Effects of Fat Content on the Sensory Properties, Melting, Color, and Hardness of Ice Cream[1]

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ABSTRACT

Ice creams were prepared that varied only in the percentage of milk fat (0.1, 3, 7, or 10%) and the corresponding total solids. All mixes were formulated to have similar freezing points and percentages of water frozen. Quantitative descriptive analysis was used to develop a ballot, which was then used by a trained sensory panel to assess the appearance, flavor, and texture of the vanilla ice creams. The color, hardness, and melting characteristics of the ice creams were also measured. Melting time and sample hardness were not significantly different among the 0.1, 3, and 7% fat samples of ice cream, but these characteristics of the lower fat ice creams differed from those of the 10% fat samples. The 10% fat samples took longer to melt and were softer than the 7% fat samples. The sensory analysis was more sensitive than the analytical measurement for detecting textural differences between ice cream samples. The panelists determined that removing the fat from ice cream made it more icy and more crumbly with fewer visible air holes. Sweetness was not influenced by fat content below 7%. The creamy flavor increased as the fat content of the ice creams increased. The milk powder flavor increased as the fat content decreased, even though the sample with 0.1% fat had less milk powder than the sample with 10% fat. Milk powder flavor was the major flavor component that was distinguished by the panelists when they evaluated the lower fat samples for aftertaste. Corn syrup was more perceptible in the lower fat samples even though all samples had the same concentration of corn syrup solids (4.5%).
(**Key words**: ice cream, fat, sensory properties)

Received April 20, 1998.
Accepted August 20, 1998.
[1]Use of trade names, ingredient names, and identification of specific equipment models is for scientific clarity and does not constitute product endorsement by the authors, Cornell University, or the Northeast Dairy Food Research Center.

INTRODUCTION

Ice cream is characterized by unique physical properties, such as hardness and melting properties, which are influenced by ingredients, air entrapment, and ice content (8). Typical ice cream contains at least 10% fat and a predetermined quantity of air (40 to 50% by volume) whipped into it (17). Consumers are interested in eating lowfat and fat-free dairy products, including ice cream, which is reflected in consumption data that show consumers are looking for reduced fat and fat-free products that have acceptable taste and appearance (4).

The dairy industry has developed a variety of fat-free ice cream products. Unfortunately, the flavor and mouthfeel of fat-free ice cream products are not acceptable to a large number of consumers. One major criterion that consumers require is that ice cream products (fat-free or otherwise) taste good. Furthermore, consumers require that fat-free ice cream products have an acceptable mouthfeel and appearance. Regulatory removal of the standard of identity for ice milk (2) has provided an economic impetus for the production of low fat frozen desserts of high quality that can be labeled as ice cream.

Since consumers have started demanding lower fat foods, ice cream manufacturers have been struggling with the following question: if milk fat is taken out of ice cream, what can be added to simulate the role of fat in establishing the texture and flavor of ice cream? Typically, the answer has been bulking agents, which produce minimal negative effects on ice cream production, shelf-life, and price. Bulking agents that are based on carbohydrates, such as maltodextrin and polydextrose, are currently used in low fat formulations (13). Although the effects of varying the fat content as well as other ice cream constituents on the flavor and texture of ice cream have been reported (3, 10, 12, 16), no studies have focused on the effects of reducing the fat content of ice cream below 10% without the addition of fat replacers.

Quantitative descriptive analysis has proven effective for identifying and measuring the sensory attributes that are most influenced by the removal of fat

TABLE 1. Ice cream mix formulations with varying fat percentages.

	Fat			
Ingredient	0.1%	3%	7%	10%
Corn syrup solids[1] (36 DE[2])	4.50	4.50	4.50	4.50
Sugar	13.05	13.05	13.05	13.05
Vanilla[3]	0.20	0.20	0.20	0.20
Stabilizer[4]	0.20	0.20	0.20	0.20
Cream	0.00	7.40	17.70	25.31
Skim milk	78.15	70.45	59.90	51.83
NDM	4.12	4.45	4.85	5.41

[1]Star-Dri™ (A. E. Staley Manufacturing Co., Decatur, IL).

[2]Dextrose equivalent.

[3]2× Extract (#271024; Fantasy-BlankeBaer Corp., Fenton, MO).

[4]Dricoid™ 200 (Kelco, Merck & Co., Rahway, NJ) is composed of guar gum, mono and diglycerides, xanthan gum, and carrageenan.

from fluid milk products (11). Phillips et al. (11) used this approach to develop ingredient blends to simulate the sensory properties of the fat in milk. Similarly, to develop a fat substitute for use in reduced fat and fat-free ice cream, one must determine and quantify the sensory and physical attributes that must be replaced. The objective of this study was to identify and quantify the sensory and physical properties that are the most important to the flavor, appearance, and mouthfeel of 10% fat ice cream.

MATERIALS AND METHODS

Ice cream mixes were prepared to vary only in the level of milk fat (0.1, 3, 7, or 10%). Mix formulations are shown in Table 1, and mix compositions are shown in Table 2. All mixes were formulated to have similar freezing points and similar percentages of water frozen as calculated by the method of Sommer (14), which is based on data provided by Leighton (5). The percentage of the product that is frozen was calculated for comparison (Table 2).

Each mix was pasteurized at 80°C for 25 s and then homogenized through a two-stage homogenizer (APV-Gaulin, Philadelphia, PA) at 13,800 kPa for the first stage and at 3500 kPa for the second stage. The mixes were cooled to 4°C and stored for processing the next day. Prior to freezing, 0.2% vanilla extract (2× extract, #271024; Fantasy-BlankeBaer Corp., Fenton, MO) was added. Mixes were frozen in a continuous freezer (Technogel Model 80; Technogel, Inc., Bergamo, Italy) to achieve an overrun of 90%. The temperature of the products as they left the freezer was –6°C. The samples were packaged in 0.473-L (1-pt) round containers with covers and stored for at least 24 h at –40°C. The microbiological quality of the ice cream products was monitored by standard plate count procedures (7).

Analytical Methods

The overrun on each individual container of ice cream was determined, and only the samples that had retained the required overrun (85 ± 5%) were used for analyses. All analytical measurements were conducted on ice cream samples that had been tempered overnight at –13°C. Each sample was analyzed in triplicate. Hardness measurements were obtained at room temperature (25° ± 2°C) using a texture analyzer (TAXT2; Texture Technol. Corp., Scarsdale, NY) equipped with a 2.5-cm diameter acrylic cylindrical probe (TA-11; Texture Technol. Corp.). The penetration speed of the probe was 2 mm/s to a distance of 20 mm. The ice cream that had been hardened at –40°C was cut to fill a small cylindrical cup 6 cm in diameter to a depth of 30 mm and then tempered overnight to –13°C for analysis.

A Macbeth® Color-Eye® Spectrophotometer (model 2020; Kollmorgen Instruments Corp., Newburgh, NY) was used to measure ice cream color and to calculate L (whiteness), a (redness), and b (yellowness) values based on illuminant A, which is an incandescent lamp.

The melting characteristics of the ice cream samples were analyzed at room temperature (25° ± 2°C). The ice cream that was hardened was cut from a 0.473-L container into cylinders (6-cm diameter, 2.5 cm thick, and 45 ± 5 g), tempered to –13°C, and

TABLE 2. Ice cream mix composition.

	Fat			
	0.1%	3%	7%	10%
Sucrose equivalents,[1] %	22.2	22.2	22.2	22.1
Relative sweetness,[2] g/100 g	16.0	16.0	16.0	16.0
Milk SNF	11.0	11.0	11.0	11.0
Total fat, %	0.1	3.0	7.0	10.0
Milk solids, %	11.1	14.0	18.0	20.9
Total solids, %	28.7	31.5	35.2	38.3
Water	71.3	68.6	65.0	62.0
Freezing point,[3] °C	–2.29	–2.38	–2.51	–2.62
Water frozen (–5.56°C),[3,4] %	56.48	54.72	52.13	49.42
Water frozen (–13°C),[3,5] %	79.30	78.46	77.23	75.96
Product frozen (–13°C),[3,5] %	56.53	53.78	50.01	46.89

[1]The equivalent concentration of sucrose that would cause the same freezing point depression as the sugars and milk sugars in this mix (8).

[2]Sweetness relative to sucrose.

[3]Calculated values.

[4]Corresponds to freezer outlet temperature.

[5]Corresponds to temperature at which samples were tempered.

TABLE 3. Statistical models used in ANOVA for data in Tables 4, 5, and 6.

	Independent variables[1]	df	Analyzed	Error term	Equation
Table 4 Color	T	3	Classification	Error	Y = T + R
	Error	8			
Table 5 Hardness Melting	T	3	Classification	Error	Y = T + R
	Error	8			
Table 6	T	3	Classification		$Y = T + P + W + (P \times T) + (P \times W)$
Sensory	P	10	Block	$P \times T$	$+ (W \times T) + (P \times W \times T) +$ Error
	Week	1	Block	$P \times W$	
	$P \times T$	30	Block		
	$P \times W$	10	Block		
	$W \times T$	3	Block		
	$P \times W \times T$	30	Block		
	Error	88			

[1]P = Panelist, W = week, T = treatment, and R = replicate.

placed on a sieve suspended over a balance. The mass of the ice cream melt that drained was recorded as a function of time. The melting characteristic of the ice cream was reported as the half-life of the ice cream (the time needed for half of the original mass of the ice cream to drain from the sieve).

Sensory Analysis

Descriptive analysis was used to develop terms for the ice creams containing varying percentages of fat (15). Ten panelists were given samples and asked to provide terms, first independently and then in group discussions, that described the samples and, in particular, the ways in which the samples differed. The discussions eliminated redundant terms and qualified or modified vague terms. Following the group discussions, terms from the literature (1) on dairy evaluation were presented for incorporation into the potential list of terms. In the second session, the subjects tasted the various samples again and were asked to modify the final list of descriptive terms from the first session. In a third session, any discrepancies in the lists of descriptive terms that were derived by the panelists were resolved during the discussion. At this time, reference foods (not necessarily ice cream) were provided as clear examples of individual terms (e.g., milk powder flavor, creamy flavor, and corn syrup flavor). A fourth session was held to resolve any remaining differences and to make any final modifications to the potential list of descriptive terms to be used on the scorecard. The terms that were developed encompassed the appearance, flavor, and texture of ice cream. The descriptive terms for each major sensory attribute category were appearance: textural appearance, graininess, gummy or sticky, air holes, glossiness, yellowness, and whiteness; flavor: sweetness, creaminess, cooked, corn syrup, milk powder, vanilla, astringent, bitter, oxidized, and aftertaste; and texture: iciness, stickiness, meltability, air holes, and coldness. A higher score reflected an increasing intensity of the descriptive terms. The score for textural appearance increased as the product was rated from crumbly to smooth.

Following the terminology development, the panel was trained. The training consisted of evaluation of samples of ice cream varying in fat content by use of the descriptive terms developed to describe and quantify appearance, flavor, and textural characteristics on a scale from 1 to 9. Reference foods were brought in to provide clear examples of individual terms. This procedure was repeated until panel consensus was achieved.

Experimental Design and Statistical Analysis

After the panel was trained, the influence of fat on the sensory characteristics of the ice cream was measured. The sensory evaluations were conducted at room temperature (25 ± 2°C) under normal fluorescent lighting with samples that had been tempered overnight at –13°C. The measurements involved testing of samples of ice cream with 0.1, 3, 7, or 10% milk fat. Samples of ice cream containing 0.1 or 10% fat were given to the panelists as endpoint anchors. Testing was done over a 2-wk period with two tests per week using 10 panelists. Independent sets of ice cream were prepared each week. The statistical model was descriptive term = panelist + fat concentration + week + replicate + interactions + error.

The ANOVA models are listed in Table 3. Statistical analyses were used to determine whether fat concentrations had any effect or any significant interaction with other independent variables on panel scores for each descriptive term. If fat content did have a significant ($P < 0.05$) effect, then means were compared using Duncan's multiple-range analysis (18).

RESULTS

Calculated Values

The ice cream mixes were formulated to have similar initial freezing points (Table 2). The calculated freezing points varied by 0.33°C from a low of –2.62°C to a high of –2.29°C for samples of ice cream containing 10 and 0.1% fat, respectively. The similar freezing points were obtained by keeping the percentages of sucrose equivalents and milk SNF constant in the ice cream formulations. The ice cream mixes were formulated based on the recommendation that 50% of the water in the ice cream should be frozen at the freezer exit temperature (–5.56°C) (9). All of the ice cream samples met this criterion (Table 2). The calculated percentage of water frozen at the temperature at which the ice cream exits the freezer (–5.56°C) was 49.42 and 56.48% for the samples containing 10 and 0.1% fat, respectively (Table 2). During processing, each sample had an appropriate consistency for filling the sample containers. At the tempering temperature (–13°C), the calculated percentage of water that was frozen varied from 75.96 to 79.3% for the samples containing 10 and 0.1% fat, respectively. The percentage of product that was frozen was also calculated for comparison purposes. The percentage of product that was frozen took into account not only the percentage of water that was frozen but also the variation in total solids with varying fat content (16). Hence, the sample with the lowest total solids had the highest percentage of product frozen [i.e., 0.1% fat sample (Table 2)].

TABLE 4. Effect of fat on ice cream color.[1]

Color value	Fat				LSD
	0.1%	3%	7%	10%	
L	84.0[c]	86.1[b]	86.9[b]	89.1[a]	1.42
a	–0.7[d]	–0.2[c]	0.3[b]	0.8[a]	0.46
b	5.6[b]	6.9[ab]	7.5[a]	7.8[a]	1.34

[a,b,c,d]Means in the same row with no common superscripts differ ($P < 0.05$).

[1]Color as measured by a Macbeth® Color-Eye® Spectrophotometer (model 2020; Kollmorgen Instruments Corp., Newburgh, NY). L = Measure of whiteness, a = measure of redness (less greenness), and b = measure of yellowness (less blueness).

TABLE 5. Effects of fat on the hardness and melting characteristics of ice cream.

	Fat				LSD
	0.1%	3%	7%	10%	
Hardness,[1] kg	12.86[a]	11.58[a]	10.79[a]	7.68[b]	3.08
Melting,[2] min	37.3[b]	37.2[b]	39.5[b]	67.3[a]	7.37

[a,b]Means in the same row with no common superscripts differ ($P < 0.05$).

[1]Kilograms = N/9.806 m/s^2 as measured with a TAXT2 Texture Analyzer (Texture Technol. Corp., Scarsdale, NY) equipped with a 2.5-cm diameter acrylic cylindrical probe (TA-11). Penetration speed was 2 mm/s to a distance of 20 mm.

[2]Reported as the half-life (minutes) of ice cream.

Analytical Results

The color of the ice cream increased in whiteness ($P < 0.05$) as the fat content increased from 0.1 to 10% fat. Correspondingly, ice cream samples were more red and less green as the fat content increased, as reflected by increasing a values. The b value increased as the fat content of the samples increased, which corresponded to the sample being more yellow and less blue (Table 4).

Following the change in composition toward a higher concentration of water (i.e., toward a higher ice content), hardness increased from 7.68 kg for 10% fat ice cream to 12.86 kg for 0.1% fat ice cream; no difference ($P > 0.05$) was found among the 0.1, 3, and 7% fat samples (Table 5).

The melting properties of the ice cream were influenced by the fat content. Increasing the fat content of ice cream from 7 to 10% caused an increase ($P < 0.05$) in the half-life of the ice cream. The melting results corresponded to the hardness determinations [i.e., there was no difference ($P < 0.05$) for the 0.1, 3, or 7% samples, and significant difference occurred when the percentage of fat was increased from 7 to 10% (Table 5)].

Sensory Analysis Results

Appearance. The sensory response to the ice cream samples was affected by the variation in fat content. The sensory attribute of the textural appearance corresponded to whether an ice cream sample cut smoothly or crumbled when cut into with a spoon. Similarly, graininess was related to whether the surface had the typical appearance of a full fat product or the granular icy appearance of a fat-free ice cream. Although these attributes are similar, the sensory panel found differences ($P < 0.05$) for each percentage of fat when scoring the samples for textural appearance but no significant difference in the graininess scores for the samples containing 0.1 or 3% fat (Table 6). The appearance term, air holes, described whether or not discrete air pockets were observed as the panelist scraped the surface of the ice cream with a spoon. Although all of the samples had the same amount of air incorporated into them (90% overrun), the panelists scored the higher fat samples as having more of these visible, discrete air pockets than the lower fat samples (Table 6). Differences ($P < 0.05$) in the air hole scores were observed for each percentage of fat that was tested. The appearance term, stickiness, referred to the adhesion of the product to itself. Panelists also referred to it as the scoopability of the ice cream when scraped with a spoon. The scores for the appearance attributes of stickiness, air holes, and glossiness increased as the percentage of fat in the ice cream increased (Table 6).

Flavor. The sensory scores for flavor were also influenced by the percentage of fat; however, the differences in scores for the various flavor attributes were not as great as those for appearance (Table 6). All of the ice cream samples were formulated to have relative sweetness values of 16 [contained the sweetness equivalent of 16% sucrose (wt/wt)]. Correspondingly, no significant ($P > 0.05$) differences in sweetness were observed as the fat content of the ice cream was increased from 0.1 to 7%. Similarly, Li et al. (6) found that the differences in fat content (0 to 10%) had no effect on the perception of sweetness.

The flavor scores for creaminess were lower ($P < 0.05$) as the fat content of the ice cream was reduced from 10 to 7 to 3%. However, there was no difference ($P > 0.05$) in creaminess scores for the samples containing 0.1 and 3% fat. Creamy flavor and cooked flavor, which can be difficult for sensory panelists to distinguish (11), were distinguished by this panel. During training, heavy cream that was diluted with water to a concentration of 10% fat was provided to panelists to help them distinguish creamy flavor. Similarly, cooked milk aided panelists in discerning cooked flavor.

TABLE 6. Effect of fat on the sensory attributes of ice cream.

Attributes and descriptor[1]	Fat				Duncan's factor
	0.1%	3%	7%	10%	
Appearance					
Textural appearance (crumbly to smooth)	1.6^{d}	2.4^{c}	6.2^{b}	8.4^{a}	0.19
Graininess	8.0^{a}	7.5^{a}	3.5^{b}	2.2^{c}	0.24
Air holes	1.5^{d}	2.0^{c}	6.3^{b}	8.2^{a}	0.18
Glossiness	1.6^{d}	2.1^{c}	5.7^{b}	7.2^{a}	0.18
Whiteness	2.9^{c}	3.2^{c}	5.8^{b}	7.1^{a}	0.24
Yellowness	1.5^{c}	2.1^{b}	2.5^{ab}	2.9^{a}	0.17
Stickiness	1.8^{b}	2.2^{b}	4.6^{a}	4.9^{a}	0.21
Flavor					
Sweetness	3.4^{b}	4.0^{b}	3.9^{b}	4.7^{a}	0.23
Creaminess	1.6^{c}	2.0^{c}	6.1^{b}	8.3^{a}	0.17
Cooked	2.8	2.4	2.3	2.3	0.21
Corn syrup	4.1^{a}	3.5^{b}	2.9^{c}	2.8^{c}	0.17
Milk powder	7.8^{a}	6.7^{b}	2.9^{c}	1.6^{d}	0.21
Aftertaste	7.0^{a}	6.0^{b}	2.9^{c}	1.4^{d}	0.25
Vanilla	3.0^{c}	3.6^{b}	4.1^{b}	4.9^{a}	0.19
Astringent	1.1	1.0	1.0	1.0	0.04
Bitter	1.1	1.0	1.1	1.0	0.07
Oxidized	1.1	1.0	1.0	1.0	0.04
Texture					
Iciness	8.2^{a}	7.8^{a}	3.9^{b}	1.5^{c}	0.18
Stickiness	1.6^{c}	2.0^{c}	4.8^{b}	5.6^{a}	0.17
Meltability	8.4^{a}	7.9^{a}	4.4^{b}	2.9^{c}	0.18
Air holes	1.6^{c}	1.9^{c}	6.2^{b}	7.8^{a}	0.19
Coldness	8.4^{a}	8.1^{a}	4.3^{b}	2.1^{c}	0.22

[a,b,c,d]Means in the same row with no common superscripts differ ($P < 0.05$). Critical values to compare means using the Duncan's test were calculated by multiplying the Duncan's factor times the following least significant Studentized range values: 2.81, 2.95, and 3.05. Lack of superscripts in a row indicates no differences ($P > 0.05$) between means.

[1]Attributes increase in intensity as value increases (nine-point scale).

During the development of terms, the panelists were supplied with NDM, buttermilk powder, whey powder, and milk protein concentrate. Panelists concluded that, unlike the traditional ice cream judging ballot, which was designed to encompass a variety of issues related to ice cream quality, these ingredient flavors did not need to be distinguished individually for this study. The descriptor of milk powder flavor was developed to encompass all of the flavors that were associated with milk ingredients.

The panelists considered strong milk powder and corn syrup flavors to be undesirable attributes in ice cream. The various ice cream samples were formulated to have the same amount of corn syrup solids (4.5%) and milk SNF (11.0%) (Table 1). However, as the fat content was decreased, the sensory scores for both milk powder flavor and corn syrup flavor increased significantly (Table 6). One might assume that the higher score for milk powder flavor corresponded to more powdered milk in the lower fat samples; however, the opposite was true. The amount of powdered milk used in the ice cream samples increased as the fat content increased. It was not the amount of milk powder that determined the milk powder flavor but the absence of fat that increased the perception of milk powder flavor (Table 6). Ironically, corn syrup, which is usually added to low fat ice creams, was more perceptible at lower fat levels. Higher scores for aftertaste corresponded with the higher scores for corn syrup and milk powder flavor that were observed in the lower fat samples. The panelists considered the increased aftertaste scores that were observed with the lower fat samples to be undesirable (Table 6).

The vanilla intensity in the ice cream samples was diminished as the fat content decreased. It was not clear whether the lower scores for vanilla flavor with lower fat content were caused by poor dispersion of the vanilla on the tongue in the absence of fat, the colder nature of the ice creams, or the interference from the flavors of milk powder and corn syrup. All samples were scored as having no astringent, bitter, or oxidized flavors.

Texture. The textural attributes showed significant changes at each percentage of fat but no differences ($P > 0.05$) in the texture attributes between the samples containing 0.1 and 3% fat. Iciness, meltability, and coldness decreased as fat content increased; stickiness and air hole content increased.

As the fat content increased between 0.1 to 3%, sample differences were only detected by some appearance and flavor attributes—namely, textural appearance (crumbly to smooth), air holes, glossiness, yellowness, milk powder flavor, aftertaste, and vanilla and corn syrup flavors.

Analytical Analysis Versus Sensory Analysis

The analytical measures of color corresponded well with the sensory scores for color. As the fat content in the ice cream samples was reduced from 10 to 0.1%, the samples were less white, less red, and less yellow (Table 4). Similarly, the sensory panel scored the samples as being less white and less yellow as the fat content decreased (Table 6).

When analytical measures of hardness and meltability were compared with corresponding sensory scores, the sensory panel was more sensitive to changes in fat content. The sensory panel detected differences in the textural attributes between the samples containing 3 and 7% fat samples, but the analytical measurements indicated no difference ($P > 0.05$) (Tables 5 and 6). For the meltability texture attribute, differences were detected by sensory analysis between the samples containing 3 and 7% fat (Table 6), but the analytical measurement for the melting characteristic showed no difference ($P > 0.05$) (Table 5). Furthermore, iciness was different between 0.1 and 7% fat content, but the analytical measurement for hardness showed no significant difference between the 0.1 and 7% fat contents (Tables 5 and 6).

DISCUSSION

A decrease in the concentration of fat and, therefore, total solids increased the concentration of ice in the ice cream samples. As the fat content of the ice cream decreased, the sample was less white, harder, and melted more quickly. The ice cream was then perceived by sensory panelists as being more icy and more crumbly. In addition to the lower fat samples tasting less like cream, the lack of fat followed an increase in perception of the undesirable flavors of corn syrup, milk powder, and aftertaste.

The analytical measurements were less sensitive than the sensory panel for quality assessment of reduced fat ice creams (7% and lower). The sensory analysis not only was more sensitive to the textural differences between ice cream samples but also distinguished ice creams based on flavor, which is the final indicator of ice cream quality.

The perception of sweetness was not affected ($P > 0.05$) by the increase in fat content up to 7%. Creamy flavor increased as the fat content of the ice creams increased. Milk powder flavor, which increased as the fat content of the ice creams decreased, was the major flavor component that was distinguished by the panelists when the lower fat samples were evaluated for aftertaste. Corn syrup, which is commonly added to commercial low fat ice creams to achieve the desired freezing characteristics, was more perceptible at lower fat contents.

Our formulations varied in fat content only. The fat solids were not replaced with other ingredients; hence, the mixes varied in solids by the same amount that they varied in fat content (Table 2). The various mixes were formulated to have similar freezing points, and, therefore, the percentage of the water in the product that was frozen (grams of water frozen per total grams of water) varied by only a small amount. Consequently, the samples were analytically similar, as demonstrated by the melting and hardness determinations, which were not different ($P > 0.05$) for the 0.1, 3, or 7% fat samples (Table 5). The percentage of the total product that was frozen (grams of water frozen per total grams of water and solids), however, corresponded better to the sensory scores for appearance and textural attributes. The higher concentration of water in the lower fat samples added to the iciness, coldness, and color differences judged by the panel. The sensory scores for flavor were overwhelmingly dependent on fat content. Formulation of frozen products based on the percentage of the water in the product that is frozen (percentage of water frozen) has its shortcomings. The percentage of the water in the product that is frozen does not account for how much water is in the product. The calculation of the percentage of the product that is frozen takes into account not only the percentage of the water that is frozen but also variations in the total solids content.

CONCLUSIONS

An effective fat substitute for use in ice cream needs to impart a creamy flavor and mask undesirable flavors. It should not impart flavors of corn syrup or milk powder or have an aftertaste. When fat is removed from ice cream, the associated solids provided by the fat must be replaced. Replacing these total solids with a substitute may greatly improve the appearance attributes of the low fat product; however, the fat replacer must impart cohesiveness to the product without reducing the capability of the ice cream to be scooped. Additionally, a fat replacer must moderate the coldness perception in the mouth and slow the melting of the product.

Future work is needed to study various fat substitutes in ice cream formulations and to evaluate the effects on the sensory attributes as well as the effects on the analytical evaluation of the ice cream to determine whether the same relationships hold.

ACKNOWLEDGMENTS

The authors thank the Northeast Dairy Foods Research Center (Ithaca, NY) for the financial support of this project. The advice and technical support from David Barbano are gratefully acknowledged.

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