Effect of Milk Fat on the Sensory Properties of Chocolate Ice Cream[1]

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ABSTRACT

Nonfat (0.5%), low fat (4%), reduced fat (6%), and full fat (9%) chocolate ice creams were made. Whey protein and polydextrose were 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 or was heat-shocked at –12°C. Hardness, viscosity, and melting rate were measured through physical methods. Trained panelists conducted descriptive sensory analyses of the samples at 0 and 4 wk. Attribute ratings were analyzed by analysis of variance and least significant difference mean separation. Milk fat at concentrations of 9 and 6% produced more creaminess and smoothness, as well as a less intense cocoa flavor, than it did at concentrations of 4 or 0.5%. Consumer acceptance (n = 98) did not differ among the fresh ice creams. Data showed that ice creams containing higher milk fat concentrations are better protected against heat shock damage in terms of cocoa flavor and smoothness of texture.
(**Key words**: ice cream, chocolate, milk fat)

Abbreviation key: **FF** = full fat ice cream, **LF** = low fat ice cream, **NF** = nonfat ice cream, **RF** = reduced fat ice cream.

INTRODUCTION

About 50% of US ice cream makers introduced reduced fat, light, low fat, or nonfat frozen desserts in 1996. However, volume share of these products dropped from 17.1% in 1996 to 16.6% in 1997 (4). This drop in consumption suggests consumers are considering flavor quality when selecting the level of fat.

Consumers progressively increased their acceptance scores of vanilla ice cream as fat content was increased in increments of 2% from 4 to 10%, even though they claimed to prefer a lower fat-type of product. Consumers expressed no preference among vanilla ice creams containing 0.5, 1, 2, and 4% fat (8).

Little research has been done on chocolate ice creams, which contain more complex flavoring and have more complex textural attributes than vanilla ice cream. About 500 volatile compounds have been detected in cocoa, and each may react differently with milk fat and fat replacers. Important flavor volatiles in cocoa include pyrazines, aldehydes, ketones, furans, other carbonyls, alcohols, and esters (6, 10, 11, 16, 17, 18). Cocoa powder also contains theobromine, caffeine, and other compounds that produce bitter and sour tastes; therefore, chocolate ice cream requires more sweeteners than do most other ice creams. Cocoa, cocoa butter, and the additional sweeteners contribute to the high total solids typical of chocolate ice cream. Cocoa butter and milk fat have a eutectic interaction that may affect flavor release during the consumption of chocolate ice cream (14, 15). The texture and viscosity of food material influence the perceived intensity of flavor (2, 7).

Hatchwell (3) found that chocolate ice cream without milk fat lacked creamy, milky, and chocolate-like flavors and instead was described as dark, woody, fudgy, and reminiscent of a dirty ashtray. Trained sensory panelists at the University of Missouri, who sampled commercial products, rated nonfat chocolate ice cream as harder and more bitter than lowfat and regular full fat chocolate ice creams (E. A. Prindiville, 1998, Milkfat and whey protein fat replacers in chocolate ice cream, unpublished M.S. Thesis, Univ. Missouri, Columbia).

The present investigation expanded upon previous studies of fat replacers in vanilla ice cream to include chocolate, a more complex flavoring ingredient (8). The objective of the research was to determine the effect of milk fat on the sensory properties of chocolate ice cream. Descriptive analysis and consumer acceptance tests were used in conjunction with physical tests to determine the differences among sensory properties of fresh and stored chocolate ice creams of varying fat content.

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MATERIALS AND METHODS

Treatments

Formulations. Ice cream was made with 0.5, 4.0, 6.0, and 9.0% milk fat to represent the commercial categories of nonfat, low fat, and reduced fat, and regular ice creams, respectively (Table 1). To maintain total solids, milk fat was replaced with equal mixtures of polydextrose (Cultor Food Science, Groton, CT) and Simplesse® Dry 500 (NutraSweet Kelco, Deerfield, IL). Target composition of each treatment was 11% nonfat milk solids, 16% sucrose equivalence, 3% cocoa powder, 0.4% stabilizer, and 41.6% total solids. Three batches (replicates) of each ice cream were made.

Storage. Ice cream was hardened and stored in circulating air at –30°C for up to 5 d for sensory and physical evaluation of fresh product. A set of samples was moved to storage at –12.2°C for 4 wk (heat-shock), and the remainder was maintained at –30°C for 4 wk (control).

Processing

Liquid ingredients were placed in a 66-L vat and warmed. Dry ingredients were then added. Mixing was accomplished with an emulsifying agitator. The mix was pasteurized at 81.5°C for 25 s (HTST) 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% using a Technogel Model 80 Continuous Freezer (Technogel, Bergamo, Italy). Ice cream was collected into 180-ml lidded, foamed plastic containers; 90 ml were collected for sensory analyses and 180 ml for texture profile and melting rate analyses.

Microbial, Compositional, and Physical Tests

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

Composition. Fat content was determined using the Monjonnier ether extraction method (15.8F), and total solids content was determined by the forced-draft oven method (15.10C) in Standard Methods for the Examination of Dairy Products (1).

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

Texture profile analysis. Texture Profile Analysis (TPA) was conducted using a microprocessor controlled texture analysis system in conjunction with data collection and analysis software (TA.XT2, XT.RA Dimension, Version 3.7, 1993, Stable Micro Systems, Haslemere, Surrey, England). Ice cream was collected directly into 180-ml foamed plastic cups and carefully leveled to avoid compaction. The conditions for analysis were as follows: a 2.25-mm probe penetrated tempered (–17.8°C) ice cream to a depth of 22.5 mm at 3 points/cup. The analysis also used contact area = 15.90 mm^2, force = 5.0 g; probe speed during penetration = 3.3 mm/s; probe speed pre- and postpenetration = 3.0 mm/s; acquisition rate = 200 pps; double peaks were plotted as force versus time.

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 every 10 min the amount of ice cream drained into the cup at 21 ± 0.5°C. Melting profiles were plotted as the ratio of the weight of all drained ice cream to the

TABLE 1. Ingredients used in ice cream mixes containing 0.5% milk fat (NF), 4% milk fat (LF), 6% milk fat (RF), and 9% milk fat (FF).

Ingredient	NF	LF	RF	FF	Source
	(%)				
Skim milk	60.7	54.6	51.1	45.7	Prairie Farms, Carlinville, IL
Cream	0.8	10.3	15.8	24.2	Prairie Farms
NDM	5.9	5.9	5.9	5.9	Mid-American Dairymen, Sabetha, KS
Simplesse® 500	4.2	2.5	1.5	0.0	NutraSweet Kelco, Deerfield, IL
Polydextrose	4.2	2.5	1.5	0.0	Cultor Food Science, Groton, CT
Sugar	11.0	11.0	11.0	11.0	Fleming Companies, Oklahoma City, OK
36 DE[1] Corn syrup	9.8	9.8	9.8	9.8	Cargill, Eddyville, IA
CC-452 Stabilizer	0.4	0.4	0.4	0.4	Continental Colloids, Chicago, IL
10–12% Russet cocoa	3.0	3.0	3.0	3.0	Gerkens Cocoa, Lititz, PA

[1]Dextrose equivalents.

TABLE 2. Mean values and significance of effects of milk fat level on the physical and compositional properties of ice cream containing 0.5% milk fat (NF), 4% milk fat (LF), 6% milk fat (RF), and 9% milk fat (FF) at 0 wk.

	Fat	Total solids	Viscosity	Melting	Hard	Chewy	Adhesive	Gummy	Springy	Cohesive
	F values									
Trt[1] (df = 3)	1861.07**	2.91	6.28**	1492.03***	3.45*	1.15	4.17**	2.92*	0.51	0.28
Batch(Trt)	1.74	0.00	1.04	339.87**	24.47***	5.10***	2.51*	6.71***	0.84	8.65***
LSD*	0.2	2.2	60.0	0.03	94.0	53.8	351.8	47.7	0.1	0.1
df	24	24	12	24	84	84	84	84	84	84
	Mean Scores									
FF	8.7[a]	42.3	102[ab]	0.833[c]	811.60[a]	179.01	70.20[b]	217.21[a]	0.816	0.283
RF	5.4[b]	42.2	149[a]	0.787[d]	699.09[b]	129.17	7.00[b]	146.79[b]	0.877	0.273
LF	3.7[c]	42.3	58[bc]	1.246[b]	693.08[b]	156.46	571.10[a]	174.63[ab]	0.894	0.260
NF	0.5[d]	42.4	40[c]	1.569[a]	675.23[b]	160.37	296.60[ab]	180.43[ab]	0.861	0.272

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

[1]Treatments.

*$P < 0.05$.

**$P < 0.01$.

***$P < 0.001$.

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.

Descriptive Analysis

Descriptive analysis (5) was conducted at 0 wk (fresh ice cream) and at 4 wk (heat-shocked vs. control treatments). Through discussion and consensus in three training sessions, eight panelists (three females, five males, ages 25 to 45 yr) generated attribute terms with definitions (Table 2).

During the evaluation period at 0 wk, eight panelists attended six sessions over a 3-d period. All samples served during a day were from the same production replication. During each session, one sample of each of the four formulations was presented in random order to each judge.

At 4 wk, the panelists attended one retraining session. During the evaluation period at 4 wk, seven judges evaluated 48 samples randomized over eight sessions (4 formulations × 3 production replications × 2 storage treatments × 2 subsamples). Each judge received the same combination of samples.

Ice cream (–12.2°C) was served monadically in lidded, 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. Panelists were instructed also to rest between samples to avoid fatigue. Appearance characteristics were evaluated under artificial daylight in a MacBeth light box (Gretag Macbeth, New Windsor, NY). Attributes were rated on a 15-cm line scale.

Hedonic Evaluation

Consumer acceptance (13) was determined by asking 98 untrained volunteers from the university to indicate their degree of liking on a 9-point scale (1 = dislike extremely to 9 = like extremely). Ice cream (–12.2°C) was served in lidded, foamed plastic cups under red lights in individual booths. Serving order was randomized. Panelists were instructed to rinse their mouths before each sample and to expectorate all water and ice cream.

Statistical Analysis

Data related to percentage of fat, percentage of total solids, hardness, viscosity, melting rate, and sensory analyses were analyzed using SAS® (12). Analysis of variance was performed to evaluate the effects of judge, fat concentration, storage conditions, replications, and subsamples and the interactions of these on the dependent variables. Significant means were separated by least significant difference. Significance was pre-established at $\alpha < 0.05$.

RESULTS AND DISCUSSION

Microbial Tests

Microbial tests provided no evidence of contamination during processing.

Physical Tests

Results of physical tests are shown in Table 2. The composition of each ice cream satisfactorily met the requirements of the experimental plan. There was a

TABLE 3. Terms used in descriptive analysis of ice cream containing 0.5, 4, 6, or 9% milk fat.

Attribute	Definition as worded on score sheet
Color	Light brown to dark brown (white light)
Foaminess	Verbal instructions to look for bubbly foam (white light)
Separation of color	Verbal instructions to look for dark and light streaks in melted ice cream (white light)
Air holes	Small pits or holes in untouched surface of ice cream (red light)
Smooth appearance	Surface texture due to consistently small particles (red light)
Chocolate or cocoa	Refer to chocolate and cocoa references (Hershey's™ Milk Chocolate bar[1] and cocoa used in mix)
Cooked milk aroma	Refer to evaporated milk reference (Schnuck's evaporated milk[2])
Sweet	Refer to sucrose solution (sucrose in aqueous solutions)
Cocoa	Refer to cocoa powder and unsweetened chocolate references
Chocolate	Refer to semi-sweet and milk chocolate (Nestle™ semi-sweet morsels,[3] Hershey's™ Milk Chocolate[1])
Cooked milk	Refer to evaporated milk
Cocoa aftertaste	Refer to cocoa powder and unsweetened chocolate references
Chocolate aftertaste	Refer to semi-sweet and milk chocolate references
Off-flavor	Please specify if possible
Firm	Resistance to change in shape while chewing—angel food cake is more firm than whipped cream
Chalky	Dry and powdery particles in ice cream
Creamy	Combination of thickness and lubricative feeling as ice cream melts—refer to skim milk and cream
Airy	Air felt as tongue pushes to roof of mouth—whipped cream and angel food cake vs. marshmallow creme
Rate of melt	Amount of time required for frozen ice cream to turn into liquid
Icy	Amount of ice crystals
Smooth texture	Lack of detectable particles or lumps
Viscosity	Thickness of ice cream after it has melted
Mouth coating	Residue left in the mouth after expectoration—refer to cream for high mouthcoating

[1]Hershey Foods Corporation, Hershey, PA.

[2]Schnuck's Foods, St. Louis, MO.

[3]The Nestle Co., Inc., White Plains, NY.

significant difference in viscosity among the ice cream mixes ($P < 0.01$). Viscosity tended to increase with fat content with the exception that reduced fat was inexplainably more viscous than full fat. Melting rate differed significantly among treatments ($P < 0.001$) and among batches within treatments ($P < 0.05$). With the exception of reduced fat, the drainage of ice cream became slower as fat content was increased. Because reduced fat was more viscous than full fat, it would be expected that reduced fat would hold its shape longer than would full fat. There was a significant difference in hardness among treatments ($P < 0.05$) and among batches within treatments ($P < 0.001$). In particular, full fat ice cream was significantly harder than all other ice creams. Other significant attributes included gumminess ($P < 0.05$) and adhesiveness ($P < 0.01$); however, these descriptions are not easily related to fat content, as shown by a lack of pattern among the mean scores. The ice creams did not differ in springiness, chewiness, or cohesiveness.

Descriptive Analysis of Fresh Ice Cream

During training, the judges generated and defined 23 terms with which to evaluate the ice creams (Table 3). Table 4 presents mean values for those attributes that were found to be significantly different among ice creams containing different concentrations of milk fat. All five terms describing appearance were used significantly ($P < 0.001$): brown color, foaminess, separation after melt, visible air holes in frozen ice cream, and smoothness. Each of these attributes was evaluated with some level of inconsistency as indicated by significant replication and interaction effects. In particular, the assessment of the amount of visible air holes was significantly affected by replication, treatment × replication, and judge × treatment interactions. Additionally, there was a significant difference in separation of color among subsamples nested within replication, implying that there were differences from cup to cup within a batch of ice cream. Separation of color and foaminess were used similarly by the panelists: the two ice creams containing the most milk fat, reduced fat and full fat, were significantly less foamy and less separated than nonfat ice cream. They were also significantly lighter brown than low fat and nonfat, which were also significantly different from each other. Smooth appearance decreased as fat content was decreased, and nonfat appeared significantly less smooth than the other ice creams.

Of nine terms describing flavor and aroma, five (Table 4: sweet through off-flavor) exhibited significant differences among treatments: intensity of cocoa flavor ($P < 0.001$), sweet ($P < 0.01$), cocoa aftertaste ($P < 0.001$), chocolate aftertaste ($P < 0.05$), and off-flavor ($P < 0.001$). The two lower fat ice creams were rated significantly higher in cocoa flavor and cocoa aftertaste than were the two higher fat ice creams. Chocolate aftertaste was inversely related to cocoa aftertaste, although the judges appeared to have difficulty in consistently assessing chocolate aftertaste. The judges did not find significant differences in chocolate flavor among ice creams. The ice cream containing 0.5% fat was significantly sweeter than were the other ice creams, perhaps because fat was not sufficiently present to impede exposure of sweeteners to the tongue. Li et al. (8) failed to find an effect of fat content (0.5 to 10%) on sweetness in similar studies with vanilla ice cream. Chocolate ice cream containing 0.5% fat was rated significantly higher in off-flavors than were the other ice creams, although there was no consistent pattern in the descriptions of reported off-flavors. Li et al. (8) showed by free-choice profiling that sensory quality increased and by a consumer preference panel that preference increased as fat content in vanilla ice cream was increased from 0.5 to 10%. Furthermore, time to reach maximal intensity of vanilla flavor was longer when fat percentages were above 2% indicating that flavorants in the low fat samples defused to the receptor sites faster and reached maximum flavor intensities sooner than did flavorants in the higher fat samples.

Seven terms were used to describe significant differences in mouthfeel and texture (Table 5: firm through viscous) among treatments: firm ($P < 0.001$), chalky ($P < 0.001$), icy ($P < 0.05$), melting rate ($P < 0.01$), smooth ($P < 0.001$), creamy ($P < 0.001$), and viscous ($P < 0.05$). Chalkiness tended to increase as fat content was decreased. The two ice creams containing the most fat were significantly creamier, smoother, and slower melting than were the other ice creams. The full fat treatment increased firmness of mouthfeel significantly compared with the other ice creams. The instrumental analysis of hardness (Table 2) supported the findings of the sensory panel in that full fat was significantly firmer (harder) than the other ice creams.

TABLE 4. Mean scores of descriptive analysis attributes and significance of effects of milk fat level on the sensory properties of ice cream containing 0.5% milk fat (NF), 4% milk fat (LF), 6% milk fat (RF), and 9% milk fat (FF) at 0 wk.

	Effect[1]								Mean scores by Trt			
Attribute	Trt (df = 3)	Judge (df = 7)	Rep (df = 2)	J × T (df = 21)	J × R (df = 14)	T × R (df = 6)	Sub(R) (df = 3)	LSD[2]	NF	LF	RF	FF
	F values											
Brown color	73.88***	11.25***	0.36	1.65*	0.82	6.13***	0.23	0.981	10.4[a]	6.6[b]	4.1[c]	3.9[c]
Foamy	5.84***	11.21***	0.43	5.28***	1.16	1.50	0.27	1.181	8.7[a]	7.7[ab]	6.3[c]	6.9[bc]
Separated color[3]	7.14***	10.09***	5.95**	2.11**	1.59	1.48	10.44***	1.146	8.4[a]	7.6[ab]	5.9[c]	6.6[c]
Air holes	189.09***	10.20***	12.50***	6.14***	1.75	4.07***	1.42	0.710	8.5[a]	2.1[b]	1.1[c]	1.0[c]
Smooth appearance	83.98***	17.76***	0.32	3.62***	1.89*	2.03	3.38*	8.470	7.3[c]	12.3[b]	13.0[ab]	13.2[a]
Sweet	6.44***	6.57***	6.04**	1.14	1.15	0.71	0.62	0.987	10.3[a]	9.1[b]	8.3[b]	8.5[b]
Cocoa	6.43***	11.47***	1.67	1.51	0.40	2.39*	0.92	1.153	9.4[a]	9.4[a]	7.3[b]	8.0[b]
Cocoa aftertaste	6.60***	42.83***	6.77**	1.90*	1.99*	1.05	0.73	1.102	7.7[a]	7.0[a]	5.7[b]	6.0[b]
Chocolate aftertaste	3.06*	82.57***	7.77***	2.86***	1.09	0.50	0.16	0.857	6.1[ab]	5.8[b]	6.9[a]	6.8[a]
Off-flavor	13.42***	20.01***	0.66	7.60***	1.33	1.13	1.43	0.517	1.7[a]	0.6[b]	0.3[b]	0.3[b]
Firm	5.85***	18.76***	7.62***	1.53	1.08	1.69	1.85	1.017	9.8[b]	9.7[b]	9.4[b]	11.4[a]
Chalky	6.20***	15.41***	0.16	1.57	1.38	1.89	0.76	0.975	3.4[a]	2.4[ab]	1.4[c]	1.7[bc]
Creamy	13.37***	27.54***	2.47	1.62	1.89*	3.43**	0.52	0.840	8.3[b]	9.0[b]	10.6[a]	10.4[a]
Melting rate	5.29**	16.89***	2.91	2.41**	2.10*	0.42	0.65	1.081	7.7[a]	7.7[a]	6.5[b]	6.0[b]
Icy	2.74*	35.99***	0.59	1.29	3.91***	2.54*	3.52*	0.895	2.9[a]	2.7[a]	1.7[b]	2.3[ab]
Smooth texture	7.96***	14.93***	0.53	0.77	2.00*	1.23	0.60	0.853	10.9[b]	10.9[b]	12.6[a]	11.9[a]
Viscous	3.29*	23.15***	5.82***	1.78*	0.83	1.54	0.22	1.126	7.5[b]	8.0[b]	9.3[a]	8.2[ab]

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

[1]Trt = Treatment, Rep = replication, J × T = judge × Trt, J × R = J × Rep, T × R = Trt × Rep, and Sub(R) = Subsamples per replication.

[2]$P < 0.05$; df = 135.

[3]Color separated in melted ice cream.

*$P < 0.05$.

**$P < 0.01$.

***$P < 0.001$.

TABLE 5. Mean scores of descriptive analysis attributes and significance of effects of milk fat level and storage conditions on the sensory properties of ice cream containing 0.5% milk fat (NF), 4% milk fat (LF), 6% milk fat (RF), and 9% milk fat (FF) at 0 wk.

	Effect *F* values and Probabilities						Mean scores by fat level								
				Storage treatment			Control Storage[1]					Heat-shocked[2]			
Attribute	Judge 6	Fat (df = 3)	Storage (df = 1)	LSD[3]	Control[1]	Shocked[2]	LSD[3]	NF	LF	RF	FF	NF	LF	RF	FF
Brown color	24.09***	74.19***	1.37	0.529	6.5	6.8	1.058	11.2^{a}	6.5^{b}	4.4^{c}	4.0^{c}	11.1^{a}	7.4^{b}	4.7^{c}	4.0^{c}
Separated color	34.08***	4.96***	0.12	0.663	7.1	7.0	1.315	7.8^{ab}	8.7^{a}	5.5^{d}	6.5^{bcd}	7.3^{bc}	6.1^{cd}	7.3^{bc}	7.3^{bc}
Air holes	17.32***	78.76***	6.58*	0.569	3.1^{b}	3.8^{a}	1.139	8.7^{a}	1.5^{cd}	1.2^{cd}	0.9^{d}	9.0^{a}	2.8^{b}	2.3^{bc}	1.2^{cd}
Smooth appearance	13.81***	40.00***	6.45*	0.571	11.4^{a}	10.7^{b}	1.143	7.7^{c}	12.3^{a}	12.5^{a}	13.1^{a}	6.8^{c}	10.9^{b}	12.2^{a}	12.8^{a}
Cooked milk aroma	183.96***	3.22**	0.27*	0.405	2.5	2.4	0.810	1.7^{b}	2.4^{ab}	3.1^{a}	3.0^{a}	2.2^{b}	2.3^{ab}	2.4^{ab}	2.9^{ab}
Sweet	22.01***	5.20***	4.25*	0.425	9.0	9.4	0.851	9.8^{a}	8.8^{b}	9.4^{ab}	7.9^{b}	10.0^{a}	9.6^{ab}	9.2^{ab}	8.8^{b}
Cocoa flavor	32.17***	4.82***	0.04	0.599	8.0	8.1	1.199	9.1^{ab}	8.2^{bcd}	7.4^{cd}	7.5^{cd}	9.5^{a}	8.3^{bc}	7.0^{d}	7.6^{cd}
Cocoa aftertaste	77.97***	5.35***	0.19	0.533	5.6	5.7	1.068	6.7^{ab}	5.4^{c}	5.0^{c}	5.2^{c}	7.1^{a}	5.9^{bc}	5.0^{c}	4.9^{c}
Off flavor	3.52***	4.35***	2.31	0.472	0.8	0.5	0.945	1.9^{a}	0.5^{c}	0.2^{c}	0.7^{bc}	1.5^{ab}	0.1^{c}	0.1^{c}	0.2^{c}
Firm	22.72***	3.23**	9.45**	0.714	9.2^{a}	8.1^{b}	1.429	9.0^{ab}	8.8^{abc}	8.9^{abc}	10.1^{a}	7.6^{cd}	8.1^{bcd}	7.0^{c}	9.7^{a}
Chalky	15.16***	9.05**	0.54	0.581	2.8	3.0	1.164	4.6^{a}	2.6^{bc}	1.7^{c}	2.3^{bc}	4.6^{a}	3.4^{b}	2.3^{bc}	1.8^{c}
Creamy	32.40***	27.19***	1.83	0.546	9.5	9.1	1.093	6.8^{c}	9.1^{b}	11.3^{a}	10.6^{a}	6.3^{c}	8.5^{b}	10.5^{a}	10.9^{a}
Melting rate	6.65***	5.49***	2.51	0.722	5.7	6.3	1.446	7.0^{ab}	6.4^{ab}	4.9^{cd}	4.5^{d}	7.7^{a}	6.6^{ab}	6.0^{bc}	4.8^{cd}
Icy	25.79***	4.61***	12.33***	0.657	2.3^{b}	3.5^{a}	1.315	3.5^{b}	2.1^{bcd}	2.1^{bcd}	1.5^{d}	5.1^{a}	3.4^{bc}	2.7^{bcd}	2.6^{bcd}
Smooth texture	26.46***	16.28***	15.17***	0.452	11.7^{a}	10.8^{b}	0.904	10.4^{c}	11.9^{ab}	12.4^{a}	12.1^{a}	8.5^{d}	11.0^{ab}	11.6^{ab}	12.2^{a}
Viscous	41.90***	7.14***	0.17	0.627	9.1	8.9	1.256	7.7^{cd}	9.1^{ab}	9.9^{ab}	9.6^{ab}	7.0^{d}	8.7^{bc}	10.1^{a}	9.9^{ab}
Mouth coating	80.38***	2.90**	0.82	0.599	4.6	4.3	1.200	3.9^{ab}	4.4^{a}	5.1^{a}	5.1^{a}	3.1^{b}	4.4^{a}	4.9^{a}	5.0^{a}

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

[1]Control treatment = 28 d at –30°C.

[2]Heat-shock treatment = 28 d at –12°C.

[3]$P < 0.05$.

*$P < 0.05$.

**$P < 0.01$.

***$P < 0.001$.

Surprisingly, iciness and viscosity scores were not directly related to fat content. The full fat ice cream did not differ significantly from the other ice creams, but reduced fat was significantly less icy and more viscous than low fat or nonfat ice cream. The physical tests of melting rate and viscosity corroborated the findings of the sensory panel.

Hedonic Evaluation

There was no difference ($P < 0.05$) among consumer acceptance scores of chocolate ice creams. Mean acceptance scores were 6.7, 7.2, 6.8, and 6.8 for nonfat, low fat, reduced fat, and full fat, respectively. The differences among ice creams of varying fat content observed by the descriptive analysis panel were insufficient to affect preferences of this consumer panel. Had the formulations not included Simplesse 500® and polydextrose to displace the fat in the lower fat formulas, preferences would likely have been observed.

Storage

Overall, heat-shocked ice creams were rated as icier, less smooth in appearance and texture, and less firm than were the control ice creams (Table 5). Visible air holes in frozen ice cream were more likely to appear after the heat-shock treatment. The heat-shock treatment also produced differences among the ice creams that were not evident after the control storage treatment.

After both storage treatments, nonfat ice cream appeared significantly less smooth and had more visible air bubbles than the other ice creams. After the heat-shock treatment, low fat ice cream also appeared significantly less smooth than did reduced fat or full fat. Separation of color was more apparent in low fat and full fat among the control samples, whereas heat-shocked samples were not significantly different from each other.

Differences in cocoa flavor were slightly more pronounced among heat-shocked ice creams than among ice creams stored under control conditions. All heat-shocked ice creams were similar in cooked milk aroma, although there were differences among ice creams stored under the control conditions. The cooked milk aroma may have disappeared or have been masked by some other flavor that developed during the heat-shock treatment. Chocolate aroma, flavor, and aftertaste and cooked milk flavor were not affected by fat content or by storage treatment.

The storage conditions appeared to have little effect on the relative differences among ice creams in terms of creaminess, chalkiness, viscosity, melting rate, or airiness. Under both storage conditions, reduced fat and full fat ice creams were significantly creamier than low fat, and all were significantly creamier than nonfat. Chalkiness was most evident in nonfat and low fat after both storage treatments and was increased slightly in low fat after the heat-shock treatment. Airiness was not significantly affected by storage or by fat level.

The heat-shock treatment caused the most changes in nonfat ice cream. The control nonfat ice cream was similar to the other control ice creams in terms of iciness, smooth texture, and mouthcoating, but after the heat-shock treatment, the nonfat ice cream differed significantly from the others. These attributes were not affected by the heat-shock treatment in the other ice creams.

There was no significant difference in firmness among ice creams containing different fat concentrations stored under control conditions. However, heat-shocking caused nonfat and reduced fat to become significantly less firm than full fat or low fat.

CONCLUSIONS

As the percentage of milk fat is decreased from 6.0 to 0.5%, an increase in cocoa flavor can be expected. Whether this relationship is due to the ability of milk fat to dissolve flavor volatiles or to the milk fat contribution to the physical structure, which in turn influences flavor transport, was not determined. The association of intense cocoa flavor with low creaminess, low smoothness, high chalkiness, and fast melting rate suggests that milk fat provides physical barriers that slow the release of cocoa flavor volatiles into a vapor phase.

Milk fat contributes to the stability of texture and flavor during storage. The nonfat and low fat ice creams were most adversely affected by heat-shock treatment and showed the greatest changes in iciness, smoothness, and mouthcoating. The cocoa flavor of the nonfat ice cream was also more noticeable after storage than it was in the other ice creams.

Milk fat significantly influences important texture and flavor properties of chocolate ice cream in ways that are not exactly simulated by equal quantities of whey protein fat replacers and polydextrose.

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