

Chapter 2

Composition and Formulations

Introduction

Ice cream is comprised of a mixture of air, water, milk fat or nondairy fats, milk solids-not-fat (MSNF), sweeteners, stabilizers, emulsifiers, and flavors. The functions and limitations of each of these components are described in Table 2.1. An ice cream mix is the unfrozen blend of the ingredients used to supply these constituents, except the air and flavoring materials. Mix formulations are defined as percentages of the constituents, e.g., percentage of fat, MSNF, sugars, stabilizers, and emulsifiers (the sum of which equals the total solids). These components can be combined in varying proportions within acceptable ranges. Furthermore, a wide variety of ingredients can be chosen to supply these constituents, and both the percentage and the source of a constituent can affect quality of a mix. For example, milk fat and MSNF can be derived from multiple combinations of cream, butter, and fresh, concentrated or dry whole milk or skim milk. Ingredients to supply the mix components will be discussed in Chap. 3.

The composition of ice cream varies in different countries and in different localities and markets within each country (Table 2.2). The best ice cream composition for a manufacturer to produce is often difficult to establish. Consideration must be given to legal requirements, quality of product desired, raw materials available, plant equipment and processes, trade demands, competition, and cost. These considerations will affect the choice of a minimum, average, or high component concentration and the selection of ingredients (Table 2.3). Some firms may choose to manufacture products from only one mix formulation while others may cater to economy, regular, and premium markets with several formulations.

The milk fat content of ice cream may vary from less than 1 to 20%, depending upon such factors as regulations, expected characteristics, price, and competition. Within the ice cream category, usually at >8–10% fat, as the fat content of ice cream is increased, the MSNF must be decreased so as to avoid high viscosity and the potential for “sandiness” (i.e., the crystallization of milk sugar or lactose in the finished ice cream). Local preferences, qualities of ingredients, and the technique of

Table 2.1 Functions and limitations of selected ice cream constituents

Constituent	Functions	Limitations
Milk fat	Increases richness of flavor Lubricates and insulates the mouth	Relatively high cost and smoothness of texture Hinders whipping May limit consumption due to high calories and satiating effect
Nondairy fats	Provides good structure and texture at lower cost than milk fat, if appropriate solid fat content	Contributes little to flavor and may impart off-flavor May contribute to greasy texture
Milk solids-not-fat; milk/whey protein concentrates	Improves body and texture (protein) through emulsification and water holding capacity Promotes development of overrun	High amount may cause cooked or salty flavor Potential for sandiness (lactose crystallization) at high concentration
Whey solids	Less expensive than conventional sources of MSNF	High amount of lactose causes freezing point depression Potential for sandiness greater than for conventional sources of MSNF
Sugar	Lowers freezing point Imparts sweetness to the ice cream Improves flavor/texture	Excess sweetness possible Lower hardening temperature needed Ice cream is softer, affecting scooping and the potential for greater recrystallization
Corn syrup solids	Lower cost than sugar Improve body and texture Increase stability of the ice cream	Impart off flavor and chewy texture when overused
Stabilizers	Enhance smooth texture Provide body Enhance shelf life	Excess chewiness may occur Increase melt resistance
Egg yolk solids	Improve whipping ability Impart custard flavor	Foamy melted product Egg flavor may be undesirable
Emulsifiers	Promote fat destabilization, leading to dryness, smoothness, and good melting properties	Increase potential for churning of fat
Total solids (TS)	Smoother texture Firmer body Higher nutrient content Lessen excess coldness	Heavy, soggy, or sticky body Reduce coldness
Flavoring	Increases acceptability	Intensities and harshness may be unacceptable
Coloring	Improves attractiveness Aids flavor identification	Artificial shades Allergic reactions of some people to yellow no. 5 or no. 6 Some consumers dislike added colors

Table 2.2 Minimum standards for ice cream among several of the major ice cream producing and consuming countries

Country	Milkfat (%)	Milk protein (%)	Total milk solids (%)	Total solids (%)	Food solids per liter (g)	Weight per liter (g)
Australia	10	— ^a	—	—	168	—
Brazil	3 ^b	2.5	—	—	152	475
Canada	10	—	—	36	180	—
Denmark ^c	5	—	—	—	—	—
Finland ^c	8	2.5	—	—	—	—
Germany ^c	10	—	—	—	—	—
Italy ^c	8	2.5	—	32	—	—
New Zealand	10	—	—	—	168	—
Norway ^c	9	—	—	35	—	500
United States	10	—	20	—	192	540
United Kingdom ^c	5	2.5	—	—	—	—

^aNot specified^bMinimum total fat is 8%, balance can be comprised of nondairy fat^cStandards specific to “Dairy Ice Cream,” whereas “Ice Cream” allows nondairy fat and has unspecified compositional standards, except the UK, which specifies 5% nondairy fat and 2.5% milk protein in “Ice Cream”**Table 2.3** Average values for fat and total solids contents, overrun and cost amongst the categories of ice cream

Component	Economy	Standard	Premium	Superpremium
Fat	Legal minimum, usually 8–10%	10–12%	12–15%	15–18%
Total solids	Legal minimum, usually 35–36%	36–38%	38–40%	>40%
Overrun	Legal maximum	100–120%	60–90%	25–50%
Cost	Low	Average	Higher than average	High

manufacture are fully as important as the composition in determining the best ice cream for a locality.

The future will continue to bring many changes in the composition and form of frozen dairy desserts as manufacturers try to gain market share and increase profitability. As an example, frozen desserts can be used to carry health-promoting constituents—vitamins and minerals or fiber or nutraceuticals (minor constituents of foods that have been shown to have health-promoting effects). The favorable effects of conjugated linoleic acid (CLA), omega-3 fatty acids, dietary fiber, and antioxidants on human health may prompt the increase of their concentrations in frozen desserts. Also, genetically engineered plants that produce flavorings are already being grown; more will be developed. They will enable more profitable production of better flavorings.

Descriptions of Commercial Frozen Desserts

Ice Cream and Related Products

Within the category of ice cream there are numerous variations of formula, dairy ingredients, sweeteners, stabilizers and emulsifiers, flavors, fruits, nuts, colors, methods of freezing, sizes, shapes, techniques for dispensing into packages, and other variables that make possible the creation of a wide variety of products (Table 1.5). Many of these are described in the following section.

Ice cream. Ice cream composition is highly regulated in many legal jurisdictions but increasingly the formerly strict compositional standards are being liberalized to allow more flexibility, as in Europe for example (Table 2.2). Readers are strongly encouraged to confirm all regulatory standards before using these for product development or export purposes, as they continue to evolve over time. The US compositional standards can be found in the Code of Federal Regulations, Title 21 Food and Drugs, Part 135 Frozen Desserts and subsections for definitions of ice cream and frozen custard, goat's milk ice cream, mellorine (ice cream with nondairy fat substituted for milk fat), sherbet and water ices. According to US standards, ice cream is a food produced by freezing, while stirring, a pasteurized mix containing at least 10% milkfat, 20% total milk solids (TMS), safe and suitable sweeteners, and defined optional stabilizing, flavoring, and dairy-derived ingredients. The finished ice cream weighs at least 4.5 lb/gal and contains at least 1.6 lb of food solids per gallon. These limits establish the maximal overrun, the increase in volume from whipping, at approximately 100% since the average mix weighs about 9 lb/gal (1,080 g/L). Furthermore the limits establish a minimum total food solids content in the mix of approximately 35.6%. Milkfat may be substituted for MSNF in 1% increments up to 14%. Other food fats are excluded except as components of flavoring ingredients or in incidental amounts added for functional purposes. Whey solids, including modified whey products, may be added to ice cream to replace up to 25% of the MSNF. For example, a product containing 12% milkfat need contain only 8% MSNF, 2% of which may be derived from sweet whey. Approved additives to mixes containing at least 20% TMS are five forms of casein and hydrolyzed milk proteins. The latter may not exceed 3% by weight of the ice cream mix (21 CFR 135—Frozen Desserts).

The regulations for ice cream products within each legal jurisdiction globally vary considerably from those of the United States (Table 2.2). In Europe, Euroglaces (the European Ice Cream Association) has prepared a Code for Edible Ices that includes standard definitions of products with appropriate translations. This was first published in 1996 and revised in 2006 to allow much more liberal compositional standards that will enable a wider range of product options to be offered to consumers. In this code, "Edible Ices" are made from a mix with approved food ingredients, have a solid or pasty texture which is obtained from freezing, and are stored, transported, sold, and consumed in a frozen state. "Ice Cream" is an edible ice and is an emulsion

typically composed of water and/or milk, edible fats, proteins, and sugars. Dairy and/or nondairy proteins are optional but dairy and/or nondairy edible fats are mandatory. “Milk Ice” is an edible ice that contains at least 2.5% of exclusively dairy fat and at least 6% MSNF and contains no nondairy proteins or fats. “Dairy Ice Cream” is an edible ice that contains at least 5% dairy fat, at least some dairy protein and contains no nondairy proteins or fats.

Many of the European countries adhere to these standards or continue to push for changing regulations to do so, although differences exist. In “Dairy Ice Cream,” nondairy proteins and nondairy fats are not permitted by any country, but minimum fat and protein levels vary. For fat, Germany specifies a minimum content of 10%, Norway 9%, Italy, Belgium, Spain, Finland, and Switzerland are all at 8%, France, UK, Hungary, and Portugal at 5%, and Greece at 4%. Italy, Belgium, Spain, Finland, and UK specify a minimum dairy protein content of 2.5%, while the others simply state that dairy protein is required. Norway specifies a minimum total solids content of 35%, Italy 32%, and Switzerland 30%, while none of the others specify this value. Norway specifies a minimum weight of 500 g/L and Switzerland 450 g/L, although none of the others have such requirements. For “Ice Cream” in which the term “Dairy” is not specified, there are fewer regulations, with most countries simply stating that either dairy and/or nondairy fats are mandatory while either dairy and/or nondairy proteins are optional. Hungary and Portugal require food protein in “Ice Cream,” Spain requires dairy protein and the UK requires a minimum of 2.5% dairy protein.

In Australia and New Zealand, a minimum milk fat content of 10% and 168 g food solids per L is required in “Ice Cream,” although light, low-fat, and nondairy versions are all available. In Canada regular ice cream must contain at least 10% milk fat and 36% total solids but there is no minimum for TMS. Nondairy fats can replace milk fat in “Frozen Desserts,” but not in “Ice Cream.” Canada requires a minimum of 180 g food solids/L but no minimum weight per volume. Nevertheless, this acts to control the maximum amount of overrun that can be incorporated to practical levels. Brazil requires 3% milk fat and permits addition of other edible fats to provide the minimum of 8% total fat in ice cream. A reduction in total fat of up to 7% is permitted in fruit ice creams. Ice milk must contain at least 2.5% each of milk fat and milk protein while containing a minimum of 28% total solids. In India ice cream can be made from milk of the cow or buffalo. The minimums for content of fat, protein, and total solids are 10%, 3.5%, and 36%, respectively. Fat content may be reduced in proportion to amounts of bulky flavorings added but not below 8%. The limit on added stabilizers and emulsifiers is 0.5% and on added starch is 5%. Overrun is specified as a maximum of 100%. Outside of these compositional standards, products are known as “Frozen Desserts.”

Standards for ice cream provide opportunities for manufacturers to go beyond the minimum requirements to make a range of product qualities, defined loosely as “economy,” “regular,” “premium,” or “superpremium” ice creams (Table 2.3). Economy ice creams typically are at the minimum requirements for composition and maximum limits for overrun, are made with the most economical ingredients, and sell for the lowest price. Increasing amounts of higher quality ingredients as

Table 2.4 Suggested mixes for hard-frozen ice cream products

Composition (%)							
Milk fat	10.0	11.0	12.0	13.0	14.0	15.0	16.0
Milk solids-not-fat	11.0	11.0	10.5	10.5	10.0	10.0	9.5
Sucrose	10.0	10.0	12.0	14.0	14.0	15.0	16.0
Corn syrup solids	5.0	5.0	4.0	3.0	2.0	—	—
Stabilizer ^a	0.35	0.35	0.30	0.30	0.25	0.20	0.15
Emulsifier ^a	0.15	0.15	0.15	0.12	0.10	0.10	—
Total solids	36.5	37.5	38.95	40.92	40.35	40.3	41.65

^aHighly variable depending on type; manufacturers recommendations are usually followed

well as less overrun characterize standard, premium, and superpremium products, all of which fall within the legal definitions of “Ice Cream.” Whereas economy ice cream may be made using the more concentrated and shelf-stable forms of milk, such as butter, skim milk powder, and dry whey, superpremium products are more likely to be prepared from fresh concentrated milk and cream. Furthermore, economy ice creams tend to contain high amounts of corn sweeteners and stabilizers, and to be flavored artificially, whereas premium and superpremium ice creams may contain mostly sucrose as sweetener, little or no stabilizer, and natural flavors. Suggested formulations for a range of ice cream products based on component composition are shown in Table 2.4. Higher fat and total solids will lead to progressively higher quality products. As fat and total solids contents are increased, concentrations of MSNF levels, corn syrup solids, stabilizers, and emulsifiers are all generally reduced, to keep viscosity down and optimize textural quality.

Frozen custard, French ice cream, French custard ice cream. Formulations for frozen custard, also known as “French ice cream,” are generally the same as for other ice creams of the same flavor, except that egg yolk solids or other optional egg ingredients are added. In the United States the minimum amount of egg yolk solids for custard is 1.4% or 1.12% for bulk-flavored products. Canada has no standard for frozen custard. The French product “glace aux oeufs” must contain at least 7% egg yolk solids. The German product called “Kremeis” contains at least 240 g of whole or whipped egg per liter of milk used in the formula.

Reduced fat. Fat-reduced (“light”), low-fat, and nonfat products have increasingly gained in popularity with the global obesity epidemic and the desire for consumers to reduce caloric intake while satisfying their demand for sweet and creamy desserts, and also with increasing nutritional knowledge regarding the increased risk of cardiovascular disease with higher intake of saturated fats. Much improvement in the quality of these products has been made in the last two decades. Formulations and ingredients for light and low-fat ice cream products are discussed in Chap. 15.

In the United States, ice cream made with 25% less fat than the reference ice cream is termed “reduced fat.” Australia and New Zealand have similar definitions.

Light or Lite. In the United States, ice cream made with 50% less fat or 1/3 fewer calories than the reference ice cream, provided that in case of the caloric reduction

less than 50% of the calories are derived from fat. Canadian standards permit 5–7.5% fat by weight.

Low-fat (also “Low in fat”). In the United States, ice cream containing not more than 3 g of milkfat per serving of 4 fl oz, which can weigh as little as 60 g. Australia and New Zealand require not more than 3 g fat per 100 g of ice cream. In Canada this product with 3–5% fat by weight is labeled *ice milk*.

Nonfat (also “no fat”). In the United States, ice cream containing less than 0.5 g of milkfat per serving. This product can contain no fat ingredient or ingredient that contains fat except if the name of the ingredient in the ingredient statement bears an asterisk that refers to the statement: “adds a trivial amount of fat.” Australia and New Zealand permit 0.15 g of fat per 100 g of ice cream.

Bulky flavored ice cream. A product containing a significant volume of coloring and flavoring ingredients including cocoa, fruit, nuts, confections, or cookies. In the United States, reduction in the minimal fat content is permitted as follows: 2.5 times the weight of cocoa solids or 1.4 times the weight of fruit, fruit juices, or nuts. Weights of dehydrated fruits or fruit concentrates may be calculated at their natural levels before being multiplied by 1.4. In Canadian regulations, dilution of minimum fat content from 10 to 8% by wt. and from 50 to 40 g/L for ice cream is permitted when adding bulky flavors.

Gelato. Italian-style ice cream that is typically lower in fat (4–8%) and overrun (25–60%) but higher in sugar (up to 25%, including corn syrups such as high maltose syrup) than regular formulations, which tends to keep it more soft and pliable. In addition, it is characterized by the traditional serving style of being fresh, soft-frozen, and scooped from well-decorated shallow stainless steel serving trays and having highly intense, fresh flavors. Gelato formulations are discussed in Chap. 15.

Turkish ice cream (Maras ice cream). Turkish ice cream is distinguished by a much more elastic texture than regular ice cream, from the presence of salep, a flour made from an orchid root, and mastic, a resin that imparts chewiness. *Maras*-style ice cream can be so sticky that it needs to be eaten with a knife and fork.

Soft serve. Ice cream and related products that are sold as drawn directly from the scraped-surface freezer without hardening. Ice cream, frozen custard, low-fat ice cream, or frozen yogurt can all be served soft-frozen although there are typically slight variations in soft-serve formulations compared to their hard-frozen counterparts. Soft-frozen products are typically prepared at the site of consumption from mixes that have been processed in dairy processing facilities and are packaged and distributed in bulk. In the United States in 2010, 6.5% of regular ice cream, 61% of low-fat ice cream, and 71% of frozen yogurt was soft-frozen. Low-fat mixes for soft serve typically contain 3–5% fat, 11–14% milk solids-not-fat, 13–15% sweetener, and 0.3–0.5% stabilizer/emulsifier. Mixes used for soft-frozen ice cream are relatively low in total solids, 30–35%, compared with those used for hard-frozen ice creams, 36–40%. However, the amount of overrun in the soft-frozen desserts is commonly 50% vs. 90–100% for hard-frozen ice creams. Soft-serve freezers are of the batch type.

The refrigeration system maintains a set temperature so that frozen product can be dispensed over an extended time. This means that mixes must be formulated to limit churning of fat caused by agitation within the freezer cylinder during times of slow product turnover. Soft-frozen products are discussed in Chap. 8.

Mellorine. In the United States, a food similar to ice cream but having the milk fat replaced in whole or part with vegetable or animal fat. It contains, by FDA Standard of Identity (21 CFR 135.130), not less than 6% fat and 2.7% protein, the milk-derived protein having a protein efficiency not less than that of milk protein. For mellorine containing bulky flavoring agents the minimal content of fat and protein is calculated in the same way as for ice cream. Vitamin A must be present at the rate of 40 IU per gram of fat. This standard of identity has not been utilized in the US market for a number of years, although products of this composition are very common in other countries and are variably referred to as “Ice Cream” (e.g., Euroglaces standard), in which the distinction is made between this and “Dairy Ice Cream” containing milk fat, or “Frozen Dessert” (e.g., Canada).

Specialty Items

Aufait. Two or more layers of ice cream with pectinized fruits or preserves spread thinly between the layers; or the fruits may be stirred gently into the ice cream as it comes from the freezer to give a marbled appearance.

Bisque. Ice cream containing appropriate flavorings and particles of grappenuts, macaroons, ginger snaps, sponge cake, or other bakery products.

Cake roll. Layered ice cream on moist cake, rolled like a jelly roll.

Confection. Ice cream with appropriate flavorings plus particles of candy such as peppermint, butter crunch, or chocolate chip.

Fanciful name. Ice cream that, because it contains a combination of flavoring ingredients, is best described with a name that “stirs the fancy” of the potential consumer, e.g., “Rocky Road.”

Fancy molded. Ice cream or frozen yogurt molded into shapes of fruit or other attractive or festive forms. The group includes brick ice cream in one, two or more layers, or with fancy centers.

Fruit. Ice cream containing fruit, with or without additional fruit flavoring or color. The fruit, such as strawberry, may be fresh, frozen, canned, or preserved.

Gelatin cube. Ice cream in which fruit-flavored gelatin cubes are substituted for fruit.

Mousse. Whipped cream plus sugar, color, and flavoring and frozen without further agitation. Condensed milk may be added to improve consistency.

Neopolitan. Two or more distinct flavors in the same package.

Nut. Ice cream containing nutmeats such as walnuts, almonds, pecans, and pistachio, with or without added color or flavoring.

Puddings. High-fat ice cream containing generous amounts of mixed fruits, nutmeats, and raisins, with or without liquor, spices, or eggs. Examples are nesselrode (a mixture of chopped and boiled chestnuts, maraschino cherries, candied fruits, and liqueur or rum) and plum puddings.

Spumoni. A combination of vanilla ice cream, chocolate mousse or chocolate ice cream, cherries, and tutti frutti ice cream, or whipped cream combined with fruits arranged in a spumoni cup and hardened.

Variegated (also called ripple or swirl). Ice cream into which syrup such as chocolate, butterscotch, or strawberry has been distributed so as to produce a marbled effect in the hardened product.

Fermented Products

Frozen yogurt. Yogurt must contain live bacteria of the species *Lactobacillus delbrueckii*, subsp. *bulgaricus*, and *Streptococcus thermophilus* and is fermented to produce developed acidity, which destabilizes the casein protein to induce high viscosity and gelation. Although frozen yogurt is unstandardized in most legal jurisdictions, including the United States and Canada, it should meet similar criteria. Typically, the yogurt bacteria are added to a portion of milk that has been previously heated to 85°C for 15 min. The mixture is then incubated at about 42°C to permit acid and flavor to be produced. This cultured material is then added to the other ingredients of the mix that have been pasteurized. A typical composition in the final product might be 2% milk fat, 14% MSNF, 15% sugar, 0.35% stabilizer, and 68.65% water. This would result from combining 20% of plain, nonfat, unsweetened yogurt at 12.5% MSNF with 80% of a sweet mix containing 2.5% fat, 14.4% MSNF, 18.75% sugar, and 0.44% stabilizer. Final titratable acidity, expressed as lactic acid, would be about 0.30%, which some regulatory bodies have set as a minimum standard for acidity. Other countries prefer to set a standard for numbers of viable bacteria in the product at some time after manufacture, e.g., 10⁷/g. Some processors have added the probiotic (health-promoting) bacteria, *L. acidophilus* and/or *Bifidobacterium* spp. and/or *L. casei*, (the so-called ABC cultures) to frozen yogurt. These have the potential to become resident in the colon when ingested in high numbers where they provide numerous health benefits. Additionally, prebiotics, such as inulin, may be added to the product as nutrients for the probiotic bacteria. Frozen yogurts are discussed more fully in Chap. 15.

Lacto. A product similar to sherbet but made with fermented rather than fresh milk. The source of fermented milk can be yogurt or cultured buttermilk.

Sherbets and Related Products

Sherbet. Sherbets are frozen dairy desserts characterized by being low in milk ingredients, high in sugar, and slightly acidified. Milk solids, including milk fat, is usually limited to 5% while total sweetener content, sucrose and corn syrup solids, can approach 30% or greater in a product that contains 32–35% total solids. A general formulation might contain 1–2% milk fat and 3–4% milk solids-not-fat. Sherbets typically have an acidity not less than 0.35%, which is normally adjusted with citric acid but is calculated as lactic acid. Most sherbets are flavored with fruit, fruit juice or juice concentrates, and artificial flavorings. Citrus flavors (lime, lemon, orange) are quite common. Examples of non-fruit sherbets are those flavored with spices, chocolate, or coffee. Particulates, such as pieces of fruit, may also be added to sherbets. Overrun is typically low, for example 50%. Sherbet formulations are discussed in Chap. 15.

Soufflé. Sherbet containing egg yolk or whole eggs.

Ices and Related Products

Water ice. Also known as ice, the product is made of fruit juice, nutritive sweetener and stabilizer, with or without additional fruit acid, flavoring, color or water, and frozen with or without agitation. No dairy products or egg ingredients other than egg white are contained. A typical composition might be 14% sugar, 3.5% corn syrup solids, 0.4% stabilizer, 0.25% citric acid, and 1–2% flavor. The mix need not be pasteurized if potable water is used, although it provides a guarantee against possible yeast and mold growth from environmental contaminants. Water ices are normally quiescently frozen to make novelty items, see Chap. 9 for further details.

Sorbet or sorbetto. Sorbets are similar in composition to sherbets but excluding all dairy ingredients. They contain frozen fruit and/or fruit juice, are high in sugar, and may be stabilized with egg white, pectin, or other gum stabilizers. The volume of air whipped in is up to 20%, although with little or no protein it is hard to stabilize much volume of air. Euroglaces defines a fruit ice as an edible ice that contains at least 15% fruit (or 10% for acid, strong-flavored or exotic fruits) and a sorbet as a fruit ice that contains no added fat and at least 25% fruit.

Granita. Water ice containing sugar, water, and flavors, similar to sorbet although frozen with very little agitation so it is coarser in texture with larger ice crystals.

Novelties

The category of handheld, single-serving products is often referred to as “impulse” products, due to their typical purchase from freezers in small retail shops or vending machines, or “novelties,” implying the category is dominated by new, novel, and

exciting shapes and flavors. Such novel forms of frozen desserts include bars of various shapes (with and without sticks), sandwiches, cones, molded items, rolls, and cakes. These are discussed in detail in Chap. 9.

Drinks

Milk shakes. Milk shakes, like soft-frozen products, are usually prepared for consumption at the retail outlet directly from milk shake mixes that have been processed at a dairy processing facility and packaged and shipped in bulk containers. These products are common in fast-food outlets. A typical mix contains 3% milk fat, 13% milk solids-not-fat, 8% sugar, 3% corn syrup solids, and 0.4% stabilizer, giving a total solids content of 28.4%. Milkshakes can also be prepared in an ice cream retail shop with scooped ice cream and milk and whipped/stirred in a high-speed blender, in a more traditional manner than with a freezing machine.

Smoothie. A blend of fresh or frozen fruit, fruit juice and frozen milk shake mix, yogurt or sherbet. Smoothies are a category similar to milkshakes but containing a wider range of other flavoring ingredients. Many formulations exist for smoothies, but most typical is a blend of whole fruit and/or fruit juice or vegetable juice, cream or yogurt and crushed ice. The mixture is blended in a high-speed blender and served promptly.

Frappé (or frappe). An ice made with a mixture of fruit juices frozen to a slushy consistency, or juices mixed with crushed ice, and served as a drink. In many European countries and New England states, the term can also be used to refer to a milkshake.

Complexities of Composition

Some of the characteristics of ice cream mix that merit consideration are the desired flavor, body and texture; anticipated product cost and input costs; handling properties (including mix viscosity, freezing point, and whipping potential/overrun); food energy and nutrient value; color; and general palatability and quality of the finished product. In developing a formula to fulfill the needs of any particular situation, numerous factors must be considered. These include composition standards; the nature of the competition; type of manufacturing operation; source, availability, quality, and cost of ingredients; and production capacity. Although the methods of processing and freezing influence the characteristics of the mix and of the finished product, the effects of constituents supplied by the ingredients are also important. Therefore, each constituent contributes to the characteristics of the ice cream.

Although the traditional ingredients of ice cream were cream, concentrated or condensed milk, sugar, stabilizer, and high quality flavoring, ice cream manufacturers have found it highly desirable to use a variety of alternative ingredients, including

concentrated sources of milkfat or nondairy fats, various milk protein powders, and various corn starch hydrolysate sweeteners.

It is important to remember that MSNF in ice cream are typically nearly twice as concentrated as in milk. Therefore a concentrated source of MSNF, such as condensed skim milk or milk powder, is required. The MSNF portion of cream and milk is insufficient to supply the desired levels of MSNF in the mix. Also, water is a major component in a mix formulation (100-total solids = water, so therefore typically 60–65% water in a 35–40% total solids mix). Water can be supplied by milk or skim milk, also a small amount by that coming from cream or liquid sweeteners, or it can be from a potable water supply (municipal or well water).

Ingredient labels for representative vanilla ice creams in the United States follow with the ingredients listed in the order of highest to lowest use concentration, as they are required on the package. A total of 24 different ingredients appeared on the ingredient labels of the 38 samples examined in the market survey. The lists were composed by taking the most frequently used ingredients for each class of product. Therefore, the lists are unlikely to match exactly that on a single manufacturer's container.

Superpremium: cream, skim milk, sugar, egg yolk, vanilla extract.

Premium: milk, cream, sugar, high fructose corn syrup, egg yolk, mono-/diglycerides, carob bean gum, guar gum, lecithin, carrageenan, vanilla extract, caramel color.

Regular, no artificial flavor: milkfat, nonfat milk, sugar, corn syrup, high fructose corn syrup, whey, cellulose gum, carrageenan, vanilla extract, annatto color.

Regular, natural and artificial flavor: milk, cream, buttermilk, corn syrup, whey, high fructose corn syrup, sugar, mono-/diglycerides, cellulose gum, guar gum, calcium sulfate, polysorbate 80, carrageenan, natural and artificial flavors, annatto.

Reduced fat, sugar free: milk, cream, polydextrose, maltodextrin, egg yolk, guar gum, locust bean gum, carrageenan, vanilla extract, vitamin A.

Light, no sugar added: skim milk, cream, sorbitol, maltodextrin, polydextrose, whey protein, mono-/diglycerides, cellulose gum, natural and artificial vanilla, cellulose gel, carrageenan, acesulfame K, aspartame, vitamin A, annatto color.

Low-fat: nonfat milk, cream, sugar, corn syrup, whey, polydextrose, maltodextrin, guar gum, cellulose gum, locust bean gum, carrageenan, mono-/diglycerides, annatto color, vanilla extract, vitamin A.

Nonfat: nonfat milk, sugar, corn syrup, maltodextrin, polydextrose, mono-/diglycerides, microcrystalline cellulose, guar gum, cellulose gum, carrageenan, vanilla extract, vitamin A.

Fat free premium: skim milk, corn syrup, sugar, pectin, vanilla, vitamin A.

Fat free, sugar free: skim milk, maltodextrin, polydextrose, sorbitol, whey protein, mono-/diglycerides, natural and artificial flavors, cellulose gum, carrageenan, acesulfame potassium, vitamin A, aspartame.

In a companion survey of ingredient labels of chocolate ice creams in the United States the only two ingredients in addition to those found in the vanilla ice creams were cocoa and chocolate liquor. The latter was found only in premium ice cream. Chocolate liquor would not, of course, be found in fat free products, because the cocoa butter content would furnish too much fat to permit a label claim of less than 0.5 g of fat per serving. There also was a higher incidence of the use of whey in chocolate than in vanilla ice cream, probably because the potential for the whey flavor to be detected by consumers is much less with a highly flavored than with a delicately flavored product.

The survey disclosed that manufacturers used a wide variety of label statements to show sources of milk solids in products with lowered fat content. Whereas, skim milk and nonfat milk are interchangeable words, some manufacturers appeared to consider skim milk to represent the liquid form and nonfat milk to represent the dried form of the product, so they listed both on the label.

Among the ice creams with full fat content, the choices of label terms to indicate sources of milk solids were skim milk, milk and cream, 37%; nonfat milk (or skim milk) and milkfat, 30%; milk and cream, 20%; milk and nonfat milk, 10%; and skim milk and cream, 3%. Since it would not be possible to supply enough milkfat with milk and nonfat milk to make a full fat ice cream, the products so labeled should be considered mislabeled.

Canada permits the use of category terms to indicate the presence in frozen desserts of one or more products within the category. "Milk Ingredients" are those products that have the same chemical composition as milk with either concentration of SNF components or fat, e.g., milk or skim milk in the fresh, concentrated or dried form, cream, and butter. "Modified Milk Ingredients" are those milk products that differ in chemical composition from milk, i.e., the fat or protein has been fractionated or the ratio of lactose:protein:minerals have been modified, although this is generally by physical processing rather than chemical modification per se, e.g., whey and whey products, caseinates, buttermilk, and fractionated milk fat.

Energy Value and Nutrients

The energy value of a food represents the contribution that food makes to the total energy requirements of the body. The unit customarily used by nutritionists for measuring human energy needs and expenditures and the energy value of foods is the kilojoule (SI unit) or kilocalorie (pre-SI unit, although still commonly used to designate energy content of foods). A kilocalorie is the amount of heat required to raise the temperature of 1 kg of water by 1 °C. A calorie is the amount of heat required to warm 1 g of water 1 °C, although the common use of the term "Calorie" (properly denoted by capital C) refers to a kilocalorie. 1 kcal = 4.18 kJ.

Digestion is the disintegration of the food into simple nutrients in the gastrointestinal tract to prepare them for absorption. Metabolism consists of the chemical changes that nutrients undergo from the time they are absorbed into the body until

they appear as excretory products. It includes the distribution of the absorbed food, the building (anabolism) and breaking down (catabolism) of tissues, and the absorption and release of energy. All nutrients are equally important to the extent they are needed in a particular diet.

The energy value and nutrients of ice cream depend upon the food value of the ingredients from which it is made. The milk products that go into the mix contain the constituents of milk, but in different amounts. On a weight basis ice cream contains three to four times as much fat, and about 12–16% more protein than does milk. In addition, it may contain other food products, such as fruit, nuts, eggs, candies, and sugar, and these may enhance its nutritive value. Ice cream contains about four times as much carbohydrate as milk. Like milk, ice cream is not a good source of iron and some of the trace minerals.

Ice cream is an excellent source of food energy. The fact that the constituents of ice cream are almost completely assimilated makes ice cream an especially desirable food for growing children and for persons who need to maintain or put on weight, for example the elderly. For the same reason, though, portion control is essential for persons who need to reduce or who do not wish to gain weight, so that it becomes part of a balanced and healthy diet and the contribution it makes to energy is fully accounted for.

Energy (Caloric) Content

The wide variation in the composition of ice cream and related products makes it impractical to provide nutritional data that will apply to all products. It is, however, possible to calculate for practical use the food energy value of a given product if the composition is known.

The total energy value of ice cream depends on (1) the percentage of carbohydrates including lactose, added sweeteners, many bulking agents, and sugars that may be present in fruit or flavoring; (2) the percentage of protein including that from milk, whey protein-based fat replacers, nuts, eggs, or stabilizer; and (3) the percentage of fat from any source including cream, emulsifier, egg, cocoa, or nut fat.

When the energy contents of fats, proteins, and carbohydrates are measured in a calorimeter, their yields are 39.7 kJ/g (9.45 kcal/g), 23.7 kJ/g (5.6 kcal/g), and 17.2 kJ/g (4.1 kcal/g), respectively. Not all the digestible food material is assimilated by the body. On average 5% of the fat, 8% of the proteins, and 2% of the carbohydrates are not absorbed. The amount of energy normally expected to be derived from milk per gram of fat, protein, and carbohydrate is as follows: fat 40.0 kJ (8.8 kcal), protein 17.9 kJ (4.3 kcal), and carbohydrates 16.2 kJ (3.9 kcal). These values are the amounts of energy released from the food nutrients as heat units or calories. They are referred to as physiological fuel values. In every day usage these numbers are rounded to 37 kJ (9 kcal), 17 kJ (4 kcal), and 17 kJ (4 kcal), respectively. Neither minerals nor vitamins furnish appreciable amounts of energy. The type of sugar has little relation to the fuel value derived from it, and all sugars have about the same energy value.

The energy value of 100 g of vanilla ice cream containing 12.5% fat, 11% MSNF, 15% sugar, and 0.3% gelatin (a protein) may be calculated as follows, assuming for the MSNF that lactose content is about 52% and protein content is about 36%:

Fat: $12.5 \text{ g fat} \times 37 \text{ kJ/g}$ (9 kcal/g) = 462.5 kJ (112.5 kcal)

Carbohydrates: $[15 \text{ g sugar} + (11 \text{ g MSNF} \times 0.52 \text{ g lactose/g MSNF})] \times 17 \text{ kJ/g}$ (4 kcal/g) = 352.2 kJ (82.9 kcal)

Protein: $[(11 \text{ g MSNF} \times 0.36 \text{ g protein/g MSNF}) + 0.3 \text{ g gelatin}] \times 17 \text{ kJ/g}$ (4 kcal/g) = 72.4 kJ (17.0 kcal)

Total: 462.5 kJ (112.5 kcal) + 352.2 kJ (82.9 kcal) + 72.4 kJ (17.0 kcal) = 887.1 kJ/100 g (212.4 kcal/100 g)

The energy value of a serving of ice cream varies with the composition of the mix and the weight of mix per volume of finished ice cream. In the United States, the serving size of ice cream for nutritional labeling purposes has been set at one-half cup or 4 fl oz (Federal Register, Vol. 58, No. 158, August 18, 1993, p. 44053). The serving size is 85 g for frozen flavored and sweetened ice, pops, and frozen fruit juices. Sundaes have a one-cup serving size. In Canada, a standard serving size is 125 mL.

Obviously, the weight of a serving of ice cream and the composition are the major variables. Ice cream is sold by volume with a minimum weight specified. Weight can be estimated by calculating the density of the mix and multiplying by the volume of mix per serving. Mix density varies from about 1.06 to 1.15 g/mL but density of the frozen product is a function of overrun and composition. The typical 4-fl-oz serving of ice cream contains between 65 and 68 g of mix when the overrun is 100%. If the overrun is 50%, the same 4 fl oz weighs 94–102 g. Overrun calculations are discussed and demonstrated in Chap. 6. As an example, let us calculate the energy content in a high solids, high-fat mix that contains 16% fat, 10% MSNF, and 17% sweeteners (47% total solids) on a weight basis and is frozen at 100% overrun.

1. Calculate mix density where densities of constituents are fat = 0.93 g/mL, MSNF = 1.58 g/mL, and water = 1 g/mL (see Chapter 6 for further details).

$$\text{Density} = \frac{100}{(16/0.93) + (31/1.58) + 53} = 1.095 \text{ g/mL}$$

2. Calculate the weight of mix in 4 fl oz (118.3 mL) when overrun is 100% (one-half of the volume is air). The mix constitutes $2 \text{ fl oz} \times 29.58 \text{ mL/fl oz} = 59.16 \text{ mL}$ and $59.16 \text{ mL} \times 1.095 \text{ g/mL} = 64.78 \text{ g}$
3. Calculate energy content:

Carbohydrates: $[17 \text{ g sweetener} + (10 \text{ g MSNF} \times 0.52 \text{ g lactose/g MSNF})] \times 17 \text{ kJ/g}$ (4 kcal/g) = 377.4 kJ (88.8 kcal)

Protein: $(10 \text{ g MSNF} \times 0.36 \text{ g/g MSNF}) \times 17 \text{ kJ/g}$ (4 kcal/g) = 61.2 kJ (14.4 kcal)

Fat: $16 \text{ g fat} \times 37 \text{ kJ/g}$ (9 kcal/g) = 592 kJ (144.0 kcal)

Total by wt.: 1030.6 kJ/100 g (247.2 kcal/100 g)

Table 2.5 Composition and energy content per serving of ice creams of widely varying fat content and overrun

Fat	MSNF	Sweeteners ^a	Density (g/serving)	Weight (g)	Overrun (%)	Energy content	
						(kcal/4 fl oz)	(kJ/125 mL)
Percentages (g/mL)							
16	10	17	1.095	64.8	100	160	710
16	10	17	1.095	97.2	50	240	1,065
10	10	17	1.042	61.6	100	120	535
10	10	17	1.042	92.4	50	180	800
5	13	17	1.120	66.2	100	105	470
5	13	17	1.120	99.3	50	160	710
0	13	22	1.150	67.9	100	90	400
0	13	22	1.150	102.0	50	135	600

^aIncludes maltodextrins, polydextrose, and corn syrups that may constitute parts of low-fat and nonfat ice creams

Table 2.6 Summary of average quantities per serving declared on nutrient labels of various categories of vanilla ice cream and frozen yogurt in central US markets

Descriptor	Weight (g)	Calories (kcal)	Fat (g)	Protein (g)	CHO ^a (g)	Sugars ^b (g)	Calcium (% DV) ^c	n ^d
Fat free/sugar free	71	90	0	3.0	19.0	4.0	8.0	2
Nonfat	67	98	0	3.5	21.0	16.0	9.5	5
Low-fat	71	103	2.2	3.0	18.2	15.2	9.0	10
Light	67	110	3.0	3.0	17.0	15.0	10.0	5
Reduced fat ^e	67	100	4.5	3.0	13.0	4.0	9.0	5
Regular (category i) ^f	69	170	8.0	2.5	16.0	14.5	7.0	4
Regular (category ii) ^g	65	135	7.2	2.1	16.0	13.4	8.0	13
Regular (category iii) ^h	65	130	7.5	2.0	14.5	12.0	8.0	2
Premium	74	160	9.5	2.6	16.0	14.4	8.5	9
Superpremium	106	260	16.3	5.0	23.0	21.3	15.0	3
Frozen yogurt	—	110	2.0	3.0	18.0	14.0	9.0	6

^aTotal carbohydrate, including sugars and polysaccharides

^bMono- and disaccharides, including lactose

^cCalcium expressed as % daily value in a 2,000 calorie diet

^dNumber of samples per category

^eReduced fat ice cream sweetened with nonnutritive sweeteners

^fFlavored with natural vanilla

^gFlavored with natural and artificial vanilla

^hFlavored with artificial vanilla

Total by serving: 1030.6 kJ/100 g (247.2 kcal/100 g) × 65.85 g/serving (118.3 mL or 4 fl oz) = 678.6 kJ (162.8 kcal)

Using the same approach, the energy content per serving has been calculated for a variety of ice creams at high and low overrun values (Table 2.5).

Energy values of one serving of representative types of ice cream vary widely as shown on nutritional labels (Table 2.6). Consumers often ask what impact consumption of ice cream may have on their weight. Data in Tables 2.5 and 2.6 show that one serving of ice cream contributes from less than 5% to more than 10% of the

calories of a 2,000 calories daily intake, which is generally deemed appropriate for adults whose activity levels are limited. As in all aspects of healthy eating, variety and moderation are important practices.

Protein Content

Ice cream has a high concentration of MSNF, which is 34–36% milk protein when obtained from traditional sources thus giving ice cream a protein content of 2.5–4% by weight. The milk proteins contained in ice cream are of excellent biological value, because they contain all the essential amino acids. Milk proteins are important sources of tryptophan and are especially rich in lysine. Milk proteins are not only known to be complete in amino acid composition, but the assimilation of ingested milk proteins is 5–6% more nearly complete than for other proteins in general. Proteins and essential amino acids are generally not deficient in the average diets of people from ice cream-consuming countries, although specific target groups, such as the elderly, may obtain needed protein from ice cream.

Protein content is calculated from determinations of the nitrogen content in the food (generally by the Kjeldahl, Dumas or similar methods, see Chap. 14). Early analysis of proteins showed that they have close to 16% nitrogen. The general practice then was to multiply the nitrogen content by the 6.25 conversion factor for the protein content. The accepted value for milk protein is 6.38.

Amounts of protein claimed on Nutrition Facts labels for a single serving of vanilla ice cream generally range from 2.0 to 3.5 g (Table 2.6). The amount is generally inversely related to the fat content (due to lowering of MSNF with increased fat, as discussed above), although the superpremium products also showed high protein values, to contribute to high totals solids. Additionally, when whey solids are added to replace up to 25% of the MSNF of a mix, protein is decreased. Dry whey contains about 12% protein as compared to about 35% in MSNF. Likewise, many of the blended milk powders used for MSNF in mix contain 20–25% protein, reduced from the 36% typically of skim milk solids. Hence the artificially flavored ice creams, those with perhaps lowest cost, also showed lower fat and lower protein than the naturally flavored ice creams.

Fat Content

Milkfat consists mainly of triacylglycerides of fatty acids, 95.8% on a weight basis. Glycerides are compounds in which one, two, or three fatty acid molecules are linked by ester bonds with the trihydric alcohol, glycerol. Mono-, di-, and triacylglycerides contain one, two, and three fatty acids, respectively. Milkfat is highly complex, containing almost 400 fatty acids. It is unique among fats and oils in that it contains 11.8 and 4.6 moles of butyric (4-carbon) and caproic (6-carbon) acids,

respectively, per 100 moles of total fatty acids. All of the butyric and 93% of the caproic acids are esterified to the third carbon (sn-3 position) of the glycerol molecule. Milkfat also contains 2.25% diacylglycerols, 1.11% phospholipids (nine different ones), 0.46% cholesterol, 0.28% free fatty acids, and 0.08% monoacylglycerols. Although milkfat is relatively low in polyunsaturated fatty acids (about 4.5%), it contains about 27% monounsaturated fatty acids.

Milkfat content in ice cream is usually determined by extracting and weighing the ether-soluble fraction (see Chap. 14). Interest in milkfat is centered on its nutritional and functional attributes. It supplies energy, essential fatty acids, fat-soluble vitamins, saturated and unsaturated fatty acids, and sterols including cholesterol. Several minor constituents are also present with unique healthful properties, unlike some of the vegetable fats. It functions to provide unique flavor, to carry fat-soluble flavors, to lubricate the mouth, and to affect the structure, thus the texture, of frozen desserts.

The nondairy fats in use are typically quite highly saturated to make them solid at refrigerated temperature for structure formation in ice cream, as discussed in Chap. 3. From a nutrition and health viewpoint, it would be desirable to use less saturated fat and/or to replace some of the saturated fat with unsaturated fat, since high levels of saturates in the diet have been associated with higher levels of cardiovascular diseases. The contribution of saturated fat from ice cream to one's total diet should be small, however, if ice cream is consumed in moderation.

Carbohydrate Content

Carbohydrates include starch, dextrin, cellulose, sugars, pectins, gums, and related substances. Carbohydrates serve as a source of heat and energy in the body. They are broken down to simple sugars under the action of specific enzymes secreted into the digestive tract and the principal end product is glucose. Sugars of several kinds may be used in the manufacture of ice cream. The commonly used sugar is sucrose, a disaccharide comprised of glucose and fructose, both of which are absorbed by the body after digestion. Sucrose from either sugar cane or beets is identical in composition. Corn syrup solids, now used extensively to replace a portion of the sucrose, come from the hydrolysis of starch to maltodextrins and lower molecular weight starch fragments, maltotriose, maltose, and glucose (dextrose). All of this is digested in the body to glucose, which is absorbed. In high fructose corn syrup, some of the glucose is converted to fructose (levulose), which is also absorbed by the body. The sugars of most fruits are sucrose, fructose, and glucose. Invert sugar, a mixture of equal amounts of the monosaccharides fructose and glucose, is sometimes used.

Lactose, milk sugar, is a disaccharide of glucose and galactose that constitutes over one-third of the solid matter in milk and approximately 20% of the carbohydrate in ice cream. Lactose is unique in that it is found only in milk, whereas other types of sugars are fairly widely distributed in nature. Adults, especially those of Asian and African descent, may produce insufficient lactase enzyme (β -D-galactosidase) to fully hydrolyze the lactose in a full serving of ice cream. Lactose cannot be absorbed

through the intestinal wall unless it has been split from the disaccharide to the monosaccharide form. This condition may result in physical discomfort due to bloating and, in extreme cases, to diarrhea. These symptoms arise when the lactose moves into the large intestine where it raises the osmotic pressure causing water to migrate into the intestine (hence the diarrhea). Furthermore, the lactose is a substrate for coliform bacteria of the colon. They ferment it, producing liberal quantities of acid and gas, the latter causing the victim to have a bloated feeling. Lactose reduced ice cream formulations are discussed in Chap. 15.

Mineral Content

Certain inorganic elements are essential for growth and performance. Those needed in substantial amounts, calcium, phosphorus, magnesium, sodium, potassium, and sulfur, are termed major minerals or macronutrients. Those needed in small amounts, copper, cobalt, iodine, manganese, zinc, fluorine, molybdenum, and selenium, are termed trace minerals. The inorganic nutrients are interrelated and should be in particular proportions in the diet. Calcium and phosphorus are of vital concern since they are very important nutritionally, especially for building strong bones and teeth, and for unique functionality in dairy foods. About 85% of the phosphorus in the human body is combined with calcium in bones and teeth. Milk and its products, including ice cream, are among the richest sources of calcium.

The mineral content of ice cream derives almost entirely from the MSNF and is therefore found in proportion to the content of MSNF, which can range from about 6 to 14%, although it is normally more like 9–11%. It should be noted, though, that when protein is lowered in MSNF due to use of whey powder or blended MSNF ingredients with low protein, this will affect the mineral content. Calcium averages about 13.8 mg/g MSNF so 70 g servings of ice cream with these extremes of concentration would contribute from 90 to 105 mg of calcium to the diet. The average, 97.5 mg, is 8–12% of the Recommended Daily Allowance (RDA) for calcium in the human diet (the RDA for children is 700–1,000 mg, teenagers 1,300 mg and for most adults is 1,000–1,200 mg, Institute of Medicine 2011), as shown on most Nutrition Facts labels (Table 2.6). Similarly, 1 g of MSNF contains about 10.7 mg of phosphorus, and 70 g of the ice creams formulated at the extremes of MSNF content would contain about 70–85 mg of phosphorus. Since the RDA for phosphorus is 1,250 mg/day for persons ages 9–18 and 700 mg/day for adults (Institute of Medicine 2011), it is obvious that ice cream can be a significant source of phosphorus. One serving can furnish about 7–10% of the RDA. Unlike calcium, phosphorus and magnesium, people generally consume too much sodium in their diet, mainly from processed and prepared foods. The sodium content of MSNF is about 5 mg/g MSNF or 30–40 mg per serving of ice cream. The Tolerable Upper Intake Level for sodium is, on average, 2.3 g/day (Institute of Medicine 2011), so a serving of ice cream is well below the limit and not a significant issue for those wanting to reduce sodium intake. Not all sodium in ice cream comes from the MSNF, however, as salt may be

added to the mix as an ingredient (although there is no specific reason to do this, see Chap. 3) or salt may come from various flavoring materials that are incorporated into the ice cream mix pre- or post-freezing.

Fortunately, milk contains little copper or iron, the two minerals that catalyze oxidation. Since ice cream is often stored for weeks to months, it is imperative that contamination of any of the ingredients with these two minerals be prevented. This is a major reason why manufacturers exclude copper from dairy equipment.

Vitamin Content

Like milk, ice cream is an important source of several vitamins, the content depending primarily on how much milk solids is contained and the weight of a serving. The fat-soluble vitamins, A, D, E, and K, are contained mainly in the fat and are absent in unfortified nonfat products. Milkfat is a good source of vitamin A. In the United States, manufacturers are required to add vitamin A to low-fat and nonfat ice creams. The content of water-soluble vitamins is proportional to the concentration of MSNF in plain ice creams. The highest concentration is expected in nonfat ice cream and the lowest concentration in high-fat ice cream. Fruits and nuts also contribute some of these vitamins. Ice cream is considered a good source of riboflavin. As with calcium, 70 g of ice cream contributes about 10% of the RDA of riboflavin, i.e., about 18 $\mu\text{g/g}$ of MSNF and from 75 to 175 $\mu\text{g}/70\text{ g}$ of ice cream. Ice cream can also furnish significant amounts of thiamin, B6, and pantothenic acid.

Palatability and Digestability

The high palatability of ice cream is an important factor in choice of it as a food. Chewing is not required with most flavors, and the smooth velvety texture soothes the palate. Its coldness makes it especially desirable during hot weather. Digestibility is generally high. The exception can be with the lactose malabsorbing person. Thus, ice cream is an ideal food for times when other foods do not appeal. No other food contributes so much food value in as attractive and appealing form or is so universally liked and distributed as is ice cream.

The Balanced Mix

A balanced mix is one in which the proportions of the ingredients will produce a satisfactory finished product—a frozen dessert in which the defects, if any, cannot be further corrected by any change in the composition or ingredients of the mix. The structure of ice cream, and the functional contributions of its components, is very complicated. Full knowledge of these functional contributions of mix components

is required to ensure the mix formulation is properly balanced. Ice cream structure is described fully in Chap. 11.

Defects caused by adding defective ingredients, such as rancid or feed flavor, or by manufacturing errors cannot be corrected by changing the concentration of the constituents. Therefore, they do not indicate a poorly balanced mix. However, other defects, such as (1) lack of flavor—insufficient concentration of flavoring, (2) lack of richness—insufficient concentration of fat, (3) sandiness—too high concentration of lactose, (4) shrinkage—generally associated with low protein levels, or (5) weak body—low total solids or low stabilizer, may be corrected by changing the composition of the mix. These defects indicate that the mix is unbalanced.

Balancing is done to give desirable results under certain limited conditions of processing and handling the mix or of handling the finished ice cream. For example, a mix may be properly balanced for a finished ice cream that is to have a rapid turnover, but the components might cause sandiness if the ice cream were to be stored for an extended time. Another mix may be properly balanced for freezing in a batch freezer but not in a continuous freezer. A mix may be thrown out of balance by changing the source of the constituents. For example, if the fat in the mix is obtained from butter, the mix may need additional emulsifier to improve its whipping ability and to give it the proper balance, but if the mix is made with sweet cream, the additional emulsifier would not be necessary. Knowledge and understanding of the role of each constituent together with its advantages and limitations are necessary in selecting a desired composition and in properly balancing a mix. Usually an ice cream mix that is properly balanced for average commercial conditions will have between 36 and 42% total solids and between 20 and 26% TMS (obtained by adding the percentage of fat to the percentage of MSNF). This does not apply to a mix for ice cream with lowered fat content, a sherbet, or an ice. (Calculations for balancing mixes are given in Chap. 6.) For easy reference the functions and limitations of the constituents of ice cream are summarized in Table 2.1, and these will be discussed more thoroughly in Chap. 3.

Nutrition Labeling Based on Composition

In the United States, the Food and Drug Administration has responsibility for food legislation, including The Nutrition Labeling and Education Act. Firms affected by this Act are those that sell more than \$500,000 of all food and nonfood products and sell more than \$50,000 of food per year. Packages having less than 12 in.² (30.5 cm²) of surface area and on which there is no nutrition claim are exempt from the rule. Those packages must bear an address or telephone number that a consumer can use to obtain the required nutrition information. Major provisions of the regulations as they affect labeling of frozen desserts are presented in the following.

All nutrient and food component quantities shall be declared in relation to a serving. A serving is an amount of food customarily consumed per eating occasion by persons 4 years of age or older. Furthermore, the serving size is to be expressed in common household measure. For frozen desserts in the United States, this reference

size was set at one-half cup (4 fl oz, 118 mL), including the volume of coatings and wafers for novelty type products. This regulation, combined with the minimum weight per gallon stipulation of the US federal standard for ice cream, 4.5 lb/gal minimum weight, sets the minimum weight of a serving at 63.8 g. This is calculated as follows:

$$\begin{aligned} &4.5 \text{ lb/gal} \times 453.6 \text{ g/lb} \times 1 \text{ gal} / 128 \text{ fl oz} \times 4 \text{ fl oz} / \frac{1}{2} \text{ cup/serving} \\ &= 63.8 \text{ g/} \frac{1}{2} \text{ cup serving (round to 64 g)} \end{aligned}$$

By consulting the weight per serving declared on the container one can easily calculate the target overrun of the manufacturer. In a 2002 survey by Prof. R. T. Marshall of the University of Missouri, the declared weight per serving of regular vanilla ice cream in half-gallon containers averaged 66 g with a standard deviation of 2 g. Seven of the 14 brands surveyed declared the serving size as 65 g. The maximal net weight per serving was 71 g, which, if a mix weight of 9 lb/gal is assumed, is equivalent to the overrun shown in the following calculation:

$$\begin{aligned} \text{Wt. of 4 fl oz of mix} &= 9 \text{ lb/gal} \times 453.6 \text{ g/lb} \times 1 \text{ gal} / 128 \text{ fl oz} \times 4 \text{ oz} = 127.6 \text{ g} \\ \frac{127.6 \text{ g mix} / 4 \text{ fl oz} - 71 \text{ g ice cream} / 4 \text{ fl oz}}{71 \text{ g ice cream} / 4 \text{ fl oz}} \times 100 &= 80 \% \end{aligned}$$

This formula can be used for any similar calculation by substituting the actual weight per gallon of mix and the target weight in g/serving to calculate the desired overrun, or if the desired overrun is known, to calculate the desired weight per serving. For example: If a 120 mL container of mix weighs 140 g and the same volume of the finished ice cream weighs 80 g, the overrun is $(140 - 80) / 80 \times 100 = 75\%$ (see Chap. 6, section “[Overrun Calculations](#)”).

In addition to the minimum weight per volume, the US standard requires ice cream to contain at least 1.6 lb of food solids per gallon (192 g/L). This equates to 22.7 g of food solids per 4 fl oz (118 mL) serving. Thus, the minimum TS in the mix would be 35.44% when overrun is set at 100%. The minimum fat content, unless the label contains a descriptor, is 10% in plain ice cream. This equates to 6.4 g/serving, and the label would read 6 g of fat. The total milk solids must equal at least 20%, so the minimum MSNF in this ice cream would be 10%. The estimated protein content would be 36% of the MSNF, or $64 \text{ g} \times 0.1 \times 0.36 = 2.3 \text{ g}$, and the label would read 2 g. If the remainder of the solids of the mix is composed of 10% sugar, 5% corn syrup solids, and 0.44% stabilizer/emulsifier, the amount of carbohydrate is 15% of 64 g plus the amount of lactose in the MSNF. If all of the MSNF is supplied by concentrated skim milk, the lactose can be estimated as 56% of the weight of the MSNF. Total carbohydrate would be $[0.10 + 0.05 + (0.56 \times 0.10)] \times 64 \text{ g} = 13.18 \text{ g}$, and this would be rounded to 13 g. The calcium content would be about 90 mg, and this is 9% of the Recommended Dietary Allowance for men and women between the ages of 25 and 50 (Institute of Medicine 2011).

The label must also show amounts per serving for calories, calories from fat, total fat, saturated fat, cholesterol, sodium, total carbohydrates, sugars (mono- and disaccharides including lactose), dietary fiber, and protein. Furthermore, the % Daily Value must be given as referenced to a 2,000-calorie-per-day diet for the above components, for vitamins A and C, and for the minerals calcium and iron. The Daily Value is based on the RDA, averaged over gender and age. A label typical for regular vanilla ice cream is shown in Fig. 2.1. The list of nutrients covers those most important to the health of today's consumers, most of whom, in developed countries, need to be concerned about getting too much of certain nutrients rather than too few vitamins or minerals as in the past. Canadian regulations issued in 2003 are similar to those of the United States. A standard serving size is 125 mL. The following is the core information to be listed in the order presented per serving: energy value (kJ and/or kcal), amounts of fat, saturated fat, trans fat, cholesterol, sodium, carbohydrates, fiber, sugars, protein, vitamin A, vitamin C, calcium, and iron. Optional health claims permitted highlight the dietary characteristics that reduce the chance of developing diseases such as osteoporosis, heart disease, some types of cancer and hypertension.

At the same time as labeling regulations were changed in the United States, the Federal Standard of Identity for ice milk was dropped. This action was made possible by the adoption of descriptors to describe foods in terms of selected important characterizing ingredients. The most important characterizing ingredient of ice cream is milk fat, and the descriptors used are as follows:

Reduced fat: 25% less fat than the reference product.

Light: 50% reduction in total fat from the reference product, or one-third reduction in calories if fewer than 50% of the calories are from fat.

Low-fat: not more than 3 g of total fat per serving.

Nonfat or fat free: less than 0.5 g of fat per serving.

Interestingly, in the calculation of the amount of fat contained, the values expressed are the free fatty acid portion, and the glycerol portion is not included. The average molecular weight of milk fat is approximately 780 g/mole, and glycerol makes up approximately 5% of the triacylglycerides. Therefore, the traditional ether extraction test of milk fat detects about 5% more lipid than must be considered in writing the nutrition facts label.

These lower fat products must not be deemed nutritionally inferior in the nutrients shown on the nutritional label; therefore, vitamin A, a fat-soluble vitamin carried by milk fat must be added. Since milk fat contains an average of nearly 40 International Units of vitamin A equivalents per gram of fat and regular ice cream is required to contain at least 6.4 g of fat per serving, the amount of vitamin A to be contained in ice creams with lowered amounts of fat would be $40 \times 6.4 = 256$ IU, and this is 5.12% of the US Recommended Daily Allowance. The rounding rule specifies that for vitamins amounts are expressed in 2 IU; therefore, the label would read 6% of the Daily Value. (Readers are referred to 21 CFR 104.20 for rules on fortification of foods.)

These lower fat products must possess physical and functional properties that resemble those of the product they replace, i.e., flavor, body, texture, and appearance must be

Fig. 2.1 Example of nutrition facts label on a half-gallon package of regular vanilla ice cream

Nutrition Facts	
Serving Size 1/2 cup (66 g)	
Servings Per Container 16	
Amount Per Serving	
Calories 130	Calories from Fat 70
% Daily Value*	
Total Fat 7g	11%
Saturated Fat 4.5g	22%
Cholesterol 30mg	10%
Sodium 55mg	2%
Total Carbohydrate 16g	5%
Dietary Fiber 0g	0%
Sugars 15g	
Protein 2g	
Vitamin A 6%	Vitamin C 0%
Calcium 8%	Iron 0%
* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower based on your calorie needs:	
	Calories: 2,000 2,500
Total Fat	Less than 65 g 80 g
Sat Fat	Less than 20 g 25 g
Cholesterol	Less than 300 mg 300 mg
Sodium	Less than 2,400 mg 2,400 mg
Total Carbohydrate	300 g 375 g
Dietary Fiber	25 g 30 g
Calories per gram:	
Fat 9	Carbohydrate 4 Protein 4

in semblance of ice cream. The same safe and suitable ingredients are to be used as for ice cream, and it is permissible to add fat analogs and water to replace fat and calories. Furthermore, it is permissible to lower the content of lactose by ultrafiltration, to add hydrolyzed dairy proteins, and to utilize safe and suitable sweeteners such as aspartame and acesulfame potassium (acesulfame K). In each case the label of the product must identify each ingredient. Finally, these products may weigh as little as 4.0 lb/gal (480 g/L), one-half pound less than the whole fat variety of ice cream.

It is permissible to label some ice creams as “healthy.” Such a product must contain, on a per serving basis, not more than 3 g total fat, 1 g saturated fat, 15% of calories from saturated fat, 60 mg of cholesterol, or 360 mg of sodium. Additionally, it must contain at least 10% of the Daily Value of at least one of the following nutrients: vitamin A, vitamin C, calcium, iron, protein, or fiber.

The market survey of US ice creams referred to above reveals the mean values shown in Table 2.6 for selected nutrients in variously labeled retail ice creams.

An informal survey of 11 ice cream products in Canada in 2011 showed that nine products ranged from 540 to 600 g/L (90–110% overrun), while two were from 700 to 900 g/L (40–70% overrun). The declared energy content ranged from 120 to 160 kcal/125 mL serving, with the two dense products reporting 195 and 290 kcal/125 mL serving. It was also interesting to note that all those who were using cream as a milk fat source declared that on the label, rather than the category term “Milk Ingredients,” presumably to enhance consumer perception of their products.

The website at http://laws.justice.gc.ca/eng/regulations/C.R.C.,_c._417/index.html contains Canadian general regulations for packaging. The Canadian laws specific to Nutrition Facts labeling can be found at <http://www.hc-sc.gc.ca/fn-an/label-etiquet/nutrition/index-eng.php>.

For those countries establishing or amending nutrition labeling regulations the Codex Alimentarius Commission produced “Codex Guidelines on Nutrition Labeling” (CAC/GL 2-1985, revised 1993, 2003, 2006, 2009, 2010). The following principle stated in the document applies to regions in which nutrition labeling is voluntary: “Nutrition labeling should not deliberately imply that a food which carries such labeling has necessarily any nutritional advantage over a food which is not so labeled.” The document states that where nutrient labeling is applied, the following should be declared: energy value; amounts of protein, available carbohydrate and fat; the amount of any nutrient for which a nutrition claim is made; and the amount of any other nutrient considered relevant for maintaining a good nutritional status. Major components of the document are (1) definitions; (2) conversion factors for calculating energy values and protein content; (3) methods for presenting nutrient content; (4) nutrient reference values; and (5) tolerances. The document can be downloaded free from the CODEX web pages.

The ingredient label should list the constituents of the frozen dessert by source in order of dominance. For example, for ice cream made with water, 10% fat from butter, 11% MSNF from nonfat dry milk, 10.5% sugar, 6% corn syrup solids, 1.4% egg yolk solids, 0.2% stabilizer, 0.05% butter flavoring, 3% pecans, and 0.01% yellow No. 5 food coloring, the ingredient label would read as follows: water, nonfat dry milk, sugar, butter, corn syrup solids, pecans, egg yolk, stabilizer (mono- and diglycerides, carob bean gum, guar gum, vegetable lecithin, carrageenan), butter flavoring, Yellow No. 5 (a food color). The word stabilizer may be left out and the parentheses deleted surrounding the names of those ingredients. On the Canadian label “Milk Ingredients” have the same chemical composition as the milk fat or SNF fraction of milk, e.g., milk or skim milk, cream, and butter, whereas “Modified Milk Ingredients” are those milk products that differ in chemical composition from milk (fractionated fat or altered ratio of MSNF components), e.g., whey and whey products, caseinates, buttermilk and fractionated milk fat. Since water is used for rehydration

of milk solids, it does not need to be listed as an ingredient when using the category term “Milk Ingredients” or “Modified Milk Ingredients.”

Some consumers are sensitive to peanuts, other nuts, egg protein, casein protein, Yellow No. 5 and other allergens. Failure to list on labels substances that cause allergic reactions has resulted in many recalls of products from the market at very high costs to the manufacturer. Producers must be vigilant to avoid cross-contamination between batches of product containing food allergens. Such an occurrence can result in the presence of allergens in product for which there is no mention on the ingredients label. In ice cream processing, a likely cause of this is failure to remove an allergenic ingredient from equipment before processing a succeeding mix. The freezer, ingredient feeder, and their supply lines pose high-risks for cross-contamination. However, the most risk is associated with rework in which sources of the product include multiple flavors or mixes. The US FDA makes available the document “Guidance on Inspections of Firms Producing Food Products Susceptible to Contamination with Allergenic Ingredients.” It can be accessed at <http://www.fda.gov/ora> under “Inspectional References.” In Canada, an overwhelming number of ice cream manufacturers use the phrase “May contain traces of peanuts/nuts” or “Produced in a plant that also processes pants/nuts” on all products, to indicate to the consumer the risk of potential cross-contaminations.

To minimize risk of unlabeled allergens in a product the FDA makes the following recommendations:

1. Check labels to ensure potential allergens are listed thereon.
2. Conduct audits of labels to confirm they match the finished product.
3. Do not store allergenic materials next to non-allergens.
4. Control dusts of allergens.
5. Design systems to minimize the amount of equipment exposed to an allergen.
6. Schedule long run times to minimize product changeovers.
7. Run non-allergen containing products before those containing allergens.
8. Remove all allergenic ingredients, products, and their packaging materials from the production system before introducing another set of materials. Have a person responsible to check and sign off on this.
9. Add rework that contains allergens to that product only.

Recommendations 1 and 2 presume that persons sensitive to dairy ingredients are well aware of their presence. The greater the number of potential allergens used in a frozen dessert the greater the number of potential customers that will avoid consumption of that product.

Reference

Institute of Medicine (2011) Dietary Reference Intakes (DRIs): estimated average requirements. Food and Nutrition Board, Institute of Medicine, National Academies, Washington, DC

Ice Cream

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