Evaluation of Rice Flour for Use in Vanilla Ice Cream¹

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ABSTRACT

The effects of varying concentrations (2, 4, and 6%) of 2 types of rice flours (RF 1 and RF 2) on the physicochemical properties and sensory characteristics of vanilla ice cream samples were assessed at different fat levels (0, 4, and 10%) and storage conditions (control vs. heat-shocked). Fat and total solids were measured as well as hardness, viscosity, and melting rate. Eight trained panelists conducted descriptive sensory analyses of the samples at 0 and 7 wk. The 2% rice flour level and to a certain extent the 4% usage level generally improved texture while affecting to a lesser extent the flavor characteristics of the samples compared with the control. The RF 2 generally had a more significant effect than RF 1, especially on the texture attributes. Although the rice flour reduced the negative impact of temperature abuse on textural properties, the samples still deteriorated in textural properties (more icy) under temperature abuse conditions. In addition, rice starch does lower perceived sweetness and can have a “flour flavor” at high usage levels. The use of rice flour appears to be most advantageous for low fat ice cream samples.

Key words: sensory, rice flour, ice cream, fat substitute

INTRODUCTION

Regular ice cream production dropped 5.2% between 2003 and 2004 in the United States. However, in the low fat and nonfat categories, hard ice cream production increased 4.5% over the same period (Anonymous, 2005). The increase in lower fat ice cream sales could be due the fact that consumers are getting more accustomed to the taste of lower fat products (Stubenitsky et al., 1999) and are appreciating the taste of reduced

fat products because of their level of motivation (Kähkönen, 2000), or it may be that they are simply making more health conscious purchases. A study by Li et al. (1997) points to the latter of the two assumptions. Acceptance scores by US panelists for vanilla ice cream increased progressively for samples varying in fat level in increments of 2% from 4 to 10%, even by panelists who claimed to prefer a lower fat type of product. Although there is clear interest in lower fat frozen desserts, the results indicate that additional work may be needed to improve their quality.

Reducing the fat in any food formulation will cause a decrease or loss of several properties of fat: viscosity, structure, opacity, slip, fatty flavor, mouthcoating, and mouth fullness (Arbuckle and Marshall, 2000). Hence, ingredients used in lower fat frozen desserts ideally should emulate the texture, mouthfeel, and functionality of fat and should convey the desired flavor profile. Replacers can be fat-, protein-, or carbohydrate-based. Several studies have assessed the effect of protein-based fat replacers on the sensory and physical characteristics of ice cream (Ohmes et al., 1998; Prindiville et al., 1999, 2000).

Starch and modified food starches are reduced in calories (4.2 to 16.7 kJ/g). As fat replacers, they modify texture and have been found to increase the viscosity of food products (Akoh, 1998). Several studies have examined the effects of carbohydrate-based fat replacers on the sensory characteristics, notably the texture, of reduced fat ice cream. King (1994) assessed the effect of different formulations, including one that had 10% (wt/wt) maltodextrin on the sensory profile of vanilla ice cream. However, an audio-based method was used to rate the intensity of the attributes, which is not the typical practice in descriptive sensory analysis. Schmidt et al. (1993) compared the rheological and melting properties of ice milks prepared with a carbohydrate- or protein-based fat replacer. Less air was incorporated in the carbohydrate-based replacer formula as compared with the protein-based replacer or control formulas. Roland et al. (1999b) examined the use of several fat replacers and their impact on the physical and sensory properties of vanilla ice cream. One of the

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formulas had 13.33% maltodextrin but had a TS content similar to the full fat version. Specter and Setser (1994) used tapioca dextrin or potato maltodextrin as fat replacers. However, these were prepared as one part dextrin-maltodextrin and 3 parts water, which implied that the maximum level used was approximately 3%. Aime et al. (2001) used modified pea starch as a fat replacer to assess its effect on the instrumental and sensory properties of vanilla ice creams of different fat levels. Although the light ice cream proved to be texturally comparable to the full fat ice cream, the trained sensory panel found the low fat and fat free ice creams to have lower viscosity, smoothness, and mouthcoating properties.

The ability of a carbohydrate-based fat replacer to be successful at mimicking textural characteristics of milk fat depends on the colloidal properties of the carbohydrates used and their impact on mouthfeel (Specter and Setser, 1994). The capability for a starch to have such characteristics becomes extremely important when temperature fluctuation and extended length of storage are prevalent issues. Milk fat in the mix is one significant factor that helps to prevent recrystallization during temperature storage and fluctuation. Modified starches could encourage viscosity development in the aqueous phase of ice cream (Jimenez-Flores et al., 1993) and control ice crystal growth (Stanley et al., 1996), thereby improving the texture of reduced fat ice creams.

With the extent of obesity in the US population (Flegal et al., 2002) and its associated illnesses, there is a real need for healthier food products with good sensory properties. To meet the high consumer acceptance obtained for full fat products, food companies must research and formulate better highly functional ingredients for low fat and reduced fat products. Rice starch is a relatively bland functional starch-based ingredient that has the potential to be utilized in lower fat foods. None of the studies mentioned above has assessed the potential of a carbohydrate to function as a substitute for the stabilizer and as a substitute for fat. In addition, no previous study has assessed rice starch or rice flour as a functional ingredient in ice cream.

The objectives of this work were first to determine the effect of varying concentrations of rice flours on the physicochemical properties and sensory characteristics of vanilla ice cream samples at different fat levels, and second to assess the effect of storage and heat shock on the sensory characteristics of the samples. The present work will expand upon the previous studies of various carbohydrates that have been utilized in lowered fat content vanilla ice creams and the effect of such replacers on the sensory characteristics in general, and texture attributes in particular, thereby determining

the potential of rice flour as a possible fat substitute in ice cream.

MATERIALS AND METHODS

Treatments

Formulations. Ice cream mixes were prepared with 0.5, 4, and 10% milk fat, which corresponded to the standard for nonfat, low fat, and full fat ice cream, respectively (Table 1). At each fat content, samples containing 2, 4, and 6% rice starch—of either Pac Gel (**RF 1**) or Pac Star (**RF 2**; PGP International, Woodland, CA)—were prepared, as well as a control sample prepared with a commercial ice cream stabilizer-emulsifier blend (Kontrol, Danisco USA Inc., New Century, KS), resulting in seven samples per fat content category for a total of 21 samples. Kontrol is a proprietary blended stabilizer-emulsifier system that contains cellulose gum, guar gum, carageenan, monodiglycerides, and polyoxyethylene sorbitan monooleate. No additional stabilizers were added to the 18 rice flour mixes so that the role of the rice flour as a stabilizer could be examined independently and without the influence of other stabilizers; however, an emulsifier, polyoxyethylene sorbitan monooleate, was added at a 0.03% rate to approximate the effect of the emulsifier added to the control mixes. The usage rate for polyoxyethylene sorbitan monooleate was selected to approximate the level that would be found in the usage rates of Kontrol. The emulsifier usage level in lower fat ice creams was not adjusted so that the effects of the rice starch could be examined independent of other variations in the ice cream formula.

The formulation of all ice cream samples included, in addition to the emulsifier, the standard ingredients of 10% nonfat milk solids, 12% sucrose equivalence, and 5% corn syrup solids (36 dextrose equivalent; Table 1).

Storage. A set of all samples was maintained at -30°C and then tempered for 24 h at -20°C prior to sensory evaluation. Another set was heat-shocked by temperature cycling for 7 wk on a 24-h regimen consisting of 16 h at -20°C and 8 h at -12°C . The heat shock method used for this study was based on information obtained from a personal communication with a large commercial ice cream manufacturer. Nonetheless, the temperature cycling approach for heat shock estimation is generally the accepted approach in the literature (Ohmes et al., 1998; Prindiville et al., 1999).

Mix Processing. For each fat level, a base mix was prepared. Whole milk and cream (4 and 10% fat mixes) or whole milk and skim milk (0.5% fat mixes) were added to a 375-L process tank and heated to approximately 40°C . Dry ingredients (sucrose, skim milk powder, and corn syrup solids) were added to the liquid

Table 1. Ingredients used in ice cream mixes containing 0.5% milk fat (NF), 4% milk fat (LF), and 10% milk fat (FF)

Ingredient, %	NF				LF				FF				Source
RF 1 or RF 2 ¹	0	2	4	6	0	2	4	6	0	2	4	6	PGP International, Woodland, CA
Milk	10	9	9	8	78	76	74	71	60	58	55	53	Cal Poly Dairy, San Luis Obispo, CA
Skim milk	70	69	67	66	0	0	0	0	0	0	0	0	Cal Poly Dairy
Cream	0	0	0	0	2	2	2	2	20	20	20	20	Cal Poly Dairy
Nonfat dry milk	3	3	3	3	3	3	3	3	4	4	4	4	Dairy America, Fresno, CA
Sucrose	12	12	12	12	12	12	12	12	12	12	12	12	Imperial Sugar Co., Sugar Land, TX
Corn syrup 36 DE ²	5	5	5	5	5	5	5	5	5	5	5	5	Cerestar USA Inc., Hammond, IN
Emulsifier ³	0	0.03	0.03	0.03	0	0.03	0.03	0.03	0	0.03	0.03	0.03	Danisco USA Inc., New Century, KS
Stabilizer, ⁴ g	0.28	0	0	0	0.28	0	0	0	0.28	0	0	0	Danisco USA Inc.

¹Rice flour types: RF 1 = Pac Gel and RF 2 = Pac Star.

²DE = dextrose equivalent.

³Polyoxyethylene sorbitan monooleate.

⁴Kontrol (stabilizer-emulsifier), in grams.

ingredients and mixed under high agitation until completely dissolved. To establish the control mixes at each fat level, 46-kg batches of each base mix were transferred to a 56-L processing tank and stabilizer-emulsifier was added and mixed under high agitation until completely dissolved. For each experimental mix, the same basic procedure was followed except the proper amount and type of rice flour, as well as emulsifier, was added to a 46-kg batch of base mix. Forty six kg of mix was removed and stabilizer was added to create the control batches.

All mixes were pasteurized at 82°C for 25 s using the PMS Universal Pilot Plant System (Processing Machinery & Supply Co., Philadelphia, PA) and homogenized at 78°C using a Gaulin LAB 100–6 TBS homogenizer (APV Gaulin GmbH, Lubeck, Germany) at 13,780 kPa first stage and 3,445 kPa second stage. Cooling was set at 5°C upon discharge from the heat exchanger. Mixes were collected into 38-L milk cans and placed at 5°C for 24 h of equilibration (aging).

All mixes were frozen using the Technogel 100 L/h continuous freezer (Technogel SpA, Azzano S. Paolo, Italy) with 517 KPa of backpressure maintained on all mixes. The target overrun was 100% and actual overrun values ranged from 95 to 105%. Product was packaged into 1.9 L paperboard rectangular containers and blast frozen for at least 24 h at –34°C before transfer to frozen storage at –30°C.

Physical and Chemical Analyses

Composition. Fat and TS contents were determined using the Babcock method (Hooi et al., 2004) and the CEM LabWave 9000 Microwave Moisture/Solids Ana-

lyzer (CEM Corp., Matthews, NC; Hooi et al., 2004), respectively.

Hardness. Ice cream samples were analyzed for hardness using the TA-XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY), which measured the force in grams required to penetrate the sample. The 1.9-L rectangular containers of ice cream were tempered at –18°C for 24 h before measurement. A 60° angle cone was used with a depth of penetration of 25 mm into the surface of the ice cream. All measurements were done in a 4°C walk-in refrigerated room. The entire test equipment and cone were tempered to the test temperature prior to use. Testing was completed within 5 min of preparation of the test sample.

Viscosity. Mix viscosity was determined using the Brookfield model RVT on mix samples aged for 48 h and tempered to 8°C. Spindle number 1 was rotated in the sample by the viscometer at 0.5, 1, 2.5, 5, and 10 rpm (if necessary), and viscosity (cP) was measured at each speed. The viscosity values at 1 rpm were used for the statistical analysis.

Melting Rate. The ice cream samples were frozen in pint containers. After tempering, pint samples were individually removed from the freezer, trimmed to approximately 230-g size, and placed on a wire screen with 2-mm openings supported by a funnel on a ring stand with a 100-mL graduated cylinder underneath. The sample and test assembly were placed immediately in a thermostatically controlled incubator at 32°C, and the volume of serum collected was measured at 10-min intervals for a period of 30 min, when total volume of serum and serum weight were recorded. The weight of the final volume melted was used for the statistical analysis.

Table 2. Terms used in descriptive analysis of ice cream containing 0.5, 4, or 10% milk fat

Attribute	Definition as worded on score sheet
Hardness	The force necessary to push the spoon into the ice cream at a 90-degree angle
Iciness	The amount of ice crystals when the ice cream is bitten between the molars
Chewiness	Amount of resistance when the ice cream is bitten using the molars
Gumminess	Perceived by biting the ice cream with the molars and then rated after the molars are pulled apart
Creaminess	Smoothness and uniformity of spread over the palate (equal volumes of whipping cream and skim milk ¹)
Melting rate	The rate at which the ice cream changes from a solid to a liquid while the sample is melting
Foaminess	Bubbly foams detected once the ice cream melts in the mouth while swirling the tongue (ultrapasteurized sweetened whipped light cream ²)
Sweetness	The perception of sweetness
Vanilla intensity	Perception of vanilla flavor (0.125% vanilla ³ mixed with skim milk and 6% sugar, 2% vanilla ³ mixed with skim milk and 6% sugar)
Phenolic flavor	Phenol note, typically found in vanilla beans (1.5% vanilla ³ mixed with skim milk)
Flour flavor	Perception of flour flavor (5% rice flour solution ⁴)
Caramel flavor	Perception of caramel or cooked flavor (evaporated fat free milk. Vitamin A and D added ⁵)
Egg Flavor	Perception of egg flavor
Metallic flavor	Perception of a metallic flavor (metal spoon)
Mouthcoating	Degree to which the mouth remains coated after expectoration (equal volumes of whipping cream and skim milk ²)
Coldness	Coldness of sample as perceived on the tongue and palate

¹Good Day, CA.²Albertsons, San Luis Obispo, CA.³Pure bourbon vanilla extract; R.R. Lochhead MFG, Paso Robles, CA.⁴Pac Gel (RF 1) and Pac Star (RF 2), PGP International, Woodland, CA.⁵Nestle Carnation, White Plains, NY.

Descriptive Analysis

Descriptive analysis was done over 2 evaluation periods (Lawless and Heymann, 1999; Prindiville et al., 1999). The first evaluation period (0 wk) consisted of fresh samples only and the second evaluation period (7 wk) included control samples (−30°C) and heat-shocked samples (temperature cycling temperatures). Eight panelists (5 females, 3 males); who were students, staff, and faculty at California Polytechnic State University, San Luis Obispo, were trained over 10 one-hour sessions. The training included tasting different ice cream samples and discussing their characteristics. The panelists generated 16 sensory attributes and definitions in the training sessions, along with reference standards for several of the attributes (Table 2).

During the first evaluation period, the panelists attended 12 sessions (1 morning and 1 afternoon session each day) for a 3-d period per week over 2 weeks. Five samples were served at each session including a warm-up sample, which was the last sample from the previous test session. The samples were given to all 8 panelists in random order over the 3-d period, according to the procedure discussed by Macfie and Bratchell (1989). There were 2 replicate evaluations (over 2 wk) with all 22 samples served within each week (21 treatments and one commercial warm-up sample for the first session).

The procedure design used for the first evaluation period was repeated for the second evaluation period (at 7 wk) in which both nontemperature cycled (control)

samples and heat-shocked samples were tested. The 0% fat level samples were not evaluated in the second evaluation period because the 0% fat level heat-shocked formulations showed clear undesirable flavor and textural characteristics. There were 2 replicate evaluations (over 2 wk) with all samples served within each week.

Ice cream (−15°C) was served monadically in 59 mL foam cups, labeled with 3-digit numbers, in individual test booths. Panelists were instructed to rinse with water before assessing each sample and to expectorate all ice cream samples. In addition, the panelists were encouraged to evaluate the reference standards whenever needed. Attributes were rated on a 15-cm line scale.

Statistical Analysis

Data related to percentage of fat, percentage of TS, hardness, viscosity, melting rate, and sensory analyses were analyzed using SAS (version 8.02, 1999 to 2001, SAS Institute Inc., Cary, NC). The ANOVA for the fresh samples was performed to evaluate the effects of judge, fat concentration, rice flour treatment (7 treatments: 1 control, and 2 rice flour types paired with 3 rice flour concentrations), replications, and the interactions of these on the dependent variables. Significant means were separated by Dunnett's test (Ott and Longnecker, 2001) for the fresh samples' sensory analyses using the 6 rice flour treatments mentioned above as compared

Table 3. Mean values and significance of effects of fat level and rice flour treatment on the physical and chemical properties of ice cream containing 0.5% milk fat, 4% milk fat, and 10% milk fat at 0 wk

Attribute	Effect				
	Fat level (df = 2)	Rice flour (df = 6)	Mean scores by fat level (%)		
			0	4	10
	<i>F</i> -value				
Fat content (%)	47,017.3***	3.67**	0.42 ^c	4.03 ^b	10.04 ^a
TS (%)	8,845.32***	296.49***	31.31 ^c	34.15 ^b	41.16 ^a
Hardness (gf)	143.05***	33.91***	8,758.3 ^a	5,769.2 ^b	3,938.8 ^c
Viscosity (cP)	14.43***	3.10*	479 ^b	1,157 ^b	5,568 ^a
Melting rate (mL)	17.18***	0.77	31.73 ^a	9.27 ^b	4.08 ^b

^{a-c}Means within a row with different superscripts differ ($P < 0.05$).

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

with the control formulation. The ANOVA for the stored samples was performed to evaluate the effects of judge, fat concentration, rice flour type, rice flour concentration, storage conditions, replications, and the interactions of these on the dependent variables. The means for the chemical analyses and the stored samples sensory analyses were separated by Tukey's (Ott and Longnecker, 2001) honestly significant difference (HSD). Significance was preestablished at $\alpha < 0.05$. It should be mentioned that the results for Tables 3 and 6 included many tests with the different sensory attributes and factors (fat level, rice flour, etc.), with a 5% significance level attached to each test. Accordingly, and in a similar manner to any data with many attributes and factors, it is safer to assume that the tests with a P -value < 0.001 show a significant difference and that tests with higher P -values should be interpreted with caution.

RESULTS AND DISCUSSION

Physical and Chemical Analyses

Results of the chemical and physical analyses are summarized in Table 3. There was a significant difference in the fat content between the 3 fat levels ($P < 0.001$). In addition, the fat levels for the different samples were consistent with the experimental plan, as shown by the means for fat levels. Rice flour treatment had a significant effect ($P < 0.01$) on the fat content of samples. The rice flours used had a small amount of emulsifier—hence their effect on fat content. This additional emulsifier contribution was unanticipated and hence, its effects on ice cream properties were not determined. Despite this significant effect, the largest difference between the treatments was only 0.2% and may not be of any practical effect. There was a significant difference in TS between the different fat levels and rice flour treatments ($P < 0.001$). Total solids tended to increase with fat content and with a higher level of rice

flour ($P < 0.05$). An increase in TS with a higher fat content was also obtained by Li et al. (1997). There was a significant difference in hardness between fat levels and rice flour treatments ($P < 0.001$). Hardness increased with lower fat content. Viscosity was significantly different among the different fat levels ($P < 0.001$) and rice flour treatments ($P < 0.05$). Viscosity showed an increasing trend with fat content; however, there was no significant difference between the nonfat and low fat samples. A significant increase in viscosity with a higher fat content was noted in previous studies (Li et al., 1997; Prindiville et al., 1999). Melting rate was significantly different among the fat levels ($P < 0.001$) but was not significantly different between the rice flour treatments. Melting rate decreased as fat content increased from 0 to 4%, but no significant difference was obtained between the 4 and 10% fat. The melting rate results obtained are consistent with previous studies (Prindiville et al., 1999; Roland et al., 1999a,b). In addition, a significant increase in hardness with a lower fat content (10% fat vs. lower fat samples and 10 vs. 0.1% fat) was obtained by Roland et al. (1999a,b) and was attributed to an increase in ice content. However, Prindiville et al. (1999) observed an increase in hardness with a higher fat content, which was not the case in this study due to the effect of rice flour on hardness. Furthermore, the Prindiville et al. (1999) study included adjusting the TS for the different fat content samples to the same level using whey protein and polydextrose. There was a significant rice flour $\times$ fat interaction ($P < 0.001$), which indicated that rice flour increased hardness to a greater extent in the absence of fat.

Descriptive Analysis of Fresh Ice Cream

Table 4 illustrates the F -values and the mean values for the different attributes. Fat content had a signifi-

Table 4. Mean scores of descriptive analysis attributes and significance of effects of fat level and rice flour treatment on the sensory properties of ice cream containing 0.5% milk fat, 4% milk fat, and 10% milk fat at 0 wk

Attribute	Effect								Mean scores by fat level (%)		
	Fat	Rice flour	Replicate	Judge	J × R	RF × F × R	J × RF × F	RF × F	0	4	10
	(F; df = 2)	(RF; df = 6)	(R; df = 1)	(J; df = 7)	(df = 7)	(df = 12)	(df = 84)	(df = 12)			
	<i>F</i> -value										
Hardness	53.09***	19.95***	1.28	3.04	3.79***	0.79	1.03	1.45	6.82 ^c	8.16 ^b	10.48 ^a
Iceiness	88.70***	22.05***	1.44	8.06**	1.09	1.75	0.64	7.84***	9.09 ^a	6.28 ^b	3.71 ^c
Chewiness	63.85***	32.95***	0.17	3.71*	2.50*	1.46	1.22	0.73	6.01 ^b	6.55 ^b	9.33 ^a
Gumminess	30.15***	19.97***	0.22	5.26**	2.71**	0.58	1.13	1.04	5.52 ^b	6.11 ^b	8.44 ^a
Creaminess	59.04***	4.29**	1.34	1.54	4.44***	1.01	0.62	2.49**	5.30 ^c	7.93 ^b	10.70 ^a
Melting rate	17.77***	13.93***	30.58***	2.49	0.29	1.78	0.86	0.90	9.96 ^a	8.62 ^b	7.30 ^c
Foaminess	1.21	0.86	0.73	3.11*	1.68	2.38**	0.99	0.94	5.14	6.00	6.17
Sweetness	0.07	1.31	1.22	5.05	0.74	0.94	0.92	1.15	8.27	8.00	8.29
Vanilla intensity	1.26	0.75	0.02	5.70**	1.99	1.37	0.67	0.85	6.11	6.42	6.81
Phenolic flavor	3.60	0.48	0.01	10.46***	3.34**	0.26	1.06	0.52	5.38	4.86	3.91
Flour flavor	5.60	5.50***	3.72	2.57*	3.27***	1.02	0.83	0.72	5.16	4.48	3.60
Caramel flavor	6.76***	0.52	2.65	8.14***	2.52*	1.04	1.05	0.94	3.59 ^b	4.28 ^a	4.91 ^a
Egg flavor	4.13*	0.27	0.02	7.07***	2.35*	0.52	1.24	0.41	3.24 ^c	4.14 ^b	5.02 ^a
Metallic flavor	9.56**	0.35	0.43	6.94*	1.22	1.34	1.06	1.17	3.86 ^a	3.43 ^a	2.64 ^b
Mouthcoating	32.11***	8.24***	0.69	1.86	4.81***	0.96	0.94	2.27*	5.51 ^c	7.39 ^b	9.47 ^a
Coldness	17.74***	6.70***	1.05	8.78***	1.15	0.95	1.03	1.16	9.72 ^a	8.82 ^b	7.18 ^c

^{a-c}Means with different superscripts within attributes differ (Tukey adjusted, $P < 0.05$).

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

cant effect ($P < 0.001$) on most of the texture-related attributes: hardness, iciness, chewiness, gumminess, creaminess, melting rate, mouthcoating, and coldness, but no significant effect on foaminess. A greater fat content was associated with an increase in hardness, chewiness, gumminess, although only the 10% fat level showed a significant increase in creaminess and mouthcoating, and a decrease in iciness, melting rate, and coldness. In addition, fat level had a significant effect on caramel flavor ($P < 0.001$), egg flavor ($P < 0.05$), and metallic flavor ($P < 0.01$). A greater fat content resulted in an increase in caramel flavor and egg flavor, and a drop in metallic flavor, at the full fat level.

The increase in iciness is expected and is typical of lower fat ice creams, especially when comparing fat free vs. full fat (Roland et al., 1999a,b) or fat free vs. reduced fat samples (Prindiville et al., 1999). Trends similar to the ones obtained in this study were noted in previous studies for creaminess (Prindiville et al., 1999; Roland et al., 1999a,b), melting rate, coldness (Stamponi-Koefler et al., 1996; Prindiville et al., 1999; Roland et al., 1999a,b), and mouthcoating (Stamponi-Koefler et al., 1996; Aime et al., 2001), especially when comparing full fat vs. fat free samples.

The rice flour treatment (rice flour concentration × rice flour type, 7 levels) had a significant effect ($P < 0.001$) on 8 of the 9 texture attributes: hardness, iciness, gumminess, creaminess, melting rate, mouthcoating, and coldness. Rice flour also had a significant effect on creaminess ($P < 0.01$). For the flavor attributes, rice flour had a significant effect on flour flavor ($P < 0.001$).

However, rice flour did not have any significant effect on the other flavor-related attributes (sweetness, vanilla, phenolic, caramel, egg, and metallic). No major inconsistencies were noted for the evaluation of the different attributes, as confirmed by the absence of significant effects for replicate (2 evaluations/replicates for all samples) or the judge × treatment (treatment = fat × rice flour) interaction. The only exceptions were a significant ($P < 0.001$) replicate effect for melting rate and a treatment × replicate effect for foaminess ($P < 0.01$). Moreover, a significant judge × replicate effect was found for hardness, creaminess, mouthcoating, and flour flavor ($P < 0.001$); gumminess and phenolic flavor ($P < 0.01$); and chewiness, caramel, and egg flavors ($P < 0.05$). In addition, a significant rice flour × fat interaction was obtained for iciness ($P < 0.001$), creaminess ($P < 0.01$), and mouthcoating ($P < 0.05$).

A Dunnett's test of difference from control was performed on all the rice flour treatment levels for all the sensory attributes across all fat levels. The control, which was the sample with no rice flour but with the Kontrol stabilizer-emulsifier, was compared with the 6 rice flour treatments. Table 5 illustrates the results of the Dunnett's tests for the different attributes that were shown to be significantly different among the rice flour treatment levels (Table 4). These attributes consisted of 8 of the 9 texture attributes, namely hardness, iciness, chewiness, gumminess, creaminess, melting rate, mouthcoating, and coldness, in addition to the flour flavor attribute.

Table 5. Mean scores of significant descriptive analysis attributes and significance levels for comparisons (Dunnett) with control (0 wk)

Attribute	Control	2% RF 1 ¹	2% RF 2	4% RF 1	4% RF 2	6% RF 1	6% RF 2
Hardness***	6.28	6.43 (1.0)	7.25 (0.19)	8.98 (<0.0001)	9.15 (<0.0001)	10.32 (<0.0001)	11.00 (<0.0001)
Iciness***	8.63	7.73 (0.21)	6.76 (0.0005)	5.65 (<0.0001)	5.75 (<0.0001)	5.60 (<0.0001)	4.43 (<0.0001)
Chewiness***	4.70	5.06 (0.90)	5.59 (0.15)	7.94 (<0.0001)	8.19 (<0.0001)	9.42 (<0.0001)	10.18 (<0.0001)
Gumminess***	4.24	4.59 (0.95)	5.75 (0.014)	6.93 (<0.0001)	7.40 (<0.0001)	7.40 (<0.0001)	9.51 (<0.0001)
Creaminess**	7.09	7.55 (0.85)	7.72 (0.61)	7.99 (0.25)	8.34 (0.051)	8.46 (0.025)	8.68 (0.0066)
Melting rate***	10.19	10.07 (1.0)	9.20 (0.071)	7.92 (<0.0001)	8.20 (<0.0001)	8.09 (<0.0001)	6.73 (<0.0001)
Flour flavor***	2.95	3.33 (0.95)	3.60 (0.66)	4.43 (0.030)	4.59 (0.013)	5.46 (<0.0001)	6.56 (<0.0001)
Mouthcoating***	6.91	6.80 (1.0)	6.85 (1.0)	8.24 (0.010)	7.41 (0.70)	7.20 (0.96)	8.77 (0.0001)
Coldness***	9.67	9.61 (1.0)	8.96 (0.28)	8.15 (0.0009)	8.36 (0.0056)	7.95 (0.0001)	7.29 (<0.0001)

¹Rice flour types: RF 1 = Pac Gel and RF 2 = Pac Star.

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

No significant differences were obtained between the control and the 2% RF 1 for any of the attributes. However, significant differences between the control and 2% RF 2 were obtained for iciness ($P < 0.001$) and gumminess ($P < 0.05$). The 2% RF 2 had a lower iciness and higher gumminess as compared with the control. The control was significantly different ($P < 0.05$) from the rest of the 4 and 6% samples for most of the attributes except for creaminess and mouthcoating. A higher concentration of RF 1 and RF 2 in general increased flour flavor, hardness, chewiness, gumminess, and creaminess compared with the control, and decreased iciness, melting rate, and coldness. For most of these terms, excluding iciness, mouthcoating, and melting rate, which varied slightly, at 4 and 6% rice flour concentrations the effect of the rice flour addition on specific attributes, as expressed by the mean score, was more pronounced for RF 2 than RF 1. Based on these results and on the absence of any significant differences among the control and the 2% rice flour samples, the control samples were dropped from the subsequent analyses to allow a more thorough ANOVA including rice flour type, rice flour concentration, and their interactions as separate effects in the ANOVA model. In addition, the 0% fat level samples were assessed by the study's researchers after storage and were considered to be of an unacceptable quality. Accordingly, the 0% fat level samples were excluded from the subsequent phase of taste sessions for stored samples.

Descriptive Analysis of Stored Ice Cream

Table 6 illustrates the results for the taste sessions after storage. Table 7 includes the means of the different attributes for the effect levels. These taste sessions included samples stored at constant temperature (control) or heat-shocked samples. Fat level had a significant effect on iciness ($P < 0.001$), creaminess ($P < 0.001$), foaminess ($P < 0.01$), mouthcoating ($P < 0.001$), and coldness ($P < 0.01$). In addition, fat level had a signifi-

cant effect on sweetness ($P < 0.05$) and phenolic flavor ($P < 0.05$), as illustrated in Table 6. The model also included all 2-way interactions and selected higher order interactions. The significance of the 2-way interactions is described later.

As illustrated in Table 7, iciness ($P < 0.001$), coldness ($P < 0.01$), and phenolic flavor ($P < 0.05$) decreased at higher fat levels, whereas creaminess ($P < 0.001$), foaminess ($P < 0.01$), sweetness ($P < 0.05$), and mouthcoating ($P < 0.01$) all significantly increased at higher fat levels. A decrease in phenolic flavor as a result of increase in fat content could be due to the masking effect exerted by fat on the phenolic flavor originating from the vanilla extract used in the ice cream mix. The significant increase in sweetness at the higher fat level (10% fat) is not consistent with previous findings by Prindiville et al. (1999), who demonstrated an increase in sweetness as a result of a decrease in fat content. The increase in sweetness obtained in this work could be the result of flavor interactions between the rice flour and the sugars of the ice cream.

The rice flour type (RF 1 or RF 2) had a significant effect ($P < 0.05$) on iciness, chewiness, gumminess, and sweetness. The RF 2 samples were less icy ($P < 0.05$) than the RF 1 samples but more gummy ($P < 0.05$), which suggests that the RF 2 rice flour had a more pronounced effect on the samples. No significant differences between the means of RF 2 and RF 1 samples were obtained for chewiness or sweetness ($P < 0.05$).

Rice flour concentration had a significant effect on hardness ($P < 0.001$), iciness ($P < 0.001$), chewiness ($P < 0.001$), gumminess ($P < 0.001$), melting rate ($P < 0.001$), sweetness ($P < 0.05$), flour flavor ($P < 0.01$), caramel flavor ($P < 0.05$), mouthcoating ($P < 0.01$), and coldness ($P < 0.001$). There were significant differences ($P < 0.05$) among all the rice flour concentration levels (2, 4, and 6%) for hardness, chewiness, gumminess, and flour flavor, which showed a continuous increase with elevated rice flour concentrations. Moreover, mouthcoating and

Table 6. Significance of effects of fat level, rice flour concentration (RFC), rice flour type (RFT), and storage (ST) conditions on the sensory properties of ice cream containing 0.5% milk fat, 4% milk fat, and 10% milk fat at 7 wk

Attribute	Replicate (df = 1)	Fat (df = 1)	RFC (df = 2)	RFT (df = 1)	ST (df = 1)	RFC × RFT	Fat × RFC	RFT × ST	RFC × ST	Fat × ST	Fat × RFT
Hardness	5.70*	0.45	62.40***	3.08	1.96	0.13	2.29	5.73*	0.38	3.76	0.07
Iciness	0.08	61.70***	22.48***	5.62*	19.31**	5.52**	0.35***	2.53	2.82	0.00	0.19
Chewiness	4.23	0.00	47.80***	6.34*	0.67	2.28	3.91*	0.35	0.04	3.74	0.00
Gumminess	0.52	4.30	44.75***	7.81*	2.05	3.54*	0.64	0.42	2.99	0.05	0.04
Creaminess	4.93	45.80***	2.90	4.61	0.02	0.21	10.43***	4.24*	0.60	0.01	0.23
Melting rate	1.23	2.54	31.15***	1.72	0.24	0.48	1.81	0.40	0.09	0.99	0.43
Foaminess	1.53	14.20**	0.92	0.65	2.41	1.61	1.90	4.33*	1.03	4.25*	0.31
Sweetness	0.22	5.54*	5.09*	6.07*	0.00	2.99*	0.06	1.10	1.10	0.13	1.36
Vanilla intensity	0.05	1.26	0.87	1.10	1.61	0.33	0.83	0.54	0.13	0.27	0.45
Phenolic flavor	3.93	9.37*	0.79	0.03	0.13	0.29	2.90	1.14	0.09	0.39	1.18
Flour flavor	0.08	0.03	10.40**	3.94	0.33	0.24	1.09	0.00	0.85	0.07	1.50
Caramel flavor	0.72	3.31	5.71*	0.41	5.41	0.06	3.96*	3.27	0.26	5.43*	0.59
Egg flavor	0.80	4.95	0.01	0.02	2.77	2.56	0.82	3.12	0.07	0.49	0.84
Metallic flavor	3.77	3.45	0.04	0.12	0.43	1.81	0.90	0.21	1.38	0.38	3.60
Mouthcoating	0.00	24.45**	10.77**	0.36	2.31	0.30	1.97	0.11	0.20	0.26	0.03
Coldness	0.15	19.64**	12.99***	0.45	31.08***	2.68	1.45	0.08	2.33	0.23	2.08

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

caramel flavor significantly increased ($P < 0.05$) with an increase in rice flour concentration. However, there were no significant differences between the 4 and 6% samples for caramel flavor or mouthcoating. Iciness, melting rate, sweetness, and coldness significantly decreased ($P < 0.05$) with higher concentrations. There were no significant differences between the 2 and 4% rice flour samples for sweetness; this was not the case for iciness, melting rate, and coldness, which showed significant differences between the 3 rice flour concentration levels.

The storage factor had a significant effect on iciness ($P < 0.01$) and coldness ($P < 0.001$). Heat-shocked ice creams were significantly more icy and less cold than the control (stored but not heat-shocked) samples. An increase in iciness as a result of heat-shocked storage has been well documented in the literature. Prindiville et al. (1999) reported an increase in iciness after heat-shocked storage in addition to changes in the presence of air holes, smooth appearance, and firmness. In addition, Ohmes et al. (1998) obtained results which suggested that scores for course-icy texture and rate of

Table 7. Mean scores of descriptive analysis attributes of storage conditions, fat level, and rice flour type and concentration on the sensory properties of ice cream containing 0.5% milk fat, 4% milk fat, and 10% milk fat at 7 wk

Attribute	Storage treatment		Fat level		Rice flour type		Rice flour concentration		
	Control	Shocked	4%	10%	RF 1	RF 2	2%	4%	6%
Hardness	8.20	7.67	8.06	7.81	7.69	8.18	5.80 ^c	8.22 ^b	9.79 ^a
Iciness	5.38 ^b	6.49 ^a	7.50 ^a	4.37 ^b	6.20 ^a	5.68 ^b	6.93 ^a	5.97 ^b	4.91 ^c
Chewiness	7.08	6.80	6.94	6.93	7.18	6.69	4.36 ^c	7.15 ^b	9.31 ^a
Gumminess	6.95	6.56	6.04	7.46	6.30 ^b	7.20 ^a	4.53 ^c	6.76 ^b	8.97 ^a
Creaminess	8.90	8.92	7.18 ^b	10.65 ^a	8.73	9.10	8.52	8.99	9.24
Melting rate	8.65	8.72	9.08	8.29	8.84	8.53	10.13 ^a	9.01 ^b	6.91 ^c
Foaminess	6.33	6.88	5.65 ^b	7.56 ^a	6.68	6.54	6.37	6.86	6.59
Sweetness	7.95	7.96	7.42 ^b	8.49 ^a	8.13	7.78	8.45 ^a	8.06 ^a	7.37 ^b
Vanilla intensity	6.42	6.62	6.73	6.31	6.61	6.43	6.80	6.64	6.11
Phenolic flavor	4.95	5.01	5.91 ^a	4.05 ^b	4.95	5.01	4.75	4.93	5.26
Flour flavor	4.69	4.62	4.71	4.60	4.39	4.92	3.37 ^c	4.53 ^b	6.07 ^a
Caramel flavor	4.12	4.55	4.12	4.55	4.43	4.24	3.58 ^b	4.82 ^a	4.61 ^a
Egg flavor	4.06	4.30	3.49	4.88	4.21	4.16	4.16	4.21	4.18
Metallic flavor	3.02	2.93	3.43	2.52	3.02	2.93	3.02	2.98	2.92
Mouthcoating	8.57	8.40	7.22 ^b	9.73 ^a	8.55	8.41	7.85 ^b	8.70 ^a	8.89 ^a
Coldness	8.49 ^a	7.85 ^b	9.31 ^a	7.03 ^b	8.23	8.11	9.10 ^a	8.30 ^b	7.11 ^c

^{a-c}Means with different superscripts within attributes differ (Tukey adjusted, $P < 0.05$).¹RF 1 = Pac Gel and RF 2 = Pac Star.

Table 8. Mean scores for significant descriptive analysis attributes of rice flour type¹ × rice flour concentration interactions for ice cream containing 4 and 10% milk fat at 7 wk

Attribute	RF 1 (%)			RF 2 (%)		
	2	4	6	2	4	6
Iceiness	7.414 ^c	5.638 ^b	5.537 ^{ab}	6.442 ^{bc}	6.298 ^{bc}	4.288 ^a
Gumminess	4.520 ^a	5.930 ^b	8.441 ^{cd}	4.536 ^a	7.586 ^c	9.500 ^d
Sweetness	8.772 ^b	8.481 ^b	7.148 ^a	8.120 ^{ab}	7.636 ^{ab}	7.586 ^{ab}

^{a-d}Means with different superscripts within attributes differ (Tukey adjusted, $P < 0.05$).

¹Rice flour types: RF 1 = Pac Gel and RF 2 = Pac Star.

melting in the mouth increased with a heat-shock treatment.

The means for the significant descriptive attributes on rice flour type × rice flour concentration are summarized in Table 8. A significant rice flour concentration × rice flour type interaction was obtained for iciness ($P < 0.01$), gumminess ($P < 0.05$), and sweetness ($P < 0.05$). The 6% RF 2 was significantly lower on iciness ($P < 0.05$) than all the other samples, with the exception of the 6% RF 1, followed by the 4% RF 1, 4% RF 2, 2% RF 2, and 2% RF 1. On the other hand, the 6% RF 2 was gummier ($P < 0.05$) than all the other samples. A continuous increase in gumminess with an increase in rice flour concentration was noted for RF 1 and RF 2, though the increase was not as large with the RF 1. The 6% RF 1 was significantly less sweet ($P < 0.05$) than the 2 or 4% RF 1. However, RF 2 showed no significant difference in sweetness at 2, 4, or 6% rice flour level.

The means for the significant descriptive attributes on fat × rice flour concentration are summarized in Table 9. A significant fat × rice flour concentration was obtained for iciness ($P < 0.001$), chewiness ($P < 0.05$), creaminess ($P < 0.001$), and caramel flavor ($P < 0.05$). There were no significant differences on iciness with the 10% fat samples, which was not the case with the 4% fat samples that showed significant differences between the 2, 4, and 6% rice flour concentrations. There were significant differences among the 3 rice flour concentrations for both rice flours, showing a significant impact of rice flour concentration on this attribute regardless

of the fat level. Creaminess significantly increased with an increase from the 2 and 4% to 6% in rice flour concentration in the low fat samples ($P < 0.05$), unlike the full fat samples that did not show significant differences and were all creamier than the low fat samples. This shows that the use of rice flour is most advantageous for the low fat samples. No major differences in trends between the 2 rice flours were noted for caramel.

The means for the significant descriptive attributes on storage × rice flour type are summarized in Table 10. A significant storage × rice flour type interaction was obtained for hardness ($P < 0.05$), creaminess ($P < 0.05$), and foaminess ($P < 0.05$). The heat-shocked RF 1 samples were significantly less hard ($P < 0.05$) than the heat-shocked RF 2 samples and the control RF 1 and RF 2 samples. No major trends were noted for creaminess or foaminess.

The means for the significant descriptive attributes on storage × fat level are summarized in Table 11. A significant storage × fat interaction was obtained for foaminess ($P < 0.05$) and caramel flavor ($P < 0.05$). The 4% fat samples were significantly less foamy than both 10% fat samples ($P < 0.05$), and the 10% fat heat-shocked sample was significantly more foamy than the 10% control sample ($P < 0.05$). The 10% fat heat-shocked sample had significantly more caramel flavor than all other samples ($P < 0.05$).

Model diagnostics were run for all attributes to check model adequacy, equal error variance, and normally distributed errors. The models for most of the 16 attri-

Table 9. Mean scores for significant descriptive analysis attributes of rice flour concentration (2, 4, or 6%) × fat level interactions for ice cream containing 4% milk fat (LF), and 10% milk fat (FF) at 7 wk

Attribute	LF			FF		
	2%	4%	6%	2%	4%	6%
Iceiness	9.145 ^d	7.633 ^c	5.727 ^b	4.711 ^{ab}	4.303 ^a	4.098 ^a
Chewiness	3.939 ^a	7.630 ^b	9.26 ^c	4.784 ^a	6.663 ^b	9.350 ^c
Creaminess	6.363 ^a	7.072 ^a	8.106 ^b	10.669 ^c	10.905 ^c	10.366 ^c
Caramel	2.973 ^a	4.972 ^b	4.422 ^b	4.177 ^b	4.661 ^b	4.808 ^b

^{a-d}Means with different superscripts within attributes differ (Tukey adjusted, $P < 0.05$).

Table 10. Mean scores for significant descriptive analysis attributes of rice flour type¹ × storage (control or shocked) for ice cream containing 4 and 10% milk fat at 7 wk

Attribute	RF 1		RF 2	
	Control	Shocked	Control	Shocked
Hardness	8.273 ^b	7.108 ^a	8.123 ^b	8.240 ^b
Creaminess	8.522 ^a	8.939 ^{ab}	9.282 ^b	8.910 ^{ab}
Foaminess	6.180 ^a	7.176 ^b	6.479 ^{ab}	6.593 ^{ab}

^{a,b}Means with different superscripts within attributes differ (Tukey adjusted, $P < 0.05$).

¹Rice flour types: RF 1 = Pac Gel and RF 2 = Pac Star.

butes showed no problems or only small problems with these assumptions. Most problems occurred only with the normality assumption. Because of the large number of observations (384) in the study, the lack of normality for some attributes should not adversely affect our results. However, more severe problems with equal variance and model adequacy were detected in the results for 3 attributes: caramel flavor, egg flavor, and metallic flavor. Alternative models were attempted, but none removed these problems. Therefore, results for these 3 attributes should be viewed with extreme caution.

CONCLUSIONS

The RF 1 and RF 2 had varying effects on the attributes of vanilla ice cream at different fat levels. At the 2% fat level and to a certain extent the 4% fat level, RF 1 and RF 2 generally improved texture while impacting to a lesser extent the flavor characteristics of the samples compared with the control. The RF 2 generally had a more significant effect than RF 1, especially on the texture attributes. The rice flours reduced the negative impact of temperature abuse on textural properties, but samples still deteriorated in textural properties (more icy) under the experimental temperature abuse conditions. In addition, rice starch does lower perceived sweetness and can have a “flour flavor” at high usage levels. The use of rice flour appears to be most advantageous for low fat ice cream samples. Rice

Table 11. Mean scores for significant descriptive analysis attributes of fat level × storage (control or shocked) for ice cream containing 4% milk fat (LF) and 10% milk fat (FF) at 7 wk

Attribute	LF		FF	
	Control	Shocked	Control	Shocked
Foaminess	5.59 ^a	5.71 ^a	7.07 ^b	8.06 ^c
Caramel flavor	4.17 ^a	4.08 ^a	4.08 ^a	5.02 ^b

^{a-c}Means with different superscripts within attributes differ (Tukey adjusted, $P < 0.05$).

flour is recommended for further development likely at usage levels between 2 to 4% or lower if used in conjunction with other functional ingredients for ice cream and frozen desserts.

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REFERENCES

- Aime, D. B., S. D. Arntfield, L. J. Malcolmson, and D. Ryland. 2001. Textural analysis of fat reduced vanilla ice cream products. *Food Res. Int.* 34:237–246.
- Akoh, C. C. 1998. Fat replacers. *Food Technol.* 52:47–53.
- Anonymous. 2005. Dairy Facts, 2005 ed. Int. Dairy Foods Assoc., Washington, DC.
- Arbuckle, W. S., and R. T. Marshall, ed. 2000. Pages 73, 262, 264–266 in *Ice Cream*. 5th ed. Aspen Publishers Inc., Gaithersburg, MD.
- Flegal, K. M., M. D. Carroll, C. L. Ogden, and C. L. Johnson. 2002. Prevalence and trends in obesity among US adults. *JAMA* 288:1723–1727.
- Hooi, R., D. M. Barbano, R. L. Bradley, D. Budde, M. Bulthaus, M. Chettiar, J. Lynch, and R. Reddy. 2004a. Chemical and physical methods 15.084. In *Standard Methods For the Examination of Dairy Products*. H. Wehr and J. Frank, ed. Am. Public Health Assoc., Washington, DC.
- Hooi, R., D. M. Barbano, R. L. Bradley, D. Budde, M. Bulthaus, M. Chettiar, J. Lynch, and R. Reddy. 2004b. Chemical and physical methods 15.115. In *Standard Methods For the Examination of Dairy Products*. H. Wehr and J. Frank, ed. Am. Public Health Assoc., Washington, DC.
- Jimenez-Florez, R., N. J. Klipfel, and J. Tobias. 1993. *Ice Cream and frozen desserts*. Pages 57–157 in *Dairy Science and Technology Handbook*, vol. 2: Product Manufacturing. Y. H. Hui, ed. VCH Publishers Inc., New York, NY.
- Kähkönen, P. 2000. Consumer acceptance of reduced-fat foods—The effects of product information. PhD Diss. University of Helsinki, Finland.
- King, B. M. 1994. Sensory profiling of vanilla ice cream: Flavour and base interactions. *Lebenson Wiss. Technol.* 27:450–456.
- Lawless, H. T., and H. Heymann. 1999. *Sensory Evaluation of Food*. Springer, New York, NY.
- Li, Z., R. Marshall, H. Heymann, and L. Fernando. 1997. Effect of milk fat content on flavor perception of vanilla ice cream. *J. Dairy Sci.* 80:3133–3141.
- Macfie, H. J., and N. Bratchell. 1989. Designs to balance the effect of order of presentation and first order carry over effects in hall tests. *J. Sens. Stud.* 4:129–148.
- Ohmes, R. L., R. T. Marshall, and H. Heymann. 1998. Sensory and physical properties of ice creams containing milk fat or fat replacers. *J. Dairy Sci.* 81:1222–1228.
- Ott, R. L., and M. Longnecker. 2001. *An Introduction to Statistical Methods and Data Analysis*. 5th ed. Duxbury Press, Pacific Grove, CA.
- Prindiville, E. A., R. T. Marshall, and H. Heymann. 1999. Effects of milk fat on the sensory properties of chocolate ice cream. *J. Dairy Sci.* 82:1425–1432.
- Prindiville, E. A., R. T. Marshall, and H. Heymann. 2000. Effect of milk fat, cocoa butter, and whey protein fat replacers on the

- sensory properties of lowfat and nonfat chocolate ice cream. *J. Dairy Sci.* 83:2216–2223.
- Roland, A. M., L. G. Philips, and K. Boor. 1999a. Effects of fat content on the sensory properties, melting, color, and hardness of ice cream. *J. Dairy Sci.* 82:32–38.
- Roland, A. M., L. G. Philips, and K. Boor. 1999b. Effects of fat replacers on the sensory properties, melting, and hardness of ice cream. *J. Dairy Sci.* 82:2094–2100.
- Schmidt, K., A. Lundy, J. Reynolds, and L. E. Yee. 1993. Carbohydrate or protein based fat mimickers effects on ice milk properties. *J. Food Sci.* 58:761–763, 779.
- Specter, S. E., and C. S. Setser. 1994. Sensory and physical properties of a reduced calorie frozen dessert system made with milk fat and sucrose substitutes. *J. Dairy Sci.* 77:708–717.
- Stamponi-Koeferli, C. R., P. Pccinali, and S. Sigrist. 1996. The influence of fat, sugar and non-fat milk solids on selected taste, flavor and texture parameters of a vanilla ice cream. *Food Qual. Prefer.* 7:69–79.
- Stanley, D. W., H. D. Goff, and A. K. Smith. 1996. Texture-structure relationships in foamed dairy emulsions. *Food Res. Int.* 29:1–13.
- Stubenitsky, K., J. I. Aaron, S. L. Catt, and D. J. Mela. 1999. Effect of information and extended use on the acceptance of reduced-fat products. *Food Qual. Pref.* 10:367–376.