manually or automatically packed in cartons or bundled.

Plastic tubs or cardboard cartons can be filled manually from a can equipped to supply single or twin flavors.

Extrusion of sticks and stickless products

Extruded ice cream products are normally produced on a tray tunnel extruder. The ice cream can be extruded directly onto trays in a variety of different shapes and sizes, or into a cup or cone, or on to a sandwich wafer.

Decoration can be applied, after which the products are carried on the trays through a hardening tunnel where they are frozen to –20°C. After hardening the products are removed from the trays ready for wrapping and packing in cartons, either manually or automatically. Such a system is continuous; depending on the capacity of the extruder and the type of product,

5 – 25 000 units can be produced per hour.

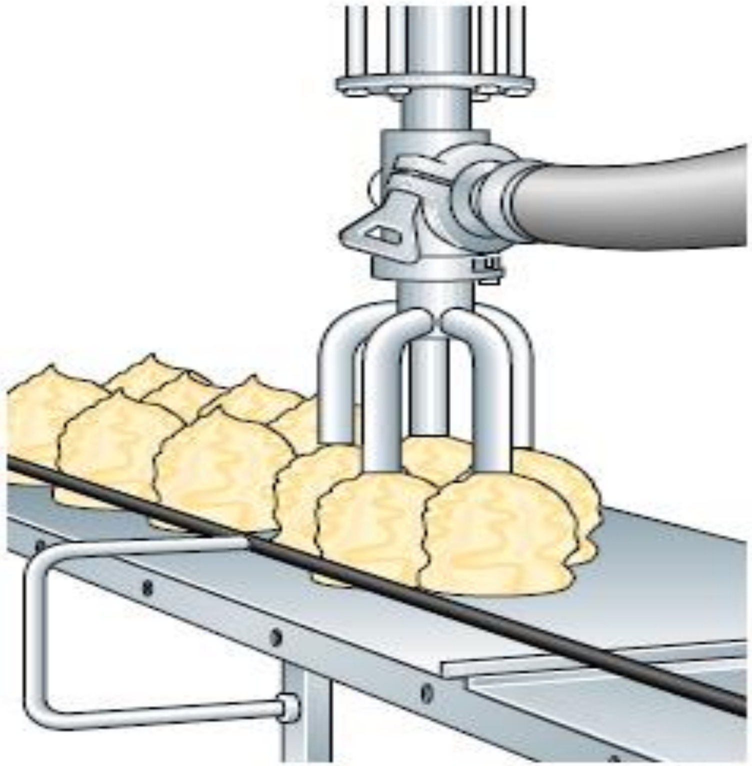


Fig. 19.5 *An extruder in a tray tunnel.*

Moulding of bars

Ice cream or water ice bars are made in special machines, also called stick novelty freezers, with pockets in which the ice cream or water ice is moulded. Ice cream is supplied direct from the continuous freezer at a temperature of approx. –3°C. The filled moulds are conveyed stepwise through a brine solution having a temperature of –40°C, which freezes the ice cream or water ice solution.

Sticks are inserted before the moulds are completely frozen. The frozen products are removed from the moulds by passing them through a warm brine solution which melts the surfaces of the products and enables them to be removed automatically by an extractor unit. After extraction the bars (novelties) may be dipped in chocolate before being transferred to the wrapping machine. Since the products are fully frozen, they can be taken straight to the cold store after wrapping and cartooning.

A variety of different shaped products can be produced in stick novelty freezers as well as products with one, two or three flavors and shell-and-core products with a core of ice cream and a shell of water ice.

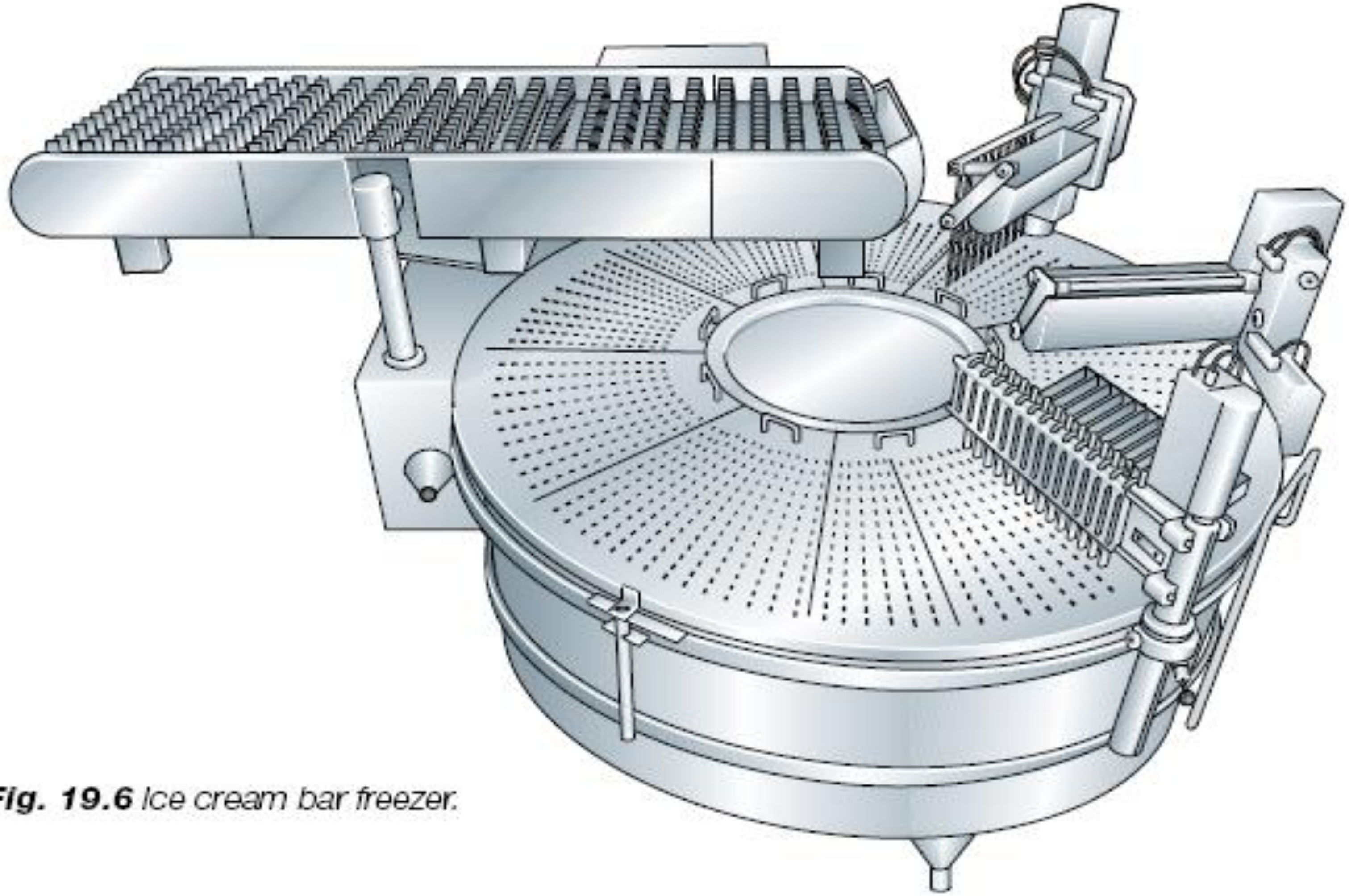


Fig. 19.6 *Ice cream bar freezer.*

Hardening and cold storage

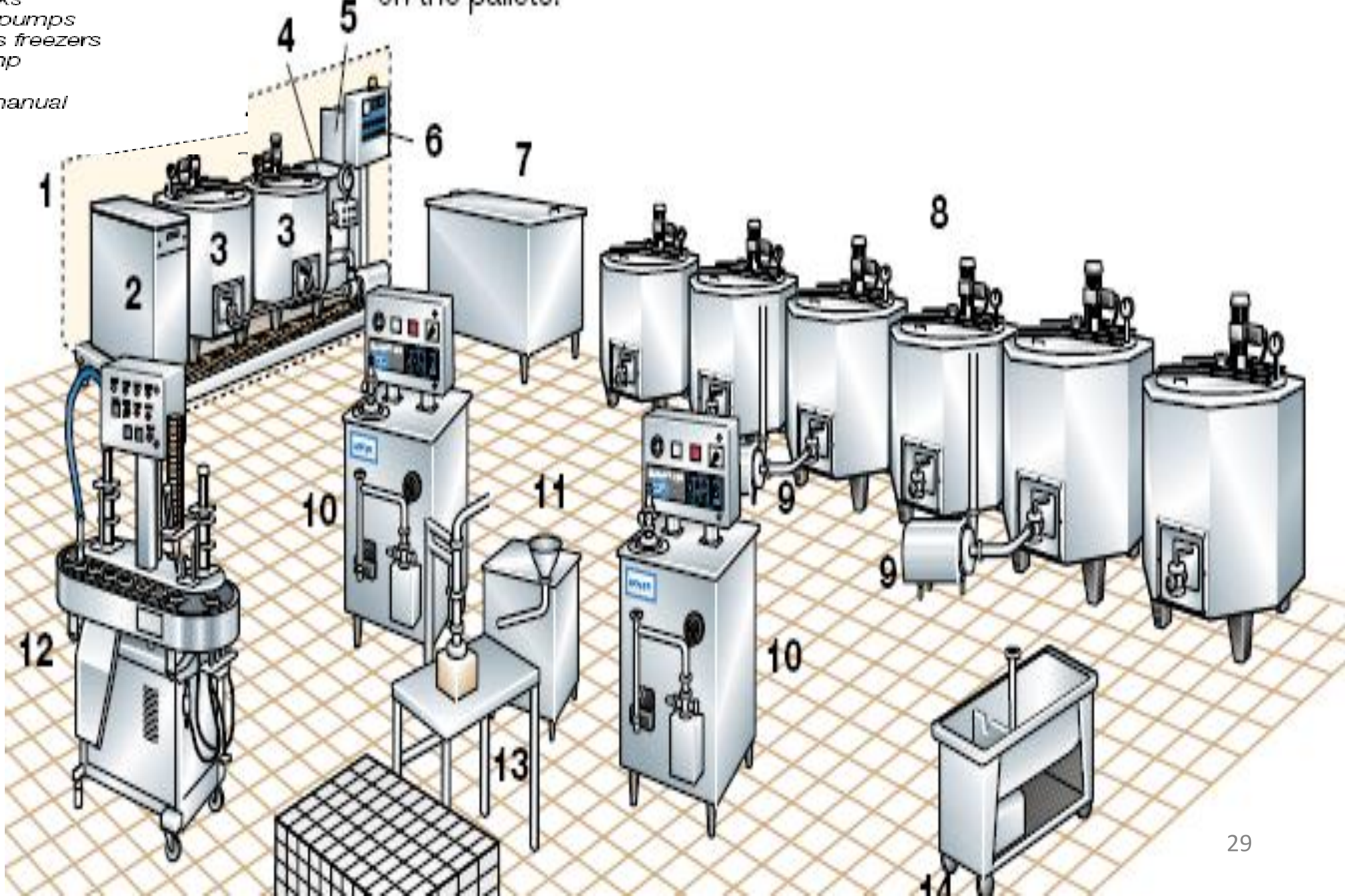
The manufacture of ice cream is not complete until it has been thoroughly hardened at a temperature of around –20°C. For products produced in an extrusion line or a stick novelty freezer, the hardening operation is included in the process. Products packed immediately after freezing must however be transferred to a hardening tunnel, figure 19.8. The faster the hardening, the better the texture. After hardening the products are transferred to the cold store where they are stored on shelves or pallet racks at a temperature of –25 °C. The storage life of ice cream depends on the type of product, the packaging, and maintenance of a constant low temperature. The storage period ranges from 0 to 9 months.

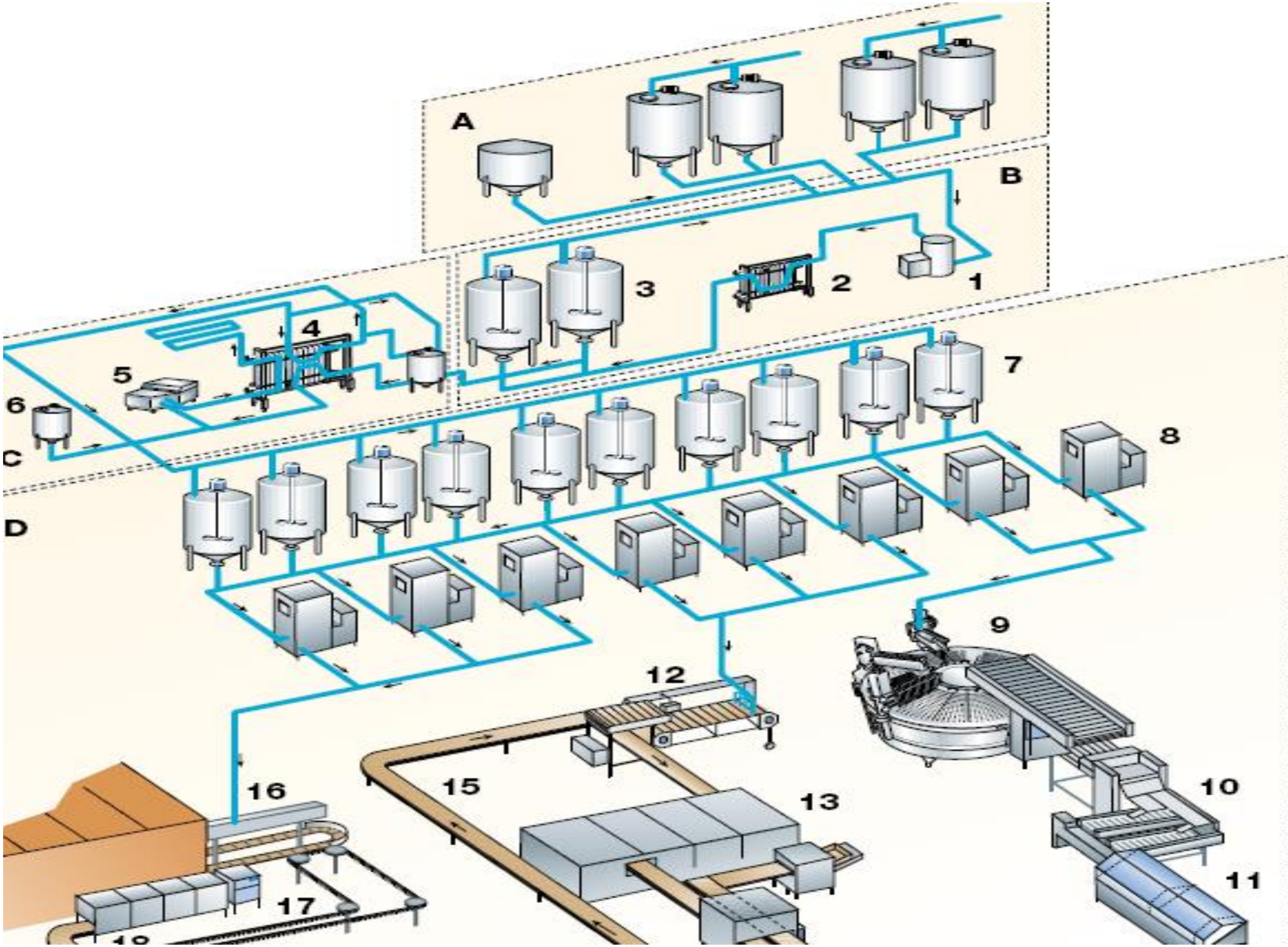
Wrapping and packaging

Cups, containers, etc. are either bundled or packed in cartons. Hand-held products like stick novelties, cones and bars are wrapped in a single or multi-lane wrapping machine before being packed in cartons. The design of the wrapping and packaging section of an ice cream processing line depends on the type of product and the capacity. Varying degrees of manual and automatic operation can be employed

Fig. 19.9 *Production plant for 500 litres per hour of ice cream products.*
1 Ice cream mix preparation modul containing
2 Water heater
3 Mixing and processing tank
4 Homogeniser
5 Plate heat exchanger
6 Control panel
7 Cooling water unit
8 Ageing tanks
9 Discharge pumps
10 Continuous freezers
11 Ripple pump
12 Roto-filler
13 Can filler, manual
14 CIP unit

on the pallets.




A
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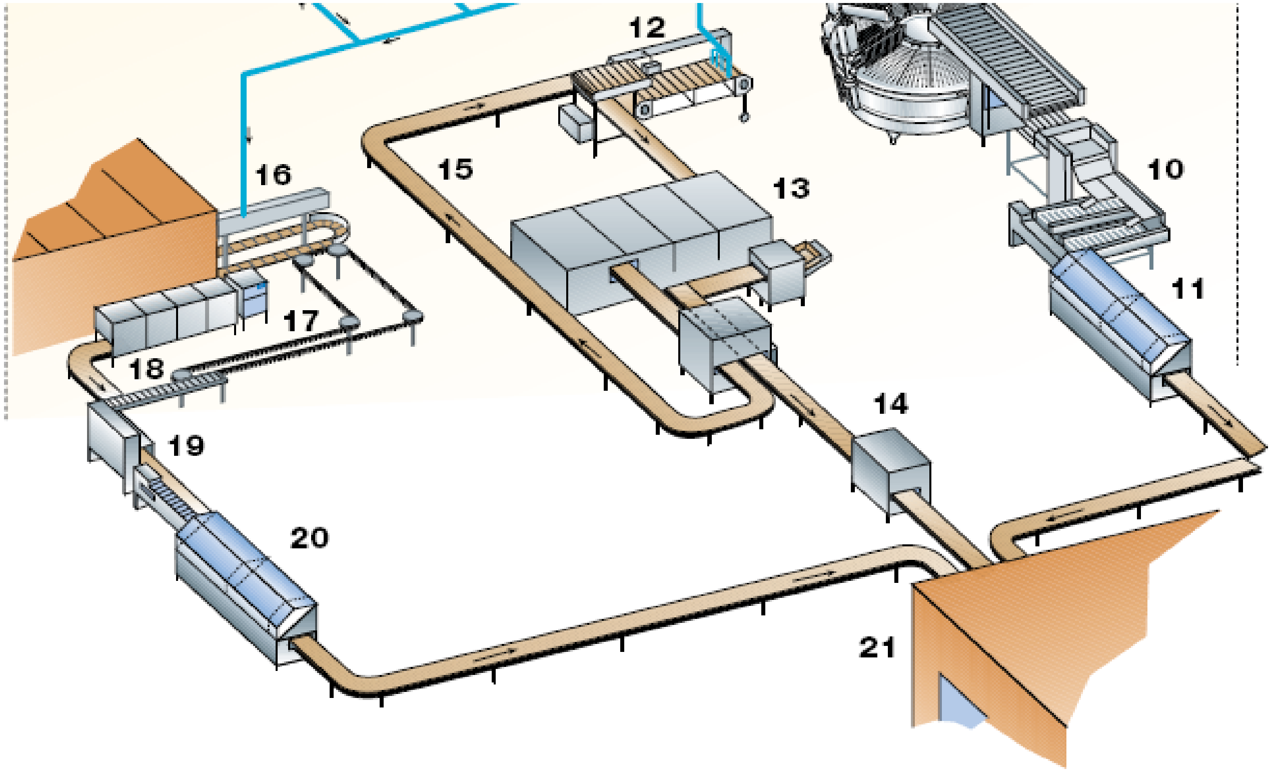


Fig.19.10 *Large ice cream plant for production of 5 000–10 000 l/h of various types of ice cream.*

A Raw material storage

B Dissolving of ingredients and mixing

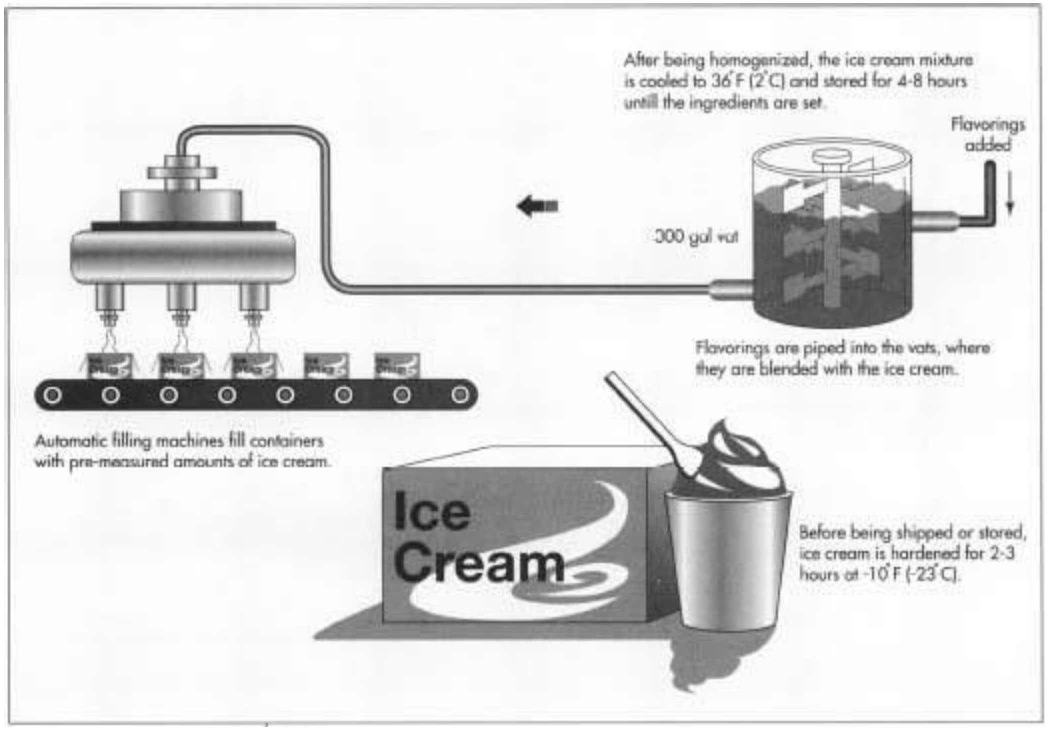
- *1 Mixing unit*
- *2 Plate heat exchanger*
- *3 Mixing tanks (at least two for continuous processing)*

C Pasteurisation, homogenisation and fat standardisation of the mix

- *4 Plate heat exchanger*
- *5 Homogeniser*
- *6 Tank for AMF or vegetable fat*

D Ice cream production plant

- *7 Ageing tanks*
- *8 Continuous freezers*
- *9 Bar freezer*
- *10 Wrapping and stacking unit*
- *11 Cartoning unit*
- *12 Cup/cone filler*
- *13 Hardening tunnel*
- *14 Cartoning line*
- *15 Return conveyor for empty trays*
- *16 Tray tunnel extruder*
- *17 Chocolate enrobing unit*
- *18 Cooling tunnel*
- *19 Wrapping unit*
- *20 Cartoning unit*
- *21 Cold storage*


After being homogenized, the ice cream mixture is cooled to 36°F (2°C) and stored for 4-8 hours untill the ingredients are set.
Flavorings added
300 gal vat
Flavorings are piped into the vats, where they are blended with the ice cream.
Automatic filling machines fill containers with pre-measured amounts of ice cream.
Ice Cream
Before being shipped or stored, ice cream is hardened for 2-3 hours at -10°F (-23°C).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Milk & Milk Products Technology

By

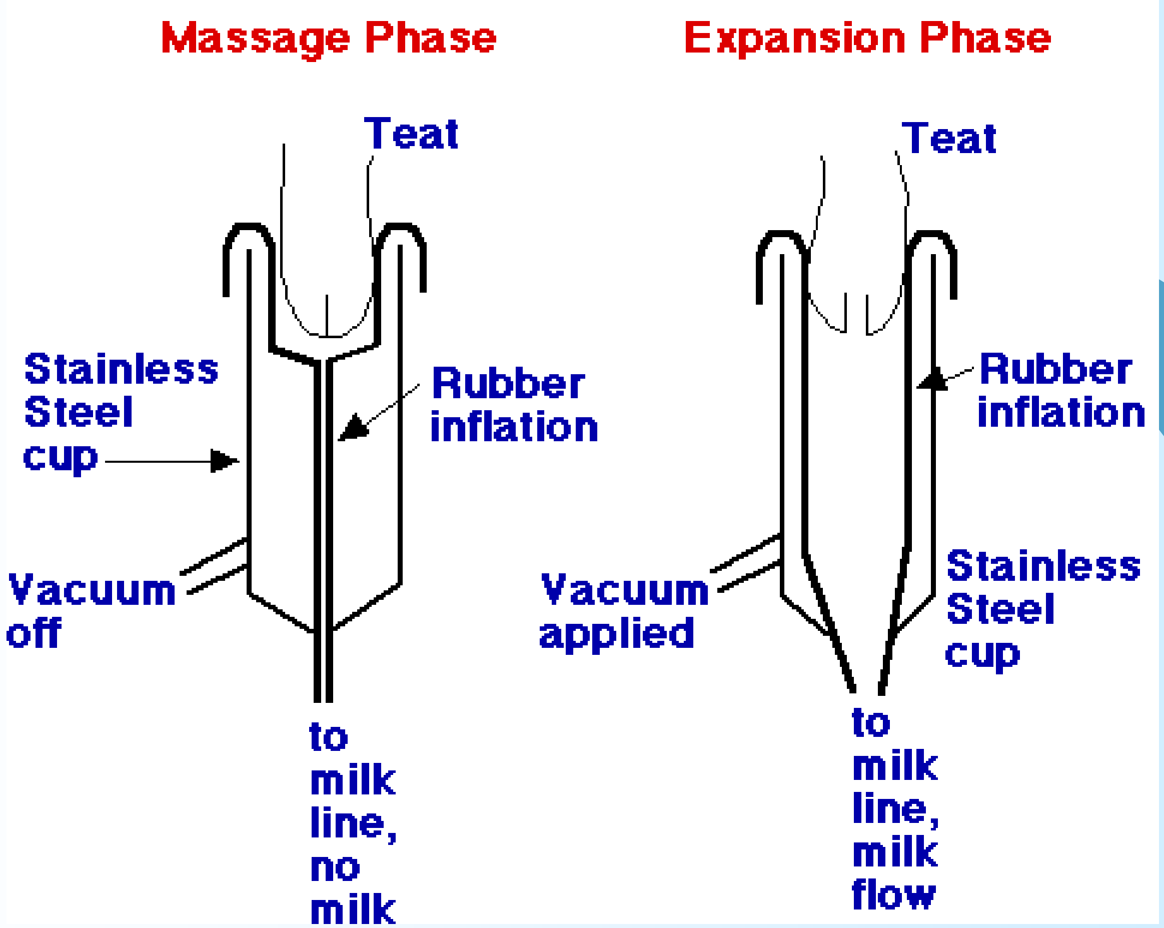
Dr. Sevim Kaya

Contents

Why milk is important for all human being and animals?

- Milk is the only food of the young mammal during the first period of its life.
- The substances in milk provide both energy and the building materials for growth.
- It also contains antibodies which protect the young mammal against infection.

Automatic Milking Machine



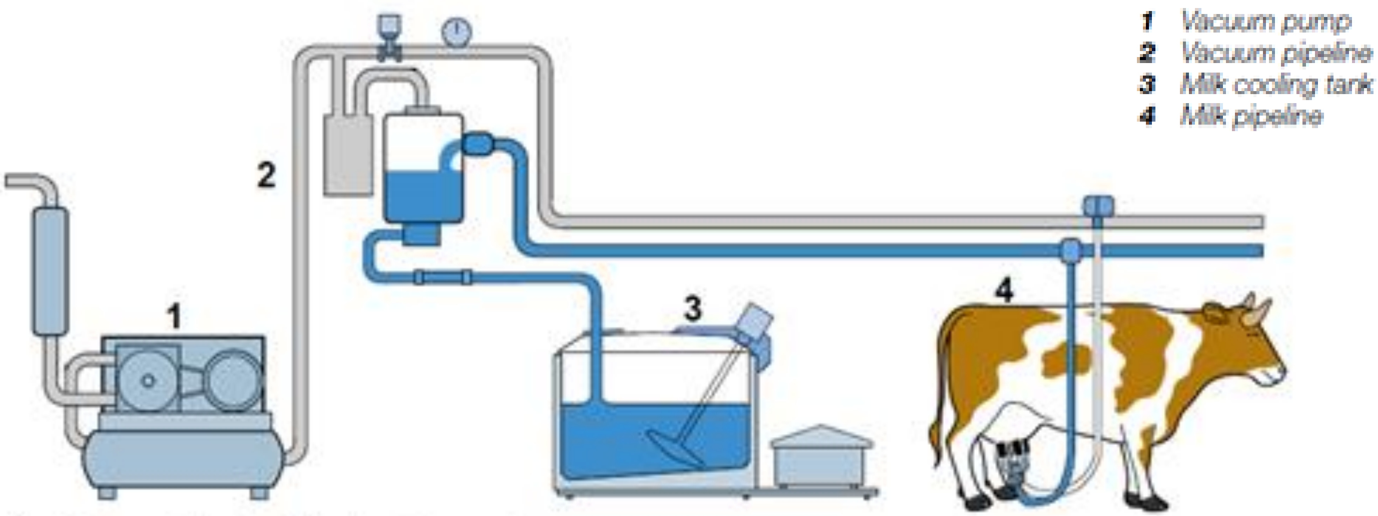


Fig. 1.8 *General design of pipeline milking system.*

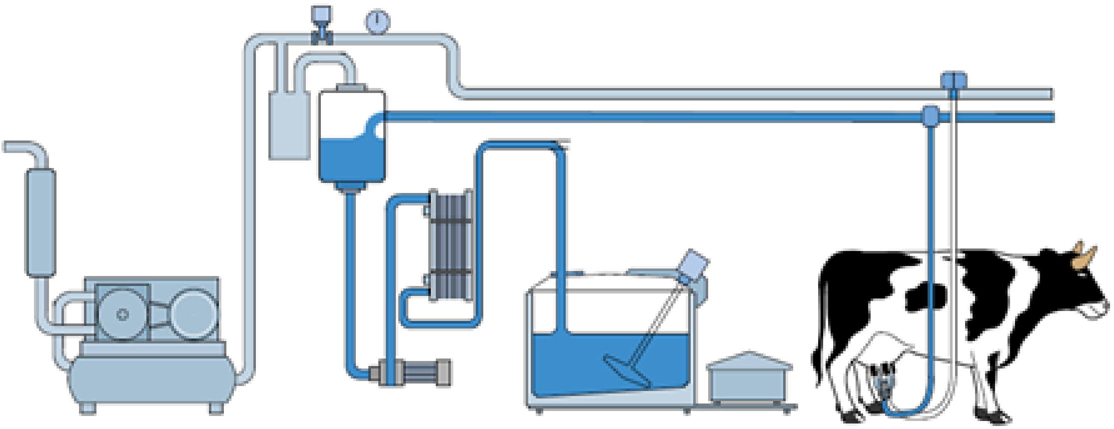


Fig. 1.12 Milking equipment on a large farm with heat exchanger for rapid chilling from 37 to 4°C.

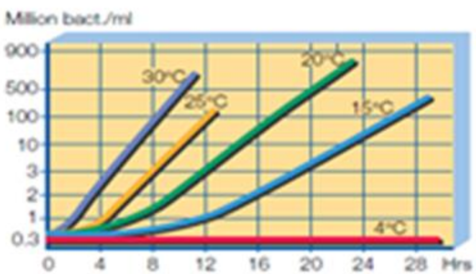


Fig. 1.9 The influence of temperature on bacterial development in raw milk.

Milk should preferably be handled in a closed system to minimise the risk of infection. It must be chilled quickly to 4°C as soon as it is produced and then kept at that temperature until processed. All equipment coming into contact with milk must be cleaned and disinfected.

Quality problems may arise if the intervals between collections are too long. Certain types of micro-organisms, known as psychrotrophic, can grow and reproduce below +7°C. They occur mainly in soil and water, so it is important that water used for cleaning is of high bacteriological quality.

Psychrotrophic bacteria will grow in raw milk stored at +4°C. After an acclimatization period of 48 – 72 hours, growth goes into an intense logarithmic phase, see the figure.

This results in breakdown of both fat and protein, giving the milk off-flavors that may jeopardize the quality of products made from it.

This phenomenon must be allowed for in planning of collection schedules. If long intervals cannot be avoided, it is advisable to chill the milk to 2 – 3°C.

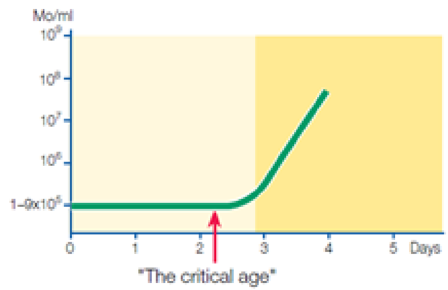


Fig. 1.13 Bacteria growth at +4°C in raw milk.

Cleaning and sanitizing

Bacterial infection of milk is caused to a great extent by the equipment; any surface coming in contact with the milk is a potential source of infection. It is therefore most important to clean and sanitize the equipment carefully.

Where hand milking is practiced, the utensils must be manually cleaned with suitable detergents and brushes.

Machine milking plants are normally provided with circulation cleaning systems (CIP) with operating instructions and recommendations for suitable detergents and sanitizers.

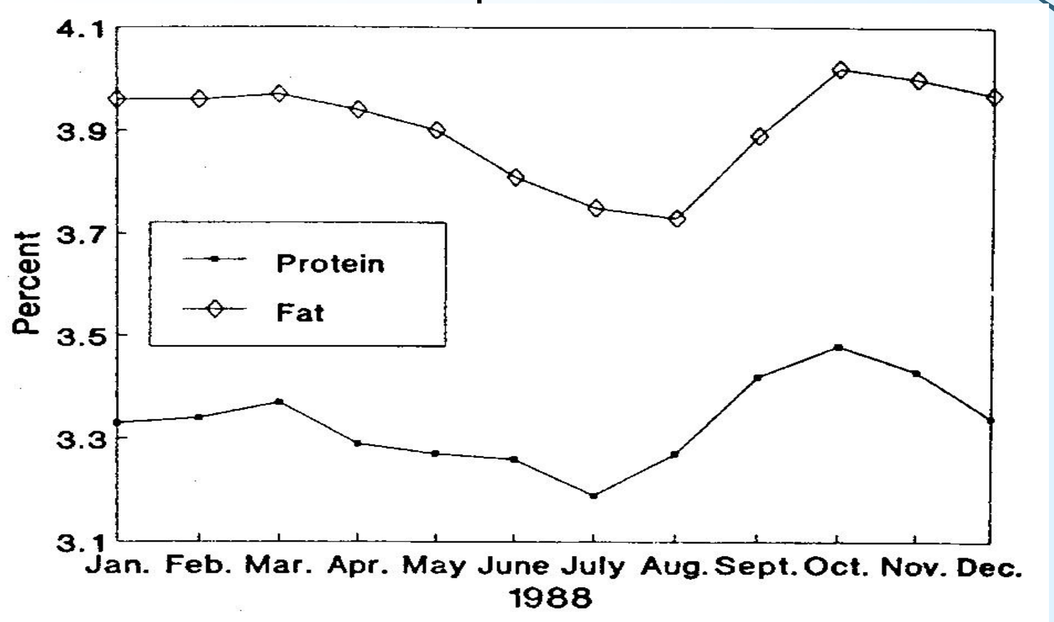
Quantitative composition of milk

Main constituent	Limits of variation			Mean value
Water	85.5	–	89.5	87.5
Total solids	10.5	–	14.5	13.0
Fat	2.5	–	6.0	3.9
Proteins	2.9	–	5.0	3.4
Lactose	3.6	–	5.5	4.8
Minerals	0.6	–	0.9	0.8

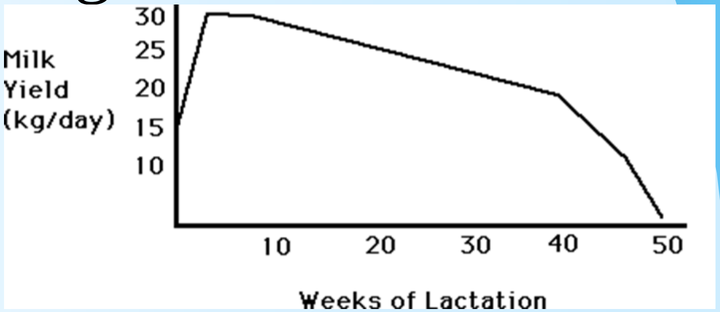
Composition of Milk from Different Mammalian Species (per 100 g fresh milk).

	Protein (g)	Fat (g)	Carbohydrate (g)	Energy (kcal)
Cow	3.2	3.7	4.6	66
Human	1.1	4.2	7.0	72
Water Buffalo	4.1	9.0	4.8	118
Goat	2.9	3.8	4.7	67
Donkey	1.9	0.6	6.1	38
Elephant	4.0	5.0	5.3	85
Monkey, rhesus	1.6	4.0	7.0	73
Mouse	9.0	13.1	3.0	171
Whale	10.9	42.3	1.3	443
Seal	10.2	49.4	0.1	502

- Season/nutrition
– milk composition is largely influenced by seasons
– winter: silaged feed; summer: fresh grass
- Differences in fat and protein content



-Major Implications on processing



Physical-chemical status of cows' milk.

	Average composition %	Emulsion type Oil/Water	Collodial solution/ suspension	True solution
Moisture	87.0			
Fat	4.0	X		
Proteins	3.5		X	
Lactose	4.7			X
Ash	0.8			X

•Stage of lactation

-Time elapsed after calving influences milk composition

-Colostrum milk = First milk produced after calving; more salts, proteins (mainly serum proteins) and less lactose; composition evolves towards its normal composition within 4 days

- Further changes occur: decrement in protein content, casein, serum proteins, ashes, fat-free dry matter; at the end of the lactation, an increment in DM content occurs

-Lactose content is almost constant during lactation; fat content is correlated to fat-free dry matter during lactation

-pH changes: 6,6 → 6,7 → 6,9 (at the end)

Factors affecting the milk composition

- Age of cow

– has a very small but consistent effect on milk composition
fat and fat-free dry matter decrease slightly with each successive lactation

- Mastitis

– = inflammation of the udder
– several species of pathogenic bacteria may cause mastitis
– causes a decrease in milk yield and a change in milk composition
– decrease in fat content, fat-free dry matter, lactose and casein and increase of serum proteins and chloride content
– the number of somatic cells increases (> 400.000/ml)
-catalase activity increases
– Cl-lactose ratio increases

Correlations

- Lactose and chlorides are negatively correlated
  - the result of the activity of the udder which maintains milk isotonic
  - if lactose-production is restricted by an infected udder, more chlorides (and thus also sodium) are added to the milk by the udder
  - this phenomenon can be used to detect mastitis infection: the number of Koestler is a valuable parameter to differentiate normal from mastitis milk

Normal milk=(100*% Clorides)/% Lactose= 1.5-3.0

Mastititis milk=(100*% Clorides)/% Lactose> 3.0

Koestler test: (NaCl conc/Lactose conc)*100

A Koestler number less than 2 indicates normal milk while a value greater than 3 is considered abnormal.

Factors influencing the composition

• Method of milking

– during milking the fat content of the milk leaving the udder increases (e.g. from 1-10%, marked differences among cows in this respect); fat-free dry matter remains constant

– the interval between milking influences fat content, but not fat-free dry matter; longer intervals result in a higher fat content

• Individual

– variations within breeds are the result of genetic and

environmental factors

- by selection high-productive animals are obtained

• Quarters

– differences in composition in the milk of different quarters of the udder of one cow mostly are negligible unless a quarter is or has been affected by mastitis

• Other factors

– contamination and processing

Milk is a/an

Emulsion*:* a suspension of droplets of one liquid in another.

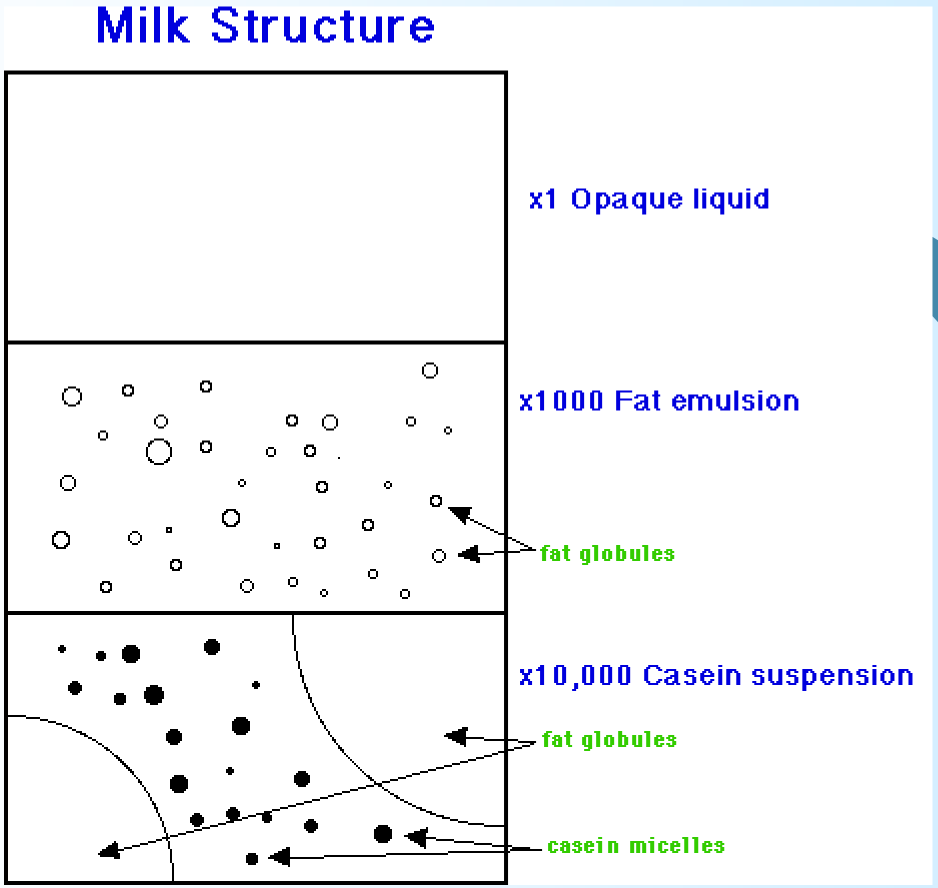
- Milk is an emulsion of fat in water
- Butter is an emulsion of water in fat

Finely divided liquid is dispersed phase, other is continuous phase

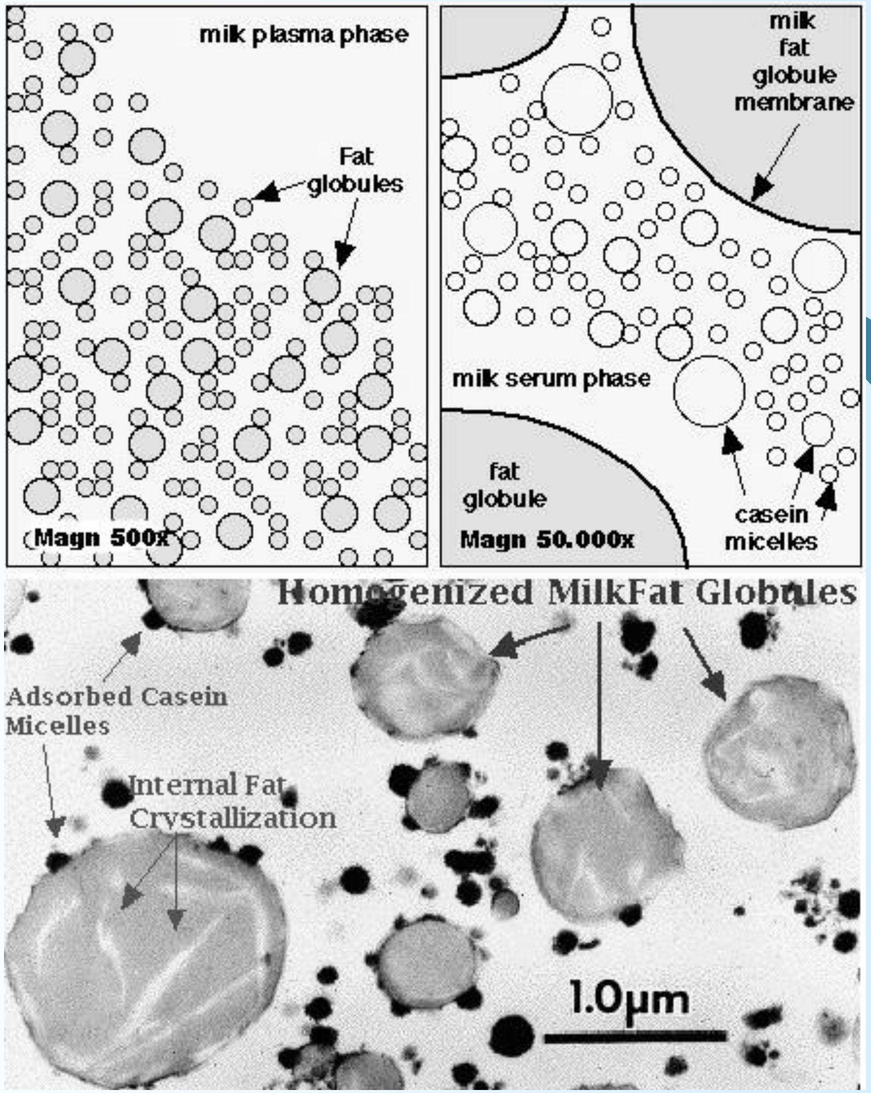
Colloidal solution: When matter exists in a state of division intermediate to true solution (ex. sugar in water) and suspension (ex. chalk in water). It is said to be in colloidal solution or collidal suspension.

Difference between colloidal solution and suspension is the size of the particles:

Size of the particles in colloidal solution << those in colloidal suspension


Milk Structure
x1 Opaque liquid
x1000 Fat emulsion
fat globules
x10,000 Casein suspension
fat globules
casein micelles

Milk viewed at different magnifications



The typical characteristics of a colloid are:

- Small particle size
- Electrical charge
- Affinity of the particles for water molecules

1. Whey proteins colloidal solution
2. Casein colloidal suspension

Stabilization of colloidal systems:

- Substances such as salts by changing the water binding => protein solubility↓

- Factors such as heat causing unfolding of whey proteins => interaction between protein↑
- Alcohol may act by dehydrating the particles

Milk can be described as:

an **oil-in-water emulsion** with the fat globules dispersed in the continuous serum phase

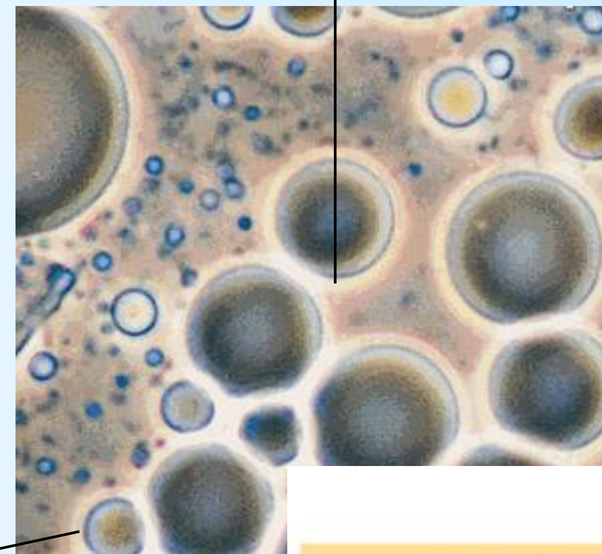
a **colloid suspension** of casein micelles, globular proteins and lipoprotein partilcles

a **solution** of lactose, soluble proteins, minerals, vitamins other components.

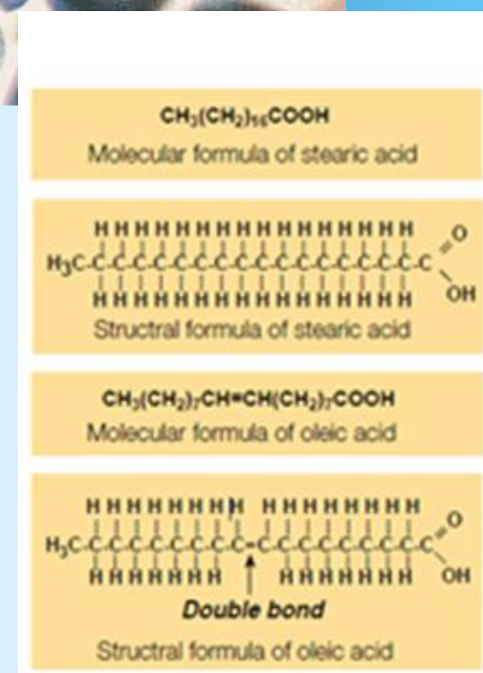
MILL FAT

- If milk fat left stand, a layer of cream will form on the surface. The cream differs considerably in appearance from the bottom layer of milk.

Fat globules



Skin (protein & phospholipids)



Skin has an important function, it protects the fat from being broken down by enzymes present in the milk.

Fig 2.19 Milk fat is a mixture of different fatty acids and glycerol.

Diameter of fat globules are 0.1-20 μm and there are 3000-4000 million fat globules in a mL of whole milk.

It is a mixture of different fatty acid esters called triglycerides, which are compounds of an alcohol called glycerol and various fatty acids.

Table shows that the four most abundant fatty acids in milk are myristic, palmitic, stearic and oleic acids.

Principal fatty acids in milk fat

Fatty acid	% of total fatty-acid content	Melting point °C	Number of atoms H	C	O	
Saturated						
Butyric acid	3.0 – 4.5	–7.9	8	4	2	Liquid at room temp-erature
Caproic acid	1.3 – 2.2	–1.5	12	6	2	
Caprylic acid	0.8 – 2.5	+16.5	16	8	2	
Capric acid	1.8 – 3.8	+31.4	20	10	2	Solid at room temp–erature
Lauric acid	2.0 – 5.0	+43.6	24	12	2	
Myristic acid	7.0 – 11.0	+53.8	28	14	2	
Palmitic acid	25.0 – 29.0	+62.6	32	16	2	
Stearic acid	7.0 – 3.0	+69.3	36	18	2	
Unsaturated						
Oleic acid	30.0 – 40.0	+14.0	34	18	2	Liquid at room temp-erature
Linoleic acid	2.0 – 3.0	–5.0	32	18	2	
Linolenic acid	up to 1.0	–5.0	30	18	2	
Arachidonic acid	up to 1.0	–49.5	32	20	2	

Melting point of fat

The first three are solid and the last is liquid at room temperature. As the quoted figures indicate, the relative amounts of the different fatty acids can vary considerably. This variation affects the hardness of the fat. Fat with a high content of high-melting fatty acids, such as palmitic acid, will be hard; but on the other hand, fat with a high content of low-melting oleic acid makes soft butter.

Determining the quantities of individual fatty acids is a matter of purely scientific interest. For practical purposes it is sufficient to determine one or more constants or indices which provide certain information concerning the composition of the fat.

FA make up ~ 90% of milk fat

Fat with high mp FA is hard
Fat with low mp FA is soft
Myristic, palmitic, stearic, oleic, butyric, caproic are the important FAs in milk.
First 4th are the most abundant.

Fatty acids with the same numbers of C & H atoms
but different # of single and double bonds have
completely different characteristics.

Iodine value (IV): the percentage of iodine
that the fat can find by the double bonds of unsaturated fatty acids.

IV gives idea about the softness and hardness of the fats.

Summer mf – soft – green pasture

Winter mf – hard – deficiency in green pasture

(IV ~ 32-37 for butter)

Refractive index (RI) fat refracts the light affected with fatty acid composition.

So used for calculation of IV

(RI ~40-46)

Nuclear Magnetic Resonance (NMR) can be used to determination of the ratio of saturated/unsaturated fat

Deterioration of milk fat

- Lipolysis
- Oxidation
- Fishy taste

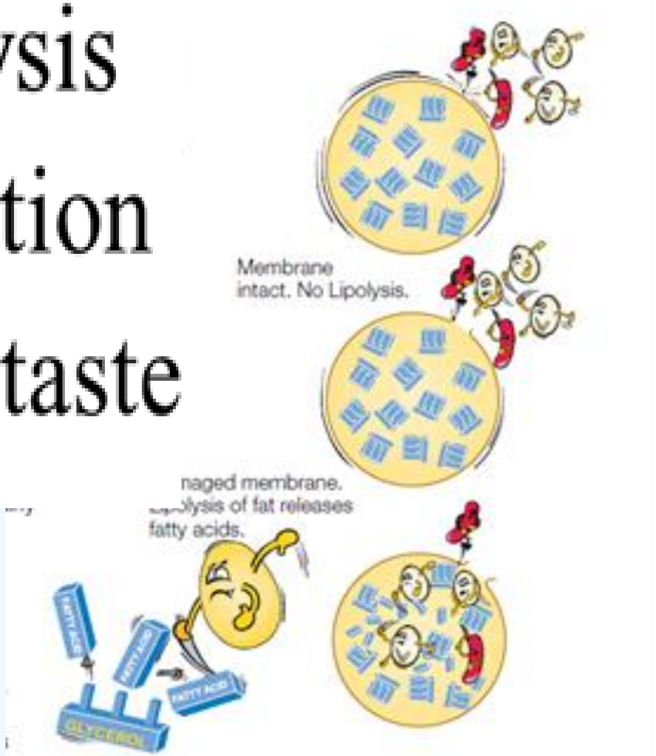


Fig 2.41 When fat globule membranes are damaged, lipolysis can release fatty acids.

Lipolysis

- The breakdown of fat into glycerol and free fatty acids is called lipolysis. Lipolysed fat has a rancid taste and smell, caused by the presence of low molecular free fatty acids (butyric and caproic acid).
- Lipolysis is caused by the action of lipases and is encouraged by high storage temperatures. But lipase cannot act unless the fat globules have been damaged so that the fat is exposed. Only then can the lipase attack and hydrolyze the fat molecules. In normal dairying routine there are many opportunities for the fat globules to be damaged, e.g. by pumping, stirring and splashing. Undue agitation of unpasteurised milk should therefore be avoided, as this may involve the risk of widespread lipase action with the liberation of fatty acids that make the milk taste rancid.

Lipolysis

- Hydrolysis of fatty acid esters by the action of lipases

– results in the common flavor defect know as lipolytic or hydrolytic rancidity and is distinct from oxidative rancidity

- By endogeneous lipases (mainly lipoprotein lipase) or by bacterial lipases
- The properties of the fat globule membrane are of major importance

– reduced contents of phospholipids or mastitis can increase the sensitivity of the fat globule for lipolysis

– other factors that destabilize the fat globule membrane, especially agitation and foaming, also promote lipolysis

– lipolysis is promoted in the manufacturing of cheese (i.e. wanted)

- Sensory perception of lipolytic rancidity is strongly affected by the pH of the product

– at low pH they are more readily tasted

- in fresh milk threshold values corresponded to acid degree values (ADV) of 4.1 to 4.5 mmol per 100 g of fat
- To prevent lipase from degrading the fat it must be inactivated by high-temperature pasteurization.
- This completely destroys the original enzymes. Bacterial enzymes are more resistant. Not even UHT treatment can destroy them entirely. (UHT = Ultra High Temperature, i.e. heating to 135 – 150°C or more for a few seconds.)

Oxidation

- Proceeds by the well-known auto oxidation reaction in three stages initiation, propagation and termination
  – unsaturated fatty acids are transformed to hydroperoxides, the primary reaction products
  – during propagation, antioxidant compounds such as tocopherols and ascorbic acid are depleted while peroxide derivatives of fatty acids accumulate
  – peroxides, which have little flavor, undergo further reactions to form a variety of carbonyl, the secondary reaction products, which are responsible for the rancid taste and odour

Oxidation

Factors affecting oxidation can be categorized into 2 groups

- Intrinsic factors

– metalloproteins such as milk peroxidase and xanthin oxidase
– endogenous ascorbic acid, which acts as a cocatalyst with copper to promote oxidation
– endogenous copper content
– endogenous antioxidants, mainly tocopherols

- Extrinsic factors

– contamination with metals
– temperature of storage
– oxygen tension
– heat treatment
– agitation
– light
– acidity

Oxidation

- Effect of heat treatment

– migration of copper from the plasma to the fat globule

– denaturation of metalloproteins and increase the availability of metals for oxidation

– high heat treatment stabilizes milk against oxidation

- probably due to exposure of sulfhydryl groups of denaturated proteins and the releaseof hydrogen sulfide
- Effect of homogenization

– reduces the sensitivity of milkfat to both copper- and light-induced oxidation, probably because oxidation sensitive membrane lipids are displaced

- Effect of light

– photooxidation is accompanied by depletion of riboflavin, ascorbic acid and some amino acids

Proteins in milk

- Proteins are an essential part of our diet.
- Proteins → free amino acids → conveyed into cells of the body → used as an construction material for body's own protein
- The most of the rxns (occur in LO) controlled by proteins

Simple amino acid:

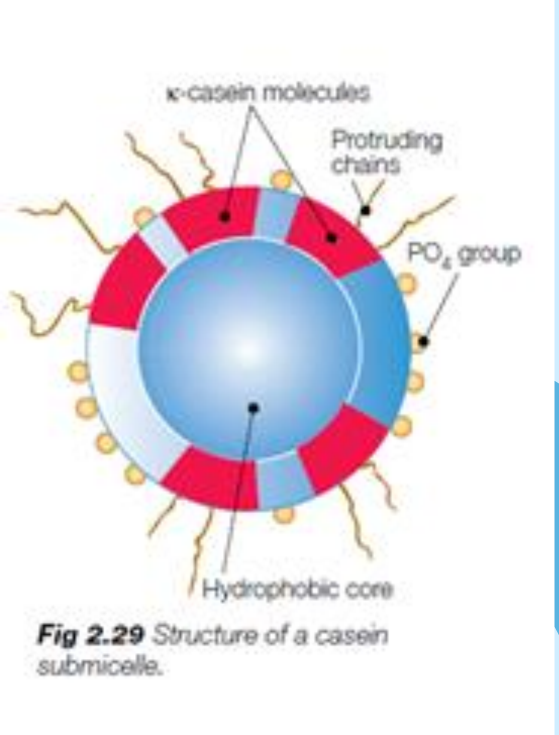
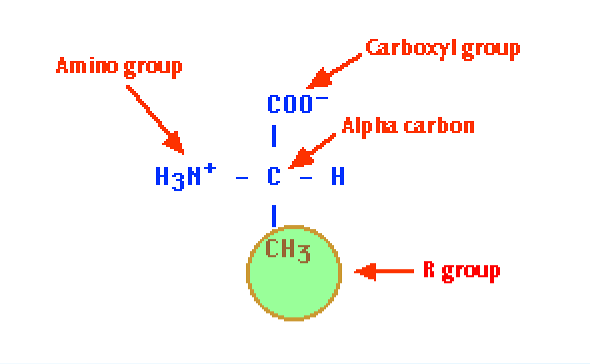


Fig 2.29 *Structure of a casein submicelle.*



Proteins

- Milk proteins: of great importance
  - human nutrition: nutritional functionality
  - behavior/properties of dairy products: technological functionality
- Normal bovine milk: 30-35 g protein/L
- Nitrogen content of milk
  - caseins
  - whey proteins
  - non-protein nitrogen (NPN)
  - minor proteins associated with the milk fat globule membrane

Caseins

- αs1-Caseins
- αs2-Caseins
- β-Caseins
- k-Caseins

Caseins

"Those phosphoproteins which precipitate from raw skim"milk upon acidification to pH 4.6 at 20°C"

- Account for 76-86% of the total milk protein essentially all occur in micelles
- Most of the caseins can be represented by four gene products: αs1-, αs2-, β- and k-caseins in the approximate ratio 40:10:35:12

Milk is a buffer solution

- Negatively charged in alkaline solution

$COOH \rightarrow COO^-$ if $pH > 6.7$

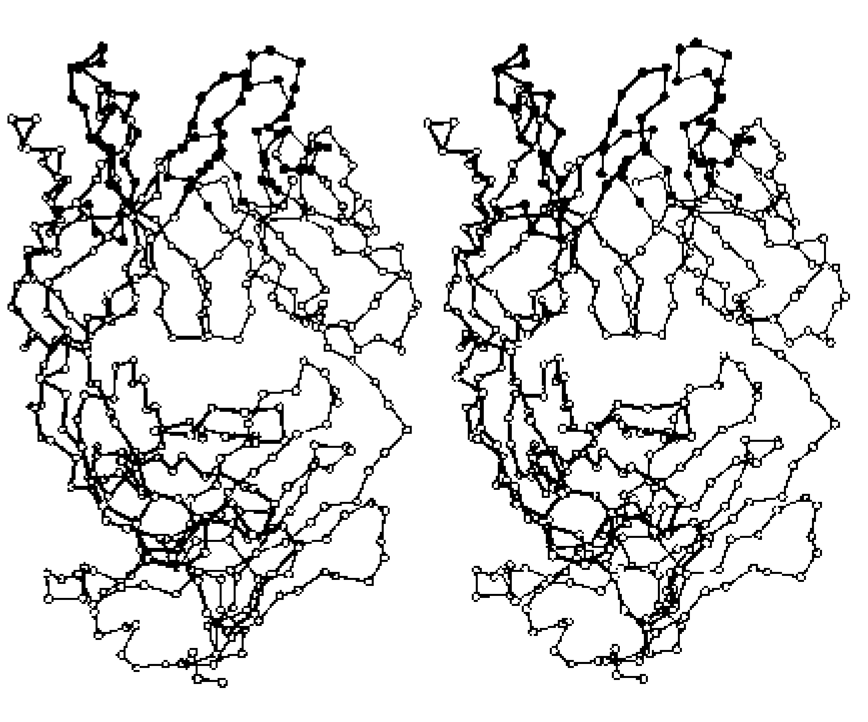
- Neutral at equal + and – charges

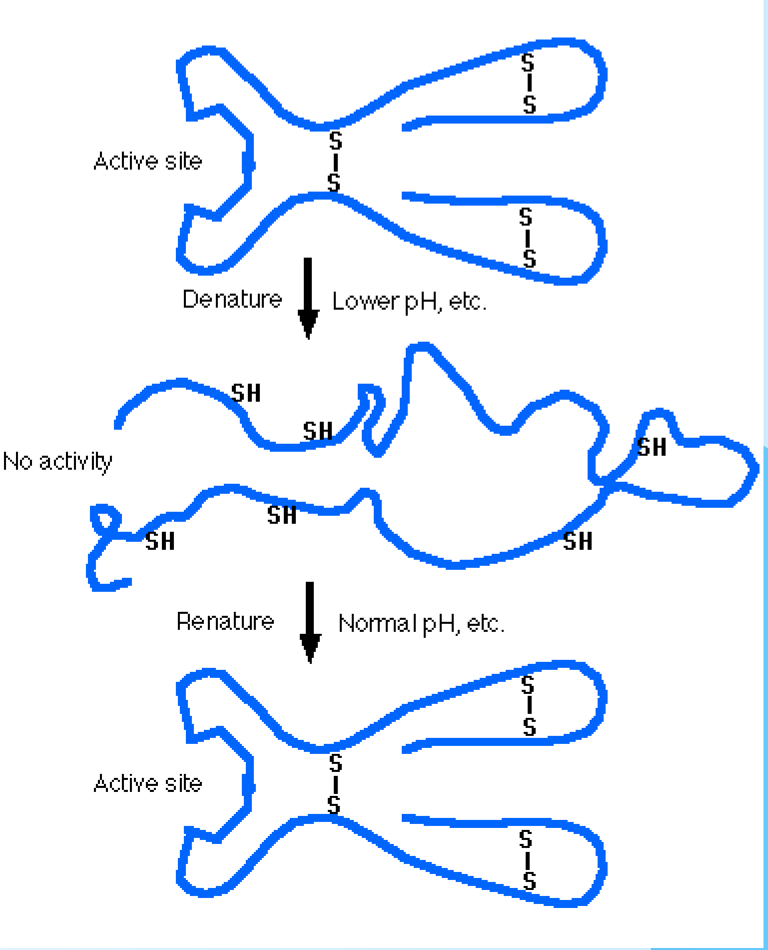
Isoelectric point (pI)

- Positively charged in acid solution

$NH_2 \rightarrow NH_3^+$ (excess H^+ ion) if $pH < 6.7$

Tertiary structure

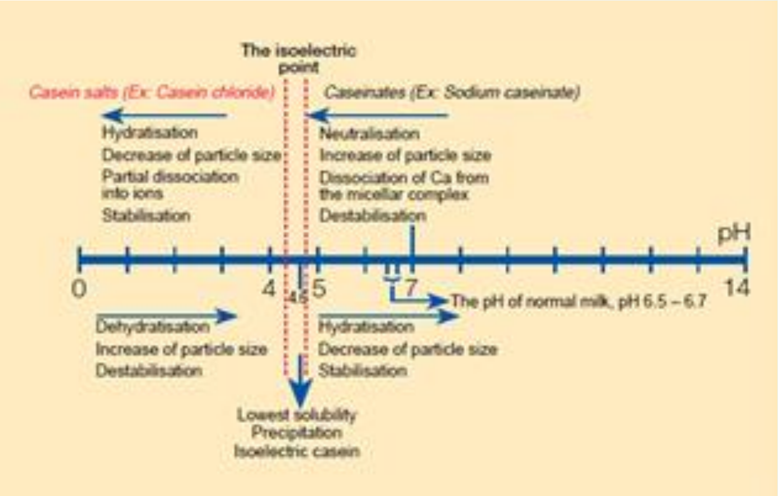




Isoelectric point

- The protein molecules no longer repel each other, but the (+)ve charges on one molecule link up with (-)ve charges on the neighboring molecules and large protein clusters are formed. The protein is then precipitated from the solution.
- If acid added→repel each other (remain in solution)
- If base added→all proteins acquire (-)ve charges (dissolve)

Three simplified stages of influence on casein by an acid and alkali respectively.



Note: If a large excess of acid is added to a given coagulum the casein will redissolve, forming a salt with the acid. If hydrochloric acid is used, the solution will contain casein hydrochloride, partly dissociated into ions.

Table 2.5

Concentration of proteins in milk

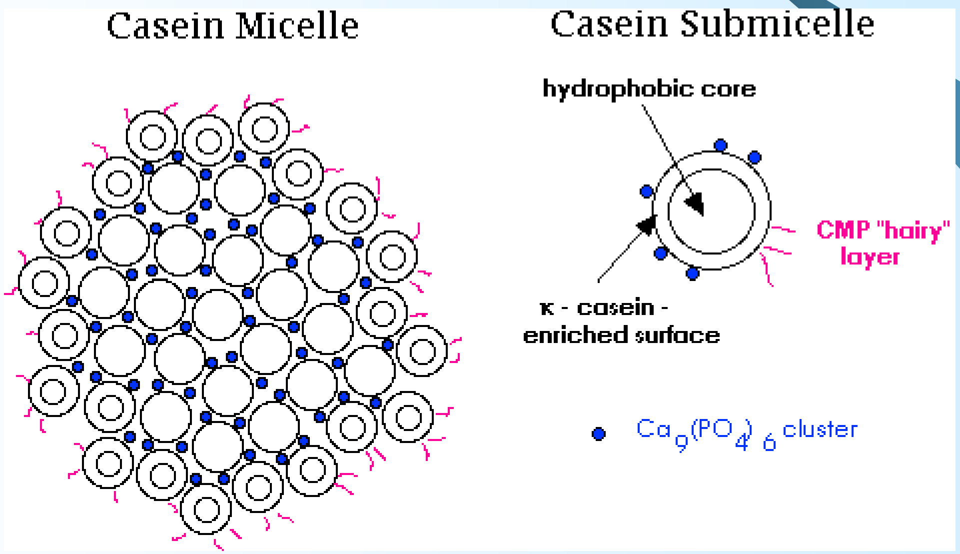
	Conc. in milk g/kg	% of total protein w/w
Casein		
α_{s1}-casein*)	10.0	30.6
α_{s2}-casein*)	2.6	8.0
β-casein**)	10.1	30.8
κ-casein	3.3	10.1
Total Casein	26.0	79.5
Whey Proteins		
α-lactalbumin	1.2	3.7
β-lactoglobulin	3.2	9.8
Blood Serum Albumin	0.4	1.2
Immunoglobulins	0.7	2.1
Miscellaneous (including Proteose-Peptone)	0.8	2.4
Total Whey Proteins	6.3	19.3
Fat Globule Membrane Proteins	0.4	1.2
Total Protein	32.7	100

*) Henceforth called α_s-casein

**) Including γ-casein

Ref: Walstra & Jennis

- Casein is found only in milk.
- It is white in color & insoluble in water (soluble in base and acid solutions) & forms salt with both.
- In fresh milk, pH: 6.7, Ca-, PO4 -salt (mainly calcium caseinate).
- pI of casein: 4.6
- At this pH, casein is ppt'ed & coagulum is formed
- That is how cultured product are made.


Casein Micelle
Casein Submicelle
hydrophobic core
CMP "hairy" layer
κ - casein - enriched surface
$Ca_9(PO_4)_6$ cluster

Lactose+LA bacteria →LA

So pH↑

Ca-casenate-phosphate + milk acid (lactic acid)

→ acid casein gel + Ca-lactate + $CaPO_4$

(ppt) (soluble) (soluble)

Relation between acidity & coagulation

- acidity comment
- 10°SH no ppt safe to heat

(0.225% LA)

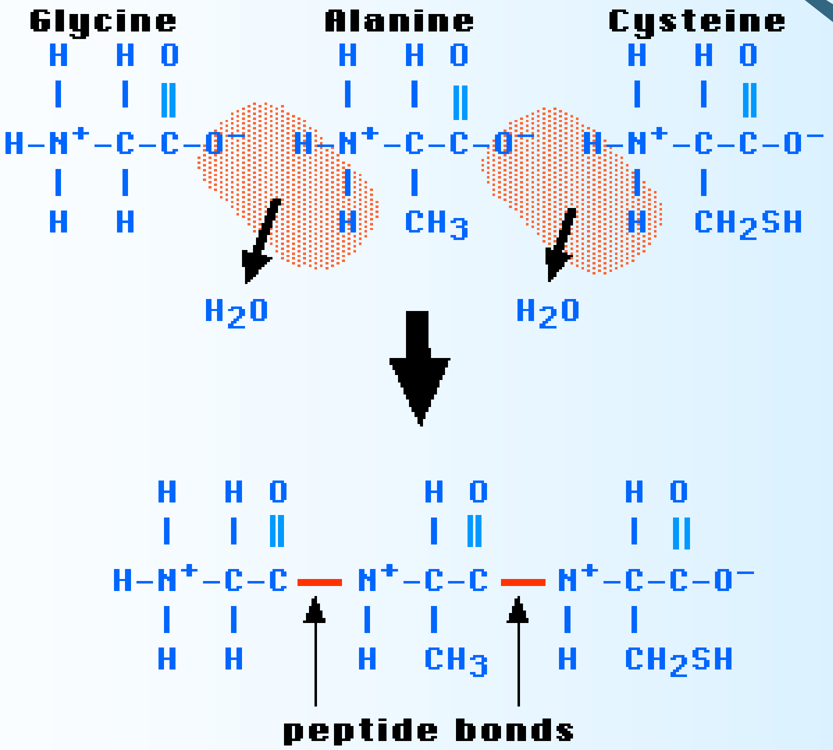
- 11.5°SH ppt at boiling point

(0.26% LA)

- 26.5°SH ppt at room temperature

(0.6% LA)

Precipitation by enzyme



chymosin

κ-casein ⟶ para- κ -casein + GMP

(ppt) (soluble)

Proteolytic enzymes hydrolysis

protein→proteoz→pepton→polypeptide→

oligopeptide→AAcid→NH_3, H_2O & others

Oxidation of protein

- When exposed to light the amino acid methionine is degraded to methional
- by a complicated participation of riboflavin (Vitamin B2) and ascorbic acid (Vitamin C). Methional or 3-mercapto-methylpropionaldehyde is the principal contributor to *sunlight flavour*, as this particular flavour is called.
- Since methionine does not exist as such in milk but as one of the components of the milk proteins, fragmentation of the proteins must occur incidental to development of the off-flavour.

Factors related to sunlight flavour development are:

- Intensity of light (sunlight and/or artificial light, especially from fluorescent tubes).
- Duration of exposure.
- Certain properties of the milk

– homogenised milk has turned out to be more sensitive than non-homogenised milk.

- Nature of package – opaque packages such as plastic and paper give good protection under normal conditions

Fishy taste

Can be induced by transformation of Phosphatidylcholine to trimethylamine.

Lactose

Lactose is a disaccharide (2 sugars) made up of glucose and galactose (which are both monosaccharides).

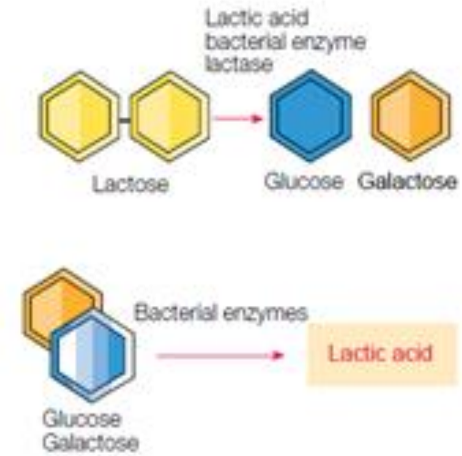
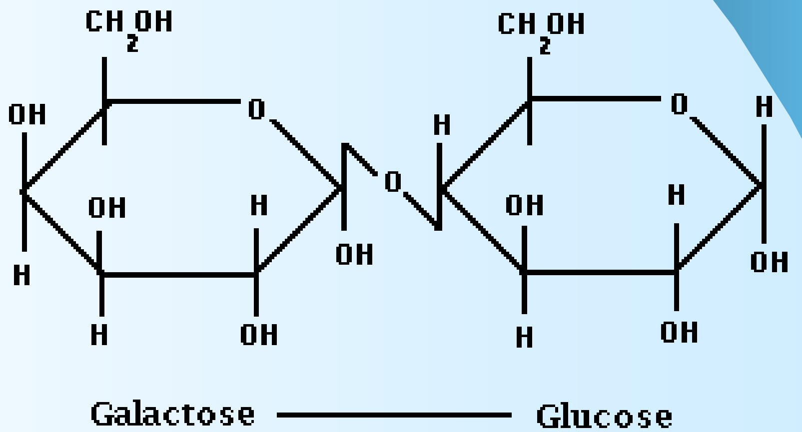


Fig 2.39 *Breakdown of lactose by enzymatic action and formation of lactic acid.*



- It is not as sweet as sucrose.
- When lactose is hydrolyzed by **ß -D-galactosidase (lactase)**, an enzyme that splits these monosaccharides,

the result is increased sweetness, and depressed freezing point.

- One of its most important functions is its utilization as a fermentation substrate.
- Lactic acid bacteria produce lactic acid from lactose,

which is the beginning of many fermented dairy products.

- Because of their ability to metabolize lactose,

they have a competitive advantage over many pathogenic and spoilage organisms.

- Relatively constant at 4.8 to 5.2 %
- Lower levels occur in colostrum and mastitis milk to
- Lactose comprises about 52 % of milk solids-non-fat,

about 70 % of whey solids and > 90 % of the solids in milk ultrafiltrate

- Lactose intolerance

– Caused by a shortage of the lactase-enzyme (β-galactosidase)

– Results in non-hydrolysis of lactose into glucose and galactose

– Undigested lactose may support growth of undesirable intestinal

flora, as well as draw water into the intestine causing diarrhoea

and abdominal cramps

Crystallization of lactose occurs in an alpha form which commonly takes a tomahawk shape. This results in the defect called sandiness.

Lactic acid fermentation

- Lactose can be fermented by bacteria that have a β-galactosidase (lactase)-system: LAB
- Lactose → glucose + galactose ⇒ 4 x lactic acid
  - glycolitic or Embden-Meyerhof pathway
  - dependent on conditions and culture, the following reaction products can be formed: D(-) lactic acid, L(+) lactic acid, racemic solution
- When 1 % lactic acid is formed, the reaction process is slowed down due to the pH drop (at this moment 20% of the lactose is metabolized; yogurt: 40%)

Lactic acid fermentation

- Important flavor compounds are:
  - diacetyl (butter flavor)
  - acetaldehyde (yogurt flavor)
  - propionic acid can be formed out of lactic acid by propionic acid bacteria
- $3\ CH_3CHOHCOOH \rightarrow 2\ CH_3CH_2COOH + CH_3COOH + H_2O + CO_2$

Alcohol fermentation

- Lactose → pyruvic acid → acetaldehyde + CO_2 → ethanol
- This fermentation doesn't occur frequently
- Mostly an undesired fermentation by yeasts
- In some sour foaming milk drinks it is desired (kefir, koumiss)

Butyric acid fermentation

- 2 $CH_3CHOHCOOH \rightarrow C_3H_7COOH + 2\ CO_2 + 2\ H_2$
- This fermentation is highly undesirable in cheese because of the gas and off-flavor
- Characteristic for *Clostridia* bacteria

Lactose separation

- Lactose is water-soluble
- Follows the aqueous phase during separation processes
- Present in skimmed milk, buttermilk, whey (often used as
- source for gaining of lactose)

Enzymes

- Enzymes are a group of proteins that have the ability to catalyze chemical reactions and the speed of such reactions. The action of enzymes is very specific. Milk contains both **indigenous** (natural) and **exogenous** (bacterial) enzymes. Exogenous enzymes mainly consist of heat-stable enzymes produced by psychrotrophic bacteria: lipases, and proteinases. There are many indigenous enzymes that have been isolated from milk. The most significant group are the hydrolases:
- lipoprotein lipase
- plasmin
- alkaline phosphatase

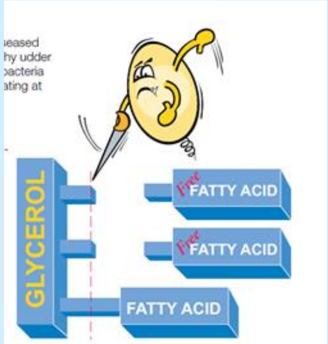


Fig 2.37 Schematic picture of fat splitting by lipase enzyme

Lipoprotein lipase (LPL): A lipase enzyme splits fats into glycerol and free fatty acids. This enzyme is found mainly in the plasma in association with casein micelles. The milkfat is protected from its action by the FGM. If the FGM has been damaged, or if certain cofactors (blood serum lipoproteins) are present, the LPL is able to attack the lipoproteins of the FGM. Lipolysis may be caused in this way.

Plasmin: Plasmin is a proteolytic enzyme; it splits proteins. Plasmin attacks both ß -casein and alpha(s2)-casein. It is very heat stable and responsible for the development of bitterness in pasteurized milk and UHT processed milk. It may also play a role in the ripening and flavour development of certain cheeses, such as Swiss cheese.

Alkaline phosphatase: Phosphatase enzymes are able to split specific phosporic acid esters into phosphoric acid and the related alcohols. Unlike most milk enzymes, it has a pH and temperature optima differing from physiological values; pH of 9.8. The enzyme is destroyed by minimum pasteurization temperatures, therefore, a phosphatase test can be done to ensure proper pasteurization.

- Peroxidase transfers oxygen from hydrogen peroxide to other readily oxidizable substances. It is inactivated at 80°C for a few sec. So it is used to determine pasteurization efficiency. (STORCH'S peroxidase test)
- Catalase splits hydrogen peroxide into water and oxygen. By determining the amount of oxygen that the enzyme release in milk it is possible to estimate the catalase content and thus to learn whether milk come from the sick animal or not. It can be inactivated using HSTS pasteurization.

Vitamins

- Vitamins are organic substances essential for many life processes. Milk includes fat soluble vitamins A , D, E, and K. Vitamin A is derived from retinol and ß -carotene. Because milk is an important source of dietary vitamin A, fat reduced products which have lost vitamin A with the fat, are required to supplement the product with vitamin A. Milk is also an important source of dietary water soluble vitamins:
- B1 - thiamine
- B2 - riboflavin
- B6 - pyridoxine
- B12 - cyanocobalamin
- niacin
- pantothenic acid
- There is also a small amount of vitamin C (ascorbic acid) present in raw milk but is very heat-labile and easily destroyed by pasteurization.

Minerals

- **Sodium (Na), Potassium (K) and Chloride (Cl):** These *free* ions are negatively correlated to lactose to maintain osmotic equilibrium of milk with blood.
- **Calcium (Ca), Magnesium (Mg), Inorganic Phosphorous (P(i)), and Citrate:** This group consists of 2/3 of the Ca, 1/3 of the Mg, 1/2 of the P(i), and less than 1/10 of the citrate in *colloidal* (nondiffusible) form and present in the casein micelle.
- ***Diffusible* salts of Ca, Mg, citrate, and phosphate:** These salts are very pH dependent and contribute to the overall acid-base equilibrium of milk.

Physical Properties

- Density
- Viscosity
- Freezing point

Density

The density of milk and milk products is used for the following;

- to convert volume into mass and vice versa
- to estimate the solids content
- to calculate other physical properties (e.g. kinematic viscosity)

Density, the mass of a certain quantity of material divided by its volume, is dependent on the following:

- temperature at the time of measurement
- temperature history of the material
- composition of the material (especially the fat content)
- inclusion of air (a complication with more viscous products)

With all of this in mind, the density of milk varies within the range of 1027 to 1033 kg m(-3) at 20° C.

- If you use an instrument like (milkotester) you will read lactodensitometer LD as omitting 1.0 showing as 27.3 or 35.1 instead 1.0273 or 1.0351.
- You can calculate DM from LD value using equation:
- **$DM = LD/4 + (1.2 \times F) + 0.55$**
- Where DM dry mass, F: fat.

Product	Fat (%)	SNF (%)	Density (kg/L) at: 4.4°	10°C	20°	38.9°C
Producer milk	4.00	8.95	1.035	1.033	1.030	1.023
Homogenized milk	3.6	8.6	1.033	1.032	1.029	1.022
Skim milk, pkg	0.02	8.9	1.036	1.035	1.033	1.026
Light cream	20.00	7.2	1.021	1.018	1.012	1.000
Heavy cream	36.60	5.55	1.008	1.005	0.994	0.978

Viscosity

Viscosity of milk and milk products is important in determining the following:

- the rate of creaming
- rates of mass and heat transfer
- the flow conditions in dairy processes

Milk and skim milk, excepting cooled raw milk, exhibit Newtonian behavior, in which the viscosity is independent of the rate of shear. The viscosity of these products depends on the following:

- Temperature:
  - cooler temperatures increase viscosity due to the increased voluminosity of casein micelles
  - temperatures above 65° C increase viscosity due to the denaturation of whey proteins
- pH: an increase or decrease in pH of milk also causes an increase in casein micelle voluminosity

Cooled raw milk and cream exhibit **non-Newtonian** behavior in which the viscosity is dependant on the shear rate. Agitation may cause partial coalescence of the fat globules (partial churning) which increases viscocity. Fat globules that have under gone cold agglutination, may be dispersed due to agitation, causing a decrease in viscosity.

Freezing Point

- Freezing point is a ***colligative property*** which is determined by the molarity of solutes rather than by the percentage by weight or volume. In the dairy industry, freezing point is mainly used to determine **added water** but it can also been used to determine lactose content in milk, estimate whey powder contents in skim milk powder, and to determine water activity of cheese.
- The freezing point of milk is usually in the range of -0.512 to -0.550° C with an average of about **-0.522° C**.
- Correct interpretation of freezing point data with respect to added water depends on a good understanding of the factors affecting ***freezing point depression***.
- With respect to interpretation of freezing points for added water determination, the most significant variables are the nutritional status of the herd and the access to water. Under feeding causes increased freezing points. Large temporary increases in freezing point occur after consumption of large amounts of water because milk is iso-osmotic with blood. The primary sources of non-intentional added water in milk are residual rinse water and condensation in the milking system.

$$W_{added}=((FP1-FP2)/FP1)*100$$

FP1: natural

FP2: checked

Acidity

The acidity of a solution depends on the concentration of hydronium ions [H+] in it. When the concentrations of [H+] and [OH–] (hydroxyl) ions are equal, the solution is called neutral. In a neutral solution the number of [H+] per liter of the solution is 1:10 000 000 g or 10^{-7}.

pH represents the hydronium ion concentration of a solution and can mathematically be defined as the negative logarithm of the hydronium ion [H+] concentration.

$$pH = -\log [H^+]$$

Applied to the example above, the pH is $pH = -\log 10^{-7} = 7$

which is the typical value of a neutral solution. When [H+] is 1:100 000 g/l or10^{-6}, the pH is 6 and the solution is acid. Thus the lower the exponent, the higher the acidity.

The pH value of a solution or product represents the present (true) acidity.

Normal milk is a slightly acid solution with a pH falling between 6.5 and 6.7 with 6.6 the most usual value. Temperature of measurement near 25°C. The pH is checked with a pH-meter.

Titratable acidity

Acidity can also be expressed as the titratable acidity. The titratable acidity of milk is the amount of a hydroxyl ion (OH–) solution of a given strength needed to increase the pH of a given amount of milk to a pH of about 8.4, the pH at which the normally used indicator, phenolphthalein, changes color from colorless to pink. What this test really does is to find out how much alkali is needed to change the pH from 6.6 to 8.4.

If milk sours on account of bacterial activity, an increased quantity of alkali is required and so the acidity or titration value of the milk increases. The titratable acidity can be expressed in various values basically as a result of the strength of the sodium hydroxide (NaOH) needed at titration.

°SH = Soxhlet Henkel degrees, obtained by titrating 100 ml of milk with N/4 NaOH , using phenolphthalein as the indicator. Normal milks give values about 7. This method is mostly used in Central Europe.

°Th = Thörner degrees, obtained by titrating 100 ml of milk, thinned with 2 parts of distilled water, with N/10 NaOH, using phenolphthalein as the indicator. Normal milks give values about 17. Mostly used in Sweden and the CIS.

°D = Dornic degrees, obtained by titrating 100 ml of milk with N/9 NaOH, using phenolphthalein as the indicator. Normal milks give values about 15. Mostly used in the Netherlands and France.

% L.a. = per cent lactic acid, obtained as °D with the result divided by 100.

°SH	°Th	°D	% l.a.
1	2.5	2.25	0.0225
0.4	1	0.9	0.009
4/9	10/9	1	0.01

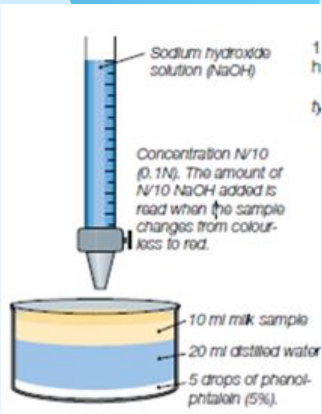


Fig 2.43 Determination of acidity in Thörner degrees, °Th.

Color of milk

- Milk seems as white due to presence of calcium caseinate and fat globules (absorbing and reflecting light respectyively). The presence of caroten and riboflavin affects the color. If caroten is turned to Vit-A, it becomes colorless. Skim milk seems as slightly blue. The gren color of whey from riboflavin.

Colostrum

The first milk that a cow produces after calving is called colostrum. It differs greatly from normal milk in composition and properties. One highly distinctive characteristic is the high content of whey proteins – about 11% compared to about 0.65% in normal milk, as shown in figure 2.44. This results in colostrum coagulating when heated. A fairly large proportion of whey protein is immunoglobulins (Ig G, dominating in colostrum), which protect the calf from infection until its own immunity system has been established. Colostrum has brownish-yellow colour, a peculiar smell and a rather salty taste. The content of catalase and peroxidase is high. Four to five days after calving the cow begins to produce milk of normal composition, which can be mixed with other milk.

Testing milk for quality

Milk from sick animals and milk which contains antibiotics or sediment must not be accepted by the dairy. Even traces of antibiotics in milk can render it unsuitable for the manufacture of products which are acidified by the addition of bacteria cultures, e.g. yoghurt and cheese.

Normally only a general assessment of the milk quality is made at the farm. The composition and hygienic quality is usually determined in a number of tests on arrival at the dairy. The out- come of some of these tests has a direct bearing on the money paid to the farmer.

The following are the most common tests carried out on milk supplies.

The common tests carried out on milk supplies are:
- taste and smell
- cleaning
- sediment
- hygiene
- somatic cell count
- bacteria count
- protein content
- fat content
- freezing point

Chapter 2

UHT

UHT treatment

- In a modern UHT plant the milk is pumped through a closed system. On the way it is preheated, highly heat treated, homogenized, cooled and packed aseptically. Low-acid (pH above 4.5 – for milk more than pH 6.5) liquid products are usually treated at 135 – 150°C for a few seconds, by either indirect heating, direct steam injection or infusion. High-acid (pH below 4.5) products such as juice are normally heated at 90 – 95°C for 15 – 30 seconds.
- All parts of the system downstream of the actual highly heating section are of aseptic design to eliminate the risk of reinfection.
- Compared with traditional sterilization in hydrostatic towers, UHT treatment of milk saves time, labour, energy and space. UHT is a high-speed process and has much less effect on the flavour of the milk. However, regular consumers of autoclave-sterilized milk are accustomed to its “cooked” or caramel flavour and may find the UHT-treated product “tasteless”.

The basis of **UHT**, or ultra-high temperature, is the sterilization of food **before** packaging, then filling into pre-sterilized containers in a sterile atmosphere. Milk that is processed in this way using temperatures exceeding 135° C, permits a decrease in the necessary holding time (to 2-5 s) enabling a **continuous flow** operation.

Some examples of food products processed with UHT are:

- liquid products - milk, juices, cream, yoghurt, wine, salad dressings
- foods with discrete particles - baby foods; tomato products; fruits and vegetables juices; soups
- larger particles - stews

Advantages of UHT

High quality:

The D and Z valves are higher for quality factors than microorganisms. The reduction in process time due to higher temperature (UHTST) and the minimal come-up and cool-down time leads to a higher quality product.

Long shelf life:

Greater than 6 months, without refrigeration, can be expected.

Packaging size:

Processing conditions are independent of container size, thus allowing for the filling of large containers for food-service or sale to food manufacturers (aseptic fruit purees in stainless steel totes).

Cheaper packaging:

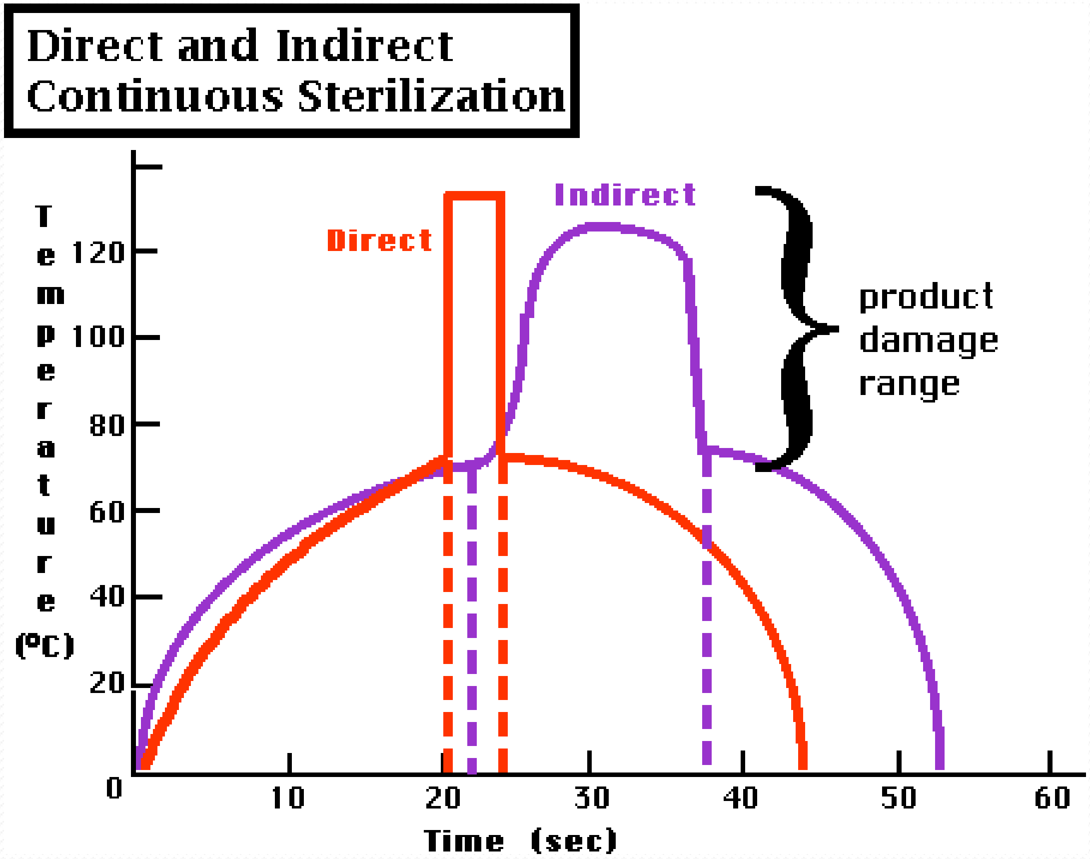
Both cost of package and storage and transportation costs; laminated packaging allows for use of extensive graphics

Production of long life milk

A. In-container sterilization, with the product and package (container) being heated at about 116°C for about 20 minutes. Ambient storage.

B. Ultra High Temperature (UHT) treatment with the product heated at 135– 150°C for 4 – 15 seconds followed by aseptic packaging in packages protecting the product against light and atmospheric oxygen. Ambient storage.

Direct,
In-container sterilization
Two processes are used for sterilization in bottles or cans.
• Batch processing in autoclaves,.
• Continuous processing systems such as: – vertical hydrostatic towers,
– horizontal sterilizers,



Direct and Indirect
Continuous Sterilization
Temperature (ºC)
0
20
40
60
80
100
120
Direct
Indirect
product
damage
range
10
20
30
40
50
60
Time (sec)

Packaging for Aseptic Processing

The most important point to remember is that it must be **sterile**! All handling of product post-process must be within the sterile environment.

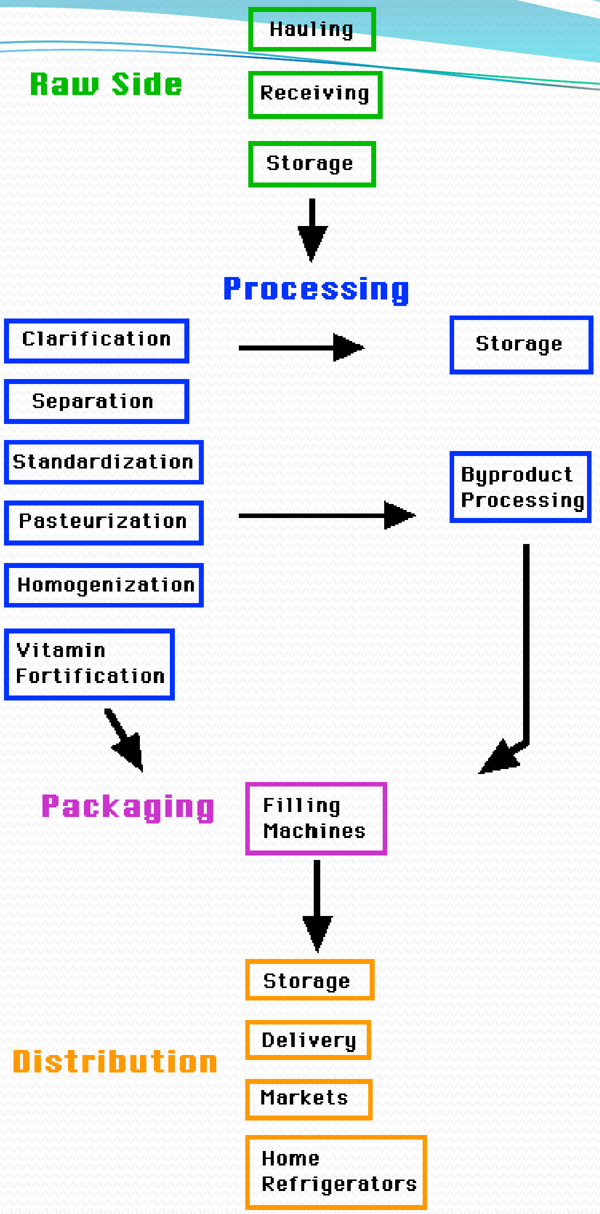
There are 5 basic types of aseptic packaging lines:

1. **Fill and seal:** preformed containers made of thermoformed plastic, glass or metal are sterilized, filled in aseptic environment, and sealed
2. **Form, fill and seal:** roll of material is sterilized, formed in sterile environment, filled, sealed e.g. tetrapak
3. **Erect, fill and seal:** using knocked-down blanks, erected, sterilized, filled, sealed. e.g. gable-top cartons, cambri-bloc
4. **Thermoform, fill, sealed** roll stock sterilized, thermoformed, filled, sealed aseptically. e.g. creamers, plastic soup cans
5. **Blow mold, fill, seal:**

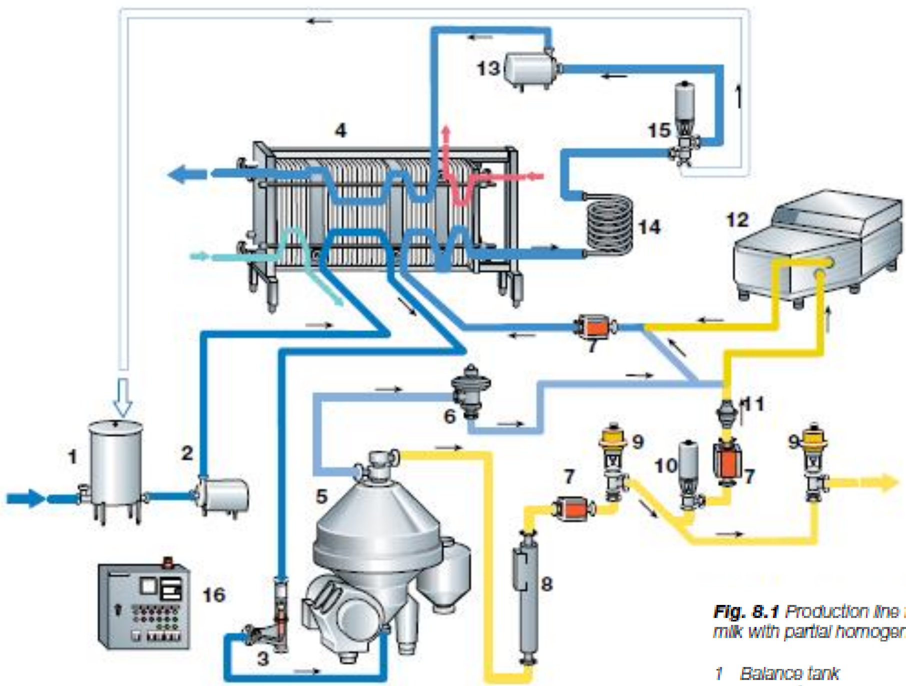
There are several different **package forms** that are used in aseptic UHT processing:

- cans
- paperboard/plastic/foil/plastic laminates
- flexible pouches
- thermoformed plastic containers
- flow molded containers
- bag-in-box
- bulk totes

It is also worth mentioning that many products that are UHT heat treated are not aseptically packaged. This gives them the advantage of a longer shelf life at refrigeration temperatures compared to pasteurization, but it does not produce a shelf-stable product at ambient temperatures, due to the possibility of recontamination post-processing.



Hauling
Raw Side
Receiving
Storage
Processing
Clarification
Separation
Standardization
Pasteurization
Homogenization
Vitamin Fortification
Storage
Byproduct Processing
Packaging
Filling Machines
Storage
Delivery
Distribution
Markets
Home Refrigerators



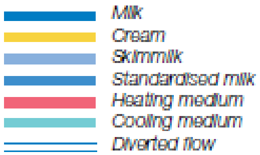
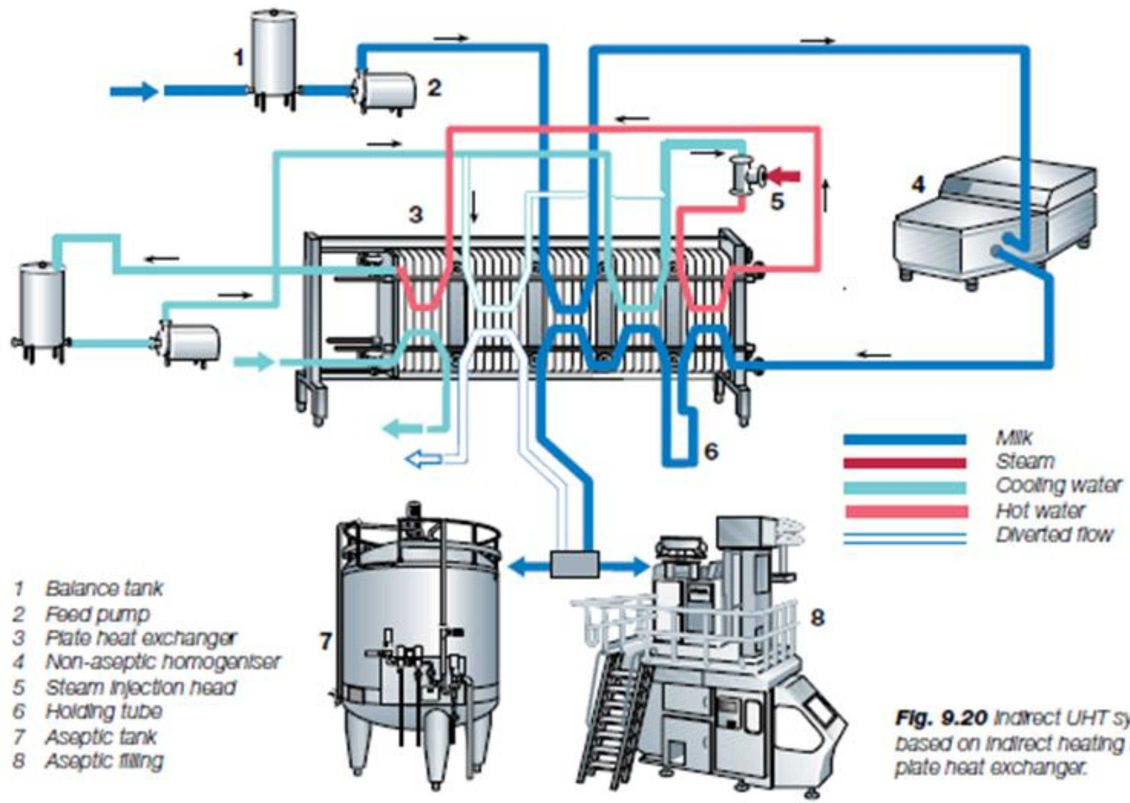


Fig. 8.1 *Production line for market milk with partial homogenisation.*

1 Balance tank
2 Product feed pump
3 Flow controller
4 Plate heat exchanger
5 Separator
6 Constant pressure valve
7 Flow transmitter
8 Density transmitter
9 Regulating valve
10 Shut-off valve
11 Check valve
12 Homogeniser
13 Booster pump
14 Holding tube
15 Flow diversion valve
16 Process control



1 Balance tank
2 Feed pump
3 Plate heat exchanger
4 Non-aseptic homogeniser
5 Steam injection head
6 Holding tube
7 Aseptic tank
8 Aseptic filling

Fig. 9.20 Indirect UHT system based on indirect heating in a plate heat exchanger.

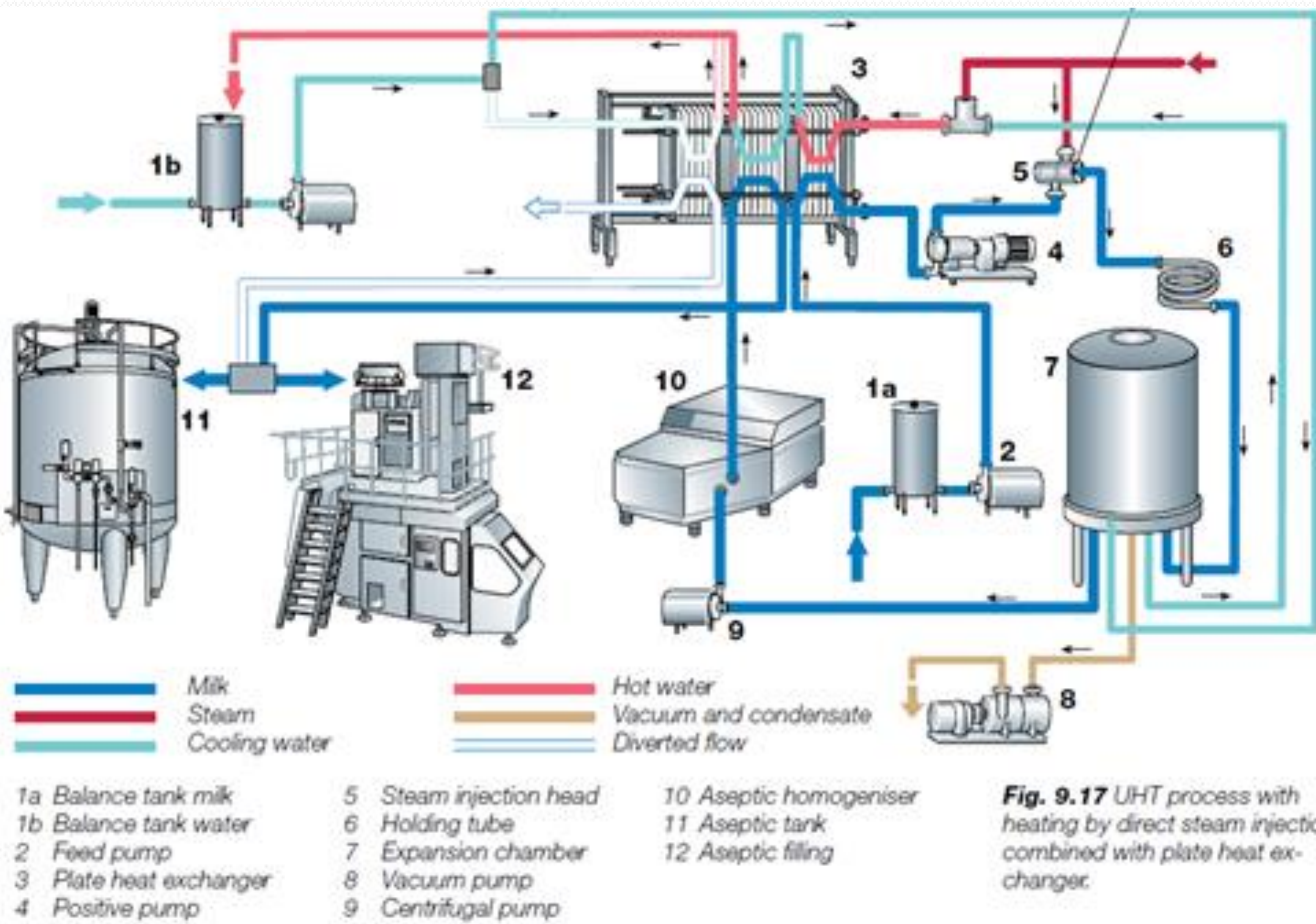


Fig. 9.17 UHT process with heating by direct steam injection combined with plate heat exchanger.

Yogurt (From Dairy Processing Handbook, tetra pak)

Yogurt (also spelled yogourt or yoghurt) is a semi-solid fermented milk product which originated centuries ago in Turkey. It's popularity has grown and is now consumed in most parts of the world. Although the consistency, flavour and aroma may vary from one region to another, the basic ingredients and manufacturing are essentially consistent

Raw milk (no antibiotics, pathogens, no pesticides) (*pH: 6.8-6.5*)

Standardization (fat and DS)

Homogenization (optional, if cream layer is wanted, not applied)

Heat treatment (90-95C- 5 min)

Cooling (44-46C)

SET YOGURT	STIRRED YOGURT

(Inoculation with 4-5% SC & incubation for 2.5h at 42-43C)

Set yogurt

Inoculation	packaging
Packaging	inoculation
Incubation	Incubation

Incubation (all until pH:4.6-4.7)

Cooling (5C)

Storage

Stirred yogurt

Inoculation

Incubation

Mixing and then cooling

(10-20C)

Packaging & Storage

(If fruit particles or flavoring agents will be added after incubation or in the set yogurt before filling the packages the particles are placed in to the packages.) After inoculation yogurt must be kept at <15C for 12-18 h to improve gelation of yogurt.

Control, preparation & storage (no antibiotics, pathogenic mo's etc) — Raw milk   MDS 12.5 - 12.7 % pH: 6.8 - 6.9

↓

Fat st. & water evaporation — Standardisation   3.15 - 2.55 % fat ; 14 - 17 % DS   pH: 6.4 - 6.7

↓

condensed milk

↓

homogenization

↓

heat treatment

↓

cooling (44 - 46 °C)   pH: 6.1 - 6.7

↓   ↓

4-5 % SC → Inoculation   in the bulk   pH: 6.1 - 6.4

2.5 h → if direct-to-vat cultures used 4-6 h

↓

Incubation → to pH: 4.6 - 4.7

Stirred yogurt

↓

mixing (if necessary fruit particles or parts ~~after~~ heat treated)

↓

cooling (10 - 20 °C) — cooling might takes place in 30 min if bulk starter used

↓ fast cooling cause shrinkage of curd (slow cooling → acidity ↑)

packaging

↓

storage (~ 5 °C)

↓

STIRRED YOGURT (fruity or not)

pH: 4 at 10 °C min

pH: 4.4 - 4.2

Set yogurt

if flavored, addition of flavor

↓

packaging → inoculation   /   inoculation → packaging

↓

Incubation (41 - 43 °C 2 - 3 h)

↓

cooling (≈ 4 - 6 °C)

↓

storage ~ 5 °C

↓

SET YOGURT (flavored or not)

YOGURT PRODUCTION

After inoculation, yogurt must be kept stable at < 15 °C for 12 - 18 h to ~~prevent~~ improve gelation of yogurt

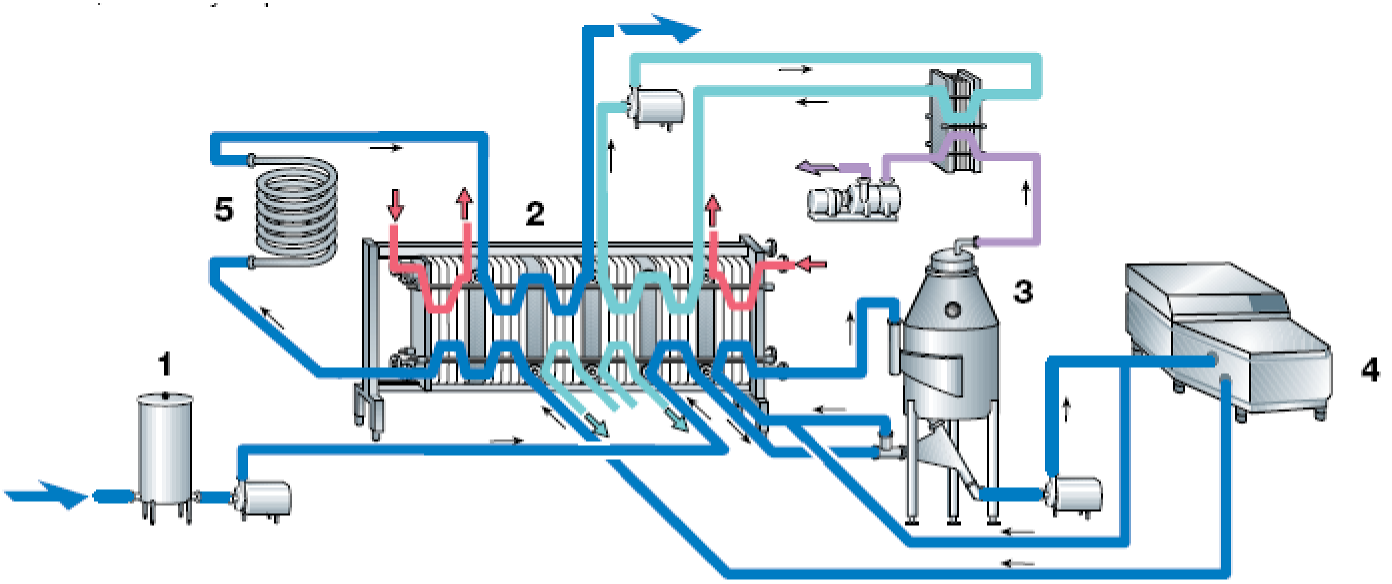


Fig. 11.9 General pre-treatment for cultured milk products.

1 Balance tank
2 Plate heat exchanger
3 Evaporator
4 Homogeniser
5 Holding tube

Production lines

The pretreatment of the milk is the same, regardless of whether set or stirred yoghurt is to be produced. It includes standardisation of the fat and DM contents, heat treatment and homogenisation.

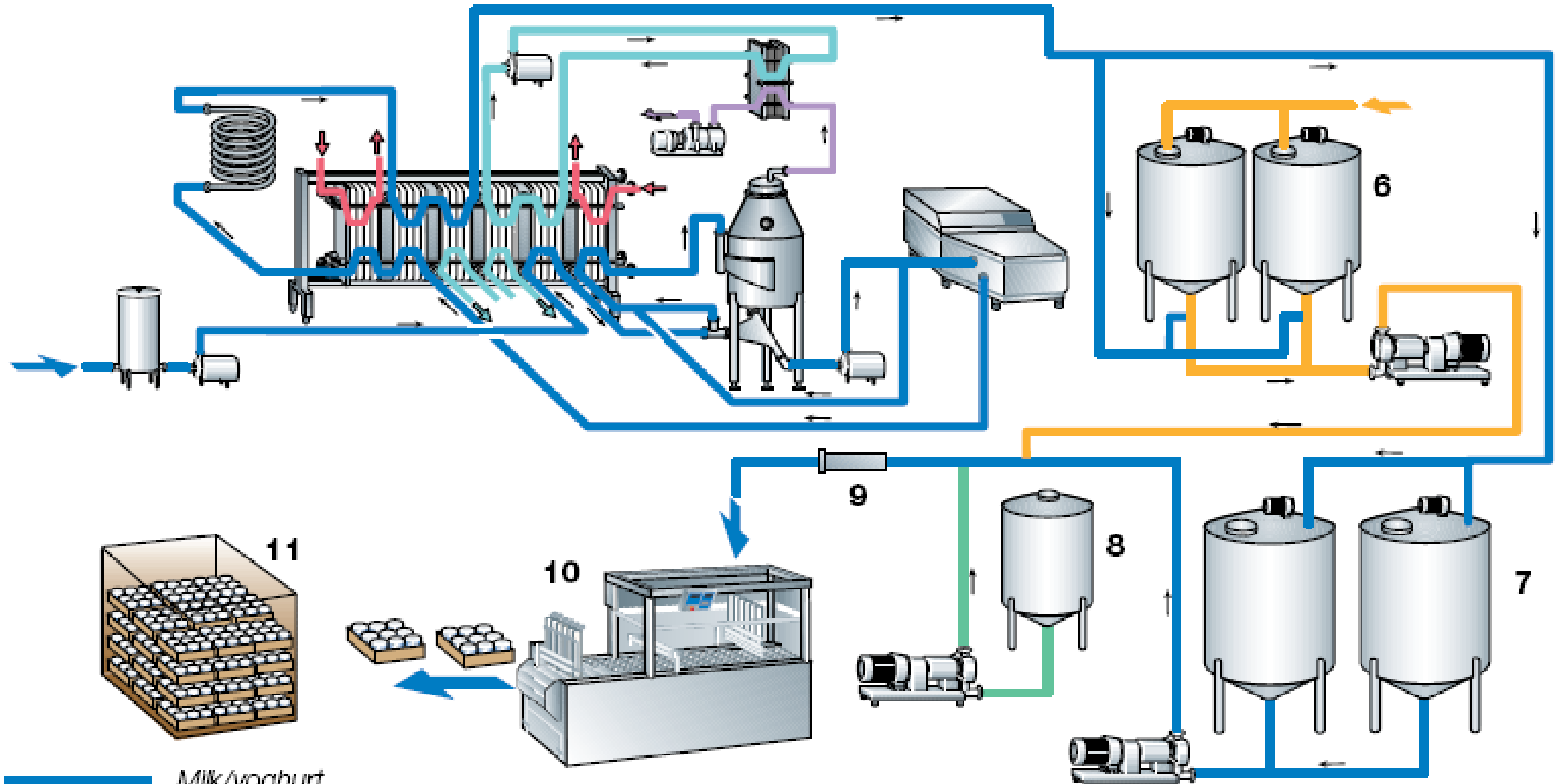
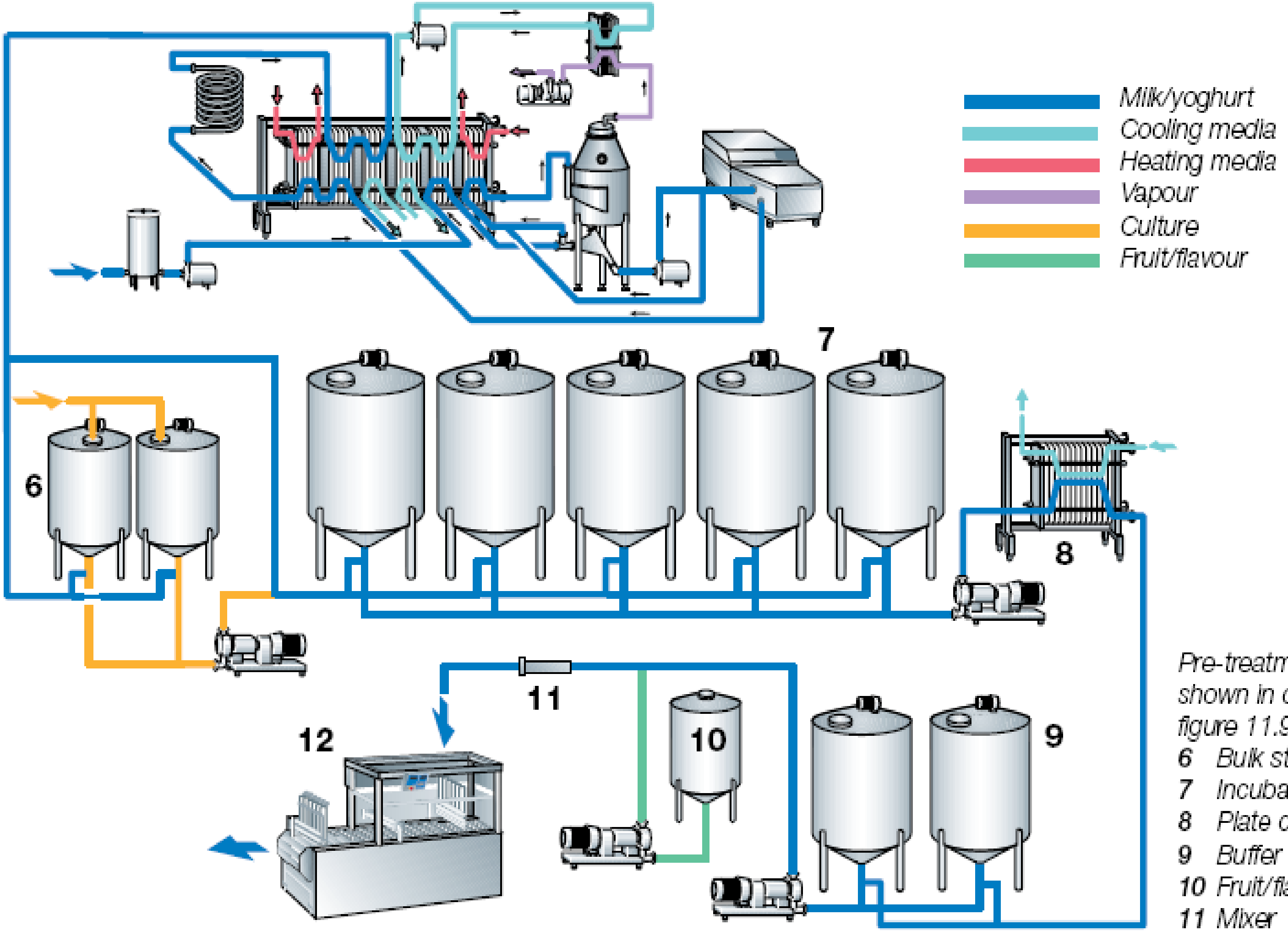


Fig. 11.17 Production line for set yoghurt.

An alternative production system

Another and more frequently used system for production of *set yoghurt* is illustrated in figure11.18. This system offers flexibility in production planning



Pre-treatment is shown in detail in figure 11.9

6 Bulk starter tanks
7 Incubation tanks
8 Plate cooler
9 Buffer tanks
10 Fruit/flavour
11 Mixer
12 Packaging

Fig. 11.14 *Production line for stirred yoghurt.*

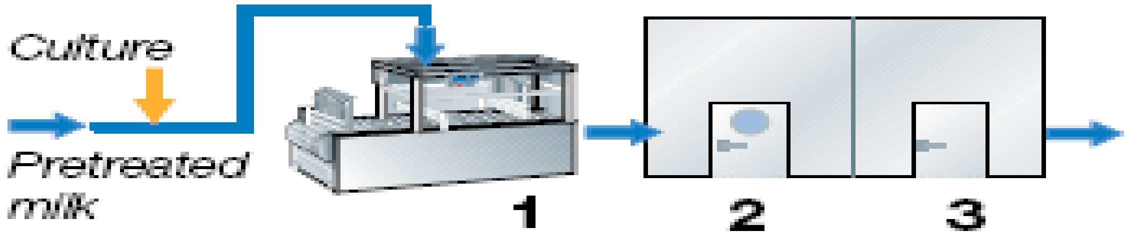


Fig. 11.3 Set yoghurt.
1 Cup filler
2 Incubation room
3 Rapid cooling room

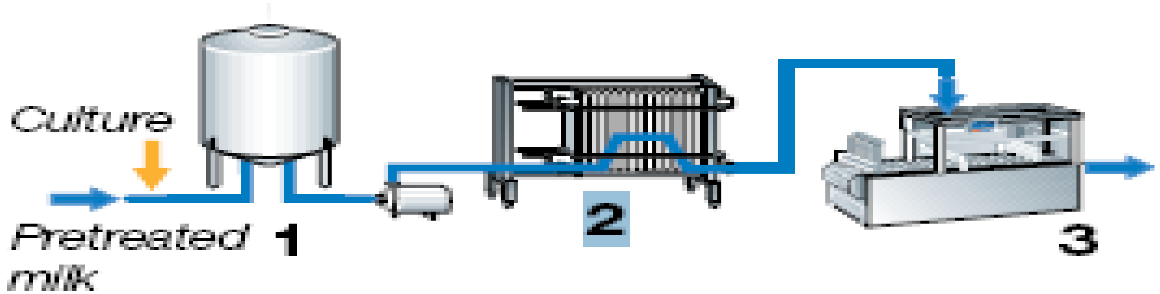
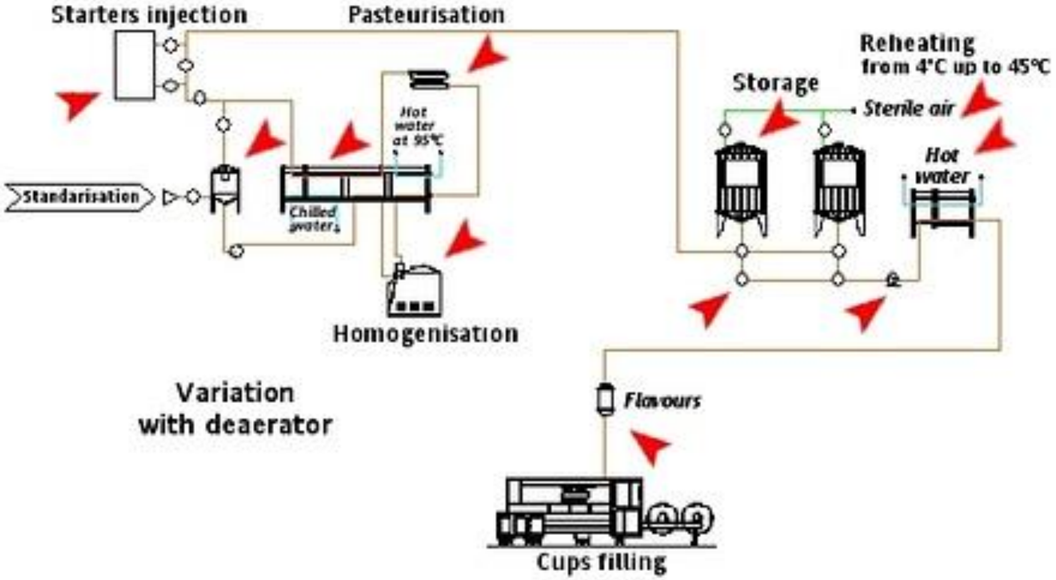


Fig. 11.4 Stirred yoghurt.
1 Incubation tank
2 Cooler
3 Cup filler

Set Yogurt


Starters injection
Pasteurisation
Reheating
from 4°C up to 45°C
Storage
Sterile air
Hot water at 95°C
Hot water
Standarisation
Chilled water
Homogenisation
Variation
with deaerator
Flavours
Cups filling

Control, preparation & storage (no antibiotics, pathogenic mo's etc) → Raw milk   MDS 12.5 - 12.7 %   pH, 6.8 - 6.9

↓

Fat st. & water evaporation → Standardisation   8.15 - 2.55 % fat ; 14 - 17 % DS   pH, 6.4 - 6.7

↓

condensed milk

↓

homogenization

↓

heat treatment

↓

cooling (44 - 46 °C)   pH, 6.1 - 6.7

↓

4 - 5 % SC → Inoculation   in the bulk 2.5 h → if direct-to-vat cultures used 4 - 6 h.   pH, 6.1 - 6.4

↓

Incubation → to pH, 4.6 - 4.7

↓

mixing (if necessary fruit particles or parts ~~after~~ heat treated)

↓

cooling (10 - 20 °C) { cooling might takes place in 30 min if bulk starter used

↓ fast cooling cause shrinkage of curd (slow cooling → acidity ↑)

packaging

↓

Storage (~ 5 °C)

↓

STIRRED YOGURT (fruity or not)

pH, 4 at 10 °C min

pH, 4.4 - 4.2

---

if flavored, addition of flavor

↓

packaging → Inoculation

or

inoculation → packaging

↓

Incubation (41 - 43 °C 2 - 3 h)

↓

cooling (≈ 4 - 6 °C)

↓

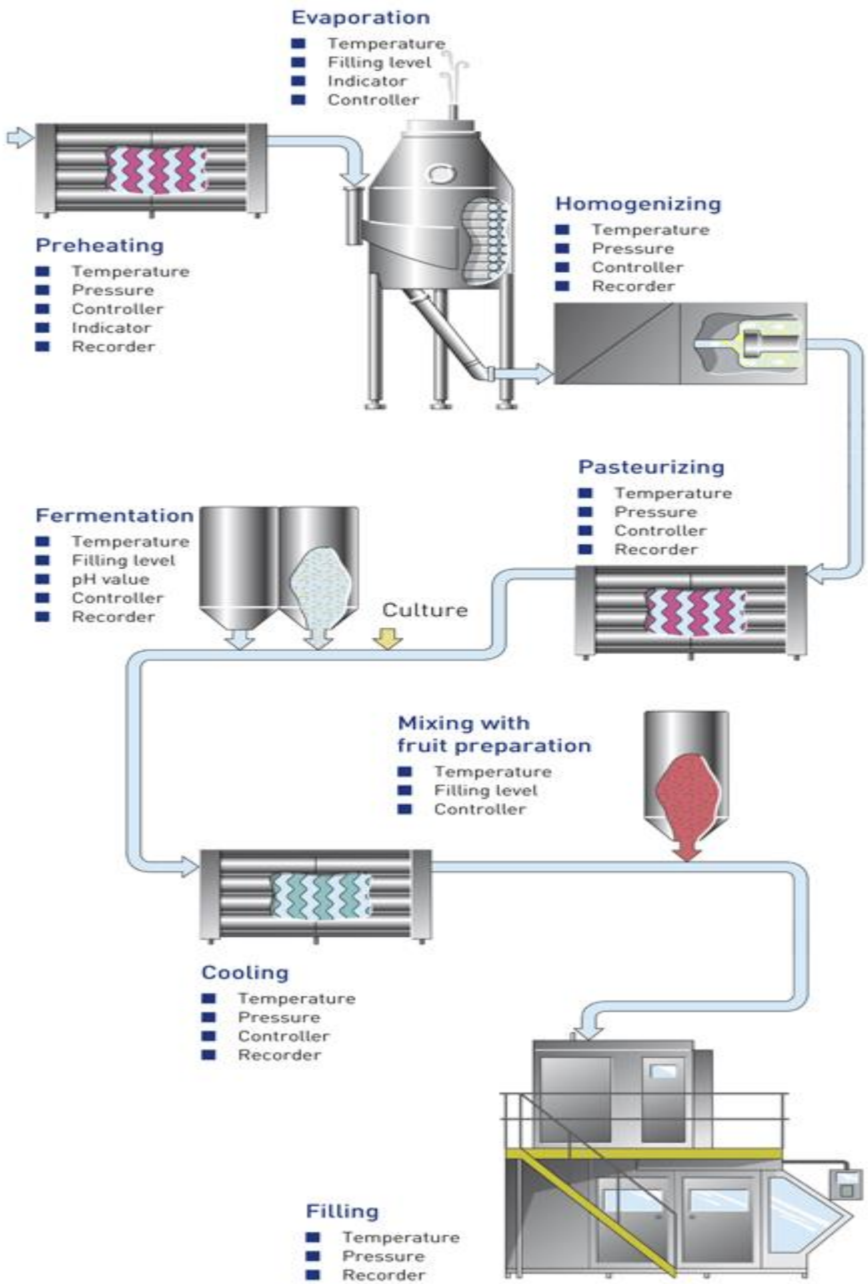
Storage ~ 5 °C

↓

SET YOGURT (flavored or not)

YOGURT PRODUCTION

After inoculation, yogurt must be kept stable at < 15 °C for 12 - 18 h to ~~prevent~~ improve gelation of yogurt



Evaporation
Temperature
Filling level
Indicator
Controller
Preheating
Temperature
Pressure
Controller
Indicator
Recorder
Homogenizing
Temperature
Pressure
Controller
Recorder
Pasteurizing
Temperature
Pressure
Controller
Recorder
Fermentation
Temperature
Filling level
pH value
Controller
Recorder
Culture
Mixing with
fruit preparation
Temperature
Filling level
Controller
Cooling
Temperature
Pressure
Controller
Recorder
Filling
Temperature
Pressure
Recorder

1. Adjust Milk Composition & Blend Ingredients

- Milk composition may be adjusted to achieve the desired fat and solids content. Often dry milk is added to increase the amount of whey protein to provide a desirable texture. Ingredients such as stabilizers are added at this time.
- The milk is **clarified** and **separated** into cream and skim milk, then **standardized** with other dairy ingredients to achieve the desired fat and milk solids-not-fat content. The various ingredients are then blended together in a mix tank equipped with a powder funnel and an agitation system.

2. *Heat treatment*

The mixture is then **pasteurized** using a continuous plate heat exchanger for 30 min at 85° C or 10 min at 95° C. These heat treatments, which are much more severe than fluid milk pasteurization, are necessary to achieve the following:

a) produce a relatively sterile and conducive environment for the starter culture,
b) denature and coagulate whey proteins to enhance the viscosity and texture;
c) this effect results from modification of the surface of the casein micelle so that milk thickens in a structurally-different manner than it would in a non-heated acid gel

Optimum results are achieved by heat treatment at 90 – 95°C and a holding time of about 5 minutes. That temperature/time combination denatures about 70 – 80% of the whey proteins. In particular the b-lactoglobulin, which is the principal whey protein, interacts with the κ-casein, thereby helping to give the yoghurt a stable “body”.

UHT treatment and sterilization of milk intended for culturing do not, however, have the same favorable influence on viscosity, for reasons not yet fully understood.

Choice of culture

Culture laboratories now use advanced techniques to produce customised yoghurt cultures to satisfy specific flavour and viscosity requirements. Some examples of end-product properties that can be achieved are:

- High viscosity with low acetaldehyde content and a fairly high final pH.
- Low viscosity and medium acetaldehyde content, suitable for drinking yoghurt, etc.

A ratio of 1:1, ST to LB, inoculation is added to the jacketed fermentation tank. A temperature of 43° C is maintained for 2-2.5 h under quiescent (no agitation) conditions. This temperature is a compromise between the optimums for the two microorganisms (ST 39° C; LB 45° C). The titratable acidity is carefully monitored until the TA is 0.85 to 0.90% (pH 4.5). At this time the jacket is replaced with cool water and agitation begins, both of which stop the fermentation. The coagulated product is cooled to 5-22° C, depending on the product. Fruit and flavor may be incorporated at this time, then packaged. The product is now cooled and stored at refrigeration temperatures (5° C) to slow down the physical, chemical and microbiological degradation.

3. Homogenize

The main motives for homogenizing milk intended for cultured milk production are to prevent creaming during the incubation period and to assure uniform distribution of the milk fat.

Homogenization also improves the stability and consistency of cultured milks, even those with low fat contents.

Homogenization with subsequent heating at high temperature, usually 90 – 95°C for about 5 minutes, has a very good influence on the viscosity..

4. Cool Milk

The milk is cooled to 42°C to bring the yogurt to the ideal growth temperature for the starter culture.

- **5. Inoculate with Starter Cultures**

The starter cultures are mixed into the cooled milk.

- **6. Hold**

The milk is held at 108°F (42°C) until a pH 4.5 is reached. This allows the fermentation to progress to form a soft gel and the characteristic flavor of yogurt. This process can take several hours.

- **7. Cool**

The yogurt is cooled to 7°C to stop the fermentation process.

8. Add Fruit & Flavors

Fruit and flavors are added at different steps depending on the type of yogurt. For set style yogurt the fruit is added in the bottom of the cup and then the inoculated yogurt is poured on top and the yogurt is fermented in the cup. For swiss style yogurt the fruit is blended with the fermented, cooled yogurt prior to packaging.

9. Package

The yogurt is pumped from the fermentation vat and packaged as desired.

Other yogurt products include:
Sweetened stirred style yogurt with fruit preparation
Fruit-on-the-bottom set style: - fruit mixture is layered at the bottom followed by inoculated yogurt, incubation occurs in the sealed cups
Ayran
Soft-serve and Hard Pack frozen yogurt

Probiotic yogurts: it has become quite common to add probiotic bacterial strains to yogurt (those with proven health-promoting benefits, in addition to ST and LB. These could include *Lactobacillus acidophilus*, *Lactobacilus casei*, or *Bifidobacterium* spp. When probiotics are added, it has also become common to add ingredients known as prebiotics, such as inulin, which will, after digestion, aid in the growth of the probiotics in the colon. Inulin, for example, is a polymer of fructose (fructo-oligosaccharide) that is indigestible in the small intestine because we do not have sufficient enzymes to cleave the fructose bonds. However, in the colon, bacterial enzymes can easily release free fructose, which has been shown to positively affect the growth of the probiotic organisms.