FROZEN DAIRY PRODUCTS

ICE CREAM

There are numerous types of edible ice, essentially mixtures of water, sugar, flavor substances, and other components, which are partly frozen and beaten to form a rigid foam. In most types, milk or cream is an important ingredient. Some examples of the composition are given in Table 17.1. Nowadays, a part of the milk solids-not-fat is often substituted by whey constituents to lower ingredient costs. In some countries, the milk fat is often substituted by vegetable fat, for instance, partly hydrogenated palm kernel oil. Dairy ice cream is the product discussed here.

Soft ice cream often causes microbiological problems, though it is kept cold and its high sugar content may, to some extent, act as a preservative. Pathogenic organisms will not grow, but they are not killed. Bacteria are enabled to grow if the temperature becomes too high locally or temporarily, as can easily happen with the practices at vending places. Abundant growth can occur in poorly cleaned processing equipment and in the mix, if stored for too long. Hence, strict hygienic measures have to be taken. Large numbers of enterobacteria (*E. coli*, *Salmonella* spp.) are frequently found.

TABLE 17.1
Approximate Composition (Percentage by Weight) of Some Types of Ice Cream

Constituent	Dairy Ice Cream	Ice Milk	Sherbet	Ice Lolly
Milk fat	10	4	2	0
Nonfat milk solids	11	12	4	0
Added sugar	14	13	22	22
Additives	0.4	0.6	0.4	0.2
% Overrun[a]	100	85	50	~0
Edible energy, kJ/100 ml	390	300	340	370

[a] % overrun means the relative increase in volume by air beaten in.

Manufacturing of Ice cream

The first stages of the manufacture need little elaboration. Composing the *mix* is relatively simple. The additives are 'emulsifier,' stabilizer (a thickening agent, usually a mixture of polysaccharides), and flavor and color substances. The role of the additives is discussed in Subsection 17.3.3. Clearly, ingredients such as fruit pulp and ground nuts should be added after the homogenization.

Pasteurization of the mix primarily serves to kill pathogenic and spoilage microorganisms. Additives added after homogenization should usually be pasteurized separately. The second important objective is to inactivate lipase because it is still a little active even at a very low temperature. Bacterial lipases should thus be prevented from occurring. Finally, quite intense heating of the mix is desirable (especially for hardened ice cream) to decrease its susceptibility to autoxidation; a cooked flavor may be undesirable, according to the added flavor substances.

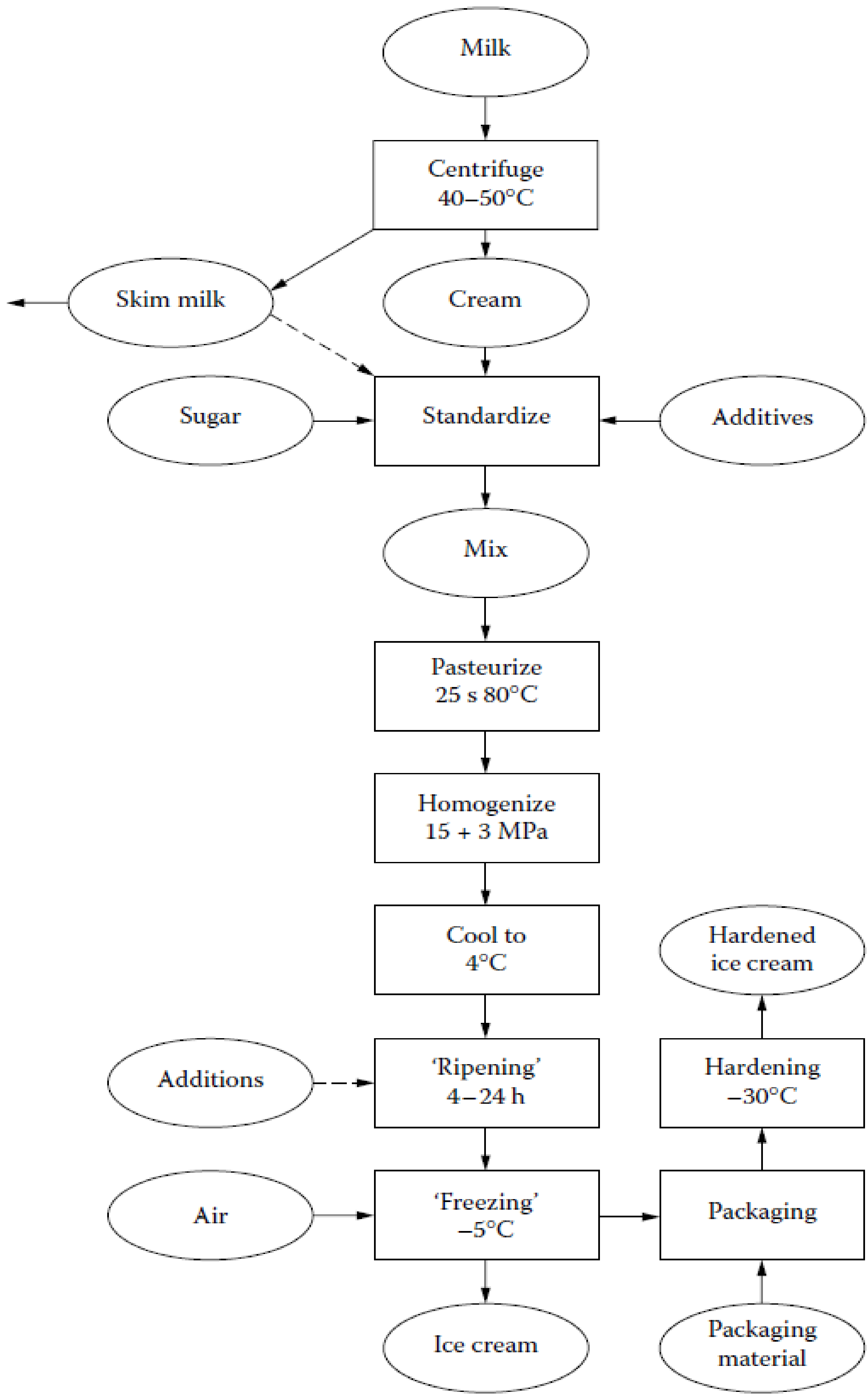
Homogenization is specifically meant to give the ice cream a sufficiently fine, smooth texture (see Subsection 17.3.2). Excessive formation of homogenization clusters should be avoided as it causes the mix to become highly viscous and the desirable fine texture not to be achieved; consequently, the homogenization pressure should be adapted to the fat content, to the pasteurization intensity, and, if need be, to the further composition of the mix (see Section 9.7).

Cooling and *ripening* (keeping cold for some time) are desirable for two reasons. The fat in most of the fat globules should largely be crystallized before the ice cream mix enters the freezer; it is important to note that considerable undercooling may occur because the fat globules are very small (Subsection 2.3.5.2). Certain stabilizers such as gelatin and locust bean gum need considerable time to swell after being dispersed. Some added emulsifiers need considerable time at low temperature to displace protein from the fat globules (Subsection 17.3.2).

Freezing implies rapid cooling of the mix to a few degrees below zero; in this way, ice is formed while air is beaten in. This must run simultaneously: after the bulk of the water is frozen, any beating in of air becomes impossible, and freezing after air is beaten in leads to insufficient churning of the fat globules (see next subsection) and can damage the foam structure. Moreover, the vigorous beating enables rapid cooling, because of which small ice crystals can be formed. Figure 17.9 gives the approximate amount of frozen water as a function of temperature; a different composition causes a somewhat different curve. Usually, freezing is done in a scraped-surface heat exchanger — essentially a horizontal cylinder that is cooled externally by means of direct evaporation (–20 to –30°C) and equipped with a rotating stirrer (150 to 200 r.p.m.) that scrapes the wall. A layer of ice is formed on the wall. Pieces of ice are broken from the layer by the scraper and are distributed throughout the mass. A layer of ice about 50 ∝m thick is left. In its simplest design the cylinder is partly filled and the stirrer beats air cells into the mix. In continuously working machinery, air and mix enter the equipment in predetermined volume quantities (allowing the overrun to be exactly adjusted) while the stirrer reduces the air cells in size. The process of manufacture takes a few minutes. The mix leaves the freezer at –3.5 to –7°C. A second heat exchanger may be applied, in which the mix is cooled further, while stirred, to about –10°C without additional beating in of air. Deeper cooling cannot be achieved in a flow-type exchanger because the product becomes too firm.

Packaging of ice cream often is a complicated operation, especially if mixtures or exceptional shapes are wanted. In the latter case the packaging step may be associated with the start of the hardening in order to give the portions appropriate shape retention.

The *hardening* process serves to rapidly adjust the temperature of the ice cream to such a level as to retain its shape and to give it a sufficient shelf life with respect to chemical and enzymatic reactions, as well as to the physical structure. The packaged ice cream can be passed through a so-called hardening tunnel, in which very cold air (say, –40°C) is blown past the small packages for some 20 min. Likewise, packaged ice cream can be passed through a brine bath of low temperature.



Flow sheet for the manufacturing of Ice Cream

Role of various components

Fat is of special importance for the flavor and for a solid structure to be formed during freezing and therefore for consistency, appearance, and melting resistance. A high fat content leads to a dry, almost grainy texture, a low fat content to a smooth, homogeneous, somewhat slimy texture.

Milk solids-not-fat contribute to the flavor. They are also responsible for part of the freezing-point depression and for an increased viscosity. The protein partly serves to stabilize the foam lamellae during air incorporation; it is essential for the formation of fat-globule membranes during homogenization. Lactose can crystallize at low temperature. The crystals formed should be small in order to prevent sandiness. To that end, cooling should be quick during freezing, and afterward temperature fluctuations should be avoided.

Sugar, often sucrose, is essential for the taste and for the freezing-point depression. Too little sugar may cause too much ice to be formed; too much sugar often makes the ice cream overly sweet. To overcome this, part of the sucrose may be replaced by a substitute such as glucose syrup, which is less sweet and leads to a greater freezing-point depression per kg sugar. The sugar also causes a higher viscosity, especially when most of the water has been frozen. However, the most important role of the sugar is that it causes far less water to freeze than otherwise would be the case. As a result, the consistency of the ice cream is softer and its mouthfeel less cold.

The role of the *stabilizer* or, more properly speaking, of the thickening agent is not quite clear. Among those used are gelatin, alginate, carrageenan, pectin, locust bean gum, guar gum, xanthan, carboxymethylcellulose, and mixtures. Of course, these substances affect the consistency and, consequently, also the heat transfer during the freezing. If little clumping of fat globules occurs as, for instance, in low-fat ices, the desired firmness and prevention of excessive Ostwald ripening of air bubbles must be achieved by means of thickening agents. However, these agents may cause the consistency of the product to become somewhat slimy in the mouth. Furthermore, the thickening agents are often assumed to counteract the Ostwald ripening of ice and lactose crystals, and even to prevent crystallization of lactose. Many thickening agents at high concentrations (as is the case in ice cream at low temperature) do, indeed, lower the crystallization rate and thereby slow down Ostwald ripening, but it is very unlikely that they can inhibit crystallization.

Emulsifier is not needed in the proper sense of the word (more than sufficient protein is present during homogenization) and it does not play a significant role in foam formation either. It serves to stimulate the fat globules to clump and to become attached to the air bubbles. The emulsifiers used include egg yolk, monoglycerides, poly(oxyethylene) sorbitan esters (Tweens), and esters from citric acid and monoglycerides.

Flavoring agents are self-evident. Sometimes an antioxidant is added.

Naturally, *ice crystals* are essential for the consistency and for the coolness in the mouth. Moreover, the low temperature causes the sweetness to be less intense. The crystals should not be too large; hence, freezing should be fast and the storage temperature should not fluctuate.

Air cells play a threefold part. They make the ice cream light; otherwise it would be too rich. They soften its consistency and thereby make it deformable in the mouth. They moderate the coldness by lowering the rate of heat transfer; otherwise the ice cream would be far too cold in the mouth. The amount of air may be bound to a maximum because, according to statutory requirements, the density of the ready-made ice cream may not be below a given value, generally 500 kg/m^3.