

COMPARISON STUDY OF EGG YOLKS AND EGG ALTERNATIVES IN FRENCH VANILLA ICE CREAM

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ABSTRACT

Egg alternatives may replace egg as a functional ingredient in French vanilla ice cream due to their functional and dietary benefits. These egg alternative ingredients include modified corn starch (MCS), whey protein concentrate (WPC) and soy protein isolate (SPI). The objective of this study was to compare the physical and sensory properties of several commercially available egg alternatives in a vanilla ice cream formulation. The SPI exhibited a significantly lower L value compared with the other egg alternatives, whereas the control exhibited a significantly higher b value compared with the other treatments. The apparent viscosity value of MCS was approximately 10-fold greater than the other egg alternatives. There were no significant differences in appearance and mouth-feel among the control, MCS or WPC treatments, whereas SPI exhibited a significantly lower mouth-feel score compared with the other treatments. The control exhibited significantly higher flavor and acceptability scores compared with the other egg alternatives, whereas SPI treatment exhibited least desirable flavor and acceptability. Consumer panelists would purchase the control with the egg alternative formulations.

PRACTICAL APPLICATIONS

The egg alternatives were used to replace egg as a functional ingredient in French vanilla ice cream production. These alternatives can deliver functionality at a lower cost and can be incorporated to produce a suitable ice cream.

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KEYWORDS

Color analysis, egg alternatives, sensory, texture analysis, vanilla ice cream

INTRODUCTION

Ice cream is a high cost-value dairy product, with considerable costs related to ingredients and energy required for frozen storage, distribution and retail sale (Clarke 2004; Alvarez *et al.* 2005). Eggs are considered a high profile ingredient because of their high nutritional value and multi-functional properties (Arbuckle 1986). Eggs are among many ingredients used in the formulation of rich ice cream. Many ice cream makers use frozen egg solids because of the following beneficial effects: (1) firmer ice cream at a given drawing temperature; (2) increased whipping rate; (3) less change in percent overrun while unloading the freezer; (4) improved appearance while ice cream is melting; (5) slightly improved texture; and (6) increased food value (Frischknecht 1945; Masurovsky 1945; Marshall *et al.* 2003).

Egg yolk has been used as an emulsifier in traditional ice cream formulations. However, the use of egg yolk has given way in modern formulations to specific ingredients that deliver much greater functionality at a lower cost (Goff and Jordan 1989; Adapa *et al.* 2000; Barford 2001). For the reasons stated previously, food designers have aspired to develop ingredients that emulate eggs in frozen desserts. Additionally, the desire to replace eggs in food systems has been brought about by consumer trends toward low cholesterol foods, reduced allergens, lack of refrigeration requirements and fewer microbial concerns (Moonen and Bas 2004).

Several egg alternatives have been evaluated as emulsifying agents in oil-in-water emulsions. Fat (Euston 1997; Innocente *et al.* 1999), whey protein (Zayas 1997; Takeda *et al.*, 2001; Aryana *et al.* 2002), soy proteins (Aoki *et al.* 1980; Yao *et al.* 1990; Rir *et al.* 1994) and carbohydrates (Garti *et al.* 1997; Chouard 2004). Many ingredient manufacturers have challenged themselves to develop low-cost egg alternatives to be used in dairy-based desserts, i.e., ice cream.

With the advent of egg alternatives available, food manufacturers can be easily overwhelmed with choices. The literature is scarce in comparing eggs with the highly sought after low-cost replacers. The hypothesis of this study is that egg alternatives may replace egg as a functional ingredient in French vanilla ice cream. The objective of this study was to compare a number of egg alternatives that are advertised as replacers to eggs in French vanilla ice cream. Appearance and mouth-feel play a vital role in consumer acceptance of ice

cream. Therefore, physical and sensory analyses were performed to compare and evaluate the egg replacers with the egg-based control in French vanilla ice cream.

MATERIALS AND METHODS

Liquid egg yolks used for the control formulation were obtained from Ballas Egg Products Corp. (Zanesville, OH). The level of egg alternatives used to replace eggs were those suggested by the manufacturers. The egg alternatives used included Frigex, a modified corn starch (MCS) (National Starch and Chemical, Bridgewater, NJ), Eggstend 300, a whey protein concentrate (WPC) (Parmalat Ingredients, Ontario, Canada) and soy protein isolate (SPI) from Natural Products, Inc. (Grinnell, IA). The ingredients used in the ice cream formulations are presented in Table 1.

A 10-gallon batch of ice cream mix was prepared for each treatment. Three batches of ice cream were produced for each treatment. Each batch was pasteurized at 74C/30 min in a double-jacked steam kettle (Green MFG Co., Chicago, IL). The mix was cooled to 32C and homogenized (Creamery Pkg Manufacture, Chicago, IL) at 1500 psi. The homogenized mix was tempered for 24 h at 4C. Samples were collected for color and rheological analyses. After aging for 24 h, a Vogt instant freezer (VS-85 Cherry-Burrell Corp., Cedar Rapids, IA) was used to freeze the mixtures to -10C with a 100% overrun. The frozen ice cream was packaged into half-gallon, pint and 6-oz paperboard containers for sensory, texture and melt tests, respectively. Once packaged, the containers were immediately placed in a hardening room with circulating air at -22.2C.

Color Measurement

The samples of ice cream mix were measured with a Hunter Lab Miniscan MS/S 4000S Spectrocolorimeter (Hunter Lab Inc., Reston, VA) calibrated

TABLE 1.
FORMULATIONS OF ICE CREAM MIXES

Treatment	Cream	Milk	Sugar	Nonfat dry milk	Stabilizer	Egg yolk	Egg alternatives
Control	20	52	13.34	3	0.46	3.22	-
WPC	20	52	13.34	3	0.46	-	3.22
MCS	23	48	13.34	3.7	0.46	-	3.22
SPI	22	49.5	12.9	3.85	0.46	-	3.22

Values are in pounds (lb).

MCS, modified corn starch; WPC, whey protein concentrate; SPI, soy protein isolate.

with a white tile and light trap. The ice cream was measured according to the procedure described for translucent semi-solid foods (Hunter Associates Laboratory Inc., 2004). The sample was placed into a 6.25-cm glass sample cup with a 10-mm black ring and white ceramic disk. Values of lightness (L), redness (a) and yellowness (b) were determined using illuminant C and a 10° viewing angle. Hue angle was calculated with the formula $\tan^{-1}(b/a)$.

Viscosity Measurement

Apparent viscosity of the ice cream was determined using the Bohlin VOR rheometer (Bohlin Rheology, AB, Lund, Sweden). The ice cream mix samples were removed from refrigerated temperature (4C) and immediately placed in a concentric cylinder with a 5° cone angle. The gap between the cone and plate was set at 0.150 mm. The rheometer was cooled to 4C prior to viscosity analysis to simulate the refrigerator's temperature. Samples were removed from the refrigerator and allowed to relax in the cup for at least 5 min. The apparent viscosity was calculated within shear rates 0.925/s to 92.5/s. The apparent viscosity at a shear rate of 9.26/s was used for statistical analysis.

Melting Properties

The melting rate was determined over 60 min at 5 min intervals at 22C according to Prindiville *et al.* (1999). Approximately 80 g of ice cream was taken directly out of -18C frozen storage and placed on a number 7 mesh screen. The screen was placed on top of an analytical balance (0.0001 g) with a trapdoor. A 100-mL beaker was placed on the balance and below the mesh screen to collect and weigh the melting ice cream.

Texture Analysis

Ice cream hardness was determined using TA-XT2 Texture Analyzer (Texture Technologies, Scarsdale, NY) with a 5-cm flat blade attachment. Prior to penetrating the sample, the blade was cooled for 2 min at -18C . Ice cream samples were taken immediately from -18C storage to the Texture Analyzer platform. The pint container was sliced in half to obtain a smooth surface. The hardness values were taken in three different locations equally distanced from each other and away from the walls of the pint container. All three measurements were taken within 45 s. The following settings were used for measurements on the Texture Analyzer: test mode, compression; pretest speed, 2.0 mm/s; test speed, 1.0 mm/s; posttest speed, 2.0 mm/s; distance, 6 mm; trigger, auto at 20 g; acquisition rate, 200 pps.

Sensory Analysis

A consumer test with a total of 102 untrained panelists (72 female and 32 male), 18–80 years old, participated in a consumer study. Panelists were prescreened for potential food allergies and on the basis of having consumed ice cream.

Each panelist evaluated four samples of French vanilla ice cream at one session. One sample was the control in the study. Ice cream samples were removed from frozen storage (–18C) and immediately offered to panelists in odorless plastic cups coded by three-digit random numbers. Samples were served to panelists monadically. The order of serving was determined by random permutation. Questionnaires were provided with samples. The panelists were instructed to use unsalted crackers and distilled water to cleanse their palate before tasting the samples any time during the test as needed. The panelists evaluated the ice cream on a 9-point hedonic scale (Meilgaard *et al.* 1991) to determine degree of liking for the ice cream products (9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely). The samples were rated for appearance, texture/mouth-feel, flavor/taste and overall acceptability on the same scale. Analysis of variance (ANOVA) was used to determine the statistical significant difference between the ice cream samples.

Statistical Analysis

Treatments were compared after three replications for their physical and sensory characteristics following a one-way complete randomized design. The analysis of variance and means comparison were conducted by the general linear model and ANOVA procedures with Statistical Analysis System software (version 8.2, SAS Institute, Inc., Cary, NC). Comparisons among treatments were analyzed by using Fisher's least significant difference, with a significance level at $P < 0.05$.

RESULTS AND DISCUSSION

Color Measurement

The soy-based egg alternative exhibited a significantly lower whiteness value (L) compared with the other egg alternatives but was not significantly different from the control (Table 2). Dervisoglu *et al.* (2005) observed similar drop in whiteness values for ice cream fortified with soybean protein concentrates. The control was significantly higher in b value (yellowness) compared with the other treatments, probably due to the presence of egg yolk.

TABLE 2.
COMPARISON OF THE PHYSICAL CHARACTERISTICS FOR FRENCH VANILLA ICE
CREAM FORMULATED WITH EITHER EGG YOLK OR EGG ALTERNATIVES

Treatments	Color		Viscosity (mPa·s)	Hardness (gram – force)
	<i>L</i> *	<i>b</i> *		
Control	88.11 ± 0.18 ^{AB}	12.92 ± 0.10 ^A	58.33 ± 3.83 ^B	4,356.2 ± 1,027.49 ^B
MCS	88.61 ± 0.65 ^A	7.22 ± 0.89 ^C	852.5 ± 51.23 ^A	3,529.2 ± 819.22 ^B
WPC	88.55 ± 0.36 ^A	7.48 ± 0.69 ^C	69.83 ± 10.63 ^B	6,638.1 ± 1,665.04 ^A
SPI	88.01 ± 0.34 ^B	8.62 ± 0.18 ^B	54.17 ± 3.97 ^B	6,440.7 ± 1,936.51 ^A

Values are expressed as mean ± SD.

Means followed by the same letters in the same column are not significantly different ($P < 0.05$).

MCS, modified corn starch; WPC, whey protein concentrate; SPI, soy protein isolate.

Viscosity Measurements

MCS exhibited a significantly higher mix viscosity compared with all other treatments (Table 2). The apparent viscosity value was approximately 10-fold greater than the other treatments. Similar results are reported elsewhere. Schmidt *et al.* (1993) compared maltodextrin (N-Lite D) and whey (Simplese)-based fat mimicker effects on ice cream properties. The authors reported that addition of maltodextrin-based N-Lite D made the ice cream more viscous (fourfold) compared with whey-based Simplese and control. Ohmes *et al.* (1998) reported that the use of a whey-based fat replacer containing stabilizers increased the viscosity of the ice cream approximately 100-fold compared with other fat replacers and the control. Muse and Hartel (2004) determined that viscosity of ice cream increased with the addition of higher molecular weight polysaccharides compared with lower molecular weight ones. Complex polysaccharides are known to increase the viscosity of food systems (Whistler and BeMiller 1997).

Melting Properties

The control was the first treatment to exhibit drip loss, which occurred after 5 min (Fig. 1). The egg alternatives did not exhibit any drip loss until the 15-min measurement interval (Fig. 2). MCS and WPC substitutes exhibited a significantly lower drip loss after 60 min. Arbuckle (1950) reported that an increase in the viscosity of ice cream increased the resistance to melting and improved smoothness of ice cream body. An increase in viscosity associated with modified starch is reported in the present study. Fat destabilization is reported to have the largest effect on the melting rate of ice cream (Muse and Hartel 2004). Destabilized fat in ice cream takes the form of clumps of fat

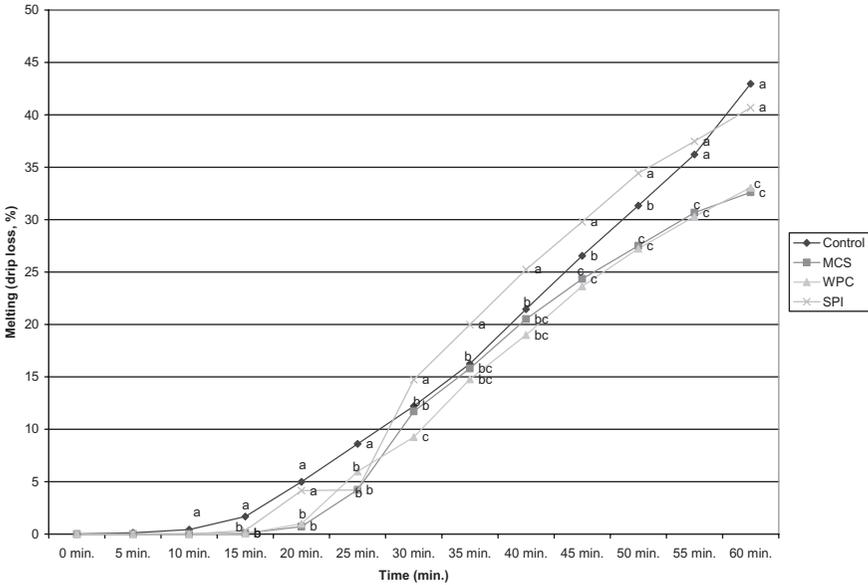


FIG. 1. COMPARISON OF THE PERCENT MELT FOR FRENCH VANILLA ICE CREAM FORMULATED WITH EGG YOLK OR EGG ALTERNATIVES FROM 0 TO 60 MIN MCS, modified corn starch; WPC, whey protein concentrate; SPI, soyprotein isolate. The different letters within each treatment suggest a significant difference at $P < 0.05$.

globules that coat and support the air cells and chains of fat globules that build a fat network in the ice cream (Marshall *et al.* 2003). Ice creams with lower levels of destabilized fat have faster melting rates and do not retain their shape well during melting (Muse and Hartel 2004). The fat network helps maintain the ice cream on the screen (Tharp *et al.* 1998). The authors attributed the fat destabilization to high viscosity and to types of ice cream components during freezing. The low drip loss associated with MCS and WPC may be explained by their respective composition. Ice creams made from MCS and WPC exhibited higher viscosities compared with those made from SPI and the control (Table 2). MCS and WPC may have contributed to the fat destabilization of ice cream to a greater extent.

Texture

WPC and SPI alternatives were significantly harder than the control and MCS treatments (Table 2). Even though starch-based substitutes exhibited higher viscosity, hardness was significantly lower compared with protein-based substitutes. Significantly greater hardness was obtained for WPC and

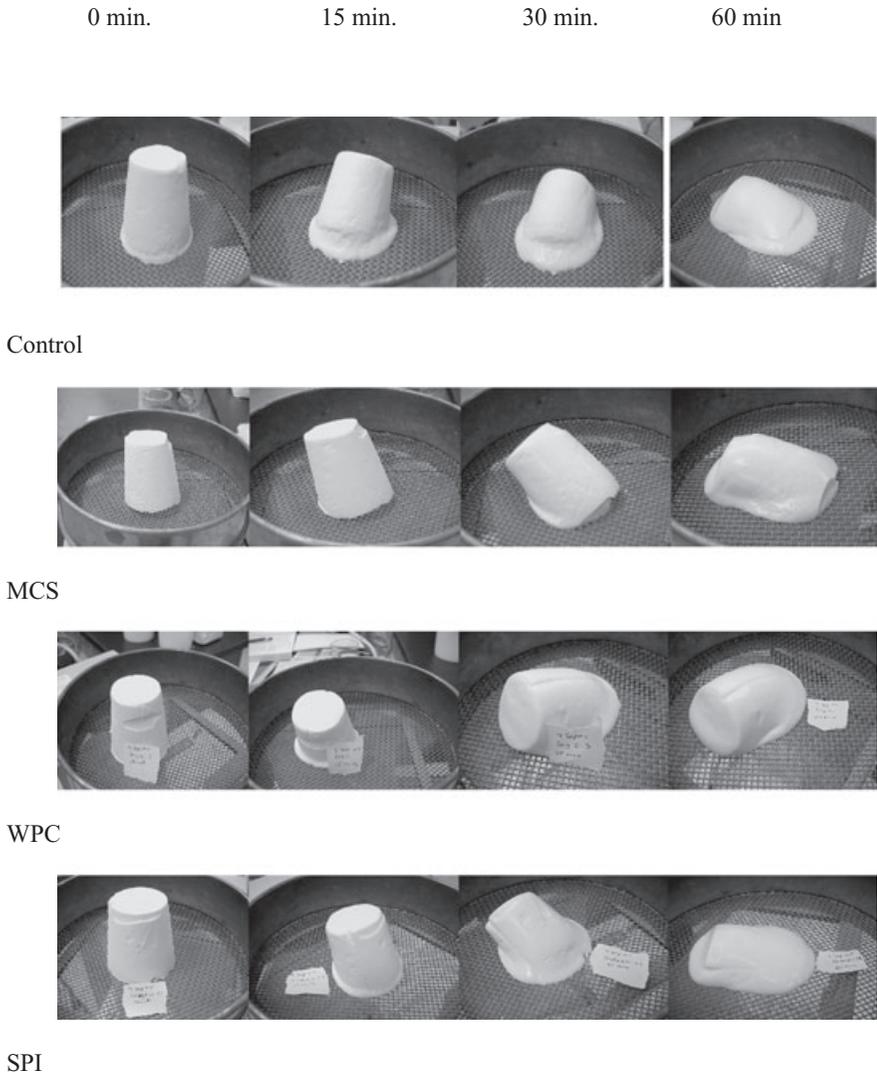


FIG. 2. REPRESENTATIVE IMAGE COMPARING THE MELTING PROPERTIES OF FRENCH VANILLA ICE CREAM FORMULATED WITH EITHER EGG YOLKS OR EGG ALTERNATIVES OVER 60 MIN AT ROOM TEMPERATURE
MCS, modified corn starch; WPC, whey protein concentrate; SPI, soy protein isolate.

TABLE 3.
CONSUMER SENSORY STUDY COMPARING ACCEPTABILITY ATTRIBUTES FOR FRENCH
VANILLA ICE CREAM FORMULATED WITH EGG YOLK AND EGG ALTERNATIVES

Treatments	Sensory attributes				
	Appearance	Texture/mouth-feel	Flavor/taste	Acceptability	Willing to purchase (%)
Control	7.12 ± 1.37 ^A	7.20 ± 1.42 ^A	7.44 ± 1.31 ^A	7.35 ± 1.28 ^A	81.7
MCS	7.15 ± 1.49 ^A	7.16 ± 1.68 ^A	6.91 ± 1.70 ^B	6.88 ± 1.73 ^B	68.4
WPC	6.82 ± 1.41 ^A	6.93 ± 1.42 ^A	6.92 ± 1.63 ^B	6.91 ± 1.44 ^{AB}	68.4
SPI	6.67 ± 1.34 ^B	6.32 ± 1.68 ^B	5.59 ± 2.10 ^C	5.91 ± 1.85 ^B	36.1

Values are expressed as mean ± SD following a hedonic scale of 1–9 (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely).

Means followed by the same letters in the same column are not significantly different ($P < 0.05$).

MCS, modified corn starch; WPC, whey protein concentrate; SPI, soy protein isolate.

SPI compared with the control and MCS. The difference may be related to the protein content and protein structure of these egg alternatives, which were whey and soy isolates, respectively. The proteins may have organized themselves into network structures. Hardness of ice cream is measured as the resistance to deformation when an external force is applied, and it is affected by the overrun, ice crystal size, ice phase, ice volume and extent of fat destabilization (Muse and Hartel 2004). Also, fat replacers were found to reduce ice cream hardness compared with full-fat ice creams (Prindiville *et al.* 1999; Roland *et al.* 1999; Trgo 2003).

Sensory Analysis

The consumer panelists reported no significant differences in appearance among the control, MCS or WPC, whereas SPI alternative exhibited a significantly lower appearance score (Table 3). There were no significant differences in mouth-feel among the control, MCS or WPC. The SPI alternative exhibited a significantly lower mouth-feel score compared with the other treatments.

The control exhibited a significantly higher flavor score compared with the other treatments, whereas consumers scored SPI egg alternative treatment as the ice cream with the least desirable flavor. The control and WPC exhibited the highest acceptability scores, whereas consumer scored the SPI treatment as the ice cream that was given the lowest acceptability value. Eighty-one percent of the panelist would purchase the control compared with 36% for the SPI egg alternative ice cream. Roland *et al.* (1999) tested different fat replacers in ice cream formulation, including polydextrose, maltodextrin and milk protein concentrates. The authors reported that samples containing maltodextrin had

the greatest cream flavor and the best textural characteristics, prompting the panelists to score maltodextrin as the best overall single fat replacer in ice cream. Dervisoglu *et al.* (2005) tested three levels of soybean protein concentrate (1.5, 3.0 and 4.5%) in ice cream formulation. The authors reported that flavor scores of samples with 1.5% soy protein concentrate were similar to the control samples, whereas those formulated with 3.0 and 4.5% soybean protein concentrate rated inferior to the control for flavor and texture. The authors reported that panelists criticized these samples for having a strong soybean flavor. In the present study, substituting eggs with 3.5% SPI drastically reduced the sensory scores and the consumer's willingness to purchase such ice creams, although the consumer panel did not observe a significant difference in texture, appearance and acceptability.

CONCLUSIONS

MCS and WPC improved the melting characteristics of the ice cream compared with the control while providing comparable sensory traits. The data suggests that these alternatives may be incorporated to produce a suitable ice cream, although SPIs were found to be the least desirable egg alternatives studied in ice cream formulation. Even though the starch-based and dairy-based egg substitutes did exhibit competitive physical properties compared with the control, the whole-egg control had a substantially higher willingness-to-purchase percentage compared with the egg substitutes investigated.

REFERENCES

- ADAPA, S., DINGELDEIN, H., SCHMIDT, K.A. and HERALD, T.H. 2000. Rheological properties of ice cream mixes and frozen ice creams containing fat and fat replacers. *J. Dairy Sci.* 83, 2224–2229.
- ALVAREZ, V.B., WOLTERS, C.L., VODOVOTZ, Y. and JI, T. 2005. Physical properties of ice cream containing milk protein concentrates. *J. Dairy Sci.* 88, 862–871.
- AOKI, H., TANEYAMA, O. and INAMI, M. 1980. Emulsifying properties of soy protein: Characteristics of 7S and 11S proteins. *J. Food Sci.* 45, 534–535.
- ARBUCKLE, W.S. 1950. Emulsifiers in ice cream. *Ice Cream Trade J.* 46(10), 106, 114.
- ARBUCKLE, W.S. 1986. *Ice Cream*, The AVI Publishing Company, Inc, New York, NY.

- ARYANA, K.J., HAQUE, Z.Z. and GERARD, P.D. 2002. Influence of whey protein concentrate on the functionality of egg white and bovine serum albumin. *Int. J. Food Sci. Technol.* *37*, 643–652.
- BARFORD, N.M. 2001. The emulsifier effect. *Dairy Ind. Int.* *66*(1), 32–33.
- CHOUARD, G. 2004. More than gelling. Colloidal systems for permanent stabilization. *Food Market. Technol.* *18*, 15–18.
- CLARKE, C. 2004. *The Science of Ice Cream*, The Royal Society of Chemistry, Cambridge.
- DERVISOGLU, M., YAZICI, F. and AYEDEMIR, O. 2005. The effect of soy protein concentrate addition on the physical, chemical, and sensory properties of strawberry flavored ice cream. *Eur. Food Res. Technol.* *221*, 466–470.
- EUSTON, S.R. 1997. Emulsifiers in dairy products and dairy substitutes. In *Food Emulsifiers and their Applications* (G.L. Hassenheutl and R. Hartel, eds.) pp. 111–146, Chapman & Hall, New York, NY.
- FRISCHKNECT, C. 1945. Use of dried eggs in ice cream. *Ice Cream Rev.* *28*(10), 41, 58, 60.
- GARTI, N., ASERIN, A., STERNHEIN, B. and MADAR, Z. 1997. Fenugreek galactomannans as food emulsions. *LWT-Food Sci. Technol.* *30*, 305–311.
- GOFF, H.D. and JORDAN, W.K. 1989. Action of emulsifiers in promoting fat destabilization during the manufacture of ice cream. *J. Dairy Sci.* *72*, 18–29.
- INNOCENTE, N., CORRADINI, C., BLECKER, C. and PAQUOT, M. 1999. Emulsifying properties of the total fraction and the hydrophobic fraction of bovine milk proteose-peptone. *Int. Dairy J.* *8*, 981–985.
- MARSHALL, R., GOFF, H.D. and HARTEL, R.W. 2003. *Ice Cream*, Kluwer Academic Press, New York, NY.
- MASUROVSKY, B.I. 1945. Egg solids improve ice cream quality. *Ice Cream Trade J.* *41*(9), 56, 61.
- MEILGAARD, M., CIVILLE, G.V. and CARR, B.T. 1991. *Sensory Evaluation Techniques*, 2nd Ed., CRC Press, Boca Raton, FL.
- MOONEN, H. and BAS, H. 2004. *Emulsifiers in Food Technology*, Blackwell Publishing, Oxford.
- MUSE, M.R. and HARTEL, R.W. 2004. Ice cream structural elements that affect melting rate and hardness. *J. Dairy Sci.* *87*, 1–10.
- OHMES, R.L., MARSHALL, R.T. and HEYMANN, H. 1998. Sensory and physical properties of ice creams containing milk fat or fat replacers. *J. Dairy Sci.* *81*, 1222–1228.
- PRINDIVILLE, E.A., MARSHALL, R.T. and HEYMANN, H. 1999. Effect of milk fat on the sensory properties of chocolate ice cream. *J. Dairy Sci.* *82*, 1425–1432.

- RIR, L., FELDMAN, L., ASERIN, A. and GARTI, N. 1994. Surface properties and emulsification behavior of denatured soy protein. *J. Food Sci.* 59, 606–607.
- ROLAND, A.M., PHILLIPS, L.G. and BOOR, K.J. 1999. Effects of fat content on the sensory properties, melting, color, and hardness of ice cream. *J. Dairy Sci.* 82, 32–38.
- SCHMIDT, K., LUNDY, A., REYNOLDS, J. and YEE, L.N. 1993. Carbohydrate or protein based fat mimicker effects on ice milk properties. *J. Food Sci.* 58, 761–763, 779.
- TAKEDA, K., MATSUMURA, Y. and SHIMIZU, M. 2001. Emulsifying and surface properties of wheat gluten under acidic conditions. *J. Food Sci.* 66, 393–399.
- THARP, B.W., FORREST, B., SWAN, C., DUNNING, L. and HILMOE, M. 1998. Basic factors affecting ice cream meltdown. In *Ice Cream Proceedings of the International Symposium*, (International Dairy Federation, Brussels, ed.) pp. 54–64, Athens, Greece.
- TRGO, C. 2003. Texture in foods. In *Semi-Solid Foods*, Vol. 1 (B.M. McKenna, ed.), Woodhead Publishing Ltd., Cambridge.
- WHISTLER, R.L. and BEMILLER, J.N. 1997. *Carbohydrate Chemistry for Food Scientists*, American Association for Cereal Chemists, Inc., St. Paul, MN.
- YAO, J.J., TANTEERATARM, K. and WEI, S. 1990. Effects of maturation and storage on solubility, emulsion stability, and gelation properties of isolated soy proteins. *JAACS* 67, 974–979.
- ZAYAS, J.F. 1997. *Functionality of Proteins in Food*, Springer-Verlag, New York, NY.