Chapter 10
Ice Cream and Frozen Desserts

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10.1 Introduction

Ice cream is among the most favorite desserts in the USA, and vanilla, chocolate, and strawberry are the preferred flavors. Ice cream is a frozen food made of a mixture of dairy products such as milk, cream, and nonfat milk, combined with sugars, flavoring, and inclusions, such as fruits and nuts. Functional ingredients, such as stabilizers and emulsifiers, are often included in the product to promote proper texture and enhance the eating experience. According to US standards, ice cream must contain at least 10% milk fat, before the addition of bulky ingredients, and must weigh a minimum of 4.5 pounds to the gallon. Ice cream containing at least 1.4% egg yolk solids is called French ice cream or frozen custard. Superpremium ice cream is a denser product because it contains 16–18% milkfat and low overrun (20–50% range). Ice creams with reduced fat levels, which are described later in this chapter, contain the same ingredients as regular ice cream, and follow the labeling guidelines established by the FDA. Soft-serve ice cream is a frozen dessert that is soft frozen just before serving on the premises, so the formulas differ from hard-frozen products. The fat content of soft-serve mixes is in the range of 4–12%, and the serum solids vary inversely from 11% to 14% with fat content (Marshall et al., 2003).

Ice cream is one of the most popular desserts in the USA, with approximately 5.83 billion liters (2.6 billion gal) produced in 2019 (USDA, 2021). Most of the ice cream produced in the USA is the hard-frozen type, but the production of soft serve has increased over the past decade. The US per capita consumption of ice cream,

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sherbet, and other commercially produced frozen dairy products was 18.7 pounds in 2019. It is estimated that 98% of all US households purchase ice cream (USDA, 2021).

Ice cream and related products are members of the "frozen dairy desserts family" and are defined in the Code of Federal Regulations (CFR) Title 21, Part 135. These frozen desserts are defined as follows:

Reduced fat ice cream contains at least 25% less total fat than the referenced product (either an average of leading brands or the company's own brand). *Light* ice cream contains at least 50% less total fat or 33% fewer calories than the referenced product (the average of leading regional or national brands). *Low-fat* ice cream contains a maximum of 3 g of total fat per serving (1/2 cup). *Nonfat* ice cream contains less than 0.5 g of total fat serving.

Mellorine is a food similar to ice cream but having the milk fat replaced in whole or part with vegetable or animal fat. The FDA Standard of Identity specifies that it contains not less than 6% fat and 2.7% protein. The milk-derived protein has 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 (21 CFR 135.130).

Sherbets have a milkfat content of between 1 and 2% and slightly higher sweetener content than ice cream. Sherbet weighs a minimum 6 pounds to the gallon and is flavored either with fruit or other characterizing ingredients (21 CFR 135.140).

Water ices are similar to sherbets, but contain no dairy ingredients; no egg ingredient, other than egg white; and the mix need be not pasteurized (21 CFR 135.160).

Other frozen dairy desserts, including but not limited to gelato and frozen yogurt, are not defined in the CFR and are not regulated by the FDA.

Each product category may differ in the type of flavoring, the composition in terms of dairy ingredients and other food solids, and the extent of product overrun (increase in ice cream volume due to air incorporation). Table 10.1 summarizes the compositional differences of the major classes of frozen dairy desserts. The optional milk ingredients that these frozen dairy desserts may contain are listed in Table 10.2. Within the restrictions imposed by the 2022 CFR, 21 CFR 135.110 (Table 10.1), ice cream is basically defined as that food produced as a result of freezing, while stirring, a pasteurized mix that consists of one or more of the dairy ingredients listed in Table 10.2 and other non-milk-derived ingredients (that are safe and suitable). The latter serve functions such as nutritive carbohydrate sweeteners, stabilizers, emulsifiers, flavorings, and coloring agents.

The sensory evaluation of ice cream and frozen desserts is not easy. It requires training and continuous practice with prepared samples before a person can develop the necessary skills, knowledge, and senses to judge ice cream. In addition to the expertise of the judge, proper environmental conditions during evaluation are necessary to judge the products correctly. This chapter covers in detail the physical and chemical characteristics of the most common frozen desserts, the ingredients, and their influence on sensory attributes such as flavor, body, and texture. The possible causes and corrections of off-flavor, body, and texture defects are discussed as well.

Table 10.1 Federal Standards of Identity for the composition of frozen dairy deserts

Product	Weight (lb/gal)	Total solids (lb/gal)	Total milk solids (%)	Milk fat (%)	Whey solids (%)	Egg yolk solids (%)	Caseinates	Overrun (%)
Ice cream[a]	≥4.5	≥1.6	≥20	≥10	≤2.5	<1.4	b	90–100
Bulky-flavored ice cream[c]	≥4.5	≥1.6	≥16	≥8	≤2.0	d	b	
Frozen custard[e]	≥4.5	≥1.6	≥20	≥10	≤2.5	≥1.4	b	90–100
Bulky-flavored frozen custard[e]	≥4.5	≥1.6	≥16	≥8	≤2.0	≥1.12	b	
Mellorine[h]	≥4.5	≥1.6	g	f	g	i	j	
Reduced fat ice cream	≥4.5			k			b	
Light ice cream	≥4.5			l			b	
Low-fat ice cream				m			b	
Sherbet	≥6.0		2–5%	1–2%	0–4%	i	j	30–40
Water ices	≥6.0		0	0	0	0	0	25–30

From: Code of Federal Regulations Title 21, Part 135.110–135.160

[a]Increases in milk fat may be offset with corresponding decreases in nonfat milk solids, but the latter must be at least 6% in frozen custard and ice cream and 4% in low-fat ice cream. Corresponding adjustments may be made in bulky-flavored products

[b]May be added to ice cream mix containing not less than 20% total milk solids, providing that caseinates are prepared by precipitation with gums, ammonium caseinate, calcium caseinate, potassium caseinate, and sodium caseinate

[c]Adjustment in composition in bulky-flavored frozen desserts is determined by calculation based on the actual quantity of bulky flavor used. However, the analysis must never be lower than the minima given in the table

[d]Less than 1.4% egg yolk solids by weight of food exclusive of the weight of any bulky-flavor ingredients

[e]Also designated French ice cream or French custard ice cream

[f]Milk fat replaced by a minimum of 6% vegetable or animal fat

[g]At least 2.7% milk-derived protein having a protein efficiency ratio (PER) not less than that of whole milk protein, 108% of casein

[h]For bulky-flavored mellorine, in no case shall the fat content of the finished food be less than 4.8% or the protein content less than 2.2%

[i]Egg yolk solids are allowed

[j]Caseinates are allowed

[k]Ice cream made with 25% less fat than the reference ice cream

[l]Ice cream made with 50% less fat or 1/3 fewer calories than the reference ice cream, provided that in case of caloric reduction less than 50% of the calories are derived from fat

[m]Solids from concentrated, dried, and modified whey used singly or in combination may not exceed 25% of the total milk solids content permitted

Composition is determined by calculation based on actual quantity of the bulky flavor used. However, the milk fat content and the nonfat milk solids content must never be lower than 2 and 7%, respectively. (Total milk solids must not be less than 9%)

Table 10.2 Optional dairy ingredients approved for use in ice cream and frozen custard[a]

Cream	Fresh, dried, plastic (concentrated milk fat)
Butter and butter oil	
Milk	Fresh, concentrated, evaporated, sweetened condensed, super-heated condensed, dried, skim, concentrated skim, evaporated skim, condensed skim, super-heated condensed skim, sweetened condensed skim, sweetened condensed part-skim milk, nonfat dry milk, sweet cream butter milk, condensed sweet cream butter milk, dried sweet cream butter milk, skim milk that may be concentrated from which part or all of the lactose has been removed
Whey[b]	Whey and whey products recognized as GRAS by the FDA, whey solids are limited to not more than 25% of milk solids nonfat
Casein[c]	Precipitated with gums
Caseinate[c]	Salt of ammonium, calcium, potassium, or sodium
Buttermilk[d]	Fresh, condensed, or dried; for churning of sweet cream
Hydrolyzed milk proteins	Added as stabilizers at a level not to exceed 3% by weight of ice cream mix containing not less than 20% total milk solids

From the Code of Federal Regulations Title 21, Part 135.110

[a]The Federal Standards of Identity provide quality standards for certain of the above ingredients

[b]Generally recognized as safe

[c]Not considered to be milk solids (does not satisfy milk solids requirements)

[d]Titratable acidity of not more than 0.17%, calculated as lactic acid, for a solution of 8.5% total solids

The use of scorecards to evaluate and record the quality of ice cream is also part of this chapter. Special emphasis is given to the Annual Collegiate Dairy Products Evaluation ice cream scorecard. The information in this chapter should provide the necessary background and guidelines for individuals to become skilled judges of the quality of frozen dairy products after a reasonable period of rigorous training and practice.

10.2 Ingredients

The quality of ice cream may be influenced by several factors: (a) the quality of mix ingredients such as milk, cream, nonfat milk, sugars, flavoring, and inclusions; (b) processing conditions; (c) freezing; (d) packaging; and (e) handling and storage conditions. These factors determine the sensory attributes of the product as sweet flavor, body and texture, and cold sensation that are perceived by consumers. The quality and sensory attributes of ice cream can be evaluated through its color, microbial, chemical, and physical analyses, although these measurements are not necessarily a direct indication of the "eating quality" of the ice cream as perceived by the consumer in terms of the most desirable flavor, texture, color, appearance, and overall quality. That is the reason why human senses, as opposed to machines, are still used widely in evaluating ice cream products. Even though the perception and

preferences of the sensory attributes vary among different individuals, judging and scoring of ice cream products are important tasks of the quality control programs of ice cream processors. Finished products are evaluated for sensory quality after freezing and throughout the different stages of storage, shipping, handling, and distribution.

The sweeteners. The sweeteners commonly used in ice cream are sucrose (cane or beet sugar), dextrose (corn sugar), and various corn syrups (Marshall et al., 2003; Goff & Hartel, 2013). Honey, when used, imparts both sweetness and a characteristic flavor. Corn syrup is produced by converting starch into a mixture of simpler sugars including dextrose, maltose, maltotriose, maltotetraose, and dextrins (in ascending order of molecular weights). Members of the mixture with lower molecular weights exhibit greater sweetness, while the higher-molecular-weight members have the ability to limit water migration and ice crystal formation more effectively. The dextrose equivalent (DE) designation of a given corn syrup provides an indication of the distribution of starch conversion sugars present. High DE values imply a high degree of conversion into dextrose, the simplest sugar produced from starch. Other available corn syrups are designated as high maltose and high fructose; the latter is produced by an additional processing step that converts dextrose into fructose. Fructose provides the most sweetness for a given amount of added sweetener.

In an aqueous solution, such as found in ice cream, approximately 2 parts of 42 DE corn syrup, 3 parts of lactose, or 1 part of high-fructose syrup are required to impart the equivalent sweetness of 1 part of sucrose (the common standard). The generally accepted sweetness level for vanilla ice cream is a 13–15% sucrose equivalent (equal to 13–15% sucrose in the mix).

The relative hardness of ice cream produced at any given temperature depends on what proportion of water is frozen at that temperature, which in turn largely depends on the freezing point of the ice cream mix and the temperature at which the finished product is stored (Tobias, 1981, 1982; Bodyfelt, 1983a, b; Bodyfelt et al., 1988; Goff, 2002; Clarke, 2006; Goff & Hartel, 2013). The freezing point of ice cream is particularly influenced by soluble solids, especially sweeteners. Furthermore, the amount of ice and the size distribution of ice crystals affect the relative hardness of ice cream (Wibley et al., 1998; Hartel et al., 2004; Amador et al., 2017).

During freezing, latent heat of water is removed and this results in the formation of ice crystals. The remaining solution becomes more concentrated in terms of the soluble constituents because of the transformation of a part of water into ice crystals by the freezing process. This process is called freeze concentration (Hartel, 1996; Marshall et al., 2003; Goff & Hartel, 2013). Viscosity and glass transition states influence the freezing process and textural properties of ice cream. Water bound by stabilizers is not available to freeze initially or to refreeze during subsequent storage (Miller-Livney & Hartel, 1997). Low storage temperature and the presence of stabilizers reduce the kinetic energy of water molecules, thereby reducing their mobility during temperature fluctuations of storage (Fennema, 1993). A high proportion of bound water in ice cream, or other frozen dairy desserts, serves to reduce the amount of water to be frozen. This increases the resistance of the ice cream to heat shock

during storage with less chance of recrystallization, thus improving the body and texture of the product.

Mineral salts present in milk, lactose, and added sugars reduce the freezing point of the ice cream mix (Hartel et al., 2004; Goff & Hartel, 2013). The monosaccharides, fructose, and dextrose equally lower the freezing point of a solution (or a mix) and concomitantly reduce the freezing point to a greater extent by weight than the disaccharides sucrose, maltose, and lactose. The higher-molecular-weight sugars that are present in corn syrup depress the freezing point to a lesser extent than do disaccharides, when compared on an equal weight basis. Each of the various sugars used in ice cream bind water to a different extent. The higher DE sugars and dextrins in corn syrup are the most effective binders of water, with the exception of stabilizers. The low DE corn syrups (e.g., 36 DE and 42 DE) lack sweetening power compared to the higher DE corn syrups, but the low DE sweeteners limit water migration more effectively and therefore have greater "body building" properties in ice cream and reduced fat ice creams (Anter et al., 1986; Marshall et al., 2003).

Liquid sugars of poor-quality or corn syrups can be sources of off-flavors in frozen dairy desserts, especially in vanilla-flavored products (Marshall et al., 2003). Dark syrups, wherein nonenzymatic browning (Maillard reaction or caramelization) has taken place, may impart a stale, caramelized flavor. Certainly more serious is the fermentation of liquid sugars or corn syrups, which generally makes them unusable in ice cream. When conducting sensory evaluation of ice cream, one should be alert to the possible flavor shortcomings that can stem from certain sweetener sources. Indeed, one of the most common attributes of vanilla ice cream is "syrup flavor," which will be discussed fully later in this chapter.

Emulsifiers. Emulsifiers provide several important functions, such as decreased whipping time, controlled fat destabilization, enhanced smoothness of texture, increasing resistance to melting and shrinkage, and improved dryness (Pelan et al., 1997; Goff et al., 1989; Goff & Hartel, 2013). A degree of destabilization of fat globules is essential to produce ice cream with desirable body (Goff & Jordan, 1989; Amador et al., 2017). Fat destabilization is described as the following process: emulsifiers, being better surfactants than the proteins, displace proteins from direct contact with the fat globule surface (Segall & Goff, 2002; Goff & Hartel, 2013); during freezing of the mix, the fat globule partially crystallizes and is exposed to shearing forces, allowing separate fat globules to partially coalesce with one another (van Boekel & Walstra, 1981; Akbari et al., 2019). The partially coalesced fat globules stabilize air cells, forming three-dimensional network structures with the air cells (Berger, 1997; Zhang & Goff, 2004; Goff & Hartel, 2013). Emulsifiers also contribute to the formation of small, uniformly dispersed air cells; protect against texture deterioration due to heat shock; and provide a semblance of a "richness" sensation. Over-emulsification may result in fat churning, a grease-like mouth coating, and/or an "emulsifier" taste. At times, even lower levels of emulsifiers may impart an aftertaste when they and/or other ingredients are old, oxidized, or have deteriorated in some other way. Commonly used emulsifiers include lecithin, mono- and diglycerides of fatty acids, polysorbate 80 (polyoxyethylene (20) sorbitan monooleate), and polysorbate 65 (polyoxyethylene (20) sorbitan tristearate)

(Marshall et al., 2003). Depending on the specific emulsifier(s) used, the concentration may vary from 0.03% to 0.2% (Mann, 1997). Polysorbate 80 leads to more extensive fat destabilization compared to mono- and diglycerides (Hartel et al., 2004).

Stabilizers. There are many important functions of stabilizers in ice cream and related products (Goff & Sahagian, 1996; Vega et al., 2004; Abbas Syed, 2018). One of them is to bind water, which in turn promotes small ice crystal formation and helps keep ice crystals from growing in size during recrystallization, i.e., when storage temperatures fluctuate or become too high (referred to as "heat shock") (Donhowe & Hartel, 1996; Hagiwara & Hartel, 1996; Sutton & Wilcox, 1998; Flores & Goff, 1999). Small ice crystals are favored by ice cream evaluators, as large ones produce unappealing "coarse" or "icy" mouthfeel.

Stabilizers also prevent the separation of clear serum during meltdown by modifying the ice crystal/serum interface (Sutton & Wilcox, 1998; Goff & Hartel, 2013). Another stabilizer function is to develop viscosity in the ice cream mix, since a more viscous mix has a better capacity to retain air bubbles (Cottrell et al., 1980; Bolliger et al., 2000b; Chavez-Montes et al., 2004; Abbas Syed, 2018). Stabilizers are usually proprietary blends of gums such as guar, locust bean, carrageenan, alginates, and carboxymethyl cellulose (CMC). Depending on the type and concentration of gums in the frozen dairy dessert mix, and the milkfat and solid content of the mix, stabilizers are used at levels ranging from 0.15% to 0.5% (Clarke, 2006). The typical usage level for stabilizers in ice cream is 0.5% (Marshall & Arbuckle, 1996). Although most commercial ice creams contain stabilizers and emulsifiers in small concentrations, some manufacturers exclude these body and texture-modifying agents from the formulation of certain brands, especially those products categorized and promoted as "premium quality" or "all natural" (Tobias, 1981, 1982, 1983; Bodyfelt, 1983a, b; Bodyfelt et al., 1988).

Flavoring and inclusion agents. Space does not permit the listing of all the possible or sum total flavorings used in ice cream and other frozen dairy desserts. As a general principle, there is no point in comparing one flavor type against another, as the choice is generally a matter of personal preference. The evaluator should be aware that flavorings range from natural to artificial, but, as a general rule, the natural source may be preferred from several viewpoints. However, the use of natural flavoring is not always a guarantee of high quality. For example, some sources of fresh or frozen strawberries (as well as certain other berries or fruits) may be deficient (lacking) in flavor intensity, though used at the recommended level (Bodyfelt et al., 1988; Marshall et al., 2003; Goff & Hartel, 2013). Other possible problems with berries or fruits may involve (1) the utilization of the wrong, or a less satisfactory, variety; (2) improper stage of ripeness at harvest; (3) physical damage prior to preservation; (4) excessive and/or improper storage prior to preservation; (5) high and fluctuating temperatures in frozen storage; and/or (6) an inadequate quantity of fruit incorporated into the product.

The most popular flavor of ice cream in the USA is vanilla, which accounts for nearly one half of all ice cream sales (IDFA, 2017). Since vanilla is a delicate flavoring, it will not "cover-up" or mask potential off-flavors as effectively as stronger flavors such as mint or chocolate, which is not exactly a flavoring because the whole

ice cream base formulation needs to change when chocolate ice cream is made. However, if used at the same level, double-strength vanilla is much more effective at covering up possible flavor defects in frozen ice cream than single-strength vanilla flavoring (Im & Marshall, 1998).

Off-flavors in the mix are more difficult to detect in the presence of stronger flavorings, such as mint. To manufacture a vanilla ice cream with an ideal flavor requires that (1) the dairy products, sweeteners, and all other ingredients be free of flavor defects; (2) the mix be correctly processed; and (3) the vanilla flavoring be of the highest quality. The perceived flavor should not only exhibit the desired intensity but also blend pleasingly with the background or the complementary flavor provided by the mix. While vanilla ice cream provides a rigid test for overall sensory and quality control, these general manufacturing requirements also apply to other ice cream flavors. A common axiom in the manufacture of dairy products is that "the quality of the finished product can be no better than the quality of the ingredients."

The rating for bacteria content must be performed in the laboratory, where equipment, laboratory technique, and additional time are required. Due to these requirements, bacteria are not evaluated in any sensory evaluation contests. In many situations, the results of the standard plate count and coliform count may not be available at the time the product is evaluated, in which case the "full score" may be allowed with a notation that the data were not available or the analysis not undertaken. As in milk evaluation, actual microbial counts are more meaningful than point scores. For instance, coliform counts of >50 or total plate counts of >500,000 CFU/ml require a score of "zero," but obviously the latter reported values would reflect a more inferior product.

10.3 The Ice Cream Scorecard

Measuring ice cream quality can be done by various standards, but numerical scores are helpful in ice cream operations, academia, and institutions that need to judge the quality of products based on established ideal characteristics. Bodyfelt et al. (1988) developed a scorecard and scoring guides for ice cream. The card had various category criticisms for flavor, body and texture, color appearance and package, melting quality, and bacterial content. The scoring guide for vanilla ice cream had a score range of 1–10 for flavoring system, sweeteners, processing, dairy ingredients, and others. The scorecard and guidelines were modified through the years and served as the basis for the development of the current Collegiate Dairy Products Evaluation Contest (CDPEC) scorecard. The scorecard in Fig. 10.1 is the one developed and approved by the CDPEC coaches committee and is used throughout the USA in college judging contests. The card has two category criticisms, flavor plus body and texture.

The scoring guides that accompany the scorecard are presented in Table 10.3. Scoring guides are useful in training new evaluators and in promoting


Ice Cream

SAMPLE 1

FLAVOR SCORE: 1 2 3 4 5 6 7 8 9 10 NO CRITICISM: 10 NORMAL RANGE: 1-10

___ 1. Acid
___ 2. Cooked
___ 3. High Flavor
___ 4. High Sweetness
___ 5. Lacks Fine Flavor
___ 6. Lacks Freshness
___ 7. Low Flavoring
___ 8. Low Sweetness
___ 9. Old Ingredient
___ 10. Oxidized
___ 11. Rancid
___ 12. Salty
___ 13. Syrup Flavor
___ 14. Unnatural Flavor
___ 15. Whey

BODY AND TEXTURE SCORE: 1 2 3 4 5 NO CRITICISM: 5 NORMAL RANGE: 1-5

___ 1. Crumbly
___ 2. Fluffy
___ 3. Greasy
___ 4. Gummy
___ 5. Icy
___ 6. Sandy
___ 7. Soggy
___ 8. Weak

SAMPLE 2

FLAVOR SCORE: 1 2 3 4 5 6 7 8 9 10 NO CRITICISM: 10 NORMAL RANGE: 1-10

___ 1. Acid
___ 2. Cooked
___ 3. High Flavor
___ 4. High Sweetness
___ 5. Lacks Fine Flavor
___ 6. Lacks Freshness
___ 7. Low Flavoring
___ 8. Low Sweetness
___ 9. Old Ingredient
___ 10. Oxidized
___ 11. Rancid
___ 12. Salty
___ 13. Syrup Flavor
___ 14. Unnatural Flavor
___ 15. Whey

BODY AND TEXTURE SCORE: 1 2 3 4 5 NO CRITICISM: 5 NORMAL RANGE: 1-5

___ 1. Crumbly
___ 2. Fluffy
___ 3. Greasy
___ 4. Gummy
___ 5. Icy
___ 6. Sandy
___ 7. Soggy
___ 8. Weak

Fig. 10.1 Scorecard of the Collegiate Dairy Products Evaluation Contest (samples 3–8 appear on separate pages)

standardization of judgments among different evaluators. Further modifications of the scorecard will be suggested later in this chapter when other frozen products are discussed.

Various flavor defects that may be encountered in vanilla ice cream are described as follows:

Acid:	Tingly taste sensation on tongue, may be accompanied by unclean or other bacterial flavors
Cooked:	Common, eggy, custard, not serious defect, scorched or burnt definite defect
High flavor:	Harsh taste when first placed in mouth, unbalanced blend.
High sweetness:	Candy-like sensation, not refreshing
Lacks fine flavor:	Harsh, lacks balance, not perfect, minor defect
Lacks freshness:	Stale, some marginally old dairy ingredient, slight old ingredient, or other flavors

Table 10.3 Scoring guide for flavor defects of vanilla ice cream

Flavor criticisms	Intensity of defect		
	S	D	P
Acid	4	2	U
Cooked	9	7	5
High flavor	9	8	7
High sweetness	9	8	7
Lacks fine flavor	9	8	7
Lacks freshness	8	7	6
Low flavoring	8	6	4
Low sweetness	9	8	6
Old ingredient	6	4	2
Oxidized	6	4	1
Rancid	4	2	U
Salty	8	7	5
Syrup flavor	9	7	5
Unnatural flavor	8	6	4
Whey	7	6	4

Normal range 1–10. Range of scores for each class of flavor quality: excellent 10 (no criticism), good 8–9, fair 6–7, poor 5 or less
S slight, *D* definite, *P* pronounced
U indicates product of unsalable quality. Official rules prohibit the use of such products in contest

Low flavoring:	Flat, bland, lacks vanilla
Low sweetness:	Flat or bland taste
Old ingredient:	Old or deteriorated dairy ingredients, persistent aftertaste, does not clean up
Oxidized:	Cardboardy, astringent, oily, tallowy
Rancid:	Persistently repulsive, unpleasant aftertaste, blue cheese, baby puke
Salty:	Quickly perceived taste
Syrup flavor:	Unnatural sweetness, (Karo) corn syrup, caramel, may be sticky or gummy also
Unnatural flavor:	Imitation vanilla, accidental mixing of another flavor with vanilla
Whey:	Graham cracker-like, stale condensed milk, slight salty taste, may be off color or crumbly

10.4 Techniques of Ice Cream Scoring

As indicated earlier in this chapter, scoring and judging ice cream correctly is not easy and requires knowledge and experience. Therefore, it is often done by students and professionals who were trained in contests like the CDPEC and dairy industry. With proper training, individuals are able to dependably evaluate the sensory quality of ice cream and other related products more reliably than the untrained consumer.

In the CDPEC, products that meet the standards of ideal ice cream are given the highest mark in the range 1–10 for flavor criticisms and 1–5 for body and texture criticisms. Ice cream with no criticisms is considered perfect and is given a score of 10 and 5 in each category, respectively. Ice cream products rarely receive a perfect score. When a defect is identified, the smallest deduction a judge can make is one point. The deduction can increase depending on the severity of the defects identified. Defects are described as slight, definite, or pronounced depending on the intensity of the defect. Those product samples (representative of a lot) that receive a "zero" in any one or more quality categories should or would generally be regarded as unsalable products.

Tempering the samples. The technique of judging ice cream (Bodyfelt et al., 1988) is markedly different in many respects from the judging of other dairy products. Since ice cream is a frozen product, it must be evaluated, in part, in that condition in order to ascertain the typical or desired body and texture characteristics. Consequently, arrangements must be made to store (temper) the samples at a uniformly low temperature so that the ice cream retains its appropriate physical properties, yet the temperature maintained must not be so low that the ice cream is intensely cold and unnecessarily hard. When ice cream is too cold, the recovery of the sense of taste from temporary anesthesia, due to extreme cold, requires a longer period than is expedient for satisfactory and efficient work. Furthermore, evaluators will have greater difficulty in determining the actual body and texture properties if the ice cream is too firm. Additionally, tempering is necessary for practical purposes since dipping will also be nearly impossible if the ice cream is really cold.

Generally, temperatures between −18 and − 15 °C (−0.4 and 5 °F) are satisfactory for tempering ice cream prior to judging (Goff & Hartel, 2013). This can be best achieved by transferring the ice cream samples from the hardening room to a dispensing cabinet at least several hours prior to judging, or preferably tempered overnight. This length of time ensures that the ice cream tempers uniformly. Exposing ice cream to room temperatures for tempering purposes is most unsatisfactory since the ice cream rapidly melts along the outer edges, while the center remains too firm for dipping.

If satisfactory evaluation is to be performed, the importance of proper tempering of ice cream and related products cannot be minimized. Significant, measurable loss of ice crystal structure occurs between −20 and –10 °C (−4 and 14 °F), and the frozen fraction of ice cream decreases rapidly from −10 to 0 °C (14–32 °F) (Eisner et al., 2004). Some freezer cabinets are not satisfactory for product tempering, as they do not maintain a uniform temperature throughout the unit. Temperatures should be measured at different locations throughout the cabinet to help insure uniform tempering of samples. Overfilling a tempering cabinet can cause some samples to be warmer than others, since crowded conditions inhibit the movement of air. Placement of all samples, if possible, at the same height within the cabinet (with air space between containers) usually helps insure uniform tempering.

Conditions for best work. Convenience is an important adjunct to efficient evaluation. The samples, therefore, should be arranged so that they are easily accessible without causing too much inconvenience in securing portions for sensory

examination. This arrangement involves providing ample spacing of the samples to minimize or eliminate possible congestion when a number of people are conducting the product evaluation. Placing an especially designed "dolly" under the ice cream case so that the cabinet may be moved and/or arranged at will has been found to be a convenient form of mobility in the laboratory or evaluation setting (Bodyfelt et al., 1988). Thus, the ice cream is readily accessible, conveniently located, and properly tempered. The temperature of the room should be comfortably warm. Attempting to judge ice cream in a chilly room usually results in hurried work and hasty, questionable judgments; in fact, it is better that the room be too warm than too cold.

Sampling. When ice cream (or another frozen dairy dessert) is properly tempered, sample portions may be easily secured for completing all aspects of the sensory evaluation. Generally, a good-quality ice cream dipper, scoop, or spade, rather than a spoon, is preferred for obtaining samples (Fig. 10.2).

Exercising certain precautions is deemed advisable for the sampling process (Bodyfelt et al., 1988). If the product surface has been exposed, then any dried surface layer (to a depth of approximately 0.8 cm (1/4 in)) should be removed before securing the sample for evaluation. When a meltdown test is conducted, the test sample need not be large, but its volume must be uniform across all lots of ice cream being compared. For the meltdown examination, a No. 30 scoopful of ice cream placed on a clean, numbered petri dish is quite satisfactory. The petri dish should be set in a convenient place (but away from heat sources) where melting qualities may be observed from time to time during the overall evaluation process. Small samples for tasting may be removed from the product package by either a metal or plastic scoop (dipper) when desired. Individual, 15.2-, 20.3-, or 25.4-cm (6-, 8-, or 10-in) paper plates have been used satisfactorily for holding the individual samples during the course of tasting. One or more samples may be placed on the same plate for study and comparison. Care must be exercised that portions of several samples are not intermixed.

Fig. 10.2 Several types of scoops and spades used for dipping ice cream samples

The manipulation and conveying of sample portions to the mouth for tasting may be done by means of a clean plastic, bright metal, compressed paper, fiber, or wooden spoon. Some judges prefer metal or plastic spoons to all others for judging ice cream. Spoons should be easy to clean between samples. It is important that spoons not impart any atypical or foreign off-flavors to the product. Plastic, compressed paper, fiber, and wooden spoons are all generally satisfactory; providing an adequate supply is available so that heavily used or worn spoons may be discarded at will. Single-service plastic spoons are most commonly used. In using wooden spoons, precautions must be taken to guard against a slightly "woody" taste.

Intermittent or unrestricted dipping of "used" spoons into the container of ice cream should absolutely not be tolerated for reasons of personal hygiene. Having placed a reasonable-sized portion (a small scoopful) of ice cream onto an individual plate for sensory study, the evaluator can then taste from this "individual" sample as often as needed. The evaluator is free to secure additional samples from any product container (with the appropriate dipper) when needed, in order to complete the process of product evaluation.

10.5 Sequence of Sensory Observations

Since the physical condition of ice cream changes so rapidly when exposed to ordinary temperatures, the evaluator must be alert and constantly observing during the "time restrictive" sampling and evaluation process, in order not to overlook any possible sensory defects associated with a given product sample, particularly body and texture features. An orderly sequence of observations (Bodyfelt et al., 1988) has been found to be most effective in evaluating ice cream for sensory characteristics. The steps are listed in the following paragraphs.

Examine the container. Note the type and condition of the container, the presence or absence of a liner and cover on bulk containers, and any package defects that may be present.

Note the color of the ice cream. Observe the color of the ice cream, its intensity and uniformity, and whether the hue is natural and typical of the given flavor of ice cream being judged.

Sample the ice cream. During the course of dipping the sample, carefully note the way the product cuts and the feel of the dipper as its cutting edge passes through the frozen mass. Note particularly whether the ice cream tends to curl up or roll in serrated layers behind the dipper, thus indicating excessive gumminess or stickiness. The "feel" of dipping (i.e., the resistance offered), the evenness of cutting, the presence of spiny ice particles, and whether the ice cream is heavy or light and fluffy should be especially noted. The way the sample responds in the dipping process often gives a fairly accurate impression of its body and texture characteristics (Fig. 10.3).

The "scoopability" (rigidity) of ice cream as perceived by human subjects has been correlated with instrumental measurements. The effect of various ice cream

mix compositions and processes on the microstructural (ice crystal and air-cell sizes) and sensorial (scoopability and creaminess) characteristics was studied using cryo-scanning electron microscopy (cryo-SEM) and oscillatory thermo-rheometry (OTR). Ice cream was prepared using conventional freezing and a combined freezing and low temperature extrusion (LTE) process. The LTE-processed ice cream was reported to have smaller ice crystals as the higher shear force of the process prevented aggregation. Air bubbles were better stabilized in LTE ice cream because of higher viscosity. However, the higher shear forces of the LTE process led to increased aggregation and partial coalescence of fat globules. The OTR storage modulus (G' – indicator of elasticity) and loss modulus (G'' – indicator of flowability) values were compared to sensory evaluation of scoopability and creaminess by an industrial sensory panel on a six-point scale. The sensory characteristics were reported to be a function of loss modulus. In the low temperature range ($T = -15$ °C) (5 °F), a lower value of G'' indicated less rigidity and improved scoopability. In the molten ice cream ($T > -1$ °C) (30.2 °F), higher G'' values corresponded to a higher degree of creaminess. The LTE-processed ice cream was reported to be more scoopable and creamier than conventional ice cream. It was concluded that OTR can be successfully used to quantify the quality of ice cream (Wildmoser et al., 2004).

Begin judging. After a sample portion has been secured, the examination for further body and texture characteristics and for flavor should begin immediately. As a general rule, little conception of the flavor may be gained by smelling the sample. Until the ice cream is melted within the mouth, the sample portion is so cold that for all practical purposes the odoriferous substances remain practically nonvolatile and, therefore, little or no aroma may be detected. When the sample is liquefied and warmed to near body temperature, detection of the flavor characteristics is not particularly difficult. This detection is best accomplished by placing a small teaspoonful or bite of frozen product directly into the mouth, quickly manipulating the sample between the teeth and palate, and simultaneously noting the taste and/or volatile sensations (Bodyfelt et al., 1988).

Since the body and texture characteristics of a frozen product are to be determined, the sample placed into the mouth should initially be in the frozen state. Immediately after placing a portion into the mouth, roll the sample between the

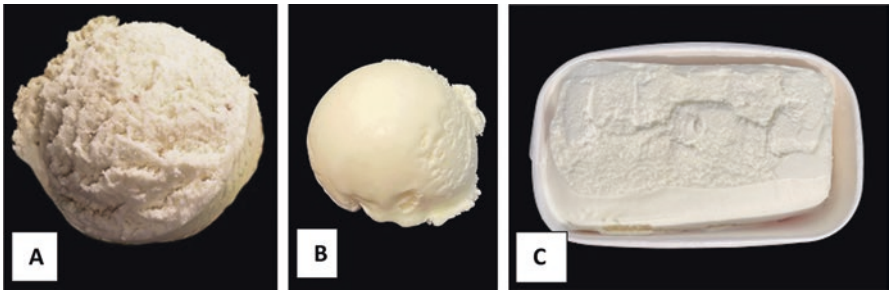

Fig. 10.3 Examples of vanilla ice cream defects observed when whipping: (**a**) brittle, crumbly, friable; (**b**) elastic, gummy, pasty, sticky; (**c**) shrunken. (Courtesy of Elizabeth C. Alvarez)

incisors and bring them together very gently, noting (relatively) how far apart the teeth may be held by the ice crystals and for how long. The evaluator should note also whether any grittiness is apparent between the teeth. A small portion between the incisors may reveal the presence of minute traces of a gritty or sandy texture (lactose, sucrose, or glucose crystals). By pressing a small portion of the frozen ice cream against the roof of the mouth, thus melting the sample quickly, the relative degrees of smoothness, coarseness, coldness, the presence or absence of sandiness, and the relative size of ice crystals may be determined. Certain body characteristics of the ice cream may become apparent by the resistance to mastication that the product offers in the mouth. Further discussion about the proper chew for ice cream evaluation is found later in the section on body and texture in this chapter.

Expect delayed taste reaction. When ice cream is first placed into the mouth, its low temperature temporarily numbs the sense of taste. The sensation of cold is usually predominant. Until the sensory nerve centers recover from the temporary anesthesia, a flavor sensation is usually not experienced. The duration of this temporary impairment of taste (Bodyfelt et al., 1988; Wehr & Frank, 2004) is dependent upon the size of the sample, its temperature, and its heat conductivity. In order not to needlessly impair the sense of taste, an evaluator should use as small or modest a sample as possible to accommodate evaluation of body and texture. A robust correlation between the melting of the ice crystals from −10 to 0 °C (14–32 °F) and the sensation of coldness in an ice cream sample has been established (Eisner et al., 2004). Evaluators should take care in consistent size of bites evaluated.

Sense the flavor. While manipulating the sample about the mouth to ascertain some of its body and texture characteristics, the evaluator should be aware that (1) the physical properties of the ice cream are constantly changing; (2) the period of temporary taste anesthesia (from coldness) is of fairly short duration; and (3) a hint of the flavor will soon manifest itself as an initial taste sensation. The judge should be alert and prepared to detect this sensation, whether it is prompt or otherwise.

The first perceived sensory reaction will probably be one of the fundamental tastes (if present), and in the order of salty, sweet, sour, and/or bitter. As the sample is warmed in the mouth, the volatile, flavor-contributing substance(s) will soon evoke a perceived aroma (smell). Since sweetness is practically always perceived prior to detection of volatile, odor-contributing substances, the characteristics of the sweetener should be noted at once. Ice cream may be perceived as pleasantly sweet, intensely sweet, lacking in sweetness, or "syrup flavor"; the latter denotes a departure from a simple, basic sweet taste.

By the time the quality and quantity of sweetness is assessed, other flavor notes will likely have registered with the taster, including possible off-flavors that may be traceable to the dairy ingredients. The judge should note, particularly, whether the flavor is harsh (coarse) or delicate, mild, or pronounced; whether the flavor seems creamy, pleasantly rich, or possesses a pronounced, objectionable, or unnatural taste; and whether the mouth readily "cleans up" after the sample has been expectorated. These are but a few of the numerous characteristics that should be observed and noted in the process of evaluating ice cream flavor (Bodyfelt et al., 1988).

After the sample has been held in the mouth for sufficient time to nearly attain body temperature, and the flavor characteristics noted, it should be expectorated. Occasionally, a sample may be swallowed, but this is the exception rather than the rule. When the sensory evaluation is in progress, the judge's focus should be on tasting and observing, not on satisfying one's sense of hunger. Unfortunately, in ice cream scoring, the keenness of flavor perception may soon be lost or destroyed. Some experienced judges may actually consume a small amount of ice cream just before judging begins in order to adjust their palates and mental processes to this product. But once judging is underway, absolutely all samples should be expectorated after completing the flavor evaluation task.

Note the melting qualities. By the time the flavor attributes have been determined, the samples previously set aside for the observation of melting properties should have softened sufficiently to yield an impression of those characteristics. The judge should observe whether each ice cream sample has retained its form and approximate size, even though some free liquid may have leaked (oozed) out, and whether the melted liquid appears homogenous and creamy, curdled, foamy, or watery (wheyed-off).

Record the results. Once all of the sensory observations have been completed, the judge should record the sensory observations on a scorecard and assign the appropriate numerical values. If the ice cream judge is to make efficient use of limited time and be reasonably accurate in one's observations, a certain routine or technique similar to that just described should be followed.

10.6 Requirements of High-Quality Vanilla Ice Cream

There are specific criteria for sensory quality that apply to each flavor of ice cream. However, since so many flavors of ice cream (and other related products) are produced in the USA, only a select few will be discussed in depth here. Vanilla ice cream is a logical candidate for in-depth coverage due to consumer popularity and to its vulnerability to off-flavors. Out of a total of the 10 most popular flavors of ice cream in the USA, vanilla and chocolate hold first and second place (IDFA, 2017).

10.6.1 Color and Package

Color. The color of vanilla ice cream or reduced fat ice cream should be attractive, uniform, pleasing, and typical of the specific flavor (French, old-fashioned, vanilla bean, etc.) stated on the label. Colorants may or may not be added to dairy frozen desserts. As long as the shade of color reasonably resembles the natural color (β-carotene pigment) of cream and is neither too pale nor too vivid, color criticisms are generally resisted for vanilla-flavored products. Ice cream flavors other than vanilla should also exhibit a color that is in harmony with and/or suggestive of the

stated flavor on the package. The possible color defects of vanilla ice cream are discussed here.

Table 10.4 (Bodyfelt et al., 1988) is a guide for scoring the color, the appearance, and the package of vanilla ice cream; however, with minor revisions it can be adapted for all ice cream flavors.

Gray, dull. Though infrequently encountered, a gray, dull color is easily recognized by its "dead," soiled white, and unattractive appearance. Such ice cream suggests lack of cleanliness in manufacture, and, therefore, it is one of the more serious and objectionable color defects. If the gray color is caused by the use of flavoring with ground vanilla beans, which may be apparent by the presence of small pepper-like particles of the ground bean, the color should not be criticized. Ice cream that displays ground particles of vanilla bean (often labeled "vanilla bean") is in demand by some consumers and may be preferred in some locales of the USA.

Not uniform. Lack of color uniformity in vanilla ice cream is comparatively uncommon but may be easily recognized when it occurs. Although the most appealing color for vanilla ice cream may be a moderate creamy shade of white, certain portions may be darker or lighter than others. Particularly, this may be true of the top or bottom surface or portions next to the side of the container where some desiccation may have occurred. This defect is often associated with age (extended product storage).

If the color uniformity defect is restricted to the surface layer (which is usually discarded when taking samples), it is not considered serious. At times, streaks or waves of different color may be encountered throughout the mass of a vanilla ice cream. This appearance can be caused by varying overruns attained from multibarrel freezers or may derive from different freezers that have a common discharge.

Table 10.4 A scoring guide for color, appearance, and package of vanilla ice cream

Intensity of defect					
Defect[a]	Slight[b]	Moderate	Definite	Strong	Pronounced[c]
Dull color	4	3	2	1	–[d]
Nonuniform color	4	3	2	–[d]	–[d]
Too high color	4	3	2	–[d]	–[d]
Too pale color	4	3	2	–[d]	–[d]
Unnatural color	4	3	2	1	0
Soiled container	3	2	1	0	0
Product on container	4	3	2	1	–[d]
Underfill/overfill	4	3	2	1	0
Damaged container	3	2	1	0	0
Defective seal	2	1	0	0	0
Ill-shaped containers	4	3	2	1	0

[a]"No criticism" is assigned a score of "5." Normal range is 1–5 for a salable product. An assigned score of "0" (zero) is indicative of an unsalable product

[b]Highest assignable score for defect of slight intensity

[c]Highest assignable score for defect of pronounced intensity

[d]A dash (–) indicates that the defect is unlikely to occur at this intensity level

Sometimes, a nonuniform color may originate from successive changes in the flavor source (and associated color) throughout the freezing and packaging process.

Too high, vivid. A high color level is often objectionable because it appears unattractive and often connotes an "artificial" impression. Although individual preferences for color vary, evaluators have a general tendency to downgrade products that have an obvious, excessive intensity of color. Such a product conveys the idea of cheapness, imitation, poor workmanship, or a general lack of understanding and care on the part of the manufacturer.

Too pale, chalky, lacking. A pale, chalky, or snow-like color is the opposite of too high in color. This defect is not particularly serious, although a lighter-colored product may not have as much eye appeal as a creamy shade of white color. However, uncolored ice cream, especially vanilla, should not necessarily be criticized for lack of color. For special markets, ice cream without any form of added color is a must; many products meet that marketing objective, and it does not seem logical to penalize the color in those circumstances.

Unnatural. Unnatural color of ice cream should be recognized at a glance; the product appearance is not "in keeping" with the impression conveyed by cream (or milk fat). An unnatural color may be any shade of yellow, orange, or tan – colors that do not correspond to the true color characteristics of milk fat. Some more common off shades of color in vanilla ice cream include lemon yellows, light green yellows, orange yellows, and occasionally red yellows or tan browns. Where the use of food colors is permitted, some manufacturers may select a particular one or combination of colorants that make their vanilla ice cream(s) appear unique or distinctive. While the selected color may accomplish this purpose, it may nevertheless be faulted by some ice cream judges. Unnatural color may also arise from the use of extensive amounts of annatto-colored Cheddar cheese whey solids (Bodyfelt, 1979), of product rerun, of remelted ice cream, or of commingling of successive freezer runs of product (that have contrasting colors).

The criticism for unnatural color is a broad designation. As a general rule, this descriptor of appearance is applied to the various deficiencies or shortcomings in the hue of natural cream color. "Unnatural" color might also describe an ice cream whose color is gray, dull, high, vivid, pale, chalky, or nonuniform. Application of the most descriptive terminology possibly helps in pinpointing the source of the problem within manufacturing operations. Generally, the several color defects of vanilla ice cream do not occur at the "serious" level. Since different types of lighting will significantly affect color characteristics as viewed by human subjects, the type of light employed during examinations should certainly be standardized. Several so-called all-natural products have appeared in the US marketplace, which absolutely have no added color to any of the flavors of ice cream. Many consumers seem to prefer products that comply with the claim "no color added." However, in turn, many ice cream judges tend to severely criticize such aforementioned products (other than vanilla) for their appearance; the most common descriptor involved is "unnatural color."

Package. The ideal frozen dessert package or container should be clean, undamaged, full, neat, attractive (pleasant eye appeal), and protective of the product.

Multiuse containers (if used) should be free of dents, rust, paint, battered edges, or rough, irregular surfaces. In general, ice cream packages should reflect neatness and cleanliness throughout, giving the consumer the impression that by use of a clean, well-formed container, the manufacturer is definitely interested in supplying a high-quality product. Some more common package defects that may be encountered are a slack-filled container, bulging container, improperly sealed container, ill-shaped retail packages or product adhering to the outside of the container, ink smears, lack of a parchment liner on the top of bulk containers, and a container that is soiled, rusty, or damaged (the last two defects pertain to refillable containers).

These packaging defects, when they occur, are generally so obvious that additional descriptors or discussion hardly seem necessary. Encountering a high proportion of defectively packaged products from a production run is most unlikely, but such a problem might occur in the absence of adequate supervision. Just a few defective packages or containers present a problem of some magnitude because consumers will simply not select and purchase damaged units of products from the retail ice cream cabinet. Thus, evaluators must keep in mind an appropriate perspective that defective containers generally render a product unsalable.

10.6.2 Melting Quality

High-quality ice cream should show little resistance to melting when a dish is exposed to room temperature for at least 10–15 min (Bodyfelt et al., 1988; Goff & Hartel, 2013). During the melting phase, the mix should flow from the center (high) portion of the scooped ice cream. The melted product should be expected to form a smooth, uniform, and homogeneous liquid in the dish. Generally, ice creams with low-overrun melt more rapidly than those with high overrun (Sakurai et al., 1996; Goff & Hartel, 2013).

The melting quality may be observed by placing a scoopful of the sample on a dish and noting its meltdown response from time to time, as the other sensory qualities are being examined. Although fiber dishes may be used, petri dishes seem to permit more accurate observation of the melted ice cream; the contrast between the product and the dish background is greater. Hartel et al. (2004) reviewed factors affecting the melting rate of ice cream and described an ice cream melt procedure that involves placing the test sample on a stainless-steel screen. In setting out the samples and examining them for meltdown, some precautions are necessary:

1. Select a uniformly heated, well-lit area for placing and observing the samples (>20 °C (70 °F), if possible).
2. Set the sample out for meltdown at the beginning of the judging (if feasible).
3. Absolutely avoid dipping some of the samples with a warm dipper and others with a cold dipper.
4. Be sure that the sizes of the reasonably small samples used for the meltdown test are uniform in volume (use the same scoop or spoon for each sample).

5. Always use a flat-bottom dish (not a cup), so the melted ice cream is free to spread out.
6. Once melting has started, do not disturb the samples by tilting or swirling the containers.
7. Observe the melting quality at various stages of melting (Fig. 10.3) and score on the basis of the scheme suggested in Table 10.5.

The defects of melting quality frequently observed in ice cream judging will be elaborated.

Does not melt, delayed melting. This defect is easily recognized since the ice cream retains (or tends to retain) its original shape after it has been exposed to ambient temperature for a period in excess of 10–15 min. This defect is related to the use of an excess of certain stabilizers and emulsifiers, high overrun, the age of the ice cream, and several processing and product composition interactions that promote formation of a highly stable gel (even when the temperature is above the freezing point). This attribute is considered objectionable to some, as it conveys the impression that excessive amounts of product thickeners were used. However, in other cases, this attribute is an objective.

Flaky, lacks uniformity. This defect may be noted when the sample is about half-melted, but it is more noticeable when the sample has completely melted. Flakiness is shown by a feathery, light-colored scum formation on the surface. Sometimes it resembles a fragment of crust. Usually, no indication of wheying-off (water separation) accompanies the defect. Furthermore, it is not particularly objectionable. However, it is not in keeping with an impression of the highest quality since the product is not uniform or homogeneous in appearance.

Foamy, frothy, large air bubbles. A foamy meltdown is usually only noted when the sample is completely melted. Ice cream that exhibits many small, fine bubbles upon melting is not commonly criticized, but a sample that demonstrates a mass of large bubbles, 0.3–0.5 cm (1/8–3/16 in) in diameter, is criticized. The meltdown should be uniform and attractive; this is not the case when large air bubbles or excessive foam occur. The consumer may associate the presence of foam with

Table 10.5 Scoring guide for the melting quality of ice cream

		Intensity of defect	
Defect[a]	Slight[b]	Definite	Pronounced
Does not melt	3	2	1
Flaky	3	2	1
Foamy	3	2	1
Curdy	3	2	1
Wheying-off	3	2	1
Watery	3	2	1

Bodyfelt et al. (1988)

[a]"No criticism" is assigned a score of "3." Normal range is 1–3 for a salable product

[b]Highest assignable score for defect of slight intensity

[c]Highest assignable score for defect of pronounced intensity

excessive overrun, even though this defect may not be associated with high overrun, but rather with some of the particular constituents used in the mix.

Curdy. A meltdown with a curd-like appearance lacks product uniformity and is, for the most part, unattractive. The melted ice cream appears flaky; it separates from the mass in small distinct pieces rather than leaving the impression of a creamy fluid. The surface layer may exhibit formation of dry, irregular curd particles. To the layperson, this defect suggests souring of the milk or cream, although the cause is usually another matter. Any conditions that lead to the destabilization of proteins are potential causes of this defect in frozen dairy desserts. A combination of factors may be responsible, including (1) high acidity; (2) the salt balance (related to calcium and magnesium salts); (3) age of the ice cream; (4) certain adverse processing conditions (involving temperature, time, and method of heating, homogenization pressure and temperature, and rate of freezing and hardening); and (5) the type and concentration of stabilizers and emulsifiers.

The meltdown characteristics and the formation of a curdy/flaky appearance are influenced by the protein stability, fat agglomeration, and air cell size. In the industrial processing of ice cream, formulations and processing can be modified to increase the availability of surface-active proteins for foam stabilization (Zhang & Goff, 2004; Goff & Hartel, 2013). A partially coalesced three-dimensional network formed by the fat globules with air and ice is in part responsible for the melt resistance and smoother texture of the frozen dessert. The presence of surface-active proteins will stabilize the weak fat-serum interface first. Increased emulsification results in depletion of protein from the fat molecule that increases fat destabilization, hence decreasing melting rate and enhancing shape retention during the melting process (Bolliger et al., 2000c). Stabilizers increase the resistance of the frozen product to meltdown by decreasing the mobility of water through increasing the viscosity of the serum phase (Stanley et al., 1996; Goff & Hartel, 2013). This process has been previously explained in the separate section on emulsifiers and stabilizers. Except for viscosity, all of the factors listed above, either independently or in combination, affect fat agglomeration. Substantial fat agglomeration is responsible for the "slow melt" and/or an unattractive dry, "flaky" surface of the melted product (Abbas Syed, 2018). Protein destabilization will result in melting throughout and hence "curdy" ice cream. Occurrence of these undesirable conditions may further be prevented by minimizing temperature abuse (Stanley et al., 1996).

Wheying-off (syneresis). Wheying-off will usually be noted by the appearance of a bluish fluid leaking from the melting ice cream at the initiation of the meltdown test. If the sample is disturbed during melting or the observation is delayed, it may be difficult to see this condition. Whey separation may be noted in some ice cream and reduced fat ice cream mixes even before they are frozen. This separation is a common complaint of operators of soft-serve freezers who buy their mix from a wholesale manufacturer. These mixes tend to be stored longer and are subjected to more abuse than those mixes that are made and frozen within the same plant. Factors contributing to the difficulty include (1) the salt balance of milk ingredients, (2) the mix composition (a product with a high protein-in-water concentration can be expected to be less stable than one with a lower concentration), (3) certain adverse

processing conditions, and (4) the extent of abuse (excessive agitation, air incorporation, and "heat shock").

Separation is a natural phenomenon occurring in soft-serve ice cream mixes; increasing the amount of whey proteins while maintaining the same protein content, and the use of *k*-carrageenan at >0.015% in the mix prevent visible separation, although it still occurs on the microscopic level. Locust bean gum and sodium caseinate are incompatible and undergo phase separation on a microscopic level. *k*-carrageenan has a much weaker stabilizing effect upon soft-serve ice cream emulsions formulated with sodium caseinate and locust bean gum as compared to skim milk powder emulsions stabilized with locust bean gum (Vega et al., 2005).

Watery, low-melting resistance. This defect is not consistent with the characteristics of the highest-quality ice cream. As the terms suggest, the sample melts quickly and the resultant meltdown has a thin, watery consistency. This defect is commonly associated with low solids or low stabilizer levels in the mix and may often be associated with a coarse, weak-bodied ice cream or ice milk.

Curdiness and delayed melting are two of the most common meltdown defects; they may occur simultaneously. Whey separation may be observed frequently, since protein destabilization is a common problem (Fig. 10.4).

Tharp et al. (1998) and Walstra and Jonkman (1998) reported that shape retention and melting rate depended on the degree of fat destabilization. Higher degrees of fat destabilization resulted in less fat content in the drip loss of melted ice cream samples (Tharp et al., 1998; Bolliger et al., 2000c). The presence of proteins or polysaccharides in ice cream formulations influences the shape retention of treated ice cream samples. Milk proteins affected melting and imparted body to ice cream products. A proposed mechanism for protein effects on body and texture is the formation of networks of phase-separated milk proteins and polysaccharides (Syrbe et al., 1998; Abbas Syed, 2018). Polydextrose was an important factor to improve shape retention in ice cream samples by binding water or reinforcing the existing fat network due to its complex branched structure (Smiles, 1982; Craig et al., 1996; Akbari et al., 2019). Ice cream with high overrun or fat tends to melt slowly. Air cells insulate and fat stabilizes the ice cream structure (Marshall et al., 2003; Akbari et al., 2019).

10.6.3 Body and Texture

Body and texture are important properties of ice cream and good-quality indicators. The associated body and texture defects are evaluated by biting and chewing the product. Different guidelines have been developed to evaluate the sensory attributes of ice cream (Bodyfelt et al., 1988; King & Arents, 1994). The following are the evaluation and scoring guidelines for body and texture used in the CDPEC.

Unfortunately, the terms "body" and "texture" are often used indiscriminately and loosely (Bodyfelt et al., 1988); adding to the confusion may be the combined use of the two terms, either in reference to one or to the other term. As it relates to

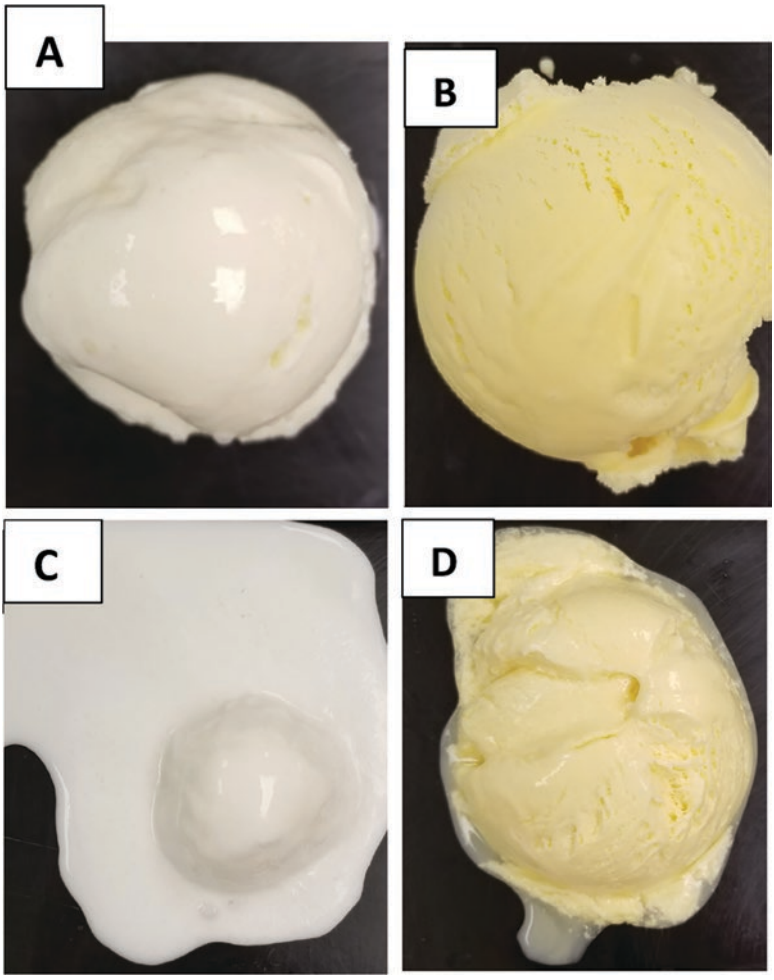

Fig. 10.4 Examples of various meltdown defects of ice cream as observed after elapse of 0, 10, 15, and 20 min: (**a**) the "ideal" melting characteristics; (**b**) does not melt; (**c**) curdy meltdown (non-homogenous); (**d**) wheyed-off (watery separation). (Courtesy of Stephanie Clark)

ice cream, *body* is best defined as the property or quality of the ice cream as a whole. *Texture* refers to the parts or structure of ice cream that make up the whole. Both the body and texture of ice cream may be partially determined by applying the senses of touch and sight when the evaluator observes the product's appearance on dipping. The desired body in ice cream is that which is firm, has substance (has some resistance), responds rapidly to dipping, and is not unduly cold when placed into the mouth.

The following is a description by Tharp (1997) about the "proper chew for ice cream evaluation" after transferring the portion to the mouth and beginning the oral manipulation of the portion: "As oral manipulation of the portion begins, it is

important to remember that many of the desirable properties of ice cream are related to the presence of ice, so focus first on those properties – the relative firmness of body and smoothness of texture. The time available for that is relatively short, because the ice disappears quickly at body temperature. If dental sensitivity permits, begin the evaluation by biting down through the portion with the front teeth – iciness will be reflected by the perception of a crunchy sound. Then, move the portion about in the mouth with the tongue, cheeks, and lower jaw. Concentrate on the degree of resistance to that movement (body) and the smoothness of the product while it is still frozen sample (texture). There are two exceptions to the generalization that body and texture stimuli will disappear when the product has melted. First, the hard crystals that characterize the sandy characteristic will persist after melting, particularly the lactose crystals. Also, the sensations that constitute the greasy characteristic – a slippery coating on the inner surfaces of the mouth, especially on the teeth – will continue to be perceived after the portion melts. After melting, with closed mouth, concentrate on the nature of the flavor. Focus on the taste elements perceived in the mouth (sweet, salty, acid, bitter). Then exhale nasally in order to allow the vapors released from the warming product to contact the aroma perception area in the nasal cavity. Concentrate on whether the aroma is acceptable and, if not, on identifying the characteristics of the undesirable elements. Don't swallow when observations have been completed – it can lead to a feeling of satiety that dulls the senses. Rather, the melted product should be expectorated in some appropriate way. Multiple samplings may be necessary to clarify observations. Finally, reflect on the flavor sensations that remain after expectoration. These residual perceptions, referred to as 'aftertaste,' make up an important element of the overall flavor judgment. A good quality product leaves behind a fresh, clean sensation, consisting only of lingering hints of the characterizing flavor and the basic dairy character. Consideration of aftertaste often makes possible the specific identification of such characteristics as the whey flavor."

Firmness, resistance, and coldness are strongly influenced by the product's temperature. As emphasized earlier, proper tempering of the samples from −18 to −15 °C (0–5 °F) is essential, particularly for properly assessing the body of samples. The desired texture of ice cream is that which is fine, smooth, velvety, and carries the perception of creaminess and homogeneity throughout. Small ice crystals and small air cells are required for portraying good product texture. If the product is too cold when evaluated, the texture may appear worse than it actually is. Just the opposite is true when the product is too warm. An experienced evaluator of ice cream will have learned to partially compensate for a less than optimum tempering effort on the samples but will still definitely prefer to observe body and texture characteristics when the product is properly tempered. Proper tempering assures a competent, conscientious ice cream judge that more relevant and objective assessments of the body and texture are being achieved. The scoring guides for the body and texture of ice cream are given in Table 10.6. The various body defects that may be encountered in ice cream are termed or classified as follows:

Table 10.6 Scoring guide for body and texture defects of vanilla ice cream

	Intensity of defect		
Body and texture	S	D	P
Crumbly	4	3	2
Fluffy	3	2	1
Greasy	4	2	1
Gummy	4	2	1
Icy/coarse	4	2	1
Sandy	2	1	U
Soggy	4	3	2
Weak	4	2	1

Bodyfelt et al. (1988)
Normal range 1–5. Range of scores for body and texture quality: Excellent 5 (no criticism)
S slight, *D* definite, *P* pronounced
U indicates product of unsalable quality. Official rules prohibit use of such products in contest

Crumbly: Brittle, falls apart when dipped.
Fluffy: Large air cells, disappears quickly in mouth, very weak.
Greasy: A distinct greasy coating of the mouth surface after expectoration, a tallowy or Chapstick® sensation on the lips after evaluation.
Gummy: Opposite of crumbly, pasty, putty-like; feels somewhat sticky like gum between the tongue and roof of the mouth.
Icy/coarse: Most common texture defect, not smooth, ice crystals or particles.
Sandy: One of the most objectionable defects in ice cream; fine hard particles, sand-like, lactose crystals.
Soggy: Heavy, doughy, pudding-like, due to lack of air cells (low overrun).
Weak: Lacking body and resistance, low solids, watery, more like ice milk.

10.7 Description of Body Defects

Body defects shown in ***italic/bold*** are evaluated in the CDPEC.

Crumbly, *brittle, friable.* A brittle, crumbly, and friable body is evident by a tendency of the ice cream to fall apart when dipped. The product appears to be dry, open, and sometimes as friable as freshly fallen snow. The particles seem to lack the needed property to stick together or be retained as a common mass (Fig. 10.4). When such a sample is dipped, many loose particles are likely to be noted on the remaining ice cream or the dipping implement. The defect may be provoked by the use of certain gums, inadequate stabilization, too high an overrun, and/or low total solids in the mix (Marshall et al., 2003; Abbas Syed, 2018). Lower-fat ice creams (7%) tend to develop crumbly texture more readily than an ice cream mix with higher fat content (10%) (Roland & Phillips, 1999; Akbari et al., 2019). A similar defect is identified as *flaky* and *snowy*. In this case, a flaky, snowy-textured ice cream manifests itself by a tendency to fall apart when dipped. In this respect, it has

the same characteristics as that noted in a crumbly body. The condition seems to be associated with low solids, low stabilizer, and/or high overrun in the product (Marshall et al., 2003).

Gummy*, pasty, sticky, elastic.* A gummy or sticky body is the exact opposite of a crumbly body. Such ice cream seems pasty, putty-like, and, under certain conditions of temperature and manipulation with a spoon, it somewhat resembles taffy (Fig. 10.4). The ice cream hangs together, so much so that it has a marked tendency to "curl" just behind the scoop as it is pulled across the surface, which leaves coarse, deep, irregular waves. Frequently, there is a correlation between a gummy body and a high resistance to melting; gummy ice cream often resists melting. If melting does occur, the mass often tends to retain its original shape.

The gummy body defect is associated with an excessive use of stabilizers, certain corn syrup sweeteners, or both (Marshall et al., 2003; Abbas Syed, 2018). One should recognize that all ice cream is sticky to some extent, due to the concentration of carbohydrates in the product. Ice cream should only be severely criticized when the stickiness is so severe that it is obviously pasty and would probably be difficult to dip or scoop. As an important economic consideration, gummy (or sticky) ice cream fails to yield as many scoops per unit volume as typical-bodied products.

Shrunken. A shrunken ice cream manifests itself by the product mass being withdrawn from the sides of the container. This defect is readily obvious when the package is first opened for examination, and the feature is not evaluated in the CDPEC. This defect may be associated with high overrun, low mix solids, fluctuations in air pressure, or substantial changes in altitude during product distribution (Dubey & White, 1997). However, under certain storage and/or transport conditions, any ice cream may shrink. Since heat shocking may be one of the contributing causes, the judge should be alert to correlate, if possible, this defect with a coarse, icy texture. All the reasons or causes of shrinkage are not clear to technologists; occurrences of the problem are often quite unpredictable. Product shrinkage may suddenly be encountered where none existed before, even when no changes were made in the product's composition or manufacturing procedures. A basic predisposition to shrinkage is apparently imparted to frozen dairy desserts by certain milk components, especially proteins (Goff et al., 1995: Abbas Syed, 2018). Certain environmental conditions, such as season of the year, stage of lactation, feed, etc., may unfavorably affect the normal formation of strong air cell walls (which contain proteins) in the frozen mix. Other associated factors seem to merely aggravate the conditions that predispose ice cream to shrinkage.

Soggy, *heavy, doughy, pudding-like.* A heavy, resistant body is best described by the terms heavy, doughy, or pudding-like. The descriptor "soggy" has also been used in association with this defect (CDPEC scorecards), although perhaps inappropriately. This defect can readily be noted when the product is dipped. Portions of an ice cream with this criticism, when placed in the mouth, seem colder than those free of the defect. Apparently, this is due to a greater heat conductivity of heavy-bodied products. This defect is associated with high solids content of the mix, especially increased fat and sugar (Dubey & White, 1997; Abbas Syed, 2018). Other suggested causes are too much stabilizer and/or a low overrun. Through product

formulation, individual ice cream manufacturers can control the "degree of bite resistance" in the body of their ice cream. Some processors may purposely strive for an extremely heavy body in order to achieve product uniqueness. Many consumers seem to prefer a product with a great deal of bite resistance.

The ice cream judge should be aware of the wide range of consumer preferences and only criticize a heavy body as a defect when it is obviously "out of line." Though this trend may change in time, many consumers are willing to pay a premium price for high solids, low overrun ice cream. The body of such products is generally quite resistant, firm, or heavy. A study of different levels of fat and sugar on the sensory properties of ice has determined that increasing levels of fat and sugar are associated with an increase in doughy texture (Guinard et al., 1997; Abbas Syed, 2018).

***Weak**, watery.* A weak, watery body is usually associated with a low-melting resistance and a thin, milky, low-viscosity meltdown. A weak-bodied ice cream conveys the impression of having a low proportion of food solids, when a sample is placed into the mouth. The mouthfeel of the sample may more likely resemble reduced or nonfat ice creams (or the former, ice milks) more than ice cream. Such an ice cream may be easily compressed by slight pressure of a spoon or scoop. This defect may also be associated with coarse texture; low solids and high overrun also contribute to causing a weak-bodied ice cream. Weak body defects have also been attributed to heat shock (Morely, 1989).

10.8 Description of Texture Defects

***Fluffy**, foamy, spongy.* A fluffy texture may be noted in high-overrun ice cream, with a general "openness" throughout the product. Such an ice cream tends to compress substantially upon dipping or applied pressure with a flat object. This defect is closely associated with a high overrun. A fluffy ice cream usually melts slowly in the dish, yielding a relatively small proportion of liquid, which is often foamy and spongy (Marshall et al., 2003). Fluffy is harshly criticized since the product may run outside of the standard of identity (4.5 lb/gallon).

***Greasy**, buttery, churned.* This defect may be noted by the presence of actual butter particles in the mouth after the ice cream has melted, or by a distinct greasy coating of the mouth surface after expectoration. Another way to recognize this defect is by a tallowy or Chapstick® sensation on the lips after evaluation. Common causes of a greasy mouthfeel are inadequate homogenization, a relatively high milk fat content, and over-emulsification of the product. In soft-serve frozen dairy desserts, churning may be due to de-emulsification of milk fat during prolonged agitation in the soft-serve freezer. If fat globule aggregation exceeds a size of about 30–50 μm, visible fat particles form in the samples with the associated buttery defect (Eisner et al., 2004; Amador et al., 2017). High-fat mixes are more susceptible to this defect; incomplete homogenization and over-emulsification aggravate this problem.

Icy, coarse*, grainy, ice pellets, spiny.* This defect ranks as the most commonly encountered texture defect in frozen dairy desserts. Such a product may be characterized by its structural makeup of comparatively large ice crystal particles; a feeling of unusual coldness within the mouth; a simultaneous lack of a smooth, velvety character; and a frequently associated rough visual effect. When a sample of a coarse or icy product (most common descriptors) is placed between the upper and lower incisors, a temporary resistance is exhibited before the incisors are finally permitted to come together. This form of a slight, temporary resistance should not be mistaken for another form of bite resistance provoked by another texture defect known as sandiness (discussed later). The resistance of coarse texture or iciness is quite temporary, almost instantaneous, while that of sandiness is of longer duration.

A coarse texture is due to comparatively large particles of frozen water; each ice crystal is sufficiently large that the coarseness is obvious. When extremely coarse, grainy textures are noted; the product is criticized as being icy or spiny. Ice cream samples with a pronounced icy texture may be readily noted during the dipping process from the "feel" of the scoop or spade as it strikes or breaks the tiny icicles or spines. A coarse, icy texture may be manifested by either the presence of localized, layer-like, ice crystals, or by grainy ice particles distributed throughout the product. The layer-like crystals are frequently found along the sides of the container where melting and subsequent refreezing may have occurred. Both kinds of ice crystals are objectionable, since the product lacks the smooth, homogenous, and velvety texture that is typically deemed most desirable for high-quality ice cream.

Ice crystals can be felt between the teeth and/or with the tongue, by immediately pressing the ice cream sample against the palate upon oral sampling (Stampanoni-Koeferli et al., 1996). As continuous melting of ice cream occurs in the mouth, larger ice particles are momentarily left behind, and they register a distinct cold sensation. Formation of ice crystals plays an important role in determining the quality of ice cream, and small crystal sizes are desirable (Adapa et al., 2000; Wildmoser et al., 2004; Drewett & Hartel, 2007; Amador et al., 2017). Ice crystals have a natural tendency to increase in size with increased storage time; the larger crystals selectively become larger at the expense of the small ice crystals, which disappear. As a result, ice cream frequently becomes more coarse with time in storage.

Much of the technology of ice cream formulation, freezing, and storage is designed to produce small ice crystals and delay their growth during storage or distribution. Since, almost invariably, ice cream will be exposed to some "heat shock" (temperature fluctuations and storage at higher than ideal temperatures), specific steps are advisedly taken to provide protection against fluctuations in storage temperature (Lucas, 1941; Tobias & Muck, 1981; Tobias, 1982; Bodyfelt, 1983a, b). Stable storage conditions at −20 °C (−4 °F) for 60 days prevented the observance of noticeable texture differences during the course of the shelf-life study of ice cream (Alvarez et al., 2005). Effective stabilizers and emulsifiers, microcrystalline cellulose, and low DE corn syrups are commonly used as "protective" agents (Stanley et al., 1996; Goff, 1997; Flores & Goff, 1999; Abbas Syed, 2018). Close control of production, inventories, and rotation of product to help ensure that the

oldest product is used first are important measures to help keep storage time minimal.

Among the many possible causes of coarse-textured ice cream are the following:

Faulty formulation
Inadequate protection against heat shock
Ineffective or improper stabilization and/or emulsification
Inadequate hydration of dry mix constituents
Incomplete protein hydration
Inadequate homogenization
Insufficient aging of the mix
Too high product temperature out of the freezer
Extended interval between freezing, packaging, and/or transfer to the hardening system
Slow hardening
Too high a hardening temperature
Fluctuating storage temperatures
Extended storage and distribution times

Some production problems are mechanical, such as dull freezer blades, which prevent the ice cream mix from freezing properly, while other product quality shortcomings are traceable to inadequate management and supervision. Sensory evaluation helps to identify the nature of product defects and pinpoint deficiencies of production and distribution.

Sandy, *gritty.* A sandy texture is certainly one of the most objectionable texture defects encountered in frozen dairy desserts, but it is also one of the easiest to detect. Such a texture conveys to the tongue and palate a definite lack of smoothness and an associated distinct form of grittiness. When the sample melts, there remains in the mouth fine, hard, uniform particles that suggest fine sand. These particles are crystals of lactose.

The presence of these sand-like particles can be noted in several ways: (1) by pressing a thin layer of the suspect ice cream against the roof of the mouth with the tongue to secure quick melting; (2) by bringing the teeth together slowly on a portion of it; or (3) by pressing a small quantity of the product between the thumb and forefinger. Sandy texture should not be confused with the coarse, icy texture, which results from the presence of comparatively large ice crystals. The lactose crystals dissolve markedly more slowly than ice crystals; therefore, they may be noted even after the ice cream has fully melted.

A high percentage of serum solids, high total food solids, product age, and "heat shock" are all related to the development of this defect (Livney et al., 1995; Abbas Syed, 2018). When sandiness occurs, the judge should be alert to the likely presence of other defects that are commonly associated with frozen dairy desserts stored under unfavorable conditions (coarse/icy, and/or shrinkage, and/or whey flavor).

10.9 Flavor

High-quality vanilla ice cream should be pleasantly sweet, suggest a creamy background sensation, exhibit a delicate "bouquet" of vanilla flavor, and leave a most pleasant, but brief, rich aftertaste (Bodyfelt et al., 1988, Bodyfelt, 1983a; Kwak et al., 2016). The flavor intensity of the vanilla, the sweetener, and the various dairy ingredients should not be so pronounced that, when first tasted, one component of the overall flavor seems to predominate over the others. All of the ingredients should blend to yield a pleasant, balanced flavor (Piccinali & Stampanoni, 1996).

The flavor evaluation of ice cream offers some difficulties unlike those encountered in the scoring of butter, cheese, and milk. In comparison to most other dairy products, ice cream is intensely sweet. This is the first obstacle confronted by the ice cream judge. The sweetness is often so pronounced to inexperienced judges that they frequently find it difficult to identify other flavor notes that may or should be present. A second obstacle to the successful evaluation of ice cream flavor is simply taste bud fatigue due to the combined effect of sweetness and coldness on the organs of taste. A third obstacle for the ice cream judge is the mouth-coating effect of milk fat. Some of the taste bud sites may be partially coated or blocked by milk fat, and hence lessen the ease of taste perception (Stampanoni-Koeferli et al., 1996; Guinard et al., 1997; Goff & Hartel, 2013).

Usually, inexperienced evaluators look forward to the judging of ice cream with considerable enthusiasm. After tasting a few samples, however, this enthusiasm probably begins to wane. The appetite is satisfied, and novice judges may have to force themselves to continue judging a set of samples that have started "to taste alike." Fortunately, experienced judges score ice cream with about the same ease as they evaluate other products. Some evaluators initially condition their mouths by tasting several samples, in order to adapt to the sweetness and coldness before actually placing flavor judgments on any of them. Frequent rinsing of the mouth with water between ice cream samples is apparently helpful for some evaluators, but this is primarily an individual preference as to whether or not it is a beneficial technique.

When evaluating ice cream for flavor, tasting is usually performed from a scooped sample on a plate. Taste sampling directly from the original container is not advised due to potential risk of personal sanitation (hygiene) problems and irreversible temperature abuse of ice cream samples. The authors and most ice cream judges prefer to evaluate one sample at a time. In this approach, the judge compares the flavor, body, and texture with a fixed, mental standard of the "ideal" product, rather than with that of another sample.

Due to the severe coldness of ice cream and reduced fat ice cream, some off-flavors may not be sufficiently volatile to be immediately detectable or recognizable. As pointed out earlier, the body and texture of the ice cream must be determined on the ice cream at the typical serving temperature, but any off-flavors present will become more apparent as the sample warms up. Warming occurs within the mouth as well as on the sample plate. After first assessing the body and texture of the sample, the evaluator may taste a warmer sample portion for at least one of several

phases of the flavor judgment that should be completed. This approach may be somewhat complicated by the fact that the "flavor balance" may change with temperature and, hence, cause some of the flavor notes to dominate others at the higher temperatures, but not at the lower ones. Thus, the best observations of the actual "flavor balance" should be undertaken at normal consumption temperatures for frozen desserts. This approach is especially important when a number of samples must be evaluated in succession. The evaluator must try to maintain accuracy and objectivity, and in the process, avoid both mental and physical fatigue as well as taste, touch, and odor adaptation. When the human senses are continuously exposed to a given stimulant, sensory perception diminishes because of the phenomenon of adaptation.

Due to the numerous ingredients that may be used in ice cream manufacture, one may expect a wide variety of flavors and potential off-flavors. In general, all frozen dairy desserts are susceptible to the development of most of the off-flavors encountered in other dairy foods. The flavoring systems used for ice cream, reduced fat ice cream, and sherbet may be obtained from several sources, and each one is manufactured by different processes. Consequently, the given source of flavoring itself may contribute to a surprising variety of flavors or flavor notes. Additionally, ice cream possesses varying degrees and qualities of sweetness. The major flavor defects of ice cream and reduced fat ice cream may be classified according to their origin, as summarized in Tables 10.3 and 10.7.

Knowledge of the possible source of off-flavors is quite useful when troubleshooting, pinpointing, and correcting difficulties with sensory quality. While the aforementioned tables cover most of the anticipated problems, there is always the chance for the highly unusual or extraordinary to happen. For instance, the eggs may be oxidized, the cream may have an intense absorbed or medicinal off-flavor, or the liquid sugar or corn syrup may be fermented. Occasionally, when production and quality control personnel least expect it, an off-flavor may be encountered that defies description. As an aid to problem-solving, a description of some of the more common flavor defects of frozen dairy desserts is presented as a review for the prospective ice cream judge.

In evaluating ice cream, the judge should particularly note the kind, the quantity, and the relative quality of the flavoring used in the product. If the ice cream is vanilla, for instance, the judge should constantly keep in mind the desired delicate "bouquet" (aroma note) that is so highly prized and sought in a high-quality vanilla ice cream. The judge should not deviate from an established mental standard or predetermined "flavor profile" of the "ideal" vanilla ice cream. Both the pure vanilla (if used) or the vanilla/vanillin blend, and the amount used, should blend with the other ingredients to provide a pleasing, refreshing, and appetizing product. The judge should be eager for a second (and a third) bite of the ice cream if it is one of high quality. Four flavor defects related to the product-flavoring system may be experienced, which are described in the following paragraphs. Flavors showing in ***italic/bold*** are evaluated in the CDPEC.

Table 10.7 Classification of ice cream flavor defects according to their cause of origin

I. Off-flavors due to the ingredients used	
A. *The flavoring system*	
1. Lacks (deficient)	3. High flavor (excessive)
2. Lacks fine flavor (harsh, lacks balance)	4. Unnatural (atypical)
B. *Sweeteners*	
1. Lacks sweetness	3. Syrup flavor (malty, Karo-like)
2. High sweet	
C. *Dairy products*	5. Oxidized (cardboardy, metallic)
1. Acid (sour)	6. Rancid (lipolytic)
2. Cooked (rich, nutty, eggy)	7. Salty
3. Lacks freshness (stale)	8. Whey (graham cracker-like)
4. Old ingredient	
D. *Other ingredients*	
1. Eggs (eggy) 2. Stabilizer/emulsifier	3. Non-milk food solids
II. Off-flavors due to chemical changes (in the mix or product)	
1. Lacks freshness (stale, old)	3. Oxidized (cardboardy, metallic)
2. Rancid (lipolytic)	4. Storage
III. Off-flavors due to mix processing	
1. Cooked (rich, nutty, eggy)	2. Caramelized/scorched
IV. Off-flavors due to microbial growth in the mix	
1. Acid (sour)	2. Psychrotrophic (fruity/fermented, cheesy, musty, unclean)
V. Off-flavors due to other causes	
1. Foreign contaminants	2. Neutralizer

Bodyfelt et al. (1988)

10.9.1 Off-Flavors from the Ingredients Used[1]

Typically, the first perceived flavor or off-flavor in a frozen dairy dessert is one associated with the flavoring material used. Due to the volatility of flavor substances, it tends to register early with the olfactory center. A defective source of flavoring could contribute to any flavor defect.

High flavor *(excessive).* This flavor condition, when it occurs, is best recognized when the sample is first placed into the mouth. The intensity of the flavoring seems so striking or sharp that the desired, pleasant flavor blend is not achieved due to the harsh tones imparted by the flavoring level observed in the product. Ice cream that is too highly or excessively flavored is not severely criticized as a rule, especially if

[1] The following materials are directly from the previous edition (Bodyfelt et al., 1998) unless otherwise noted by the update reference.

the quality of the flavoring used is high. An associative "ethanol-like" note may be present.

High sweet. An ice cream that is observed to be excessively sweet tends to exhibit a candy-like taste sensation; this defect is readily noted upon the first stages of tasting. Too much sugar (or other form of sweetener) tends to interfere with the overall desirable blend of flavor(s). Another unfortunate characteristic of a given ice cream that is perceived as being too sweet is a general lack of refreshing property.

Lacks fine flavor *(harsh, coarse).* This criticism is generally used to describe an ice cream that is basically "good" or "very good," but for some less than clear reason, it seems to just barely fall short of being "perfect" or "ideal." In some instances, such an ice cream may simply lack an overall "flavor balance" (blend), but otherwise the product appears to be free of any hint of detectable flavor shortcomings. In other instances, the sensory dimensions of a pure (real) vanilla or a vanilla/vanillin blend may be determined by close sensory examination to be slightly less than expected or desired. Experienced ice cream judges are able to recognize the desirable, delicate, balanced flavor notes of a high-quality flavor. The novice judge should remember that "lacks fine flavor" is not readily described in more definitive or specific terms. Thus, this descriptor should practically be considered a "last resort" in describing a minor flavor defect related to the flavoring system. The observations of Gassenmeier (2003), considering the loss of vanilla flavor to xanthine oxidase–catalyzed oxidation, may also apply to the loss of fine flavor in ice cream, as natural vanilla extracts contain a number of complementary flavor compounds besides vanillin that are susceptible to oxidation.

Low flavor (lacks flavoring). An ice cream with this defect is often criticized as flat, bland, or deficient in the amount of added flavoring. Even though the ice cream may be pleasantly sweet and free from any dairy ingredient off-flavor, it seems to lack the characteristic delicate "bouquet" of excellent vanilla; the desired intensity is missing. The obvious cause of this defect is failure to use sufficient quantities of flavoring. However, there are instances when certain ingredients mask the vanilla flavor, thus invoking the "lacks flavor" criticism, even though the added quantity of flavoring seemed adequate to the manufacturer.

Xanthine oxidase, an enzyme active in raw milk, may catalyze the loss of vanilla flavoring by oxidation of vanilla to vanillic acid, when flavoring is added to raw ice cream mix and stored under refrigeration prior to pasteurization (Gassenmeier, 2003).

Lacks sweetness. An ice cream that lacks sweetness is readily noted upon tasting; the product simply manifests a distinct flat or bland taste. The desired or anticipated blend of flavor is missing. An adequate amount of sweetener is required to bring out the full-flavor "bloom" in a given flavor, whether it is vanilla, fruit, or chocolate ice cream. Since preferences for the desired level of sweetness vary among individuals, the product is not severely criticized for lacking sweetness, within reasonable limits, if this is the only flavor defect encountered. However, a severe deficiency in sweetener solids may give rise to readily evident defects in body and texture or mouthfeel.

Syrup flavor *(malty or* "Karo®"*-like).* A desired property of sweeteners in ice cream as well as other food systems is that they impart the basic sweet taste and

simultaneously be free of other flavor notes. Some flavor technologists have coined the term "clean sweet" for sucrose. In the past, the more complex flavor imparted by some sweeteners was termed "unnatural sweetness." This sweetener off-flavor is still commonly encountered in certain forms of corn syrups and corn syrup solids; hence "syrup flavor" is the common descriptor for this characteristic defect. When honey is used as a sweetener, the resulting sweetness may be criticized as syrupy unless the ice cream is intended to be honey-flavored. Frequently encountered descriptions for syrup flavor might be malty, "Karo®"-like, Sugar Daddy®-like, caramel-like, molasses-like, marshmallow, or similar to low levels of burnt sugar. Some evaluators distinguish syrup flavor from high sweetness by the "catch" experienced in the throat, similar to the feeling after a dose of cough syrup. Certain forms or sources of corn syrup solids, corn syrup, and some liquid sugar blends with excessive levels of corn syrup, when used in ice cream in high proportion to sucrose, may convey a slight to distinct malty or caramel-like off-flavor. Too often, a syrup off-flavor may mask or otherwise interfere with the release of the given flavoring, especially delicate flavors like vanilla. Additionally, syrup off-flavor tends to be enhanced by the cooked flavor note of the mix. Simultaneously, a gummy or sticky body can often be associated with an ice cream or ice milk that has also been criticized for "syrup flavor."

Unnatural flavor (atypical). Frequently, the manifestation of "unnatural flavoring" in ice cream may convey the sensation of being too high in flavoring. The impression of unnatural flavoring may be of several types and intensities, depending upon the kinds and proportions of constituents used in preparation of the extract, emulsion, or flavor concentrate. For example, synthetic or imitation vanilla, which is often used to fortify vanilla extracts, may tend to produce a "quick," sharp, piercing, or burning sensation on the sides and base of the tongue. Generally speaking, the unnatural flavor criticism is observed more frequently in ice creams that are labeled "vanilla flavored" or "artificially flavored vanilla," than in products labeled "vanilla" or "real vanilla." Details of ice cream classification and associated labeling requirements (as a function of vanilla or vanilla-flavoring category added to the product) are summarized in Table 10.8. To minimize bias in ice cream judging or any product evaluation, it is crucial that the sensory observations be conducted without the evaluators examining the product labels before completion of the task.

Another form of unnatural flavor may occur due to the addition (usually unintentional) of extracts other than vanilla to the ice cream mix; the imparted flavors may be suggestive of spices, coconut, marshmallows, custard, candy, nuts, lemon, cherry, maple, "buttery," or "smoky." Numerous other unnatural flavors are possible in frozen dairy desserts, depending on the circumstances of manufacture. If one of the aforementioned or another atypical flavor notes are perceived in vanilla ice cream, the appropriate recourse is to criticize the sample for "unnatural flavor." This flavor also frequently arises through the accidental intermixing of two or more product flavors when ice cream freezing machines are converted from one flavor to another.

Table 10.8 Labeling requirements for various categories of vanilla ice cream according to the flavor source

Flavor declaration	Flavor requirements			
Ice cream type or category	Characterizing flavor declaration	Subsidiary flavor declaration	Sources	Quantity
Category 1	*Vanilla*	None	Vanilla beans, extract, or powder; *no artificial flavor* permitted	Sufficient to impart characterizing flavor
Category 2	*Vanilla* flavored	"Vanilla and artificial vanilla flavor" or "artificial flavor added" or "artificial vanilla flavor added"	Vanilla beans, extract, or powder plus artificial vanilla: i.e., twofold, or fourfold vanilla-vanillin extract (or powder)	Vanilla beans, extract, or powder, in combination with vanillin, not to exceed 1 oz. per "unit of vanilla constituent" as described in vanilla standards. Concentrations may be used where ratio of "vanilla constituent" and vanillin remain 1:1[a]
Category 3	Artificially flavored *vanilla* or artificial *vanilla*	None	Artificial vanilla, with or without vanilla beans, extract, or powder	If the amount of vanillin used is >1.0 oz. per "unit of vanilla constituent," the product must be labeled in accordance with this category. Product may be flavored exclusively or in part with other artificial vanilla, e.g., ethyl vanillin

Source: Adapted from Code of Federal Regulations 2006. Title 21, Part 135

[a]For example, if 1 gal of vanilla extract contains extractive from 26.7 oz. of vanilla beans, a maximum of 2 oz. vanillin may be used. One (1.0) unit "vanilla constituent" = total extractable flavor components of 13.35 oz. of vanilla beans with a moisture content less than or equal to 25%, or a proportionally greater amount of vanilla beans if >25% H_2O

In fact, this is probably the most common cause of this type of unnatural (or atypical) off-flavor in US commercial ice cream. This is unfortunate, since numerous consumers (through surveys) have indicated that they were the recipient of a "surprise flavor"; a "flavor" they did not bargain for at the time of purchase (Bodyfelt et al., 1988; Goff & Hartel, 2013).

The unnatural flavor problem also frequently arises through the accidental intermixing of two or more product flavors when ice cream freezing machines are converted from one flavor to another.

10.9.2 Dairy Products as a Source of Defects

***Acid** (sour).* An acid or sour off-flavor in frozen dairy desserts may be distinguished from other off-flavors by a sudden, tingly, taste sensation (on the tip or top of the tongue), plus an associated "clean and refreshing" mouthfeel. This flavor defect may be caused by the use of acid whey in the ice cream mix (Westerbeek, 1996; Abbas Syed, 2018). The off-flavor may also result from uncontrolled bacterial activity at elevated temperature; other bacterial off-flavors may also be present. In such cases, the flavor defect(s) may be more appropriately described as a combination acid (sour) and psychrotrophic bacteria-caused off-flavor (unclean, fruity, or putrid). The acidity (and/or psychrotrophic defect) may have developed in one or more of the dairy ingredients used, or the mix may have been stored at a favorable growth temperature for lactic acid forming or other types of bacteria. In any severe temperature abuse situation, the bacterial count would ordinarily be expected to exceed established regulatory limits. A serious processing and product handling error or disregard for quality control is evident when an acid taste is so intense that the evaluator is inclined to think of the sample as a sour product. Such a product should never reach the marketplace; the consumer would often be offended by the presence of this unusual off-flavor in a sweetened product such as ice cream.

Cooked. The "cooked" flavor of ice cream is commonly experienced. It is also referred to as "rich," "eggy," "sulfide," "custard," scalded milk, condensed milk, or caramel-like. These flavors, although they may differ slightly in some respects, actually have much in common. A cooked milk or cream "background flavor" is the characteristic flavor note of this group of heated flavor sensations. Depending on its intensity, this flavor sensation is usually somewhat delayed in terms of the initial perception, but then it tends to persist after the sample has been expectorated. A highly cooked or heated flavor of the product may tend to "mask" or modify the vanilla flavoring. The resulting flavor sensation may be rather pleasant, although it would usually be perceived differently than a pure vanilla flavor.

Cooked (or rich) flavor is not considered a serious defect in ice cream, unless it is so intense as to be perceived as caramel, scorched, or burnt. In fact, some manufacturers intentionally strive for a slight to moderate degree of cooked (rich, nutty, custard-like) flavor in vanilla ice cream. They believe, as do the authors (Bodyfelt et al., 1988; Goff & Hartel, 2013), that a slight to modest cooked flavor note helps convey a fuller, smoother, richer flavor in the product. Quite commonly, the dairy ingredients incorporated into ice cream will have already been pasteurized, but federal and state regulations require that the assembled or final ice cream mix must also be pasteurized. Second, or subsequent, heat treatment is likely to produce some degree of cooked flavor in the mix. As indicated earlier, this is not typically objectionable in ice cream; in fact, it may be quite desirable or preferred in many instances.

An excessive-cooked off-flavor usually results from using ingredients that have received such severe heat treatment that a scorched or burnt effect is attained. Mix pasteurization, under some adverse conditions, may also develop a cooked

off-flavor. Even though pasteurization standards require heating at a minimum of 79.4 °C (175 °F) for 25 or more consecutive seconds, some manufacturers may opt to heat to near the boiling point or above. Some mixes may be ultra-pasteurized or commercially sterilized and aseptically packaged. Again, it should be emphasized that a moderate-cooked flavor is not particularly objectionable. However, an obvious scorched or burnt off-flavor is to be avoided.

Lacks freshness (stale). The descriptor "lacks freshness" or "stale" refers to a moderate off-flavor of ice cream and related frozen desserts. This flavor defect is generally assumed to result from either a general flavor deterioration of the mix during storage, or from the use of one or more marginal quality dairy ingredients in mix formulation. For instance, some old milk, old cream, or stale milk powder (nonfat milk solids) may have been incorporated as an ingredient. If the off-flavor imparted by the "marginal" ingredients were quite intense, then "old ingredient" would probably be the most appropriate criticism. However, if the other milk components and/or mix ingredients dilute the adverse sensory aspects of the dairy ingredient(s) in question, a lacks freshness (or stale) descriptor is more applicable. Some evaluators consider the lacks freshness defect as reminiscent of "freezer burn."

Occasionally, relatively small quantities of cream or milk used as mix ingredients may manifest an old ingredient, oxidized, rancid, or unclean defect. But, unfortunately, this situation was "missed" or overlooked by production and quality control personnel. Subsequently, dilution of the "offending" dairy ingredient(s) (by higher volume "quality" ingredients) results in an overall deterioration of flavor quality, which is commonly described as stale or lacks freshness. When ice cream and reduced fat ice cream lack freshness, there may or may not be a slight aftertaste. However, if the aftertaste is strong or persistent, the judge should look for or consider more serious defects such as old ingredient, storage, oxidized, or rancid.

Old ingredient. Nearly all dairy ingredients used in ice cream are subject to flavor deterioration with age (extended storage). Poor sanitation in milk handling and processing and subsequent bacterial action may produce psychrotrophic off-flavors or an "old milk" or "old cream" flavor. Through chemical reactions, milk and whey powders may become stale and caramelized in storage. Caseinates may acquire a stale and glue-like off-flavor; syrups may ferment. With storage, various deteriorative processes may occur in stabilizers, emulsifiers, and flavoring agents. The same descriptor, "old ingredient," is used to describe a relatively large number of possible flavor defects. The cause of the problem should be pinpointed by checking all possible ingredients, through sensory examination, for their potential to adversely affect the delicate flavor of the product.

To some evaluators, old ingredient and oxidized off-flavors may resemble each other to some extent. With increased age (storage), the judge can expect that some autoxidation may have occurred, along with other possible deteriorative changes. In many instances, the old ingredient defect will not be noted immediately after the sample is placed into the mouth; but usually an ice cream with this defect will exhibit a persistent aftertaste. Typically, the aftertaste will not be pleasant; the taste buds will fail to "clean-up."

Oxidized *(cardboardy, metallic).* In dairy products, the oxidized off-flavor may vary so widely in character and intensity that several terms or descriptors are used to distinguish between the various stages. In ice cream or low-fat ice cream, this off-flavor may be encountered to such a slight intensity that the product flavor seems flat or "missing." A further development of this off-flavor may be described more accurately as astringent, metallic, or puckery (with an associated mouthfeel of shrinking of the mucous membranes). Other, more moderate intensities of the off-flavor might be described progressively as oxidized, papery, or cardboardy. In the most intense stages of the oxidation of milk products, oily, tallowy, painty, or fishy are common descriptors. The oxidized off-flavor is usually noted soon after the sample is placed into the mouth; if intense, it may persist long after the sample has been expectorated. Depending on the intensity, such an ice cream may not be entirely repulsive to the evaluator or the consumer. However, an oxidized defect definitely conveys the idea that the product is not made from high-quality ingredients, is not refreshing, or may be stale or old. Generally, the evaluator or consumer is not very eager for a second bite of such a product. Hence, when an oxidized off-flavor occurs in frozen dairy desserts, repeat sales for the product (or brand) are not as likely to occur.

Some evaluators think of metallic off-flavor as a distinctly separate defect, even though this off-flavor is commonly considered another stage or degree of the generic oxidized off-flavor. Since stainless steel has replaced monel or "white metal" in milk handling and processing equipment, the metallic defect has substantially decreased as a problem. Historically, the conditions associated with the occurrence of a metallic off-flavor were equipment made of copper or copper alloys, improperly tinned equipment, rusty milk cans and utensils, and/or storage of milk products in nonstainless steel containers or vessels. The metallic off-flavor is characterized as having a peculiarly rough, astringent, puckery mouthfeel. As indicated previously, the metallic defect is often considered one of several stages in the series of off-flavors due to lipid oxidation. The light-induced form of the oxidized off-flavor (protein oxidation) is much less likely to occur in ice cream than the metal-induced form of oxidation.

Occasionally, a light-activated defect might be encountered in frozen desserts packaged in containers that employ the transparent, "see-through" lid, but it is usually highly localized on the top surface and only after direct exposure to light (Suttles & Marshall, 1993). Since light-oxidized flavor defect is rarely observed in ice cream, it is not evaluated in the Collegiate Dairy Products Evaluation Contest. An implication of work by Gassenmeier (2003) is that the enzyme xanthine oxidase may catalyze the formation of cardboard-tasting, lipid- and oxygen-derived off-flavors in an unpasteurized ice cream mix under refrigerated storage conditions. Light-oxidized off-flavor in ice cream is influenced mainly by the riboflavin content and susceptibility of unsaturated fatty acids to oxidation (Shiota et al., 2002; Schiano et al., 2017). Double-strength vanilla significantly masks off-flavors compared to single-strength vanilla and freezing with nitrogen gas instead of air decreases oxidized flavor formation (Im & Marshall, 1998).

Rancid. Fortunately, a rancid off-flavor is infrequently observed in ice cream (Tobias, 1983; Abbas Syed, 2018). A specific, delayed, reaction time of perception is characteristic of rancidity, and it has an attendant persistent repulsiveness. However, the sweeteners and flavoring may tend to mask any potential rancidity to the extent that unless the defect is quite pronounced, this off-flavor may not be recognized for what it actually is. If rancidity were to occur in ice cream, the peculiar blend of flavors and off-flavors would typically terminate as an unclean or unpleasant aftertaste, which is characteristic of the rancid defect. Rancidity is severely criticized since it indicates either utilization of mishandled dairy ingredients or serious processing errors that led to mixing raw milk or cream with homogenized milk ingredients.

Salty. Occasionally, a salty off-taste may be encountered in frozen dairy desserts. This taste may be readily detected, since the reaction time is relatively short; hence, it is a quickly perceived taste. A salty taste could be due to added salt, the use of salted butter as a milk fat source, or it may be associated with use of a high percentage of concentrated whey, whey solids, or milk-solids-not-fat (MSNF) in the formulation. High displacement rates of MSNF with whey solids (i.e., in excess of 20–25% replacement) seems to occasionally lead to a slight salty off-taste in ice cream or ice milk. Other sensory defects may accompany the higher usage rates of some sources of dry whey (see the following discussion on the whey off-flavor). To most evaluators, a salty taste in frozen dairy desserts seems distinctly "out of place" for this form of product; hence, it is usually criticized in line with the level of intensity and the specific flavor involved.

Whey ("Graham cracker-like"). The Federal Standards of Identity limits the maximum concentration of whey solids in ice cream to 25% of the MSNF (for products engaged in interstate commerce). While the quantity of whey used in the mix is certainly a factor in the possible transmission of whey off-flavors, an even more important aspect is the whey quality. The quality of whey solids should be carefully determined; especially important is a close scrutiny of the flavor characteristics (freshness and freedom from stale, old ingredient, or oxidized-like off-flavors). Freedom from off-colors, caking (free flowing), or lumping is also critical for dry whey. Preferably, the level of whey solids used in ice cream or ice milk should be below the flavor detection threshold for the "whey flavor." However, even lower levels of whey (15–17% displacement of MSNF) may be detected by sensory test when it is of poor quality.

A whey off-flavor in frozen dairy desserts is probably best described as being "Graham cracker-like" or similar to stale condensed milk (Bodyfelt, 1979, 1988; Goff & Hartel, 2013), with an associated slight taste of salt. Some evaluators consider the sweetness "cloying" (initially pleasingly sweet, then excessive). The whey off-flavor present in ice cream is very different from how whey manifests in other dairy products; the flavor results from the complex interactions among ice cream ingredients. Extremely old or poor-quality whey solids may reflect oxidized, cheesy,

rancid, and/or unclean defects, and subsequently transmit these off-flavors to the ice cream. An unpleasant aftertaste may prevail, due to the amount and/or quality of whey solids used in the mix. Sometimes ice cream and related products that exhibit whey off-flavor may simultaneously display slight off-colors (reddish orange), as well as a friable, crumbly body and/or a gritty texture.

10.9.3 Off-Flavors Due to Chemical Changes in the Mix or Product

Lacks freshness *(stale, old).* This flavor defect may develop due to chemical changes that can readily occur in the mix or is caused by the use of a faulty ingredient in low concentration. It may also result from adverse conditions of producing, storing, transporting, handling, and distributing such perishable milk products cas ice cream, mixes, and finished products. This defect was discussed earlier and can be considered a light form of stronger defects like old ingredient, storage oxidized, or rancid. Lacks freshness can be distinguished when evaluating ice cream by its stale taste, some marginally old dairy ingredient, slight old ingredient, or other flavors.

Oxidized *(cardboardy, metallic).* This off-flavor is generally associated with chemical changes of the fat ingredient. Oxidized flavor can be identified as cardboardy, astringent, oily, or tallowy when evaluating ice cream. Processes of staling, "aging," autoxidation of milk lipids, hydrolytic rancidity, and bacteria-induced deterioration of milk proteins and milkfat represent a set of complex chemical and enzymatic activities that takes its toll on flavor stability of frozen dairy products and their mixes. The specifics of the possible off-flavors that can develop from these chemical changes have been described earlier in this chapter, but one new category that should be addressed is the so-called storage off-flavor.

Storage. The "storage" off-flavor generally refers to flavor that may develop either in the mix or in the frozen ice cream (or low-fat ice cream) during the storage period. When ice cream is stored for an extended period of time, the flavor loses its initial luster, even though no specific defects seem to stand out. In one instance, the product may simply lack the sensation of freshness. In another case, absorption of odors from the environment can cause the product to acquire a "storage-like" off-flavor, a form of "absorbed flavor" defect. Smoke, ammonia, and various chemical odors are but a few examples of absorbed substances that may be responsible. Serious storage flavor defects have been known to develop when odor, absorption, and chemical change or deterioration in storage occurred simultaneously. The storage off-flavor is commonly considered more serious or objectionable than the "lacks freshness" (stale) defect in ice cream.

10.9.4 Off-Flavors Due to Mix Processing

Cooked *(rich, nutty, eggy) and caramelized/scorched.* These are heat-induced off-flavors that might occur in ice cream and were discussed earlier under the heading of "cooked," within the section of this chapter on the role of dairy products imparted off-flavors.

10.9.5 Off-Flavor Due to Microbial Growth in the Mix

Acid *(sour), fruity-fermented, cheesy, musty, and/or unclean (psychrotrophic).* Each of these microbial-induced off-flavors is likely to occur as the result of varied degrees of temperature abuse in the handling of milk and cream ingredients and/or excessive storage temperatures of perishable mixes (i.e., higher than 4.4 °C (40 °F)). For descriptions of each defect enumerated above, the reader is directed to the discussion of microbial off-flavors of milk and cream discussed in Chap. 5.

10.9.6 Off-Flavors Due to Other Causes

Foreign *(atypical).* As a rule, a foreign off-flavor may be easily detected, but the exact substance or specific contaminant is often difficult to positively identify. This flavor defect is definitely atypical (foreign) for dairy products, or the ingredients ordinarily associated with good-quality ice cream. Detergents, sanitizers, paint, gasoline, pesticides, and other chemicals of chance contact are some of the possible serious offenders. Unfortunately, chemical substances may not only impart off-flavors but also be nauseating or toxic. Obviously, any products found to contain this defect must be severely downgraded and not marketed for human consumption.

Neutralizer. Although neutralization of lactic acid is not currently an accepted step in ice cream manufacture, the judge should be familiar with the flavor defects that may result from such an ill-advised contemporary practice. When neutralizer is used to reduce the developed acidity of milk ingredients or the mix, the end products formed by the chemical reaction of neutralization are left as residual compounds in the frozen product, where they may become apparent upon tasting. This off-flavor is recognized by a peculiar alkaline off-flavor (reminiscent of sodium bicarbonate (baking soda) or milk of magnesia). Sometimes, a slight bitter taste can be associated with neutralizer off-flavors, though this bitter note is usually rather mild. The taste reaction time for a neutralizer off-flavor is somewhat delayed, but the peculiar taste persists for some time after the sample has been expectorated. Any frozen dairy desserts exhibiting a neutralizer off-flavor are usually severely criticized by ice cream judges. In this era, the use of neutralizers in ice cream manufacture, or any type of dairy product, should certainly be discouraged, if not altogether

eliminated. In those instances where a neutralizing agent might be used, the ice cream manufacturer is also likely to experience the development of other associated serious off-flavors (besides the neutralizer defect), namely, lacks freshness or stale, old ingredient, storage, and/or spoilage (psychrotroph) bacteria-related off-flavors.

10.9.7 Other Ingredients

Eggs (eggy). Part 135 of the CFR permits the use of egg solids, but regular ice cream must contain less than 1.4% egg yolk solids by weight, exclusive of the weight of any bulky-flavoring ingredients used. When the content of egg yolk solids (by weight) is 1.4% or more, the product must be labeled "frozen custard," "French vanilla," or "French custard" ice cream. Although not widely used in contemporary ice cream, eggs have, or have had, definite functional roles in ice cream – namely, stabilization and emulsification.

Egg yolks, whether in liquid, dry, or frozen form, do not necessarily impart an off-flavor to ice cream, but they may impart a characteristic "eggy" flavor note. This derived flavor is typical for egg yolks. However, off-flavored egg solids have the capacity, similar to off-flavored milk solids, to introduce certain unwanted off-flavors. Deteriorated, poor-quality whole eggs or egg yolks readily impart a flavor defect to ice cream. A characteristic "egg flavor," imparted by high-quality egg solids, is not that easy to distinguish, since this flavor note resembles the cooked (custard or nutty) sensation, although an egg flavor is usually more persistent. When used at low levels in ice cream (less than 1.4%), high-quality egg solids are usually compatible with the desired flavor blend. Since egg yolks have good emulsifying properties, some ice creams are formulated to contain them as a supplement to, or a substitute for, stabilizers and/or emulsifiers.

Stabilizer/emulsifier. These off-flavors are due to the incorporation of poor-quality, deteriorated, or excessive amounts of stabilizers and/or emulsifiers. Low-fat ice cream may be more susceptible to this defect since it generally contains higher concentrations of these body and texture-modifying agents than ice cream. Substances used as emulsifiers are somewhat prone to imparting an off-flavor generally described as "stabilizer-like" or "emulsifier-like." Occasionally, some of the mono- and diglycerides and other emulsifiers in proprietary blends of stabilizers and emulsifiers may exhibit some degree of lipid autoxidation. Hence, this form of stabilizer/emulsifier off-flavor may be confused with the generic oxidized flavor defect. Certain soft-serve low-fat ice cream and ice cream novelty products are more likely to manifest a slight to moderate intensity of emulsifier off-flavor than conventional ice cream. The novelty products and low-fat soft-serve ice cream rely on higher concentrations of polysorbates, mono- and diglycerides, or lecithin, to provide "drier," firmer products when drawn from the freezer; hence, they are more prone to this off-flavor than ice cream.

Non-milk food solids. On a rare occasion, other approved food solids (other than dairy derived, sweeteners, flavoring agents, and stabilizers/emulsifiers) may be

incorporated into frozen dairy desserts for a special flavor effect, body and texture, or appearance function. Cookies, cake, and cheesecake are several examples that come to mind. It is conceivable that certain off-flavors could be imparted to ice cream from such sources, especially if used in relatively large quantities. Examples of materials cited here, however, should not be encountered in vanilla ice cream.

10.10 Other Frozen Dairy Desserts

Low-fat ice cream. As noted in Table 10.1, this product (formerly called ice milk) differs from ice cream principally in the quantity of milk fat content. Although low-fat ice cream is offered in a variety of flavors, vanilla is the most popular. For evaluating the sensory properties of low-fat ice cream, the ice cream scorecard and scoring guide (Fig. 10.1 and Table 10.3) are appropriate for all sensory quality parameters. Due to the lower milk fat content, low-fat ice cream would be expected to lack the typical richness, mouthfeel characteristics, and the overall flavor blend that most ice cream possesses. Also, the body and texture, as expected, can differ considerably from ice cream, due to the lower total solids content of low-fat ice cream. However, in spite of these inherent problems, many manufacturers have mastered the required technology and art for producing low-fat ice cream of excellent flavor, body, and texture. In fact, the sensory properties of many samples of low-fat ice cream may be practically free of criticism, even though they might be evaluated on the same general criteria as ice cream.

Mellorine. Despite the different language in the Federal Standards of Identity, except for the source and type of fat, this product generally resembles either low-fat ice cream (usually) or ice cream in composition. The ice cream scorecard and guide are generally applicable for conducting sensory evaluation, but certain additional defects that may be derived from vegetable or animal fats may be encountered and recorded as appropriate on the scorecard. Flavor defects of main concern in mellorine are the possibilities of oxidation, rancidity, the presence of a distinctive off-flavor derived from the specific fat source, and a lack of flavor or "blandness" (which can be attributed to varied fat sources other than dairy based). The relative hardness and melting properties of the fatty acids that constitute the fat can influence the body and mouthfeel of frozen mellorine (typically vegetable fat and/or other animal fats other than dairy, or in a blend with milkfat).

Frozen custard. Basically, this product is identical to ice cream except for the addition of egg yolk solids at a concentration of at least 1.4% by weight. Based on this requirement, frozen custard should not be criticized for having an egg solids flavor, unless a characteristic "poor egg solids" off-flavor is sensed (due to use of poor-quality egg ingredients). A greater tolerance for a "cooked" or "eggy" flavor should be extended in evaluating those products labeled "frozen custard," "French custard," or "French vanilla" ice cream.

Frozen bulky-flavored products. Due to the relatively small quantity of required flavoring, and a minimum dilution effect, ice cream composition remains essentially

unchanged when it is flavored with vanilla or other extracts. However, some flavorings such as chocolate, fruits, bakery products, candy, and nuts are often added in relatively high proportions – hence, the applied term of "bulky flavors." Bulky flavors may be added to ice cream, reduced fat ice cream, or frozen custard. Federal standards allow for alteration of the product composition by bulky flavors, as indicated in Table 10.1. Numerous bulky-flavoring ingredients are used in ice cream; a few will be discussed to illustrate the applicable principles when sensory qualities are assessed by sensory methods.

In ascertaining the quality of bulky-flavored frozen desserts (actually any flavor), the evaluator should be alert to the possible occurrence of any of the defects that may be manifested in vanilla ice cream. Some of the milder off-flavors of ice cream may be masked or partially masked by some flavorings, but not by others. However, the judge should bear in mind that even a masked off-flavor may modify the overall perception of some flavorings in an undesirable way. A smooth, creamy texture is usually desired regardless of the type of flavorings used, but somewhat different or altered characteristics of body and texture should be recognized as the norm with some flavors of ice cream. Generally, the higher the quantity of bulky flavorings incorporated into any ice cream, the greater the tendency or likelihood for development of a coarse or icy texture, and/or possibly a weaker product body. This likelihood is primarily due to the dilution of solids, added moisture from some sources of bulky flavorings, and/or higher overrun. When the added flavoring material does not incorporate air, the ice cream portion may be excessively whipped to maintain minimum weight (e.g., 4.5 lb/gal).

10.10.1 Other Ice Cream Products

Other ice cream products are the results of manipulating the processing conditions and ice cream formulations. Under these altered conditions, the products have physiochemical properties that may be like regular ice cream products or have unique characteristics that are appealing to consumers. The properties that can be influenced by manipulating the conditions may include total solids content, nutritional values, sensory properties, sweetness, viscosity, freezing point, fat stabilization, hardness, melting rate, overrun, and others.

Slow-Churned Ice Cream The typical steps in ice cream production start with preparation of the premix of the ingredients, followed by aeration and freezing in a scraped-surface heat exchanger. When making slow-churned ice cream, after the aeration and freezing step, the mix is further processed in a low-temperature ice cream extruder. Freezing and aeration of ice cream and other frozen desserts are traditionally accomplished by a scraped-surface heat exchanger, where pasteurized, chilled, and aged liquid mixes are subjected to low chamber temperatures, high-speed dashers, and surface-scraping knives. The size and uniform distribution of dispersed ice crystals, fat globules, and air bubbles are most critical for the textural

quality of finished ice cream, and the aeration and freezing steps are essential for their development (Shrivastav & Goswami, 2017). Scraped-surface ice cream freezers provide effective heat transfer and aeration to form the required ice crystals, fat globules, and air bubbles, but the attainable draw temperature is limited to approximately −5 °C (Bolliger et al., 2000a). At this temperature, less than 50% of the water in the formulation is frozen, so further freezing is typically conducted at approximately −40 °C in a hardening tunnel or hardening room for up to 3 h. During traditional hardening, ice crystals often grow and become detectable by consumers, as the ice cream loses its desirable creamy texture.

Low-temperature extrusion (LTE), also referred to as the "slow-churned" process, is an innovative rapid hardening and texturizing process that promotes the formation of smaller ice crystals through the application of low temperatures, high shear stresses, and high pressures (Shrivastav & Goswami, 2017; Goff & Hartel, 2013; Wildmoser et al., 2005). As ice cream exits the scraped-surface freezer, it enters the low-temperature extruder and is cooled to approximately −15 °C within minutes. This quick hardening often eliminates the need for traditional static hardening, and the ice cream remains pumpable due to the LTE's shear stresses that prevent accretion of ice crystals. This process also provides greater resistance to recrystallization during storage and distribution and results in a smoother texture. Additionally, LTE creates well-dispersed, small air bubbles and reduces the size of fat globules, which enhances creaminess and softens the texture, making slow-churned products easier to scoop (Goff & Hartel, 2013; Wildmoser et al., 2005). These enhanced qualities have led to the development of reduced-fat frozen desserts with similar textural attributes and improved ease of use when compared to traditional full-fat formulations (Goff & Hartel, 2013).

High-Protein Ice Cream Conventional ice cream has 4% protein and it is usually provided by skim milk powder. This level has been reported to be ideal for the sensory properties of the ice cream. High-protein ice cream can be created by the incorporation of whey protein concentrate (WPC) and milk protein concentrate (MPC) and has been shown to increase shape retention and viscosity of the product. However, increasing protein content up to 7% has been found to be detrimental to the quality attributes of ice cream with lower overrun and excessive hardness (Alvarez et al., 2005). Patel et al. (2006) observed that acceptable high-protein ice cream could be produced with a protein content up to 6.05% provided by MPC; the authors found an increase in the overall structure, viscosity, and reduction in the ice crystal size compared to the 3.78% ice cream. These changes were attributed to less free water available to form ice crystals. One week after manufacture, sensory overall structure acceptance was higher and iciness (related to crystal size) was lower at 6.05% protein content; however, at 7.19% protein concentration, the overall flavor acceptance was significantly affected. The authors reported that the vanilla flavor was masked by the WPC and that at a higher protein concentration, additional flavor needed to be added to overcome the effect on flavor. Similar results were reported by Daw and Hartel (2015), who evaluated the effect of different protein sources (skim milk powder, WPI, and MPC); the authors observed that increasing the

protein concentration significantly affected the coalescence of fat globules and meltdown rates. Roy et al. (2022) evaluated the incorporation of whey protein isolate to increase protein content to 8 and 10%; the authors reported that the sensory attributes like body and texture decreased in the high-protein samples compared to the control (4% protein).

An increase in protein concentration of ice cream could enhance nutritional value, but it has been shown to significantly affect the physicochemical properties of the final product. Increasing protein content increases viscosity, lowers the overrun, increases the ice cream melt rate, and disrupts the fat stabilization process during manufacture (Daw & Hartel, 2015).

Lactose-Free and Reduced-Sugar Ice Cream Lactose and sugar are common ingredients in regular ice cream formulations. Addition of sugars is very important for sweet taste; it also helps in maintaining the solids content, helps to reduce the freezing point of the mix, and affects the texture and sensory properties (Chamchan et al., 2017). The common sweeteners used in ice cream are sucrose (cane or beet sugar), dextrose (corn sugar), and various corn syrups. The functioning and properties of these sweeteners are discussed earlier in this chapter. Lactose is a disaccharide that is made of two monosaccharides glucose and galactose linked by β-1,4 glycosidic bond. It is the principal carbohydrate present in milk and dairy products made from milk and is also referred to as "milk sugar" (Özdemir et al., 2018). There is a consumer trend toward sugar-free ice cream because of health concerns and weight issues. Thus, the industry is developing products replacing the sugar and high fructose corn syrup in ice cream formulations with low- or zero-calorie sugar substitutes.

Lactose-free dairy products are gaining much interest and is one of the fastest-growing sections in the dairy industry – it is expected to reach a turnover of $9 billion in 2022 (Dekker et al., 2019). Lactose-free ice cream is prepared by eliminating or reducing lactose for individuals that are unable to digest lactose due to absence of lactase enzyme, commonly known as lactose intolerance. In this case, lactose ingestion can cause mild to severe symptoms and digestive discomfort. Lactose-free ice cream can be prepared either by using lactose-free milk or powder and by using lactase enzyme (β-D-galactosidase; β-D-galactoside galactohydrolase, E.C. 3.2.1.23). The enzyme is usually added after pasteurization and incubated before freezing when used directly in ice cream making. Lactose is hydrolyzed into glucose and galactose, which is sweeter than lactose itself, thus partially eliminating the addition of sugar, thereby reducing the calories as well Harju et al. (2012). It is easy to digest and absorb glucose and galactose by lactose-intolerant people (Dekker et al., 2019).

Reduced sugar ice cream is prepared by reducing the high amounts of added sugars to make the product consumable for diabetic and obese people (de Medeiros et al., 2021). Another way to reduce sugar is the use of natural sweeteners that can affect the sensory perception in a positive way but does not increase the glycemic index and caloric value. There are several noncaloric sweeteners used in ice cream

formulations such as sucralose, aspartame, acesulfame potassium, neotame, saccharin, and advantame. Sugar alcohols that have zero calories and zero carbohydrates are also used in ice cream formulations. Erythritol contains about 60–80% of the sweetness of sugar and is widely used. The most common natural sweetener is stevia, which has a sweetness level of 250–300 as compared to sucrose and is recognized as safe by the WHO and FDA (Alizadeh et al., 2014).

Removing lactose and reducing sugar have numerous effects on the final product. Lactose hydrolysis affects the texture and sensory properties (i.e., increases the viscosity, decreases the freezing point, increases sweetness, decreases total solid content). However, the added sugar is also reduced by 25%. Lactose hydrolysis also decreases the "sandiness" that is caused by the crystallization of lactose, a sensory defect that affects overall acceptability. Similarly, reduction of sugar affects the textural and sensory properties as well. It affects hardness and ice formation. The texture is usually hard and ice crystals increase in size and content, which reduces the overall acceptability as well. Sugar reduction also hinders melting, indicating the role of sugar in not only sweetness but ice content in the product. Moreover, the combined effects of lactose reduction/hydrolysis and sugar reduction give the highest acceptability properties (Abbasi & Saeedabadian, 2015).

10.10.2 Chocolate Frozen Desserts

The principal forms of chocolate flavoring for frozen dairy desserts are cocoa, chocolate liquor, or a combination of the two. Chocolate liquor contains the entire usable portion of the cocoa bean, including about 50% cocoa butter. Cocoas are made by removing varying amounts of cocoa butter from the liquor. However, the flavor character of cocoa or chocolate liquor from different sources can vary markedly. These flavor variations may be due to the source of the cocoa beans, climatic conditions during growth, fermentation conditions, whether Dutch processed (alkali-treated) or naturally processed, and the roasting conditions. Aside from flavor variations, the resulting cocoa may be light, dark, or red colored. Although the bulk of the characteristic flavor of chocolate is retained in the cocoa, some delicate, unique aroma constituents may be lost into the cocoa butter. Thus, the fat content of the given cocoa and the selected proportion of chocolate liquor to cocoa used in flavoring the ice cream will influence the flavor balance of the chocolate.

Chocolate ice cream often employs an added substance to modify or enhance the chocolate flavor; vanilla is most frequently used, but on occasion coffee, cinnamon, or salt may be added. The intent of the selected flavor modifier may be to mellow the chocolate sensation, diminish a certain harsh note, or simply to enhance or "bring out" chocolate flavor. However, the flavor modifier or enhancer should not be so intense as to actually predominate over the chocolate flavor of the ice cream.

The sweetness level of chocolate ice cream requires full consideration. Both cocoa and chocolate liquor are quite bitter, and thus, they demand a higher sweetness level in ice cream than vanilla or most other flavors. As an illustration, the

sweetness level of vanilla ice cream is commonly between 13% and 16%, expressed as sucrose, while that of chocolate ice cream may be 17–18% (expressed as sucrose). Obviously, there are distinct variations in consumer preferences for the type and intensity of chocolate flavor in ice cream. Individual preferences may span the intensity range from "just a hint of chocolate" to an overwhelming "double chocolate," from a light to a very dark color, and from a mellow, sweet to a bitter, harsh chocolate. In evaluating the flavor of chocolate ice cream, the judge's personal preference should not prejudice the rating, insofar as possible.

The overriding requirements for regular or conventional chocolate ice creams are that (1) the true chocolate flavor be readily recognizable in a supposed "blindfold test," (2) that the cocoa and/or chocolate liquor that is used be of high quality, (3) that no off-flavors be present, and (4) that any added non-chocolate flavor notes "contribute, but not predominate" in the overall chocolate flavor profile. Although some additional definitions of flavor terms and some new descriptors may need to be added, the ice cream scorecard and scoring guide in Figs. 6.1 and 6.2 can be applied to chocolate ice cream. Basic modifications are suggested in the following paragraphs.

Lacks fine flavor/harsh/coarse. These terms describe a lack of proper, expected, or desired chocolate flavor blend; an otherwise unidentifiable flavor defect or shortcoming of the chocolate; a flavor system that is somewhat lacking in the desired delicate volatile components of chocolate; or describes a product that merely seems not to project a "perfect," "ideal," or highly desirable flavor.

Lacks sweetness/bitter. This flavor defect of chocolate ice cream is self-explanatory. Adjustment of the sweetener level (increased amount) usually eliminates the defect in subsequent lots of the product.

Unnatural flavor/lacks chocolate character. These terms describe an artificial flavor; a chocolate flavor that is not readily recognizable as chocolate per se; or a flavor in which the non-chocolate components predominate. Basically, selection of another source of chocolate flavoring is suggested.

Other quality factors of chocolate ice cream. The body characteristics of chocolate ice cream are influenced by the relative proportions of cocoa and chocolate liquor used, as well as by the sugar content of the mix. Approximately 1.67 lb (0.74 kg) of chocolate liquor is required to impart the equivalent flavor intensity of l lb. (0.45 kg) of cocoa; hence, ice cream has higher total solids content when chocolate liquor is used exclusively or there is a high proportion of chocolate liquor to cocoa. But even when cocoa is used exclusively as the source of chocolate flavoring, the solids content of the mix is increased, and in either case, additional sugar (solids) is usually required and incorporated. The general effect of a product with higher solids content is a mix with increased viscosity (Wibley et al., 2004; Goff & Hartel, 2013). Descriptors listed on a conventional ice cream scorecard to describe body and texture defects are generally applicable to chocolate ice cream.

The various color defects listed on the regular (vanilla) scorecard also apply to chocolate ice cream, except that a gray off-color would not be expected to occur in chocolate. Departures from the desired range of chocolate color may be variously

described as dull, not uniform, too high (too dark), too pale (too light), or unnatural (atypical).

When evaluating the meltdown characteristics, the package, or bacterial content, the same criteria apply equally to vanilla and chocolate ice creams. Chocolate ice cream is also made and/or packaged in combination with other flavors. Several examples are chocolate almond (or other nuts), chocolate marshmallow, chocolate mint, chocolate and berries, and other chocolate-based products sold under proprietary names; this list is by no means all inclusive.

10.10.3 Fruit Frozen Desserts

The flavor of berries and fruits (strawberries, peaches, etc.) may be imparted to frozen dairy desserts by fresh, frozen, or processed fruits, natural extracts (that sometimes contain other natural flavors), imitation flavors, or various combinations of these. The flavor character, body and texture, and the appearance of the finished product, are influenced by the type of flavoring used. Generally, the flavor of the given ice cream should be reminiscent of sweetened fresh fruit and cream (e.g., strawberries and cream or peaches and cream). To overcome the problem of seasonality, availability, and perishability of fresh fruit, frozen fruit preparations are commonly used (Bodyfelt, 1973, 1974; Goff & Hartel, 2013).

The choice of the particular variety of frozen fruit should be based on quality and its suitability for ice cream. For example, a considerably softer, riper, and more flavorful peach is required for ice cream than for pie baking. Processed fruit may often exhibit a cooked, "fruit preserves" type of flavor that may not be objectionable, but it is unlike the typical or more preferred flavor of fresh fruit. Processed preparations of some fruits may be used alone, quite successfully, in combination with other forms of flavorings, or as a part of a more complex flavoring system. Processed cherries and some types of processed berries produce popular ice cream flavorings, and processed pineapple has been successfully used in combination with other flavors (especially for sherbet).

The sweetness level of fruit ice creams tends to be slightly higher than that of vanilla; the sweetener should blend smoothly into the overall flavor sensation in a well-made ice cream. There are two basic reasons for the incorporation of more sugar into fruit ice creams. The first is to compensate for the tartness of the fruit and optimize the intensity of the fruit flavor. Actually, the sweetness level of ice cream (from the mix) may already be sufficiently high to accomplish that for some fruits; hence the second reason becomes more important for quality considerations of the product. That is, sugar is generally required in the fruit preparation to reduce the freezing point of the fruit particles to prevent them from being ice-hard when the ice cream is consumed. Frozen fruits typically contain about 20% added sugar (one part of sugar to four parts of fruit).

A few flavor terms on the regular ice cream scorecard must be redefined in order to apply this scoring tool to fruit-flavored ice cream. The suggested changes are enumerated in the following paragraphs.

Lacks fine flavor. This term describes the lack of a highly desirable flavor blend; an otherwise unidentifiable flavor defect of the fruit and/or fruit flavoring; a flavor that lacks the full impact of fruit at the peak of its flavor development; or a flavor that just seems to fall short of being "perfect" or "ideal."

Cooked/processed. The terms "cooked" or "processed" describe a moderate off-flavor produced by heat treatment of the mix and/or an off-flavor that resulted from heat processing of the fruit.

Unnatural flavor/lacks specific fruit character. These terms attempt to describe an artificial or atypical fruit off-flavor; a flavor sensation in which the specific fruit is not readily recognizable; or a flavor note in which other fruit or nonfruit components seem to predominate.

Lacks freshness/stale fruit. This set of flavor defect descriptors is generally self-explanatory, but may include associated terms such as "musty," "fermented," or "rotten."

Body and texture of fruit ice cream. Since fruit preparations may be used in rather high concentration in ice cream (15–24%), there is considerable dilution of the mix, which, unless it is compensated for in some manner, can lead to a coarse texture and a decidedly weaker body. For fruit ice creams, one slight modification, listed following, seems appropriate for the body and texture segment of the ice cream scorecard.

Coarse/icy/icy fruit. The descriptor used to describe the relative coldness and size of ice crystals in frozen dairy desserts is "expanded" to encompass potential problems that may arise from fruit particles added to the product.

Other quality factors of fruit ice cream. Both the color and appearance of fruit ice cream should be closely evaluated for esthetic appeal. As with other flavors of ice cream, the color may be dull, not uniform, too deep, too light, or unnatural (atypical). The appearance also should be checked for any of the following possible defects (where applicable):

Fruit particles too small
Fruit particles too large
Too few fruit particles
Too many fruit particles
Poor distribution of fruit
Atypical color of fruit particles

10.10.4 Nut Frozen Desserts

Pecans, walnuts, almonds, peanuts, macadamia nuts, hazelnuts (filberts), and pistachio nuts are among the most popular nuts added to ice cream in the USA. Generally, ice cream is flavored with either an appropriate background flavor for the nuts (butter pecan, chocolate almond, etc.) or a concentrate of the same basic nut flavor (e.g., pistachio, black walnut). The degree and the method of roasting the nuts (light or heavy roast; dry or butter roasted) provide interesting variables that manifest themselves in the sensory properties of the ice cream. The initial quality and freshness of the nuts must be good; no deterioration should occur as a result of storage. Since some types of nuts contain a high proportion of unsaturated oil, they can be highly susceptible to autooxidation. Some nuts (walnuts and hazelnuts) are also prone to the development of hydrolytic rancidity due to the presence of lipolytic enzymes.

The size of nuts in ice cream may range from intact, whole nuts to small, broken, or sliced pieces. Except in special cases, medium- to larger-sized pieces are generally favored. In any case, the nuts should retain their firmness, crispness, and freshness in the frozen product.

Vanilla (or chocolate) ice cream scorecards are generally applicable to nut-flavored ice creams. The following revisions of flavor descriptors are suggested for the flavor of nut ice creams.

Lacks fine flavor. This term describes a general lack of the desired flavor blend; an otherwise unidentifiable, slight flavor defect of the nuts or background flavor; or a flavor that simply does not quite attain the "ideal" or anticipated flavor.

Unnatural flavor. An artificial or atypical background flavor for the particular nut is described by the term "unnatural" off-flavor.

Salty/excessively salty nuts. These self-explanatory descriptors cover the instances of excessive incorporation of salt on the nuts or in the ice cream.

Oxidized/oxidized nuts/rancid nuts. Within nondairy segments of the food industry, a generic "oxidized" off-flavor is often referred to as a "rancid" off-flavor. However, walnuts and hazelnuts may also exhibit an actual rancid (lipolyzed) off-flavor due to the lipase content of these nuts if they have not been sufficiently roasted.

For assessing the body and texture of nut ice creams, one additional criticism is suggested below.

Nut meats lack crispness. This term is generally self-explanatory; the nut pieces absorb moisture and become somewhat waterlogged or soft in consistency.

Other quality factors of nut ice creams. Both color and appearance are important criteria in measuring the sensory qualities of nut ice cream. Appearance is primarily influenced by the size and uniform distribution of the nut meats, which help determine the eye appeal of the product. In addition to obvious color defects, the following defects of appearance are possible in nut ice creams:

Nut particles too small
Too few nut particles
Too many nut particles

Poor distribution of nut meats
Atypical color of nut meats
Inclusion of nutshell fragments (important for teeth safety)

10.10.5 Candy Frozen Desserts

Chocolate chip and mint candy are probably the most popular representatives of this group of products, though many others are produced by US ice cream manufacturers. The background flavor may be vanilla, chocolate, or another flavor that is compatible with the given candy (e.g., mint chocolate chip). As with fruit and nut ice creams, the evaluator should be somewhat familiar with the quality criteria of the added materials. General quality requirements for candy-flavored ice creams are (1) a pleasing flavor blend; (2) crispness of the candy components; (3) attractive color and appearance (size and shape); (4) adequate and even distribution of candy pieces throughout product; and (5) minimal or no color migration through the ice cream. Some ice cream manufacturers have reported some success with minimizing the occurrence of overly softened candy pieces and color migration by freezing the candy before its addition to the frozen product. The suggested sensory descriptors of defects for fruit and nut ice creams also apply to candy ice cream. The judge should try to note whether a given defect seems to pertain to the background flavor or to the candy itself. The various flavor defect definitions for chocolate ice cream also apply to the flavor of any added chocolate chips or pieces.

10.10.6 Variegated Frozen Desserts

A variegated ice cream should basically emulate an ice cream sundae, although the flavored syrup, sauce, or puree is dispersed throughout the product. Chocolate, fudge, marshmallow, butterscotch, peanut butter, strawberry, and raspberry are just a few of the flavors that may be variegated or marbled. The flavoring (or slurry) syrup is usually pumped directly into the ice cream as it emerges from the ice cream freezer; the variegating substance is intended to form a definite pattern within the product. Although some indication of the regularity or uniformity of the variegation pattern is obtained in the course of normal sampling of the ice cream, a more objective visual impression can usually be realized by examining both exposed surfaces, after cutting through the center of the container. Sometimes, several cross-sectional cuts may have to be made to properly assess the distribution or the "pattern" of the variegating material with the frozen product. Typically, the ribbon of syrup should be of medium thickness, and the pattern should essentially reach into all segments of the container.

Other quality criteria include the flavor and consistency of the variegating syrups used in the ice cream. In general, the flavor should be readily identifiable, be free of

off-flavors, and produce a pleasing blend with the background or the "other" flavor(s) of the product. The syrup should not "settle out" or mix with the ice cream, but simultaneously, it should not be overly hard, gummy, crusty, or icy. The following modified definitions of flavor defects are suggested for better application in evaluating variegated ice creams.

Lacks fine flavor. A lack of the desired flavor blend; an otherwise unidentifiable flavor defect of the variegating syrup or background; or a flavor which just falls short of being "perfect" is implied by this descriptor.

Lacks flavor/variegating syrup lacks flavor. Self-explanatory.

Unnatural flavor. "Unnatural" describes an artificial or atypical off-flavor in the background flavor and/or in the variegating syrup.

Other quality factors in variegated ice cream. The body and texture of variegated ice cream should be similar to that of its unvariegated counterpart.

Low "heat shock" resistance is a typical property of variegated ice creams; consequently, it can be expected that frequently the body will be weaker and the texture more coarse than plain or regular ice creams. Another reason for a weak, coarse body in variegated ice creams is in the "overrun gradient" between the variegating syrups and the ice cream. The variegating syrups are usually quite heavy; at the time of freezing, air is incorporated only into the mix portion. If product is drawn at the same weight/unit as that of the product without variegating syrup, the ice cream mix portion obviously has to be much lighter. The same problem may be encountered in other bulky-flavored ice creams in which no overrun is formed within the more dense or solid-flavoring material.

Variegating syrup too hard, icy, or chewy. Due to the difference in physical and chemical properties, especially the "overrun gradient" between the variegating syrup and ice cream, a certain crustiness, chewiness, or iciness can occur in variegated ice cream. Appropriate composition of the variegating syrup (accounting for freezing point depression) should help guard against this defect.

Under color and appearance, the following possible criticisms for variegated ice creams are likely to occur:

Poor pattern of distribution
Too thick a ribbon
Too thin a ribbon
Syrup settled out (precipitated)
Syrup mixed with ice cream
Unnatural or atypical color (of the ice cream or the variegating syrup)

10.10.7 Direct-Draw Shakes

This product, similar in composition to low-fat ice cream, emulates the traditional milk shake (Holsinger et al., 1987). Depending on composition and whether a "thick" or "thin" shake is desired, the product is drawn from the freezer in the temperature range of −3.3 °C to −1.1 °C (26–30 °F). The mix may be flavored prior to freezing, or flavoring syrup may be added to the frozen shake and dispersed in a spindle-type mixer.

The finished product should possess a pleasing blend of flavor (chocolate is the most popular flavor) and be free of off-flavors. Opinions may vary as to the desired body and texture that appeals to the widest group of consumers. A thick, smooth-textured shake that draws through a straw is probably the choice of a majority of consumers. Product overrun is still another factor that affects coldness and mouthfeel. A product with a high overrun yields comparably less liquid as it melts in the mouth. A desirable range appears to be 40–60% overrun for direct-draw shakes.

Just as with soft serve, the sensory characteristics of shakes are also traceable to either the mix, the freezer, or to the procedures of the freezer operator (Tobias, 1969). The resolution of a particular sensory defect may be as simple as resetting a freezer control knob or as complex as reformulating the mix.

10.10.8 Frozen Yogurt

In some respects, frozen yogurt resembles ice cream, low-fat ice cream, and sherbet. This product is available in packaged, novelty, (Isik et al., 2011) or soft-serve form and in a variety of flavors, most commonly fruit flavors (Bodyfelt, 1978; Isik et al., 2011). Frozen yogurt does not have standard of identity other than that yogurt is required in the formulation. The general criteria used in the sensory evaluation of frozen yogurts are comparable to those used for sherbets or low-fat ice cream. "Chalkiness" may sometimes be observed in the mouthfeel of frozen yogurt; this is quite possibly the result of dehydration of proteins by the combined action of heat and acidity. The absolute levels of product sweetness and acidity, as well as the balance between sweetness and acidity, in association with the given flavor, are important considerations for frozen yogurt quality.

Table 10.9 outlines the elements of flavor for the sensory evaluation of frozen yogurt (Bodyfelt, 1993). This scheme assesses the given product-flavoring system, culture system characteristics, sweetener aspects, process-related considerations, and the potential for dairy ingredient off-flavors.

Table 10.9 Flavor elements of the sensory evaluation of flavored frozen yogurt

1. Flavoring system	(a) Ideal, natural-like, no criticism (b) Lacks fine flavor (lacks desired balance) (c) Lacks flavor intensity (d) Too high flavor intensity (e) Unnatural flavor (harsh, not typical of stated flavor(s); possible foretaste and/or aftertaste)
2. Culture-related aspects	(a) Acetaldehyde (green apple-like, coarse) (b) Bitter (c) Too high acid (d) Too low acid
3. Sweetener related	(a) Ideal, just right, balanced, helps flavor balance (b) Too sweet (c) Lacks sweetness (d) Syrup off-flavor (malty, Karo®-like)
4. Processing related	(a) Cooked (eggy-like, nutty) (b) Atypical (foreign)
5. Dairy ingredients related (delayed aftertaste)	(a) Lacks freshness (stale) (b) Old ingredient (c) Oxidized/metallic (d) Rancid (e) Salty (f) Whey

10.10.9 Soft-Serve Frozen Desserts

These products (usually low-fat ice cream or frozen yogurt) are commonly dispensed from a special freezer for immediate consumption by the consumer. Since the serving temperature is about −7.2 °C (19 °F), the hardening step is omitted, which eliminates the "damaging effects" of slow freezing and subsequent temperature fluctuations. As a result, soft serve should generally exhibit creamy, smooth mouthfeel properties, as well as provide excellent "flavor release."

Generally, the same requirements apply to the flavor of soft-serve as to the corresponding hard-frozen product (low-fat ice cream or frozen yogurt). Most of the body and texture criteria also apply, except that the desired or optimum characteristics should be partially redefined. The body should be fairly resistant and firm (to retain shape on a cone), but obviously not as firm as that of hardened products, which are stored and consumed at much lower temperatures (−13 °C (8 °F)). The desirable characteristics of soft serve (Tobias, 1969: Goff & Hartel, 2013) can be summarized as follows:

A desirable flavor blend and absence of off-flavors.
Smooth texture: Small ice crystals; no lactose crystals; no butter granules; and no excessive coldness.
Dry appearance; a pleasing color.
Some modest resistance to melting.
A reasonably firm, resistant body.

A neatly shaped serving portion that maintains its shape for a reasonable time before consumption.

When sensory problems are encountered with soft-serve frozen desserts, they may be traced to mix ingredients, mix composition, mix processing, age of mix, mix handling, mechanical and sanitary condition of the freezer, freezer operation procedures, and numerous other factors. For instance, on "slow business" days, the product remains in the freezer under intermittent agitation for an extended time. The effect on quality may be a progressively wetter, weak-bodied product (even though the temperature may be unaffected or even decreased); problems with overrun (weight of serving); fat separation (due to churning); and lactose crystallization (sandiness). A well-formulated mix, along with good mechanical condition of the freezer and a properly operated freezing machine, can minimize most of these problems.

Most of the soft serve on the market is low-fat ice cream, but ice cream, sherbet, water ices, and especially frozen yogurt are also available in many localities. Although vanilla is the predominant flavor (along with a number of "sundae" options), chocolate, fruit, or berry flavors and other flavor options are offered by more and more retail stores.

10.10.10 Sherbet

Sherbet is defined according to 21 CRF 135.140. Though poor-quality dairy ingredients may cause an off-flavor in sherbets, the mandatory low concentration of total milk solids (less than 5%) somewhat reduces this likelihood. In fruit sherbet, the quality is usually determined by the overall flavor blend of sweetness, tartness, fruit flavor intensity, and by how closely the given fruit flavoring emulates the true fruit flavor at its peak of quality. In nonfruit sherbet, quality differs with each specific flavoring; therefore, only a vague, general statement pertaining to the desired flavor can be made. In nonfruit sherbets, the flavoring and the sherbet base (mix) should be free of perceptible defects, and the frozen product should have a pleasing flavor blend.

The ice cream scorecard may be applied as a tool to evaluate the flavor of sherbets, if the evaluator considers the following additional criticisms and revisions of definitions.

Defective flavoring/peel flavor. Defective flavoring may be any off-flavor due to a manufacturing error, an oversight, or due to quality deterioration of the flavoring materials during shipment or storage. A "peel" off-flavor is commonly encountered in citrus fruits and is suggestive of an excessive concentration of essential oil of citrus, which is found in the peel.

Unnatural flavor. This describes an artificial flavor, a flavor that is lacking in true fruit character, or an off-flavor which is not recognizable as the flavor stated on the product's label.

Lacks tartness or excessive tartness. Self-explanatory.

Other quality factors of sherbet. The texture of sherbets can be nearly as smooth as that of ice cream. The body of sherbet may range from weak to resistant, although a heavy or even slightly gummy body need not be considered defective. Probably the most common defects of sherbet body and texture are severe coarseness and crumbliness. Inadequate stabilization, "heat shock," high overrun, low solids content, and prolonged storage are usually responsible for the development of a coarse and icy texture. Inadequate stabilization may also be responsible for crumbliness. This defect seems to be more frequently encountered in orange-flavored sherbet, presumably due to some unexplained property of one or more orange oil constituents. Addition of an emulsifier to the sherbet mix is helpful in correcting or limiting the severity of the problem.

The sugars commonly used in sherbets are sucrose, corn syrups, and, to a lesser extent, dextrose (corn sugar). The body of sherbet may be hard or soft, depending on whether too little or too much sugar was used in the formulation. Several other sherbet defects, common in yesteryear, may still be encountered occasionally. "Surface crustation" may occur, particularly when the product surface is exposed to air. Effective stabilization and partial replacement (25–50%) of sucrose with corn syrup are good precautionary steps. "Ice separation" may occur in the continuous freezer by the action of centrifugal force. Ice builds up on the freezer wall and eventually breaks away and "lands" in the product. Increasing the viscosity of the unfrozen portion of the mix by proper stabilization helps control this problem. "Separation, drainage, or bleeding" of the unfrozen syrup within the sherbet may also be a problem of inadequate stabilization and/or holding the sherbet at too high of a storage temperature.

The ice cream scorecard is satisfactory for evaluating the body and texture of sherbets with the following minor modification.

Heavy/hard. The formulation and lower overruns ($\leq$60%) of sherbet generally leads to a heavier or harder product at the typical serving temperature. Sherbets that may be formulated with lower levels of sweetener may not depress the freezing point adequately, hence a greater likelihood of a heavy/harder product at or near the serving temperature.

Both the color and appearance should be evaluated in sherbets, particularly in multiflavored products (e.g., rainbow sherbet) in which the distribution pattern of the different flavored products is a quality criterion, and in products to which fruit particles or confectionery were added. Suggested descriptors for possible color defects of sherbet are as follows:

Defective pattern
Too little added material
Poor distribution of added material
Poor appearance of added material

10.10.11 Sorbets and Water Ices

The US Federal Standards describes water ice as a food that is prepared from the same ingredients as sherbets, except that no milk fat, milk-derived ingredients, or egg ingredients (other than egg whites) are used. As indicated in Table 10.1, the minimum weight (Federal Standard) for water ices is 6 lb/gal. Sensory evaluation procedures for water ices differ little from those used for sherbet.

Water ices are products made from simple formulas and often low quality and less concentrated flavoring sources (i.e., popsicles and novelty bars on a stick). Water ices have been a long-time mainstay of the US frozen dessert industry and are generally sold through food retail and convenience stores.

French- and American-style sorbets are frozen combinations of pureed fresh fruits, fruit juices, and sweeteners; they contain no milk, cream, or eggs to reduce or control ice crystals. Hence, sorbets are constantly stirred during the freezing stage to limit or control ice crystals. High-quality sorbets are expected to exhibit a light and fluffy texture and are generally presumed to be at their best when consumed immediately after the freezing process. Some fancier styles of sorbets, originating from France and Italy, contain wines and/or liqueurs. Sorbets are commonly made fresh and sold directly to walk-up customers at retail stands and food service operations, although packaged and hardened sorbet is also available from the freezer cabinets of retail food stores.

10.10.12 Frozen Novelties

A group of products referred to as frozen novelties may be made of ice cream, low-fat ice cream, mellorine, sherbet, sorbet, ice, frozen yogurt, pudding, or combinations of several of these. They may be in many forms, such as bars (with or without a stick), coated or uncoated, “sandwiches,” pre-packaged cones, and other numerous forms. Although they should be evaluated by the processor in ongoing quality assurance procedures, novelties are seldom, if ever, judged competitively. The flavor, body, and texture of these types of products should be evaluated just as critically as their packaged counterparts, but there are some unique, potential problem areas that should be identified (Tobias, 1980). A listing of some of the more common quality problems of various types of frozen novelties that require special attention include the following:

Incomplete coverage with coatings
Coating too far down the stick
Incorrect volumes
Coating too thick
Coating too thin
Cracked coating
Slipped coating

Overrun too high
Overrun too low
Defective flavor
Defective texture
Damaged wrappers
Sticking wrappers
Broken sticks
Sugar "bleeding" from bars
"Soggy" wafers or cones (lack crispness)
High coliform count
Brine contamination

Due to their relatively small size, frozen novelties are markedly susceptible to the irreversible, damaging effects of temperature fluctuations. "Heat shock" is probably the most serious problem, but unfortunately, once the product enters the distribution system, there is limited control of frozen storage temperatures.

10.11 Conclusion

The quality and sensory attributes of ice cream as perceived by the consumer in terms of the most desirable flavor, body, and texture can be evaluated, but it is not easy. For a successful and dependable sensory evaluation of ice cream and frozen desserts, judges/students need to have experience and knowledge about the effect of ingredients, product formulation, processing manipulation, and handling on the properties of the products. Additionally, due to the uniqueness of frozen desserts, it is important that samples are prepared properly, the evaluation is conducted in a suitable environment, and the numerical standards for measuring the quality of the product are available. These subjects were covered in detail in this chapter. Special emphasis was given to the scorecard of the Collegiate Dairy Products Evaluation Contest, along with the techniques and scoring guide for vanilla ice cream. The guidelines include the description and identification of off-flavors, body, and texture defects and their sources or causes. Sensory evaluation of other frozen dairy desserts that are commercially available was also included. The materials in this chapter provide useful tools to learn and understand the sensory evaluation of frozen desserts; however, it is essential to practice as much as possible to become an experienced and accurate evaluator of ice cream quality.

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