Effect of Milk Fat, Cocoa Butter, and Whey Protein Fat Replacers on the Sensory Properties of Lowfat and Nonfat Chocolate Ice Cream[1]

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ABSTRACT

Lowfat and nonfat chocolate ice creams were made with 2.5% of milk fat, cocoa butter, or one of two whey protein-based fat replacers, Dairy Lo or Simplesse. Polydextrose was added as required so that all formulations contained the same amount of total solids. Ice cream was stored at a control temperature of –30°C. Hardness, viscosity, and melting rate were measured by physical methods. Trained panelists conducted descriptive sensory analyses of the samples at 0, 6, and 12 wk. Attribute ratings were analyzed by analysis of variance with least significant difference mean separation and orthogonal contrasting. Data were also analyzed by multivariate analysis of variance with canonical variate analysis. Consumer acceptance (n = 50) did not differ among the fresh ice creams (wk 0). Ice cream containing milk fat had less intense cocoa flavor and was more resistant to textural changes over time compared with the other ice creams. Simplesse was more similar to milk fat than was Dairy Lo in its effect on brown color, cocoa flavor, cocoa character, and textural stability but was less similar in terms of thickness and mouthcoating.

(**Key words:** ice cream, chocolate, whey protein, fat replacers)

Abbreviation key: CB = lowfat ice cream containing cocoa butter, **CV** = canonical variate, **DL** = nonfat ice cream containing Dairy Lo, **MF** = lowfat ice cream containing milk fat, **SM** = nonfat ice cream containing Simplesse.

INTRODUCTION

Ice cream manufacturers have made it a practice to substitute milkfat with fat replacers in order to create products that meet the demands of health-conscious consumers. Manufacturers have also used lowfat cocoa powders to lower the fat content of ice cream. Additionally, cocoa powders are used to decrease the quantity of cocoa butter that is used in ice cream because it is more expensive than most other ingredients. As these substitutions are made, both the texture and flavor profile of chocolate ice cream may change. Changes to a food system can impart an imbalance in the flavor profile through various mechanisms (4, 6, 7, 11). Past investigations have shown that when milkfat is removed from chocolate ice cream, the resulting flavor is harsh and undesirable (8).

Whey protein-based fat replacers such as Simplesse and Dairy Lo can mimic milkfat in terms of texture and flavor retention. Simplesse is made of round whey protein microparticulates ranging from 0.1 to 3.0 μm (22). Their size and shape are interpreted by the mouth as creamy. Schmidt et al. (19) found that ice cream containing Simplesse D-100 was more similar to full-fat ice cream in terms of rheological properties than was ice cream containing a maltodextrin-based fat replacer.

Sanchez and Paquin (15) found that at 15 to 20°C, foods containing microparticulated proteins were similar to comparable fat-containing systems in terms of texture, but differed in terms of flavor. Schirle-Keller et al. (18) found that Simplesse-100 was more similar to fat in its ability to reduce the vapor pressure of many flavor compounds, especially aldehydes, than were certain egg protein- and carbohydrate-based fat replacers. In a later study, Simplesse-100 and Simplesse-300 interacted with long chain aldehydes and unsaturated aldehydes, but not with ketones (17). The authors suggested that the aroma profile of unsaturated aldehydes in food systems containing either of the fat replacers would likely be indistinguishable from that of comparable fat-containing systems. The authors also suggested that Simplesse behaved more like fat in terms of flavor interactions than did carbohydrate-based fat replacers.

Dairy Lo is a thermally denatured whey protein concentrate that can interact with water, proteins, and flavor compounds to prevent iciness, provide opacity, control viscosity, stabilize air cells, and control emulsification (1). Ohmes et al. (13) found that ice creams containing Simplesse and Dairy Lo were not significantly different in flavor or texture from a nonfat con-

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trol; however, compared with a lowfat ice cream, the fat-replaced ice creams had greater whey, syrup, and cooked milk flavors. Vanilla flavor was not affected by the use of whey protein fat replacers, although the authors suggested that the other flavors may have masked differences in vanilla flavor.

Cocoa butter has a different melting profile than milkfat, due to differences in the types and quantities of triglycerides contained in each. Cocoa butter is hard and brittle below 27°C and melts rapidly between 27 and 33°C (20). Milkfat is soft at 40°C, semi-solid at 10 to 15°C, and solid at 5°C (15). In addition, these two fats interact to become softer than each of the individual fats would be at the same temperature in a process called the eutectic effect (20).

The unique characteristics and interactions of each fat may significantly affect the texture of ice cream as it warms from its frozen state into a liquid in the mouth. Moreover, each fat may affect the flavor profile of chocolate ice cream differently, either through solubility of flavor volatiles or physical impedance of taste and flavor compounds.

Cocoa contains more than 500 volatile compounds, some of which contribute to the flavor of chocolate ice cream (14). If whey proteins and cocoa butter do not interact with cocoa flavor volatiles in the same way that milkfat does, the flavor profile can become imbalanced and undesirable.

This investigation extended previous studies of fat replacers in vanilla ice cream (12, 13). The objective was to determine the effect of cocoa butter and whey protein-based fat replacers on the sensory properties of lowfat and nonfat chocolate ice creams. Descriptive analysis and consumer acceptance tests were used in conjunction with physical tests to determine the differences in sensory properties among fresh and stored ice creams.

MATERIALS AND METHODS

Treatments

Formulations. Chocolate ice cream was made with 2.5% of milk fat, cocoa butter, Simplesse Dry 500, or Dairy Lo (Table 1). The target composition of each treatment was 11% nonfat milk solids, 15.5% sucrose equivalence, 2.5% cocoa powder, 0.5% stabilizer (mono and diglycerides, locust bean gum, cellulose gum, guar gum, food starch, carrageenan, maltodextrin to standardize), and 38.5% total solids. Three batches of each ice cream were made (4 treatments × 3 batches = 12).

Processing

Liquid ingredients were placed into a 66-L vat and warmed. Dry ingredients were then added. Mixing was accomplished with a self-contained emulsifying agitator. The mix was pasteurized at 81.5°C for 25 s (high-temperature short-time) and homogenized in a two-stage homogenizer (APV-Gaulin GmbH, Philadelphia, PA) at 13.8 and 3.5 MPa. Pasteurized mixes were aged at 4°C for 24 to 48 h. Ice cream mixes were frozen to –6°C with an overrun of 90 to 95% with a Technogel Model 80 Continuous Freezer (Technogel, Bergamo, Italy). Ice cream was collected into 0.95-L (quart) paperboard containers (Sealright, Kansas City, MO). Samples designated for physical hardness testing were filled directly into 180-ml foamed plastic cups and carefully leveled to avoid compaction.

Storage. Ice cream was hardened and stored in circulating air at –30°C. Physical testing was conducted within 5 d of production. Sensory evaluation was conducted at 0, 6, and 12 wk.

Microbial, Compositional, and Physical Tests

Microbial. Each of the ice cream mixes was plated by the standard plate count (9) and coliform count (5) methods to provide some degree of confidence that processing and handling were done under sanitary conditions.

Composition. Fat content was determined by the Mojonnier ether extraction method (15.8F), and total solids was determined by the forced-draft oven method (15.10C) in Standard Methods for the Examination of Dairy Products (2).

Viscosity. The viscosity of melted ice cream mix tempered to 4°C was measured at shear rates ranging from 0 to 300 s^{-1} at intervals of 6 s^{-1} with a Haake VT550 with an MVI ST spindle (Haake Buchler Instruments, Paramus, NJ).

Hardness. Hardness was measured as the grams of force required for a cylindrical probe to penetrate one-half the depth of a sample. Samples were tempered to –19.0°C in a chest-type freezer for 18 h before testing. The probe was chilled in an untested sample before testing and between samples to minimize the influence of temperature on the measurement of hardness. Three measurements were recorded for each cup. An Instron Universal Testing Machine, model 1132 (Instron, Inc., Canton, MS) was used in conjunction with a strip chart recorder to plot the force. Conditions: load cell = 4.1 kg, puncture probe diameter = 3.12 mm, crosshead speed = 20 cm/min, chart speed = 1.0 mm/s, pen sensitivity = 100 × 5mV.

Rate of melt. Melting rate was determined by carefully cutting the foamed plastic cups from the ice cream samples (180 ml), placing the ice cream onto wire mesh (2.33/cm^2) over a cup, and weighing the amount of ice cream drained into the cup at 21 ± 0.5°C every 10 min.

Table 1. Ingredients used in lowfat and nonfat chocolate ice cream mixes containing 2.5% milk fat (MF), 2.5% cocoa butter (CB), 2.5% Simplesse (SM), or 2.5% Dairy Lo (DL).

Ingredient	MF	CB	SM	DL	Source
Skim milk	5.3	65.0	65.0	65.0	Prairie Farms, Carlinville, IL
Whole milk	62.5	0.0	0.0	0.0	Prairie Farms, Carlinville, IL
Cocoa butter	0.0	2.5	0.0	0.0	ADM Cocoa, Milwaukee, WI
Simplesse Dry 500	0.0	0.0	2.5	0.0	NutraSweet Kelco, Deerfield, IL
Dairy Lo	0.0	0.0	0.0	2.5	Cultor Food Science, Groton, CT
NDM	5.2	5.5	5.5	5.5	Mid-America Dairymen, Sabetha, KS
Polydextrose	2.0	2.0	2.0	2.0	Cultor Food Science, Groton, CT
Maltodextrin 100:200	2.0	2.0	2.0	2.0	Grain Processing Corp., Muscatine, IA
Sugar	10.5	10.5	10.5	10.5	Fleming Companies, Oklahoma City, OK
36 DE Corn syrup	9.2	9.2	9.2	9.2	Cargille, Eddyville, IA
CC-452 Stabilizer	0.5	0.5	0.5	0.5	Continental Colloids, Chicago, IL
10–12% Russet cocoa	2.8	2.8	2.8	2.8	Gerkens Cocoa, Lititz, PA

Melting profiles were plotted as the ratio of the weight of all drained ice cream to the weight of the original sample versus time. The data collected during a period of relatively constant draining were regressed to determine the overall rate of drainage for each ice cream.

Hedonic Evaluation

Consumer acceptance was determined by asking 50 untrained volunteers from the university to indicate their degree of liking on a 9-point scale (1 = dislike extremely, 9 = like extremely). Ice cream (tempered to –19.0°C) was dipped into individual serving cups immediately before evaluation. Samples were served in random order and were evaluated under red lights in individual booths. Panelists were instructed to rinse their mouths before each sample and to expectorate water and ice cream.

Descriptive Analysis

Descriptive analysis (10) was conducted at 0, 6, and 12 wk. Through discussion and consensus in three training sessions, 12 panelists generated 21 attribute terms with definitions (Table 2). Eight judges returned for the sessions at 6 and 12 wk, after completing one retraining session. Attributes were rated on a 15-cm line scale, with the lines anchored from "not" to "very" for each attribute.

Ice cream (tempered to –19.0°C) was scooped just before serving. Samples were served monadically in foamed plastic cups under red lights in individual booths. Panelists were instructed to rinse with water before each sample and to expectorate all ice cream and water. Appearance characteristics were evaluated under artificial daylight in a MacBeth lightbox.

Panelists met for 3 d during the evaluation period. During a single day, each panelist received four formulations from a single batch and three subsamples of each formulation for a total of 12 samples. The samples were randomized over the batch, with the first six samples being served at a late morning session and the remainder being served in the afternoon.

Statistical Analysis

Analysis of variance. Data related to percent fat, percent total solids, hardness, viscosity, melting rate, and sensory analyses were analyzed using SAS (16). Analysis of variance (ANOVA) was performed to evaluate the effects of judge, fat source, storage time, replications, subsamples, and interactions of these on the dependent variables. Significant means were separated by least significant difference (LSD). Orthogonal contrasting was used to compare sets of ingredients. Significance was preestablished at $\alpha < 0.05$.

Multivariate analysis of variance. Multivariate analysis of variance (MANOVA) was used in conjunction with Wilk's lambda statistic to determine if there was an overall difference among treatments when all dependent variables were considered. MANOVA takes into account the collinearity among dependent variables and can be used in cases in which the differences among treatments are found only through combinations of dependent variables (10). Canonical variate analysis was used to map treatments and attributes in a data space to describe differences among groups. To determine which treatments were significantly different, a confidence interval for each treatment was calculated using the Chatfield and Collins method (3). Significance was preestablished at $\alpha < 0.05$.

RESULTS AND DISCUSSION

Physical Tests

The results of physical tests are shown in Table 3. The composition of each ice cream satisfactorily met the requirements of the experimental plan. There was

Table 2. Terms used in descriptive analysis of lowfat and nonfat chocolate ice cream containing 2.5% milk fat (MF), 2.5% cocoa butter (CB), 2.5% Simplesse (SM), or 2.5% Dairy Lo (DL).

	Attribute	Definition as worded on score sheet
1	Hardness	Force necessary to push the spoon into ice cream at a 90° angle
2	Intensity of milk chocolate aroma	Refer to milk chocolate reference[1]
3	Intensity of cocoa aroma	Refer to cocoa (cocoa used in mix)
4	Character of milk chocolate flavor	How similar is the ice cream to the milk chocolate reference[1]
5	Intensity of milk chocolate flavor	Refer to the milk chocolate reference[1]
6	Character of cocoa flavor	How similar is the ice cream to the cocoa reference (cocoa used in mix)
7	Intensity of cocoa flavor	Refer to the cocoa reference (cocoa used in mix)
8	Sweetness	Refer to sucrose in aqueous solutions
9	Bitterness	Refer to caffeine in aqueous solutions
10	Cooked milk flavor	Refer to cooked milk references (2% milk cooked on stove)
11	Duration of overall flavor	After expectoration; short to long
12	Chocolate/cocoa aftertaste	Refer to cocoa powder reference
13	Sweet aftertaste	Refer to sucrose in aqueous solutions
14	Bitter aftertaste	Refer to caffeine in aqueous solutions
15	Powdery/chalky	Like dry powder or chalk dust without a puckery feeling
16	Creamy	The smoothness and body associated with fat (skim, whole milk, half & half, and cream references)
17	Melting rate	Rate at which the ice cream changes from solid to liquid while moving the tongue
18	Thickness after melting	Thickness of the melted ice cream—see skim milk and cream references
19	Mouthcoating	Degree to which the mouth remains coated after expectoration (half & half and cream references)
20	Icy	Amount of ice crystals
21	Chewy	Amount of resistance when ice cream is bitten into using the molars
22	Astringent	Degree to which the ice cream causes a drying and puckery feeling (cranberry juice reference)
23	Fluffy	The amount of air in the ice cream
24	Color	Light brown to dark brown (under white light)

[1]Hersey Milk Chocolate Bar, Hersey Foods Corporation, Hershey, PA.

no significant difference in hardness among treatments ($P > 0.05$). Each ice cream mix exhibited shear-thinning properties between 0 to 100 s^{-1}. There was no significant difference among mixes when viscosity was averaged between 100 and 300 s^{-1} ($P > 0.05$); however, DL was slightly more viscous than the other treatments at shear rates between 25 and 200 s^{-1}.

Melting rate was calculated as the average percentage weight loss per minute. Each treatment differed significantly from the other treatments ($P < 0.001$). From fastest melting to slowest melting were lowfat ice cream containg cocoa butter (**CB**), nonfat ice cream containing Dairy Lo (**DL**), nonfat ice cream containg Simplesse (**SM**), and lowfat ice cream containing milk fat (**MF**). Through visual inspection, it was noted that MF melted into a thick liquid, whereas CB melted into thin liquid. SM retained more of its shape than did DL and CB and melted into a foamy liquid. DL lost its shape more quickly than SM and MF, and melted into a foamy, color-separated liquid that did not drain well through the screen. In its pure form, cocoa butter is more solid than milk fat at room temperature; there-

Table 3. Mean values and significance of effects of fat or fat replacer on the physical and compositional properties of ice cream containing 2.5% milkfat (MF), 2.5% cocoa butter (CB), 2.5% Simplesse (SM), or 2.5% Dairy Lo (DL) at 0 wk.

	Fat (%)	Total solids (%)	Viscosity (mPa·s)	Melting rate (% min^{-1})	Hardness (g)
	Mean Scores				
MF	2.2[a]	39.8	125	0.011[c]	1283.55
CB	2.0[a]	40.2	125	0.019[a]	1239.33
SM	0.7[b]	39.6	135	0.014[b]	1275.34
DL	0.7[b]	40.9	143	0.015[d]	1274.70
	F-values				
Trt[1] (df = 3)	4.64**	2.68	1.36	37.01**	0.24
Batch(Trt) (d.f. = 8)	0.92	N/A	0.88	2.23	4.92***
LSD[2]	0.89	0.13	23.00	0.002	113.13
df	12	12	12	24	168

[a,b,c]Means with different superscripts within attributes differ ($P < 0.05$).

[1]Treatments. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

[2]$P < 0.05$.

Table 4. Mean scores of descriptive analysis attributes and significance of effects of 2.5% milk fat (MF), 2.5% cocoa butter (CB), 2.5% Simplesse (SM), and 2.5% Dairy Lo (DL) on the sensory properties of lowfat and nonfat chocolate ice cream at 0 wk.

	Effect[1]								Mean scores by Trt			
Attribute	Trt (3)	Judge	Rep (2)	J × T	J × R	T × R	Sub(R)	LSD[2]	MF	CB	SM	DL
	F-values											
Brown color	17.91***	20.72***	7.27***	0.72	1.43	3.78**	1.88	0.754	9.4[c]	9.8[c]	11.0[b]	11.9[a]
Cocoa flavor character	3.84**	24.38***	0.92	0.99	1.87*	1.14	1.37	0.740	7.2[b]	8.4[a]	7.8[ab]	8.3[a]
Cocoa flavor intensity	4.02**	9.12***	0.67	1.61*	1.64*	3.15**	0.87	0.846	7.0[b]	8.2[a]	7.6[ab]	8.3[a]
Thick	3.02*	29.94***	1.04	1.21	1.19	1.77	0.66	0.674	8.4[a]	8.5[a]	7.6[b]	8.5[a]
Mouthcoating	6.39***	69.33***	2.52	1.54*	1.34	0.79	1.38	0.641	5.9[a]	5.2[b]	5.1[b]	6.3[a]
Astringent	2.97*	85.37***	6.87**	0.99	2.98***	1.15	0.27	0.478	3.3[a]	3.2[ab]	2.8[b]	3.5[a]

[a,b,c]Means with different superscripts within attributes differ ($P < 0.05$).

[1]Trt = Treatment, Rep = Replication, J × T = Judge × Treatment, J × R = Judge × Replication, T × R = Treatment × Replication, and Sub(R) = Sub-samples per replication. Numbers in parentheses are degrees of freedom.

[2]$P < 0.05$; df = 348.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

fore, it would be expected that ice cream made with milk fat would melt more quickly than that made with cocoa butter. However, MF retained its original shape longer than the other ice creams, suggesting that milk fat stabilized the emulsion, probably through clumping of the fat globules at air cell walls.

Descriptive Analysis of Fresh Ice Cream

ANOVA and LSD. Table 4 presents mean values for those attributes that were found by ANOVA to differ significantly among the formulations. Brown color was the only attribute found to significantly differentiate appearance ($P < 0.001$): DL was significantly darker brown than SM, and both were significantly darker brown than CB and MF.

Of 13 terms describing flavor and aroma, only two exhibited significant differences among treatments: intensity of cocoa flavor ($P < 0.01$) and character of cocoa ($P < 0.01$). These two terms were used in a similar manner by panelists, suggesting that only one term was necessary to convey the difference in cocoa flavor. Significant interaction effects suggest that judges inconsistently evaluated ice cream over the 3 d for intensity of cocoa flavor. Cocoa flavor was rated as similar in CB and DL, but more characteristic of the cocoa powder reference than was MF. SM did not differ significantly from the other ice creams. Although there were differences in the characteristic and intensity of cocoa flavor, there was no difference in bitterness among ice creams. This suggests that the change in cocoa flavor was related to volatile flavor compounds rather than to taste compounds.

Three terms were used to describe significant differences in mouthfeel and texture among treatments: thickness ($P < 0.05$), mouthcoating ($P < 0.001$), and astringency ($P < 0.05$). The most noticeable difference among ice creams was mouthcoating. MF and DL coated the mouth significantly more than did CB and SM. All three of the other ice creams were significantly thicker than SM. The highly significant judge∗rep interaction indicates that astringency was not rated consistently by the judges.

Because there was no significant difference in hardness or viscosity between any ice cream containing a fat replacer and the ice cream containing milkfat (Table 3), there was little indication that the physical properties of the ice cream affected flavor release.

Sensory analysis did not compare well with instrumental analysis. The differences in cocoa flavor among ice creams were not correlated with the differences in texture. Although the judges found a difference in thickness among ice creams, there was no significant difference in viscosity as measured instrumentally. There were differences in the rates of drainage of melting ice cream, but trained judges did not note the differences in melting rate during consumption. Neither sensory nor instrumental analysis indicated differences in hardness among ice creams.

Orthogonal contrasts. Orthogonal contrasts were made between sets of treatments to compare the effect of formulating with fat (MF or CB) or with fat replacers (SM or DL) on the sensory attributes of ice cream (Table 5). The nonfat ice creams differed significantly from the lowfat ice creams (contrast 1) by being darker brown, less fluffy, and having less intense cooked milk flavor. In addition to these differences, MF was rated as having significantly less intense cocoa flavor and being less characteristic of the cocoa powder reference than the ice creams containing either cocoa butter (contrast 2) or fat replacers (contrast 3). The fat replacers allowed more cocoa flavor compounds to reach the olfactory receptors than did milk fat. Milk fat contributed a creamy texture, whereas the fat replacers contributed a powdery feeling.

Comparing the two ice creams containing fat replacers, DL was rated significantly higher than SM in chocolate aroma, thickness, mouthcoating, astringency, and brown color (contrast 4).

Although it has been suggested that chocolate ice cream is not affected by the use of cocoa butter as a fat source (21), this investigation showed that the flavor of MF was more characteristic of chocolate and less similar to cocoa than was the flavor of CB. Additionally, and perhaps related to, the perception of chocolate and cocoa flavors, MF was significantly sweeter and less bitter than CB.

Compared with CB, MF also produced a creamier ice cream that coated the mouth longer.

Chocolate flavor may be related to mouthcoating, which differed between MF and CB but not between MF and the ice creams containing fat replacers. It is less likely that chocolate flavor is related to creaminess; both contrasts 2 and 3 (Table 5) resulted in differences in creaminess, but only contrast 2 resulted in a difference in chocolate character.

Table 5. Mean scores of descriptive analysis and significance of effects of lowfat (2.5% milk fat or 2.5% cocoa butter) versus nonfat (2.5% Simplesse or 2.5% Dairy Lo) on the sensory properties of chocolate ice cream at 0 weeks.

	F-values	Mean scores of each set contrasted	
		Lowfat vs. nonfat	
Contrast 1			
Cooked milk flavor	4.58*	3.4	3.1
Fluffy	5.62*	5.4	4.9
Brown color	47.57***	9.6	11.5
		Milkfat vs. cocoa butter	
Contrast 2			
Chocolate flavor	5.07*	7.4	6.6
Cocoa flavor	9.59**	7.2	8.4
Cocoa intensity	7.97**	7.0	8.2
Sweet	5.00*	7.9	7.2
Bitter	6.46*	3.4	4.1
Creamy	4.44*	9.6	8.8
Mouthcoating	4.66*	5.9	5.2
		Milkfat vs. fat replacers	
Contrast 3			
Cocoa flavor	6.13*	7.2	8.1
Cocoa intensity	6.04*	7.0	8.0
Cooked milk flavor	6.13*	3.5	3.0
Powdery	5.53*	5.1	5.8
Creamy	5.72*	9.6	8.8
Fluffy	5.11*	5.5	4.9
Brown color	39.49***	9.4	11.5
		Dairy Lo vs. Simplesse	
Contrast 4			
Chocolate aroma	4.43*	5.4	4.7
Thick	6.28*	8.5	7.6
Mouthcoating	13.93***	6.3	5.1
Astringent	8.28***	3.5	2.8
Brown color	4.88*	11.9	11.0

*$P < 0.05$.

**$P < 0.01$.

***$P < 0.001$.

Table 6. Mean scores of descriptive analysis attributes and significance of effects of 2.5% milk fat (MF), 2.5% cocoa butter (CB), 2.5% Simplesse (SM), and 2.5% Dairy Lo (DL) on the sensory properties of lowfat and nonfat chocolate ice cream at 6 wk.

		Mean scores by Treatment			
Attribute	LSD[2]	MF	CB	SM	DL
Chocolate flavor character	0.858	7.5[a]	5.7[b]	6.8[a]	5.6[b]
Chocolate flavor intensity	0.864	7.8[a]	6.3[b]	7.0[ab]	6.6[b]
Cocoa flavor character	0.951	7.1[c]	8.7[ab]	8.0[bc]	9.2[a]
Cocoa flavor intensity	1.049	7.6[b]	8.5[ab]	8.2[b]	9.3[a]
Bitter	0.618	3.7[b]	4.4[a]	4.8[a]	4.7[a]
Powdery	0.669	3.8[b]	3.6[b]	4.3[b]	4.9[a]
Creamy	0.889	10.0[a]	7.8[b]	8.3[b]	8.6[b]
Hard	0.988	9.9[a]	9.7[ab]	8.8[b]	8.8[b]
Icy	0.920	1.1[c]	4.9[a]	3.4[b]	2.7[b]

[a,b,c]Means with different superscripts within attributes differ ($P < 0.05$).

[1]Scored on a 15-cm line; 0 = not and 15 = very.

[2]$P < 0.05$; df = 228.

Hedonic Evaluation

There was no significant difference among consumer acceptance scores of chocolate ice creams. Mean acceptance scores were 6.3, 5.8, 6.0, and 5.7 for MF, CB, SM, and DL, respectively. The differences among ice creams observed by the descriptive analysis panel were insufficient to affect preferences of this consumer panel.

Storage

Although 12 judges began the study, only eight judges were able to return for the study of storage effects. During the retraining session, the terms ‘iciness’ and ‘chewiness’ were added, and the terms ‘astringency’ and ‘fluffy’ were dropped. Mean scores of sensory attributes at 6 and 12 wk are shown in Tables 6 and 7, respectively.

Table 7. Mean scores of descriptive analysis attributes and significance of effects of 2.5% milk fat (MF), 2.5% cocoa butter (CB), 2.5% Simplesse (SM), and 2.5% Dairy Lo (DL) on the sensory properties of lowfat and nonfat chocolate ice cream at 12 wk.

		Mean scores by Treatment			
Attribute	LSD[2]	MF	CB	SM	DL
Chocolate flavor character	0.770	7.2[a]	6.9[ab]	6.3[bc]	6.1[c]
Cooked milk flavor	0.616	2.8[a]	2.5[ab]	2.2[b]	1.9[b]
Flavor duration	0.949	7.9[b]	8.4[ab]	8.9[b]	9.1[a]
Creamy	0.984	9.8[a]	7.4[c]	8.6[b]	7.4[c]
Hard	0.813	10.6[ab]	11.1[a]	9.5[c]	10.2[bc]
Icy	1.528	1.5[b]	5.4[a]	2.7[b]	4.9[a]
Chewy	1.053	8.4[a]	7.0[b]	7.0[b]	7.5[ab]

[a,b,c]Means with different superscripts within attributes differ ($P < 0.05$).

[1]Scored on a 15-cm line; 0 = not and 15 = very.

[2]$P < 0.05$; df = 228.

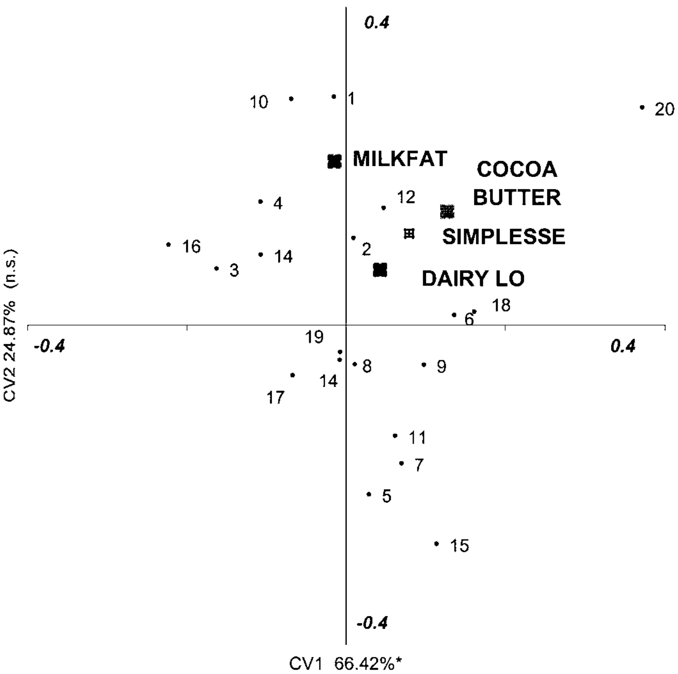

Figure 1. Canonical variate (CV) analysis of formulations. The numbers represent the sensory attributes as numbered in Table 2.

The most noticeable changes caused by storage time involved creaminess and iciness, which were not initially different among treatments. At 6 wk, MF was significantly creamier than all the others. At 12 wk, MF was still the creamiest, but SM was also creamier than DL and CB. At 6 wk, CB was significantly icier than SM and DL, which were both icier than MF. At 12 wk, DL did not differ in iciness from CB. The ice cream containing Simplesse was most able to maintain a texture similar to the ice cream containing milk fat.

MANOVA and CVA. The effects of storage and formulation treatment on the sensory properties of each ice cream are represented by the results of MANOVA. The data analyzed by MANOVA included data generated by eight judges at all three time points. The data included the scores for 'icy' but excluded the other attributes that were not evaluated at all three intervals (chewy, astringent, and fluffy). At the first training session, panelists had been asked to consider rating iciness but had decided that the samples were not icy.

The results of MANOVA of the treatments (Figure 1) indicate that there was an overall significant difference among ice creams containing different ingredients ($F = 2.52$, df = 60, $P < 0.001$). The first canonical variate (**CV**) was significant ($P < 0.05$) and represented 66.42% of the variation in the data. Those data plotted along the positive side of CV1 are associated with thickness, flavor characteristic of cocoa, bitter taste, and iciness. Therefore, CB was most associated with iciness and cocoa flavor, while MF was least associated with these attributes. Although CV2 is not significant, MF is most associated with high scores for cooked milk flavor, flavor characteristic of chocolate, and hardness, and with low scores for intensity of cocoa, intensity of chocolate, and powdery mouthfeel.

Figure 2 shows that there was also a significant difference among ice creams stored for different lengths of time ($F = 16.75$, df = 40, $P < 0.001$). The CV represented 64.99% and 35.01% of the variation and were significant at $P < 0.05$ (Figure 2). The CVA plot is not easily interpreted. The data collected at each time point are significantly different from one another, but do not follow a chronological pattern as might have been expected. It may be that the changes that occurred in the ice creams during the first 6 wk of storage were not the same as those that occurred during the second 6 wk, causing the data to fall in different directions from the original time point. It may also be that the differences among time points were related more to the sensory panel's use of attributes rather than to real changes in the products.

There was no significant interaction of treatment with storage time ($F = 1.12$, df = 120, $P = 0.07$). These results indicate that the treatments as evaluated overall did not react significantly differently to storage; however, the statistic is likely affected by the high propor-

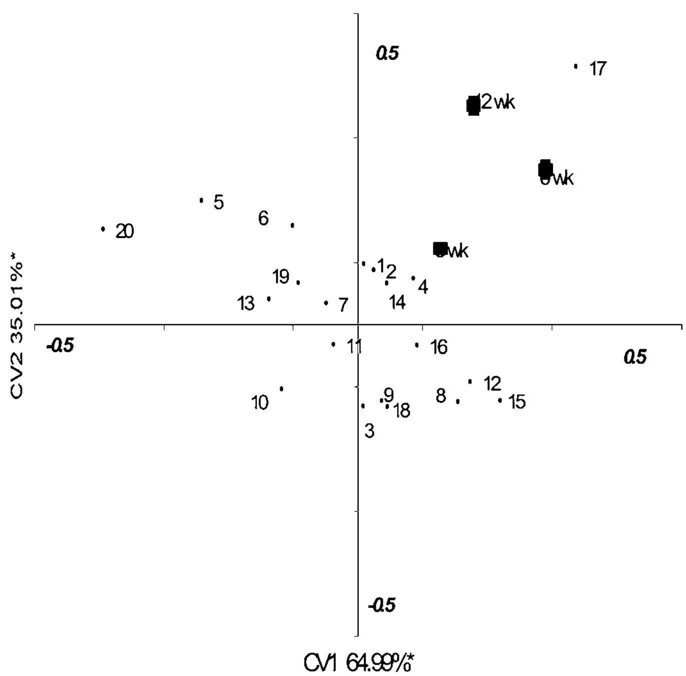

Figure 2. Canonical variate (CV) analysis of storage times. The numbers represent the sensory attributes as numbered in Table 2.

tion of attributes that did not change. Had the number of attributes been fewer, the interaction would likely have been significant.

SUMMARY

When milkfat was replaced by whey protein fat replacers, significant differences in sensory attributes resulted. These differences did not significantly affect consumer acceptance. Compared to the whey protein fat replacers, the presence of milkfat in ice cream reduced the intensity of cocoa flavor and slowed the development of icy texture over storage time. In fresh ice cream, Simplesse acted more similar to milk fat than did Dairy Lo as indicated by brown color, cocoa flavor, and cocoa character but was less similar in terms of thickness and mouthcoating. During 12 wk of storage, Simplesse was better able to slow the development of icy texture than was Dairy Lo.

When milk fat was replaced by cocoa butter, the ice cream was less creamy and caused less mouthcoating. Additionally, the ice cream containing cocoa butter had a stronger cocoa flavor than the ice cream containing milkfat. The ice cream containing cocoa butter became icy and less creamy over time. Therefore, to reduce economic costs and to take advantage of lowfat cocoa powders, milkfat can be used to replace cocoa butter in chocolate ice cream without losing any desirable sensory characteristics. Moreover, these results indicate that milkfat does more than cocoa butter to produce a balanced chocolate flavor and creamy texture.

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