Chapter 19

Ice cream

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.

Sales of ice cream to the general public in the United States started in the eighteenth century, but did not become widespread until the nineteeth century, when the first wholesale firm appeared on the market.

Categories of ice cream

Ice cream can be divided into four main categories according to the ingredients used:

- Ice cream made exclusively from milk products,
- Ice cream containing vegetable fat,
- Sherbet ice cream made of fruit juice with added milk fat and milk solids-non-fat,
- Water ice made of water, sugar and fruit concentrate.

The first two types of ice cream account for an estimated 80 – 90% of the total world production. The following description is therefore confined to these two types. Typical ice cream formulas are shown in table 19.1.

Table 19.1
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.

The ice cream process

The ice cream process consists of the basic steps shown in figure 19.1.

Reception and storage of raw materials

Raw materials are stored in tanks, silos, drums or bags depending on their physical form. Arrangements for reception depend on the capacity of the plant.

Dry products used in comparatively small quantities, such as whey powder, stabilisers and emulsifiers, cocoa powder, etc., are usually delivered in bags. Sugar and milk powder can be delivered in containers and blown to storage silos by compressed air. Bulk materials such as sugar and milk powder may also be delivered in bags that are emptied by special machines.

Liquid products such as milk, cream, condensed milk, liquid glucose and

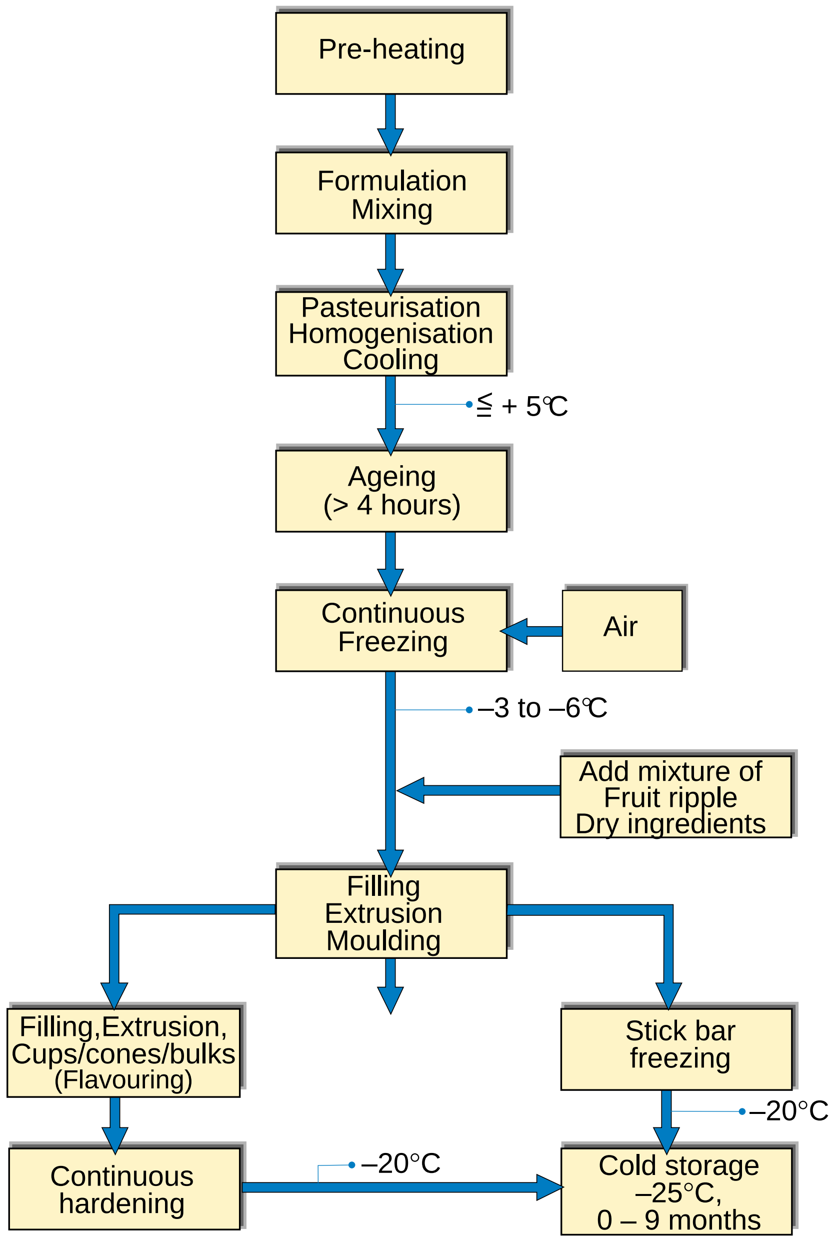


Fig. 19.1 *The ice cream process.*

vegetable fats are delivered by tankers. Milk products are chilled to about 5°C before storage, while sweetened condensed milk, glucose and vegetable fat must be stored at a relatively high temperature (30 – 50°C) to keep the viscosity low enough for pumping. Milk fat is delivered in the form of anhydrous milk fat (AMF), or in blocks of butter which are melted and pumped to storage tanks where a temperature of 35 – 40°C must be maintained. In the latter case batches for one to two days' production are prepared to avoid oxidation of the milk fat, unless it is stored under an inert gas (N_2).

Formulation

The weight and/or volume of the individual ingredients must be carefully determined before they are mixed. To obtain a well-balanced mix it is essential to calculate the percentage of milk solids-non-fat (MSNF) to be used. This is done by subtracting the percentage of fats, sugar, emulsifiers and stabilisers (E/S) you wish to use from 100 and multiplying the remainder by 0.15.

For example, to produce ice cream with 10% wt. fat, 15% wt.of sugar and 0.5% wt.of E/S, the following calculation will give the required MSNF in percent by weight:

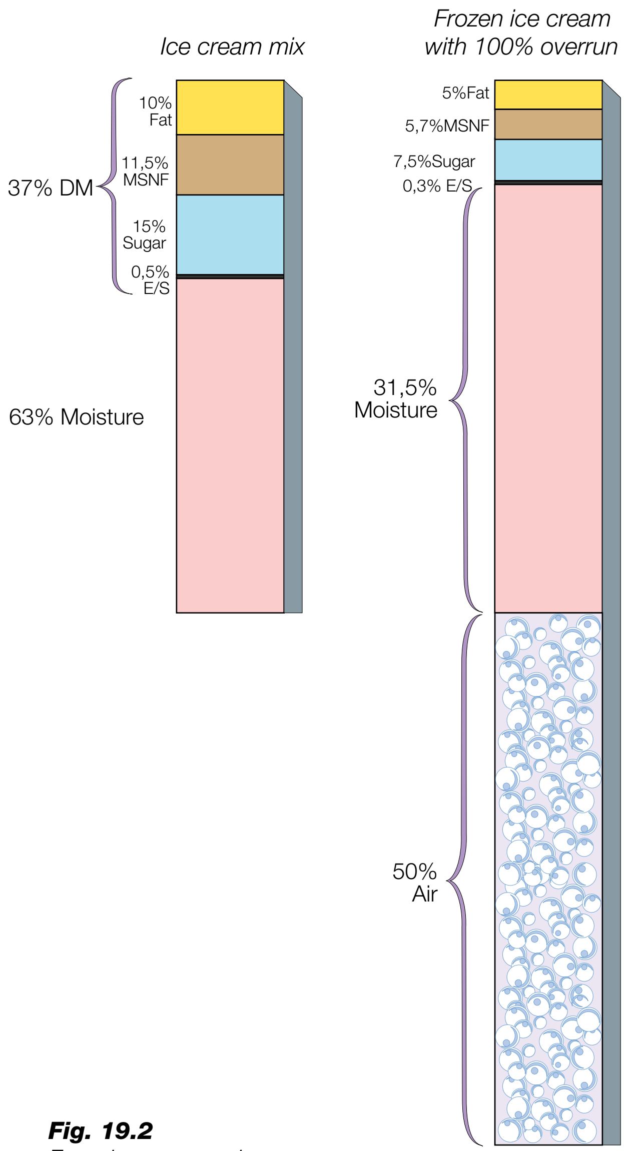


Fig. 19.2
From ice cream mix to ice cream.

(100 – 10 – 15 – 0.5) x 0.15 = 11.5 % wt. of MSNF

When the amount of MSNF is known, the total dry matter (DM) content of the mix is thus fixed and the amount of each ingredient to be used can be calculated. In addition, the overrun in a typical ice cream should be about 2.5 – 2.7 times the total DM of the mix. In the above example the overrun should thus be

2.7 x (10 + 15 + 0.5 + 11.5) = 100 %.

The compositions of the ice cream mix and the resulting ice cream are visualised in figure 19.2.

After freezing, during which a controlled volume of air is also whipped in, the volume of the original mix is almost doubled, which also means that the percentages of ingredients by volume are nearly halved.

Ingredients

The various ingredients are received, weighed and analysed 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 skimmilk. 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 emulsifcation by reducing the surface tension of liquid products. They also help to stabilise 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.

Stabilisers

A stabiliser 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 stabiliser forms a network which prevents the water molecules from moving freely. There are two types: protein and carbohydrate stabilisers. 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.

The most common ice cream flavours are vanilla, nougat, chocolate, strawberry and nut.

Flavouring

Flavouring additives are very important to the customer's choice of ice cream. The most commonly used flavours are vanilla, nougat, chocolate, strawberry and nut. These can be added at the mixing stage. If flavouring 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.

Colouring

Colouring agents are added to the mix to give the ice cream an attractive appearance and to improve the colour of fruit flavouring additives. The colouring agent is usually added in the form of a concentrate. Only approved colouring 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 pasteurised and homogenised.

In large production plants it is common to have two mix tanks of a volume corresponding to the hourly capacity of the pasteuriser, 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.

Fig. 19.3 *Continuous ice cream freezer, automatically controlled.*

Homogenisation and pasteurisation

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 homogeniser. After homogenisation at 14 – 20 MPa (140 – 200 bar), the mix is pasteurised.

In batch production the mix, including a metered quantity of fat, is first pasteurised in the combined mixing and processing tank, typically at 70°C with a hold of 30 minutes. The mix is then passed through the homogeniser, cooled to 5°C in a plate heat exchanger and transferred to the ageing tank.

In large-scale plants the homogenised mix is returned to the plate heat exchanger and pasteurised at 83 – 85°C for about 15 seconds. The pasteurised mix is then cooled to 5°C and transferred to an ageing tank.

Ageing

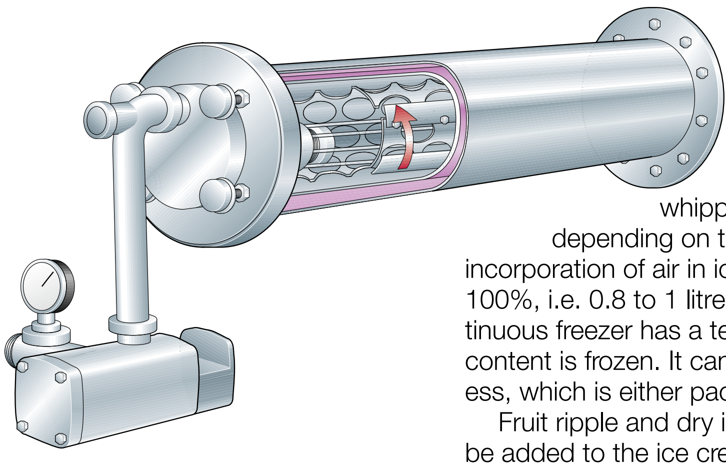
The mix must be aged for at least 4 hours at a temperature between 2 and 5°C with continuous gentle agitation. Ageing allows time for the stabiliser to take effect and the fat to crystallise.

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 19.3 shows the exterior and figure 19.4 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.



Freezing medium

Fig. 19.4 *Principle of a continuous ice cream freezer, manually controlled.*

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.

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 flavours, and the products may be decorated with nuts, fruits and chocolate. The packs are lidded 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 flavours.

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. An extrusion unit is shown in figure 19.5.

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.

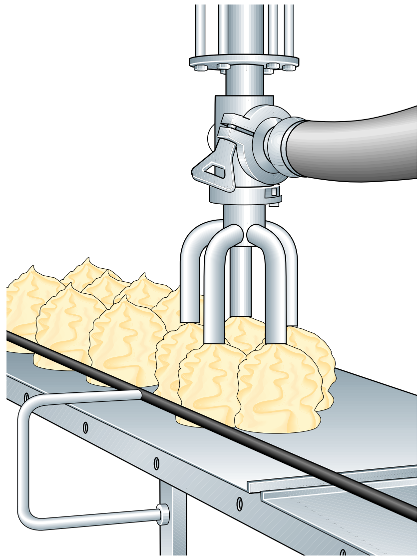


Fig. 19.5 *An extruder in a tray tunnel.*

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 cartoning.

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

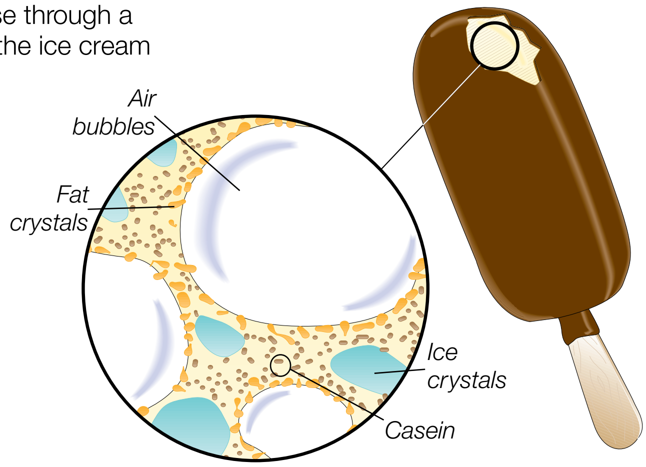


Fig. 19.7 *Texture of an ice cream bar.*

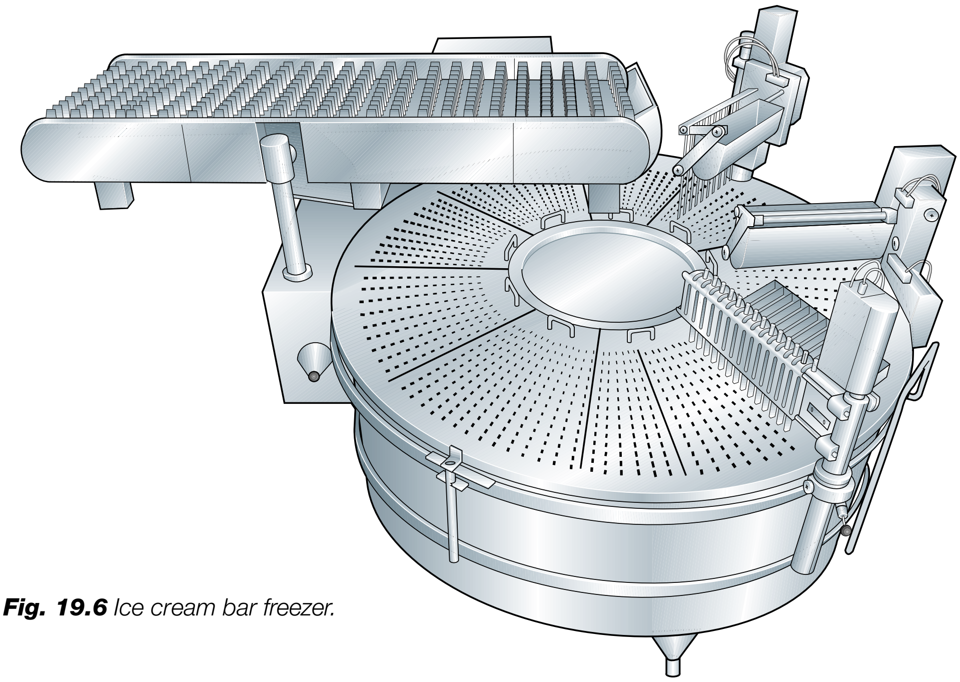


Fig. 19.6 *Ice cream bar freezer.*

Figure 19.6 shows a type of moulded stick novelty freezer for manufacturing ice cream and water ice bars. The cutaway view of an ice cream bar in figure 19.7 shows the texture of the ice cream.

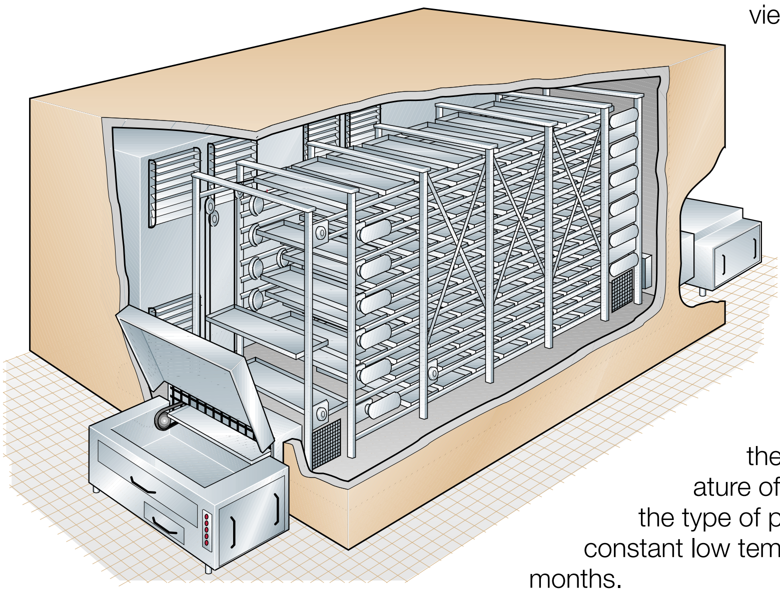


Fig. 19.8 Hardening tunnel.

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.

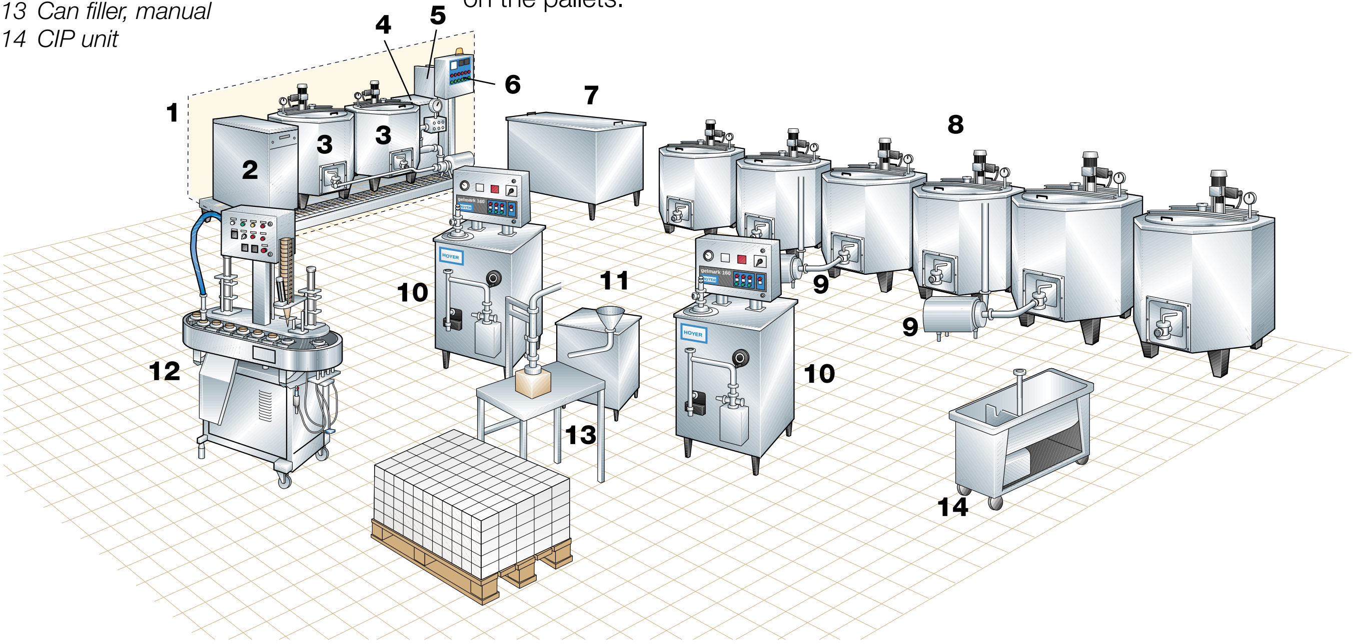
Examples of production plants

Two plants are illustrated to give an idea of the product flow in ice cream production. One of them is a relatively small plant with a hourly capacity of 500 litres of ice cream, figure 19.9, while the other one, figure 19.10, is a large plant producing 5 000 – 10 000 litres of various types of ice cream per hour.

In the small plant, the packaged and cartoned products are typically hardened in the cold store at a temperature of –35 to –40°C. To shorten the hardening period as much as possible, the cartons must be openly spaced on the pallets.

Fig. 19.9 Production plant for 500 litres per hour of ice cream products.

1 Ice cream mix preparation module 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



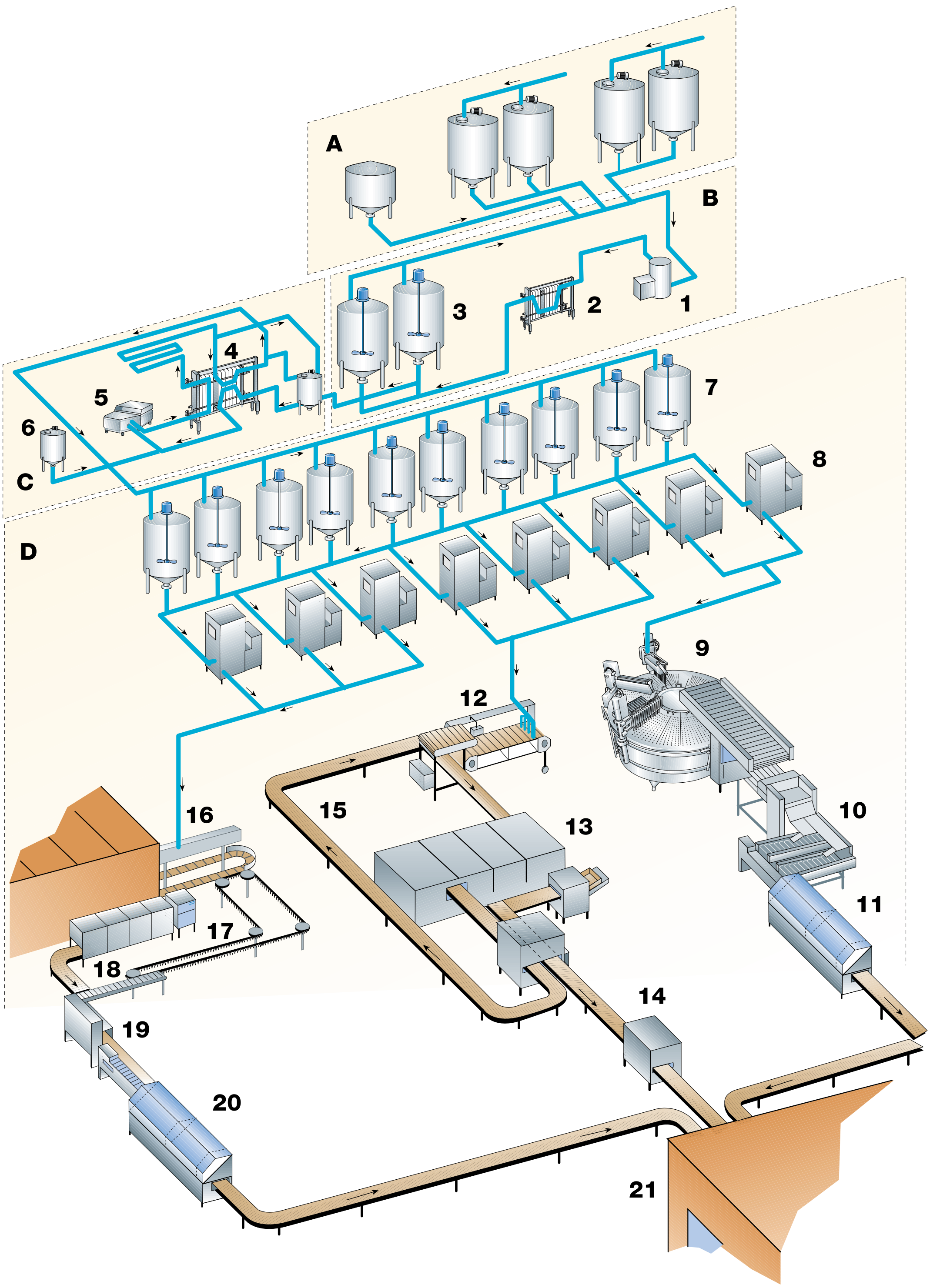


Fig.19.10 *Large ice cream plant for production of 5 000–10 000 l/h of various types of ice cream.*

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