Chapter 15
Formulations for Specialty Products

Introduction

Ice cream formulations were discussed in Chap. 2, mix ingredients in Chap. 3 and mix calculations, to turn formulations into recipes based on ingredients, were demonstrated in Chap. 6. Ice cream, as defined in Chap. 2, makes up the vast majority of the frozen dairy desserts market; however, there are a number of other frozen dairy desserts and non-dairy frozen desserts that can be manufactured to offer further choice to consumers. This chapter will review formulations for light, low-fat and nonfat products, no-sugar-added and sugar-free formulations, reduced and lactose-free formulations, gelato, frozen yogurt, sherbet, water ices and sorbet, and vegetable protein-based desserts. Most of these formulations make use of the ingredients already discussed in Chap. 3 and mix calculations shown in Chap. 6 are still required, in most cases, to balance mixes based on ingredients used. Many manufacturers offer a range of products, including many of those discussed here, to augment their mainstay ice cream formulations.

Light, Low-Fat, and Nonfat Formulations

As fat is removed from ice cream formulations, other ingredients must be added to keep the water content within reasonable limits for two reasons: (1) too much water means too much ice in the frozen product resulting in a very hard and very cold and icy product with weak body and poor keeping quality, and (2) regulations may stipulate a minimum concentration of food solids or dry matter. It is possible to formulate reduced-fat or "light" ice creams, down to about 4–5% fat, with traditional ingredients (Table 15.1). Total solids is reduced slightly but some of the displaced solids is made up with slightly enhanced levels of sugar (to maintain similar freezing curve to regular ice cream in the presence of more water), and slightly enhanced levels of corn syrup solids and stabilizer, to enhance viscosity and body. A new development in the arena of commercial light products has been the application of the low-temperature extrusion process, which takes ice cream from −5 to −12°C

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Table 15.1 Suggested mixes for low-fat ice cream or ice milk products (4–5% fat) and light ice cream products (6–8% fat)

	Percent (%)			
Milk fat	4.0	5.0	6.0	8.0
Milk solids-not-fat	12.5	12.5	12.0	11.5
Sucrose	12.0	12.0	12.0	12.0
Corn syrup solids	6.0	5.5	5.0	5.0
Stabilizer[a]	0.35	0.35	0.35	0.35
Emulsifier[a]	0.10	0.10	0.15	0.15
Total solids	34.95	35.45	35.5	37.0

[a]Highly variable depending on type; manufacturers recommendations are usually followed

under defined shear conditions in a screw extruder, to enable reduced-fat products with similar textures to their full-fat counterparts due to reduced ice crystal and air bubble size distributions. See Chaps. 7 and 11, for more details regarding low-temperature extrusion.

However, with low-fat products, less than 4% fat, there exists a greater product development challenge and the need to utilize fat replacers. Traditionally, fat replacers have been classified in relation to the materials that comprise them: carbohydrate, protein, or fat-based. Water-soluble carbohydrate polymers typically used in low-fat formulations include cellulose products, starches, dextrins, maltodextrins, and polydextrose. Carbohydrate-type fat replacers contribute bulk and increase viscosity while helping to limit growth of ice crystals. The common sources of protein-type fat replacers are cheese whey and egg white. These proteins are processed into colloidal particles that vary in diameter from 0.1 to 3.0 mm, a size range that permits them to be sensed on the tongue as creamy. Monoacylglycerols and diacylglycerols are useful in low concentrations (<1.0%) as fat-based fat mimetics. Fat replacers are discussed in detail in Chap. 3.

Fat-free formulations typically contain 12–13% milk solids-not-fat along with a combination of sugars (sucrose and corn syrup solids), either high molecular weight carbohydrates or protein-based fat replacers, and appropriate stabilizers. Suggestions for sweetener and fat mimetic combinations include:

- Sucrose 12%, maltitol 10%, corn syrup solids 4%.
- Sucrose 8%, 36 DE corn syrup solids 9%, whey or egg protein-based fat replacer 5%.
- Sucrose 15%, 5 DE maltodextrin 3%.
- Sucrose 14%, 10 DE maltodextrin 7%, 5 DE maltodextrin 2%.
- Sucrose 11%, 36DE corn syrup solids 8.5%, 5 DE maltodextrin 2%, polydextrose 2%.
- Sucrose 10%, 36DE corn syrup solids 9%, 10 DE maltodextrin 2%, whey or egg protein-based fat replacer 1.5%.

A suggestion for a sweetener and fat mimetic combination in a fat-free, sugar-free formulation includes:

- 8% polydextrose, 5% sorbitol, 5% 10 DE maltodextrin, 1% microcrystalline cellulose, 0.023% acesulfame K, 0.023% aspartame.

Flavoring Low-fat and Nonfat Frozen Desserts

Decreasing the fat content of ice cream decreases the creamy sensation and increases the intensities of flavors of skim milk powder and of corn syrup. It also impacts on added flavors, since there are many flavor components that are fat soluble, which are released to the olfactory senses as fat melts. If there is insufficient fat to carry these flavors, they are perceived quickly and tend to disappear relatively quickly from the flavor profile. Panelists found the peak intensity of flavor occurred significantly earlier during tasting of ice creams containing pure bourbon vanilla and 0–1% fat than with ice creams containing the same vanilla and 2, 4, 6, 8, or 10% fat. No significant difference was observed among the 2–10% fat group (Li et al. 1997). Free vanillin concentration, determined by HPLC, was 10% lower in ice cream containing 10% fat and 39.5% total solids that in ice cream containing no fat and 34% total solids. Hyvonen et al. (2003) showed similar results with strawberry ice cream, a more intense flavor and a faster flavor release in the absence of fat compared to 5% fat or higher. No differences in flavor profiles were seen between 5 and 18% fat. Likewise, Frøst et al. (2005) showed faster increases and subsequent decreases in dynamic flavor perception with lower fat levels in 3% fat ice cream compared to 6% or 12%.

Fat replacers used in nonfat and low-fat ice creams usually consist of modified whey proteins or starch hydroylsates. Both tend to bind and to mask delicate flavors. Whey proteins, for example, even in concentrations as low as 0.5%, are prone to bind aldehydes through hydrophobic interactions. As little as 1% milk fat can reduce the vapor pressure of flavorful substances, which impacts their volatility and hence their release and detection in the mouth. Hence the balance of volatile components needs to be varied considerably in developing flavors for nonfat frozen desserts, depending on the ingredients.

Ohmes and Marshall (1998) showed that vanillin intensities did not vary among three whey-based fat replacers added at a concentration of 4.8% to nonfat ice cream, the control low-fat ice cream that contained 4.8% milk fat, and a second control that contained 4.8% additional nonfat milk solids. However, the control that contained milk fat had lower "syrup, whey, and cooked milk" flavors than the other four samples. Samples containing a whey protein-based fat replacer (Simplesse) did not differ from either control in texture, while those containing a carbohydrate-based fat replacer were smoother and more gummy than the controls. Similarly, Liou and Grün (2007) showed that the flavor and flavor release profile of 4% fat strawberry ice creams were more similar to the 10% fat control if the fat mimetic used was protein-based rather than polydextrose-based.

Regular fat (9%) and reduced fat (6%) chocolate ice creams were more smooth and creamy in texture, had a less intense cocoa flavor, and melted more slowly compared with low-fat (4%) and nonfat (<0.5%) ice creams when all samples were adjusted to the same total solids (41.6%) with equal portions of Simplesse and polydextrose (Prindiville et al. 1999). Furthermore, fat protected against damage from heat shock. Some flavors are compatible with fat replacers. In tests by the same researchers (Prindiville et al. 2000) low-fat (2.5%) chocolate ice cream had a less intense cocoa flavor and was more resistant to textural changes over 3 months of storage than samples containing 2.5% of either cocoa butter, Simplesse, or Dairy Lo (see Chap. 3, Fat Replacers). Each of the latter is a whey protein-based fat replacer. Examinations by gas chromatography–mass spectrometry of the headspace volatiles of the samples of chocolate ice creams described above revealed that concentrations of most of the selected volatiles were negatively correlated with concentration of fat and were higher in the presence of fat replacers instead of an equal amount of milk fat (Welty et al. 2001).

Flavors that tend to be complementary to fat replacers are butterscotch, butter pecan, and cheesecake. These "heavier" flavors tend to cover flavors contributed by the fat replacers while providing flavor notes that blend well with those of the typical nonfat product.

No-Sugar-Added and Sugar-Free Formulations

The global rise in prevalence of Type II diabetes mirrors the global epidemic in obesity. Diabetic people have an impaired capacity to decrease blood glucose levels after consumption of high sugar-containing products. For these people, the large amount of sucrose and glucose normally used in ice cream needs to be replaced with an acceptable sweetener, to lower the glycemic index of the product. The sugar alcohols, or polyols, have been the sweeteners of choice, since they are absorbed much more slowly than glucose. When substituting sweeteners in ice cream formulations, the factors to be considered include sweetness, freezing point depression, and contribution to total solids. Sorbitol (a monosaccharide) has been used for many years but the intake of sorbitol must be restricted because of its laxative nature. Other polyol sweeteners include xylitol or mannitol (both monosaccharides) or maltitol or lactitol (both disaccharides). These sweeteners allow matching of the freezing curves to conventional formulations due to their freezing point depression characteristics. If necessary, sweetness levels can be boosted with a nonnutritive high potency sweetener such as aspartame or sucralose, but these by themselves do not contribute to total solids or freezing point depression. Likewise, total solids or viscosity (bulk) can be enhanced with a product like polydextrose, but this by itself does not contribute either sweetness or freezing point depression. Thus careful blending of alternative sweeteners is required to provide all of the necessary functional properties when producing no-sugar-added products. Sugar-free products have the added complication of needing to eliminate lactose from the milk solids not-fat component of the mix, which can be done through either lactose hydrolysis or with the use of milk protein-derived ingredients as sources of MSNF.

Several recent published papers have shown the potential for maltitol as a polyol sweetener for ice cream. Ozdemir et al. (2003) produced diabetic ice cream using maltitol, sorbitol, and high fructose corn syrup as the sweetening agents and compared them to a sucrose-sweetened control. Sensory analysis showed that maltitiol-based ice cream was more preferred than ice cream containing sorbitol. Bordi et al. (2004)

compared a regular 12% fat vanilla ice cream and a maltitol-sweetened ice cream using a large taste panel and showed an overall consumer preference for the maltitol-sweetened ice cream. Whelan et al. (2008) examined a number of polyol sweeteners in low glycemic index formulations. Once the freezing curves were matched, other physicochemical properties also were found to match. Sweetness and sweet taste then could be adjusted for sensory optimization with a combination of these sugars and supplementation with sucralose to boost the sweetness as necessary. Their results showed that an acceptable low-GI ice cream cannot be produced without satisfying the need for dairy and vanilla flavor as well as desired sweetness. A strong correlation was found between perceived dairy flavor, sweetness liking and vanilla flavor. From the formulations studied, a combination of tagatose (6%), polydextrose (6%) and maltitol (3%), or maltitol (15%) and trehalose (2.5%), made with milk, cream, and MPC, showed to be potential formulations that could satisfy both physicochemical and sensory requirements. Several products are currently on the market that are sweetened with maltitol and sucralose, the maltitol provides the physicochemical characteristics while the sucralose boosts the sweetness level.

Suppliers continue to make available increasing numbers and varieties of sugar-free fruits and chocolate products, including blueberry chunks, raspberry, and strawberry revels and purees, chocolate flakes and chunks, chocolate revel, and chocolate-coated peanuts and almonds.

Reduced-Lactose and Lactose-Free Ice Cream

A significant number of consumers suffer from some degree of inability to completely digest lactose. These lactose malabsorbers sometimes experience discomfort in the lower bowel when lactose that escapes being absorbed in the small intestine is fermented into acid and gas in the colon of the individual. This can cause gas pains, and, in severe cases, diarrhea. Four approaches can be used to reduce the possibility of an individual experiencing lactose malabsorption from frozen dessert products. First, the consumer may select ice creams high in fat. The higher the fat content of the ice cream, the lower the MSNF content and, consequently, the lower the lactose content. High fat ice creams tend to be the super-premium types, and the source of MSNF in such ice creams is usually limited to skim milk solids. Skim milk solids contain about 50% less lactose than do whey solids. The latter may replace up to one-fourth of the MSNF in ice cream, and whey solids, being low in cost, are often used to the extent permitted to replace skim milk solids in economy ice creams. A second approach is to consume ice cream at the end of a meal. This ensures relatively slow flow of lactose through the digestive system and reduces the load on the enzyme that is present. It also presents a more dilute solution of lactose to the colonic bacteria. The third approach is to consume frozen yogurt. This product, properly prepared, carries living yogurt bacteria that have already fermented part of the lactose in the skim milk solids used to make the yogurt. To the extent these bacteria remain alive to the time of eating they supply lactase to the human intestine.

The fourth approach to alleviating lactose malabsorption is to reduce or eliminate lactose from the frozen dessert. This can be done by hydrolyzing the lactose with purified β-D-galactosidase before the product is frozen. The enzyme is relatively expensive and several hours are needed for the process. Furthermore, since two molecules are produced for each lactose molecule split, freezing point of the mix may be lowered excessively. Another approach is to remove lactose from skim milk by ultrafiltration and diafiltration. In diafiltration after about one-half of the volume is removed by ultrafiltration, water is added to the retentate and ultrafiltration is continued until the volume is again reduced to about 50% of the initial volume, thereby continually washing out low molecular weight soluble compounds, including lactose, into the permeate. The removal of lactose by ultrafiltration reduces the concentration of dissolved solids in the product and raises the freezing point. On the contrary, hydrolysis of the lactose produces two molecules for every lactose molecule hydrolyzed and therefore, lowers the freezing point. Removal of 50% of the lactose by ultrafiltration/diafiltration followed by enzymatic hydrolysis of the remainder provides concentrated skim milk solids with about same freezing point as concentrated skim milk of the same solids content.

Gelato

Italian-style ice cream is referred to as gelato, which is the Italian word for ice cream. However, there are significant differences between traditional gelato and North American-style ice cream. Gelato is lower in fat and total solids than regular ice cream but typically higher in sugar content, to give it a soft, scoopable texture. A typical formula might contain 8.0% milk fat, 7.5% MSNF, 16.0% sugar, and optionally up to 4.0% egg yolk solids. Usually fresh dairy ingredients, cream, milk, and cocnetrated skim, are used to supply the milk fat and MSNF. Note that no stabilizer or emulsifier is recommended in this formula. It carries abundant rich flavor and has very low overrun (20–40%). It is often flavored with liqueurs and various combinations of fruit and is available in a large number of flavors usually based on fresh ingredients. The low overrun and high solids provide the distinctive body and texture and desirable release of flavor. While it is not extruded directly for consumption as is soft serve, gelato typically is frozen in a batch freezer and not hardened as such, but rather drawn into shallow tubs from which it can be scooped with a characteristic gelato paddle-shaped scoop. It is kept at appropriate temperatures at which the frozen product is pliable and sticky, which gives gelato a more warm-eating experience. Gelato is typically produced fresh daily in relatively small quantities.

Batch freezers for gelato production vary slightly from traditional batch freezers for ice cream production. The freezer has to be designed for low overrun, so typically dasher speed is low. The low overrun places more demand on the motor load due to its heavier density so the torque has to be sufficient to obtain the desired low draw temperature. Hence companies like Carpigiani, Technogel, and Taylor all produce batch freezers designed specifically for gelato production.

Frozen Yogurt

Yogurt is a well-established dairy product, and is generally characterized by live microorganisms and developed acidity (lactic acid) from fermentation of lactose by the bacterial culture. The acidity destabilizes the casein micelles in the milk, and they, in turn, establish the typical acid gel. Frozen yogurt, therefore, should be much like the unfrozen version, and be characterized also by live microorgansims and developed acidity from fermentation. Although there are no regulatory standards for frozen yogurt in most countries, these characteristics help to maintain consumer confidence and respect the meaning of yogurt. The example formulation provided below is typical of a more traditional frozen yogurt. However, a wide range of products exists in the marketplace, including those in which the acidity is not developed by bacterial culture but has been added in the form of citric acid and in which yogurt flavors or yogurt powders are used to provide yogurt-like flavor characteristics.

The frozen yogurt market in the United States has been quite cyclical. Of the 1,600 million US gallons of frozen dairy desserts produced in 2010, less than 5% or 74 million gallons was frozen yogurt. Approximately 2/3 of the frozen yogurt is soft-frozen, the remainder is hard frozen (USDA, National Agricultural Statistics Service, as reported by the International Dairy Foods Association in Dairy Facts). However, from 1993 to 1995, it averaged 150 million US gallons per year and at its peak represented 10% of the US market of frozen dairy desserts. From 1997 to 2000 it averaged 92 million US gallons per year and from 2003 to 2009, it averaged 70 million US gallons per year.

Like most frozen dairy desserts, frozen yogurt contains milk fat, milk solids-not-fat, sweetener, stabilizer, emulsifier, and water. It is low in fat, typically 2–4%. It may contain any of numerous flavoring agents, but it is most often flavored with fruits. Most often, plain, unsweetened yogurt is added to a sweet, pasteurized mix. The yogurt ingredient is cultured with a mixture of *Lactobacillus delbrueckii* sbsp. *bulgaricus* (commonly *Lactobacillus bulgaricus)* and *Streptococcus salivarius* sbsp. *thermophilus* (commonly *Streptococcus thermophilus)* bacteria after the milk has been pasteurized. Usually a very high heat treatment, e.g., 85°C (185°F) for 15 min, is given to the milk before it is inoculated with the yogurt culture, to ensure no residual bacterial species will grow during the incubation step. The minimal acidity of 0.30% that is required by some regulatory authorities is used to set a theoretical minimum amount of yogurt to be added to the mix. The amount added by most manufacturers ranges from 10 to 20% of the total weight of the mix.

In general manufacturers attempt to limit the amount of the acetaldehyde flavor in the frozen yogurt, believing that most customers do not prefer that flavor which characterizes plain yogurt. Yogurt definitely has a somewhat acidic flavor as compared with low-fat ice cream containing the same amount of fat. The apparent reason that frozen yogurt has been preferred over a similarly comprised and prepared low fat ice cream product is that the yogurt bacteria are thought by many people to assist in digestion of lactose and to have other health-promoting properties (probiotic effects). Probiotic cultures colonize in the colon, produce various short chain fatty acids, lower the colonic pH, and modify the growth rates of other colonic species. The yogurt culture organisms are not probiotic *per* se, although several species of lactic acid bacteria have been shown to have probiotic properties, including *Lactobacillus acidophilus*, *Bifidobacterium*, and *Lactobacillus casei*. Hence several frozen yogurt products in the market contain one or more of these species along with the yogurt-fermenting strains. Attempts to provide high numbers of probiotic bacteria in frozen yogurts are hampered by the susceptibility of the organisms to low pH and destruction during freezing. Addition of prebiotic components to frozen yogurt provides preferred nutrients to the probiotic bacteria that survive in the human intestinal tract, thus improving chances that the culture will colonize the small intestine of the host. Examples of prebiotics include fructooligosaccharides or inulin from sources like Jerusalem artichoke or chicory root.

A typical frozen yogurt formulation and processing instructions are as follows. A mix containing 2.5% fat, 14.4% MSNF, 18.75% sugar, and 0.44% stabilizer is pasteurized, homogenized, cooled, and aged (typical for ice cream processing). This can be prepared with traditional fat and MSNF ingredients like cream, milk, skim milk powder or condensed skim milk, or with alternative ingredients such as milk protein concentrates. This mix is combined at 80% with 20% plain, unsweetened yogurt and blended to make the frozen yogurt mix, which is then flavored and frozen as for ice cream, either for hard-pack or soft frozen. Soft serve products, including frozen yogurt, are discussed more fully in Chap. 8. The yogurt can either be purchased as plain, unsweetened yogurt or it can be prepared by blending skim milk and skim milk powder to 12.5% MSNF, pasteurizing this milk at a high temperature (e.g., 85°C (185°F) for 15 min), cooling to 40–43°C (104–110°F), inoculating with a yogurt culture (typical of yogurt processing), incubating for 4 h or until fermentation is complete (to the desired acidity), and cooling to 4°C. After blending at 80/20, the final composition will be 2% milk fat, 14% MSNF, 15% sugar, 0.35% stabilizer, and 31.35% total solids. This frozen yogurt would meet the characteristics of developed acidity and live microorganisms.

Cell viability during storage of frozen yogurts has been investigated. Recent studies have shown <1 log cycle reduction in lactic acid bacteria at −23°C for >60 weeks (Lopez et al. 1998) and <1 log cycle reduction of *L. acidophilus* and *Bifidobacterium* spp. after 90 days (Akalin and Erisir 2008) in frozen yogurt.

Sherbet

A sherbet is a frozen dairy product made from water, sweeteners, milk solids, stabilizer, and coloring. They are acidified with fruit acid and typically are fruit flavored. Sherbets contain up to 1–2% milk fat and at least 1% milk solids-not-fat, with the total milk solids between 2 and 5% (U. S. Standards: 21 CFR 135.140). Standards in other countries may vary; for example, in Canada not more than 5% milk solids, including milk fat, are permitted. Sherbets have a minimal titratable acidity of 0.35% calculated as lactic acid. The final weight per gallon must be at least 6.0 lb (U.S.).

Compared with ice cream, sherbets have the following characteristics:

- Higher fruit acid content, and a tart flavor.
- Lower overrun, ranging from 25 to 50%.
- Higher sweetener content (25–35%), therefore a lower melting point, although the high acidity decreases the sweetness.
- Coarser or icier texture and more cooling feeling to the consumer.
- Less richness of taste because of the low milk solids content.

Ices or water ices, sometimes called Italian ices, have essentially the composition as sherbets except that they contain no milk solids and no egg ingredient other than egg white. They are frozen with from 0 (quiescently frozen bars) to 30% (dynamically frozen items) overrun. Sorbets are an upscale version of ices in that they contain fruit, fruit juices, and/or fruit extracts rather than imitation flavorings. Sherbets and water ices are defined foods (21 CFR 135.140 sherbets and 21 CFR 135.160 water ices), but sorbets are not a defined food in the United States. Sorbets and water ices will be further defined below.

Of the total frozen desserts produced in 2010 in the United States, about 1.6 billion gallons, sherbets and ices comprised about 3.5% (53 million US gallons) and 4.0% (60 million US gallons), respectively. This production has remained fairly steady over a 20-year period from 1990. Nevertheless, about half of ice cream processors also produced a sherbet product. Only 2.8 million US gallons of sherbet was soft-frozen, the rest was hard-frozen. In Canada, sherbet production in 2010 was 5,966 kL, only 2.8% of the total hard and soft ice cream production. Water ice production in 2010 was 21,126 kL, about 10% of the total hard and soft ice cream production. These products are in greatest demand in the summer months. Popular flavors of sherbet include orange (about 25% of sales), lemon, lime, pineapple, raspberry, and three-flavor rainbow sherbet.

The Composition of Sherbet

Two typical sherbet formulas are given in Table 15.2. Formula 1 contains less milk solids but more corn syrup solids and would give a more coarse, acidic, chewy product than formula 2, which would give a more smooth and creamy product. Sherbet generally requires at least some fat (~0.5%) to provide a slightly more pleasant mouthfeel compared to nonfat formulations.

Another approach to making the sherbet mix is to combine ice cream mix with sugar, corn syrup, stabilizer, and water. In this case the amounts of sweeteners and stabilizer in the ice cream mix must be considered in the calculations. Tables 15.3,

Table 15.2 Sherbet formulations based on composition of components

Component	Formula 1 (%)	Formula 2 (%)
Milk fat	0.5	1.5
Milk solids-not-fat	2.0	3.5
Sucrose	24.0	24.0
Corn syrup solids	9.0	6.0
Stabilizer/emulsifier	0.3	0.3
Citric acid (50% solution)	0.7	0.7
Water	63.5	64.0
Total	100.0	100.0

Table 15.3 Sherbet formulation that will develop a smooth texture and a chewy, heavy body[a]

Ingredients	Amount (Kg)	Fat (Kg)	MSNF (Kg)	Sugar (Kg)	TS (Kg)
Sugar	9.0	–	–	9.00	9.00
Corn syrup solids 42 DE, 96.5% TS	22.0	–	–	15.92	21.23
Ice cream mix (12% fat, 11% MSNF, 15% sugar)	17.5	2.1	1.92	2.62	6.65
Stabilizer	0.4	–	–	–	0.40
Fruit puree (5+1)	15.0	–	–	2.50	4.75
Water plus color	35.3	–	–	–	–
Citric acid	0.7	–	–	–	–
Total	100.0	2.1	1.92	30.04	42.03

[a]Acidity, 0.57%; freezing point −3.1°C (26.4°F)

15.4, and 15.5 show proof sheets in which ice cream mix is used in three mixes that provide a wide range of textural and flavor release characteristics.

In general the sugar content of sherbets, sorbets, and ices is about twice that of ice cream. It is important to have the correct sweetener content to obtain the desirable flavor, body, and texture. An excess of sweetener results in a soft and sticky product while a deficiency causes the product to be hard and crumbly. Sherbets should be of the same firmness at dipping cabinet temperature as is ice cream. If the overrun is kept at 30–35% and the sugar concentration at 28–32%, firmness should be suitable for dipping at the usual cabinet temperature of −13 to −16°C (3–8°F).

When sherbets are made with sucrose as the sole source of sweetener, they tend to develop a hard crust on the surface due to crystallization of the sugar. Replacement of 20–25% of the sugar with corn syrup solids lessens the chance for the defect. The maximum amount of corn syrup solids that can be substituted favorably for sucrose is about one-third. Partial replacement with invert sugar

Table 15.4 Sherbet fromulation that will develop a medium smooth texture with a medium firm body[a]

Ingredients	Amount (Kg)	Fat (Kg)	MSNF (Kg)	Sugar (Kg)	TS (Kg)
Sugar	11.0	–	–	11.00	11.00
Corn syrup solids 36 DE, 96.5% TS	10.0	–	–	6.30	9.65
Ice cream mix (12% F, 11% NMS. 15% sugar)	17.5	2.1	1.92	2.62	6.65
Stabilizer	0.4	–	–	–	0.40
Fruit puree (5 + 1)	15.0	–	–	2.50	4.75
Water plus color	45.4	–	–	–	–
Citric acid	0.7	–	–	–	–
Total	100.0	2.1	1.92	22.42	32.45

[a]Acidity, 0.55%; freezing point, −2°C (28.4°F)

Table 15.5 Sherbet formulation that will develop a coarse texture with a medium firm body[a]

Ingredients	Amount (Kg)	Fat (Kg)	MSNF (Kg)	Sugar (Kg)	TS (Kg)
Sugar	17.0	–	–	17.0	17.0
Dextrose	7.0	–	–	5.6	6.75
Ice cream mix (12% F, 11% NMS. 15% sugar)	17.5	2.1	1.92	2.62	6.65
Stabilizer	0.4	–	–	–	0.40
Fruit puree (5 + 1)	15.0	–	–	2.50	4.25
Water plus color	42.4	–	–	–	–
Citric acid	0.7	–	–	–	–
Total	100.0	2.1	1.92	27.72	35.05

[a]Acidity, 0.55%; freezing point, −3.1°C (26.4°F)

may also result in less sugar crysatllization. Amounts of sugar added to these products with fruits or with ice cream mix need to be factored into the formula.

Sherbet mixes are then flavored with fruit juices, flavoring, coloring, and citric acid solution, as appropriate. Citric acid is the most commonly used acid in sherbets and ices and is usually added as a 50% solution. The amount of acid needed depends on the fruit used, the sugar content, and consumer preferences. A general rule is that the titratable acidity should be 0.36% at 25–30% sugar and should be increased about 0.01% for each 1% increase in sugar above 30%. This level of acidity modifies the perception of sweetness that would otherwise be created by the high level of sugars. Acid should not be added to ice and sherbet mixes until just before freezing. Heating of some stabilizers in the presence of acid will reduce their effectiveness. Adding acid to a sherbet mix in which the milk solids have been included may cause aggregation/precipitation of the protein. Minimum amounts of fruit or fruit juice (including weight of the water used to reconstitute dried or concentrated products to their original moisture content) required by type of sherbet are: citrus—2%, berry—6%, and other—10% in relation to the weight of the finished sherbet. Because citric acid may cause precipitation of proteins, it is added to the mix just before freezing. Sherbets are frozen with overrun in the range of 25–50%.

Walker et al. (2010) examined a novel, sugar-free sherbet containing soy protein from 6.0 to 7.9 g/serving. The products were sweetened with sucralose (0.10%), asesulfame-K (0.02%), and erythritol (0.10%) and contained from 14.3 to 15.4% maltodextrin. Acceptability decreased as soy protein levels increased; however, the combination of sweeteners and bulking agents was considered acceptable to a panel of 140 consumers with fairly high interest shown by consumers in these products.

Lacto is made from sherbet mix that is composed from cultured sour milk, buttermilk, or other fermented milk product.

Defects

Common flavor defects in sherbets are unnatural or atypical; excessive or insufficient flavoring; acid (sour); improperly sweetened (too little, too much, or unnatural); and metallic or oxidized. Terpenes of citrus fruit tend to cause bitterness. To avoid these defects requires selection of high quality ingredients, especially fruits, juices and flavorings, and protection of the ingredients and finished products from prolonged storage and exposure to odorous substances. Selection of desirable artificial flavors should be given special attention during product development.

As with ice cream, the most frequently observed textural defect in sherbets and ices is coarseness or iciness. Some consumers prefer the type of sherbet that freezes initially with a slightly coarse texture because it can be especially light and refreshing. Others prefer velvety smooth texture. Nevertheless, either of the types can become offensively coarse and icy. The following steps are recommended to reduce this defect: (1) set the sugar content at 28–32% with about one-fourth of this amount, by weight, being corn syrup solids or corn sugar; (2) carefully select a stabilizer and use it at the concentration proven by test in the formula; (3) draw the product from the freezer in a firm condition and harden it quickly; (4) protect the frozen product from temperature fluctuations; and (5) market the product promptly.

A crumbly body indicates an insufficient amount of or improper stabilizer. When the body is too firm, the overrun may be too low or there may be insufficient sugar in the mix. A weak or snowy body is indicative of having whipped too much air into the product. Stickiness suggests too much sugar or stabilizer in the formulation. Surface encrustation sometimes appears because some of the sucrose crystallizes. The liberated water may evaporate or may freeze into large ice crystals. The usual solution to the problem is to increase the concentration of stabilizer and/or to lower the freezing point by adding more sugar.

"Bleeding" or settling of syrup to the bottom of the container is more of a problem with sherbets and sorbets than ice cream. The internal structure of the foam of ice cream is stabilized to a much higher degree by abundant proteins and partially churned fat than is the structure of sherbets and sorbets. To prevent bleeding, one should avoid excessive overrun, provide sufficient stabilizer, hold the sugar content to less than 32%, and keep the temperature cold, i.e., below −20°C (−4°F) until tempering it to be served. Temperature abuse is the most important cause of body and texture defects in frozen desserts.

Water Ice

Water ices can be quiescently frozen in molds to make popsicle-type products or can be frozen while agitating in the same way ice cream is frozen. However, the rate of wear on the scraper blades is high because of the lack of fat to lubricate the metal surfaces that contact each other. Therefore, scraper blades must be sharpened frequently to maintain the capability to produce small ice crystals.

Formulas for ices are usually calculated for lots of 100 U of desired quantity by weight, 80 U being the "base mix" and 20 U being the flavoring, coloring, acid, and additional water. A desirable base or stock mix contains 21–25 U of sucrose, 7–9 U of corn syrup solids, and 0.4 U of stabilizer. Water makes up the remainder of the 80 U of this base mix. In other words, the base mix comprises 26.25–31.25% sucrose, 8.75–11.25% corn syrup, 0.5% stabilizer, and the balance in water, to which is added a flavor preparation at 25% by weight. Ices have a low TS content compared to ice cream; this means they have a greater tendency for sugar solids to separate and for the body to become crumbly than does ice cream. For this reason ices need more stabilizers than do ice creams.

This base is prepared by slowly adding the dry ingredients to at least part of the water, taking care to avoid creating lumps. Heating is necessary to facilitate solution of the stabilizer and to eliminate potential yeast and mold contamination. Homogenization is not required. The base is cooled before other ingredients are added. Aging for 4–12 h is necessary only if the stabilizer needs time for full activation.

This base mix is then ready for the flavoring and coloring materials. The flavor and color mixture is made from the following ingredients:

1. *Fruit and fruit juices.* The amount varies between 15 and 20% of the finished ice, depending on the intensity of the flavor. Variety of fruit and method of preparation affect the amount of these ingredients needed. Fruit seeds should be avoided.

2. *Flavoring*. Although fruit extracts and artificial flavors may not provide as desirable flavor as fruit juices, they are often needed to fortify the flavor and to produce a consistently uniform product.
3. *Coloring*. Approved food coloring should be selected to provide as near the natural color as possible while meeting the expectations of consumers as may be determined with a sensory panel.
4. *Acid solution*. To obtain the desired tart flavor, the fruit acids, citric or tartaric, should be used. Less desirable substitute acids are saccharic, phosphoric, or lactic. It is common practice to use 50% solutions of citric or tartaric acids made from equal weights of acid crystals and water. The amount of this concentrate to use varies from 250 to 600 mL/100 kg (4–10 oz per 100 lb of mix). The amount depends on the acidity of the fruit juice and the amount of sugar in the final mix. The final titratable acidity should range from 0.35 to 0.50% expressed as lactic acid.

Non-fruit sherbets or ices differ from fruit sherbets and ices mainly in the flavor-characterizing ingredients. The optional characterizing ingredients include ground spices, infusion of coffee or tea, chocolate or cocoa, confectionery, distilled alcoholic beverages (in an amount not to exceed that required to provide the flavoring), or any other natural or artificial food flavoring (except any having a characteristic fruit or fruit-like flavor).

Quiescently frozen confections consist essentially of the same ingredients as are in water ice, but usually in different proportions. A typical formula would be as follows: sucrose 13.80%, corn syrup solids 3.70%, stabilizer 0.37%, citric acid (anhydrous) 0.26%, water 80.62%, and flavor 1.25%. The ingredients are weighed and dissolved with necessary agitation. Heat is not essential in preparation but it is beneficial in the destruction of molds and yeasts should it be desired to store the mix. No overrun is involved with this type of product so the mix is dispensed into molds allowing sufficient under fill to permit expansion on freezing.

A relatively new item in the category of ices is the juice bar. It is a quiescently frozen upscale adaptation of water ice in which the major characterizing ingredient is fruit juice instead of fruit flavoring or extract in water. There is no federal standard for this product. Some manufacturers are adding nutrients to juice bars with the objective of gaining market share among health conscious consumers. For example, one such bar contains 11 g whey protein, while providing 130 cal and 100% of the RDA for vitamins A, C, and E in 100% fruit juice.

Sorbet

Sorbets are generally regarded as upscale versions of water ices that are frozen while whipping. The Italian name Sorbetto is also applied. In general, formulas for sorbets call for fruit and/or fruit juice (30–50% by weight) as the characterizing flavor rather than artificial flavorings. Fruit extracts provide enhanced flavor. Additionally, many formulas include egg white (2.6% solids), to aid in aeration, and pectin or other stabilizing gums (0.4–0.5%). Sugar content varies from 28 to 32%, and the fructose, fruit sugar, content of the fruit should be considered as part of the sugar in the formulation. Percentages of fructose vary from 7% in kiwi fruit, raspberry, passion fruit, and blueberry to 16% in ripe banana, with most fruits containing 8–10%. Moisture content of fruits varies from 75% in banana to 89–90% in melon and kiwi fruit. Citric acid may be added to enhance flavor. The remainder is water. Exotic flavors are often used in sorbets. Overrun in sorbets is usually 20% or less, in part from the lack of protein in the formulation to provide any air cell stability.

Nutrition Facts labels of two nationally distributed brands of orange, raspberry, strawberry, and lemon sorbet revealed an average of 120 cal in a ½ cup serving weighing 106 g and containing 31 g of carbohydrate and 23–27 g of sugar. The products contained insufficient fat, protein, or calcium to be noted on the label.

Fruit and flavor supply houses provide what they call bases for sorbets. Bases contain the fruit, flavor, and stabilizer needed. The manufacturer adds sugar and water before freezing.

Italian ices and sorbets should be stored at temperatures of −30°C (−20°F) or lower and served at about −10°C (15°F) depending on the amount of sugar solids contained. This means the serving cabinet used for ice cream is not satisfactory for use with dipped sorbets and ices. These products are frequently produced in a soft serve freezer and dispensed directly to the consumer.

Non-dairy Frozen Desserts

Many consumers cannot or do not wish to consume any dairy ingredients. Hence, a number of frozen dessert products have come onto the market to cater to this demand, the most common of these being soy-based although there are other products that are nut-based or hemp-based, for example. The principles and procedures for these are very similar to ice cream, in that a mix is prepared by selection and blending of ingredients, pasteurization, homogenization, cooling, and aging, and then this mix is concomitantly whipped and frozen in batch or continuous freezers and the resulting frozen product is optionally flavored with inclusions, packaged and hardened. Often, the composition of the formulation is also similar in terms of fat, protein, sugar, stabilizer, and emulsifier; however, the source of these components varies.

In the case of soy-based frozen desserts, a soy milk is prepared by grinding of prepared and cooked beans with water to a fine particle size producing a smooth texture. Soy milk can vary from 8 to 12% total solids, of which on a dry basis approximately 27.5% is protein, 14.5% is fat, 5.5% is ash, and 52.5% is total carbohydrate including 33.5% sugars and 4% dietary fiber. In a typical soy-based formulation, soy milk would be blended with sources of non-dairy fat (typical of non-dairy fat ice cream: palm oil, palm kernel oil, or coconut oil, perhaps blended with an unsaturated oil such as corn or canola to give at least 70% solid fat at 4°C), sugars, and stabilizers to produce a recipe that results in similar freezing curve, firmness, shelf-life, meltdown, and texture to ice cream. A full-fat product might be 6–8% fat. The functional properties provided by the milk solids-not-fat in ice cream have to be replaced by the functional properties of the soy protein and starch in the soy milk, perhaps supplemented with additional soy protein isolate. However, the stabilizers and emulsifiers also have to aid in water-binding, fat structuring, and aeration, perhaps more so than in ice cream since the interfacial properties of soy protein are not as good as those of milk protein. Since there is no lactose, additional sugar is needed to arrive at similar freezing properties to ice cream, perhaps up to 20% sugar (more if corn starch hydrolysates are used, less if monosaccharide sugars are used).

Ingredient listings from four vanilla soy-based products in the Canadian market in 2011 are as follows:

- Soy beverage (water, soybeans), sugar, coconut oil, guar, locust bean gum, soy lecithin, salt.
- Water, sugar, corn oil, high fructose corn syrup, soy proteins, tofu, cocoa butter, vanilla, guar, locust bean and cellulose gums, carrageenan, salt, vegetable mono- and diglycerides, caramel flavor, annatto color.
- Organic: Soy beverage (water, soybeans), brown rice syrup and/or tapioca syrup, dehydrated cane juice, soybean oil and/or safflower oil, chicory root extract, vanilla extract, carob bean gum, tapioca sugar, guar gum, carrageenan.
- Water, sugar, sunflower oil, soy protein, salts of phosphate and citrate, mono- and diglycerides, guar gum, sodium carboxymethyl cellulose, locust bean gum, carrageenan, natural and artificial flavor, natural color.

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