CHARACTERISTICS OF FROZEN DESSERTS SWEETENED WITH FRUCTOSE AND LACTOSE

by

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ABSTRACT

The objective of this research was to utilize lactose and fructose as sweeteners and sodium caseinate and whey protein as a milk solids non-fat source. A 2^3 factorial design experiment was used to determine the most suitable combinations of lactose, fructose and sodium caseinate.

Based on physical, chemical and sensory evaluations, the lower percents lactose and caseinate frozen desserts were preferred to the higher levels. Evaluation of sensory panel test information by theory of signal detection and analysis of variance showed a preference for 2% caseinate when compared to 3% caseinate.

After three months of storage (-17.8 ± 1.1 C), lactose crystallization was detected in four frozen desserts. A number of factors other than lactose concentrations per se appeared to effect this phenomenon. Problems of off-flavors, coarse texture and sandiness can be corrected by refinements in formulations and processing procedures. The frozen desserts developed in this study met all requirements for the 1960 F.D.A. Standards of identity.

INTRODUCTION

The dairy industry is faced with increased whey processing and disposal costs. Consumers' interest in nutrition and caloric intake has shifted industry's objective toward formulation of products of decreased caloric value. There is considerable need for additional attention and effort in product development and improvement in the above context as applied to frozen dairy desserts. The use of cheese whey components such as lactose and whey protein can aid in the overall utilization of whey. At the same time, incorporation of the fruit sugar, fructose, can lower caloric value and not effect the overall sweetness of the product. Wider utilization of these materials in food formulations will benefit both the food industry and the consumer by lowering whey disposal costs and caloric value of the product.

The United States currently produces approximately eleven million tons of whey annually which contains 750,000 tons of milk solids (Arbuckle 1979). Approximately half of the whey produced is utilized for human food or animal feed. The remaining fifty percent becomes industrial waste requiring expensive disposal charges.

In these experimental frozen dessert formulations, the sweeteners used were lactose and fructose. The addition of lactose separately instead of as a part of more commonly-used fluid milk forms, dried or liquid whey, cream and non-fat dry milk (NFDM), permitted the precise control of lactose levels.

Crystallization is an important problem to consider in ice cream formulations. Lactose levels must be limited due to its low solubility characteristics at low temperatures. Fructose was used as a sweetener due to its high relative sweetness. Fructose aids in weight control and has favorable metabolic effects for diabetics. Cane or beet sugar (sucrose) is believed to increase blood glucose levels--thereby initiating an insulin reaction. The insulin response tends to reduce sugar below normal levels and, in turn, to cause low blood sugar followed by a hunger reaction.

The use of sodium caseinate and whey protein concentrate (WPC) eliminated the need for NFDM, caseinates, WPC and NFDM have similar functional properties. It was expected that the replacement of NFDM with other dairy components would contribute to product acceptability in the case of consumers who have a growing concern and knowledge about the origin and properties of food ingredients. Possible shortages of or higher costs for NFDM make combinations using WPC and caseinates of increased interest.

All of the ingredients used in this study are of natural origin and should be readily accepted by consumers who are aware of such connotations. The use of lactose and WPC may also aid in by product utilization together with reduced food waste. Caseinate was used because of its favorable functional properties. Fructose, with its high sweetening power and metabolic advantages, is an acceptable sugar for use in frozen desserts.

REVIEW OF LITERATURE

The major solids constitutents in a typical ice cream mix are milkfat, sugar, and milk solids non-fat (MSNF). A common ice cream formulation contains 15% sugar, 11% MSNF, 10% milkfat and .3% stabilizer/emulsifier (Arbuckle 1979). The most typical sweetening agent used in the basic formulation is sucrose. Sucrose is used because it is relatively inexpensive, has a suitable relative sweetness and imparts desirable freezing point depression characteristics. A common MSNF source is NFDM. NFDM is used primarily to enhance air incorporation properties and impart desirable body/texture characteristics. When considering ice cream formulations, consideration must be given to the following properties: flavor, body/texture, viscosity, freezing point, and air incorporation. Sucrose was replaced in this work with sufficient amounts of fructose and lactose to give sweetness equivalent to 15% sucrose. NFDM was replaced with combinations of sodium caseinate and WPC to provide for desired air incorporation and structural properties.

The Food and Drug Administration (FDA) Standards of the United States define plain ice cream as a frozen dessert which must contain not less than 20% total milk solids and 10% milkfat. Ice cream must weigh not less than 4.5 pounds per gallon and contain not less than 1.6 pounds of food solids. Maximum stabilizer allowed is .5% (FDA

1978). Currently, ice cream manufacturers use combinations of sucrose and corn syrup solids as sweetening agents. High fructose corn syrup (HFCS) contains about 42% fructose and is a widely used form of fructose (Waldrip 1975). The use of pure fructose has been limited as a sweetening component in frozen desserts due to its relatively high cost. Fructose or levulose is widely distributed in nature and is found in many species or varieties of fruits. Fructose has the same molecular weight as dextrose ($C_6H_{12}O_6$). Fructose has a greater effect on freezing point depression as compared to sucrose because of its lower molecular weight. This carbohydrate is also a keto-structured monosaccharide and is a reducing sugar. Fructose solutions exhibit high osmotic pressure and fermentability with low viscosity properties (Waldrip 1975).

Foods sweetened with fructose rather than starch/saccharin combinations showed markedly reduced hypoglycemia properties in human tests (Doty and Vanninen 1975).

Pure fructose is available in powdered or aqueous solutions. Its melting point is 102-104 C and it is the most water soluble of all sugars. Viscosity of fructose solutions is relatively lower than that of comparable sucrose solutions. Fructose can form pleasant aromatic combinations with amino-groups of proteins. Under conditions of high temperatures and low pH, fructose solutions may result in discoloration or off flavors due to the formation of hydroxymethylfurnal or other difructose structures (Doty and Vanninen 1975). For this reason, heat treatments involved in high temperature-short-time (HTST) pasteurization might involve complications in the use of fructose for ice cream formulations.

Bates et al. (1972) suggests that fructose can form metal chelates over a wide pH range. The treatment of iron deficiency is a situation where the formulation of fructose/iron chelates are a possible advantage. The relative sweetness of fructose is 174 compared to 100 for sucrose (Schallenberger 1963). The relative sweetness of fructose is affected by temperature, pH and concentration. Sweetness intensity is decreased as acidity, concentration and temperature are increased. Fructose has great potential for reducing the caloric value of sweetened foods without affecting overall sweetness. Moderate amounts of fructose have been ingested by diabetics without causing negative effects on the control of that metabolic disease (Doty and Vanninen 1975).

The other sugar of interest in this work is the dissaccharide lactose which contains the monosaccharides glucose and galactose. This sugar shows great potential in the food industry because of its low relative sweetness value of 16 and comparative cost. High concentrations may be used in certain formulations without creating excessive sweetness. In frozen desserts, this low relative sweetness is not generally considered a major factor in overall sweetness. Unlike fructose, lactose shows a higher relative sweetness at higher concentrations (Nickerson 1978).

Sweeteners such as lactose can increase viscosity or improve texture as a result of increased total solids. Dried sweet whey has been added to frozen desserts at a substitution rate of 25% of serum solids without altering the acceptability of ice cream (Guy et al. 1974).

The low solubility of lactose (20g/100g water at room temperature) can cause crystallization problems. A texture characteristic occurs with this situation which gives an impression of sand in the oral cavity. This defect is caused by lactose crystallization (LC). Crystallization is a condition where insufficient water is available under low temperature conditions to hold the poorly soluble lactose in solution. When the size of the crystals approaches 30 microns, the product begins to appear mealy or sandy. Crystallization can be controlled by reduced concentrations of lactose, proper selection of stabilizers or enzymatic hydrolysis. Either enzymatic or acid hydrolysis produces the monosaccharides glucose and galactose and gives increased relative sweetness and solubility (Nickerson 1978).

Commercial lactose is the <u>alpha</u>-lactose monohydrate or <u>alpha</u>-hydrate (m.p. 201.6 C). The other form of lactose is <u>beta</u>-lactose (252.2 C). Lactose is found in dairy products in either of two crystalline forms; namely anhydrous <u>beta</u>- and <u>alpha</u>-hydrate or as a mixture of <u>alpha</u> and <u>beta</u> lactose (Nickerson 1974).

Mutarotation of lactose is related to LC, due to the fact the molecule exhibits isomerization which may affect both lactose crystal formation and growth rate (Haase and Nickerson 1966). The crystallization of lactose is influenced partly by the simultaneous mutarotation of beta to alpha-lactose. Mutarotation of lactose is influenced by numerous factors. It is accelerated by pH and temperature fluctuations. Alcohols and acetone retard mutarotation (Patel and Nickerson 1970). The rate of mutarotation can also be effected by salts and sugar (Nickerson 1974).

The sandy texture in ice cream is caused by the formation of alpha-lactose crystals. LC in ice cream is complicated because of the ability of lactose to exist in one or more forms. The alpha-beta- forms are in equilibrium in an unsaturated aqueous solution. At 0 C, the equilibriated solution contains 37.55% alpha-lactose and 62.25% beta-lactose (Eq. constant 1.63) (Whitaker 1933).

The most common forms of alpha-hydrate crystals are prismatic and tomahawk shapes. The crystals have irregularly shaped forms, compared to those from normal lactose solutions. There are three degrees of lactose supersaturation in ice cream: metastable, labile and glassis (Whitaker 1933).

Thurby and Sitna (1976) have shown that LC increases when the temperature was raised in the range of 15-50 C.

In dairy products, LC is more complex due to the presence of other solutes. There is evidence to show that solutes inhibit the formulation of nuclei and retard LC (Nickerson 1974).

Gelatin is a good example of a crystallization inhibitor. In supersaturated lactose solutions, the use of gelatin only is ineffective in reducing nucleation. Marine and vegetable gums are widely used in the ice cream formulations because of their ability to suppress sandiness. Corn syrup solids do not slow the rate of lactose crystal formation as previously believed. Mono- and diglycerides have satisfactory results in retarding LC in ice cream (Nickerson 1962).

Fluctuations in storage temperature have been recognized as a factor of LC. It is well-established that a high storage temperature causes crystallization to continue rapidly and that a low temperature slows the rate of LC. Nickerson (1956) also found that LC is retarded in normal ice cream when stored at -17 C due to the scarcity of lactose crystal nuclei. Seeding of either partially hardened ice cream or mix prior to freezing, resulted in an increase of the formulation of beta- to alpha-lactose. Lactose crystal nuclei did not increase LC at -12 C. The influence of temperature at -23 C was more important than crystal nuclei. Seeding of ice cream mixes affects LC but not to the same degree as temperature fluctuations.

The use of continuous freezers has assisted in the prevention of sandiness because lower temperatures are achieved more rapidly (Peeples 1965).

LC conditions in ice cream are a result of: temperature variation during handling and storage, improper use of stabilizer, too high storage temperatures and addition of fruits and nuts which have not been properly processed with a hydrocolloid such as gelatin to inhibit their nucleation attraction for lactose crystals (Peeples 1965).

Albrecht and Gracy (1956) have shown that ice cream mixes containing 17% SNF and 12% milkfat exhibited lactose crystallization. Ice cream formulations which contained 17% hydrolyzed SNF showed characteristics of excessive sweetness.

Freezing point-depression must be considered when formulating ice cream mixes. Sugars have the greatest effect on freezing point depression (Arbuckle 1977). Moroz and Troy (1977) found fructose to have a freezing point depression twice that of sucrose. Lactose has a freezing point depression similar to sucrose. Keeney and Kroger (1974) state that proteins, fat and colloids generally have a negligible effect on the freezing point of water. Generally, the higher molecular weight material exhibits the lower freezing point depression.

Replacement of NFDM with sodium or calcium caseinate and WPC is a possible alternative in ice-cream-type products. The caseinates and WPC are nutritionally complete and are a good source of essential amino acids. Both exhibit protein efficiency ratios of 2.5 or above. High quality caseinates have a bland flavor and possess excellent water binding, whipping ability and emulsion stabilizing capabilities. Sodium caseinate disperses easily in water. With the addition of slight amounts of lactose, a WPC and caseinate combination is considered an excellent alternative for NFDM (Craig 1975).

Sodium caseinate is a product made by the precipitation of casein from skim milk with dilute hydrochloric acid at a pH of 4.6-4.7. Casein belongs to the group of phosphoproteins, due to the presence of the phosphorus group attached to the amino acids threonine and serine (Nielson 1968).

Ice cream shrinkage is due to more than air cell collapse. The air cell structure is based mainly on protein material. Proteins appear to undergo a change similar to syneresis which can cause air cell collapse and shrinkage. Factors such as proper acidity and salt imbalance, especially sodium ions, appear to stabilize proteins. Over a period of time, even at low temperatures, a slight amount of proteolysis can produce shrinkage. Bacteria can produce products that are capable of destabilizing the protein structure which in turn can cause shrinkage (Nickerson and Tarssuk 1955). Milk protein properties, therefore, are the major factor affecting the stability of the ice cream structure.

WPC production is continuing at a rapid rate. WPC is essentially free of off odors and flavors and has excellent functional properties (Gillies 1974). The functional properties of WPC tend to vary because various processing methods tend to affect certain protein characteristics. Processing variations cause differences in the removal of non-protein components, such as lactose and salts (Morr, Swenson, and Richter 1973). Whey proteins impart good foaming properties but do not function as well as the caseinates in this regard.

A number of conditions can suppress whey protein's foaming properties such as pH, calcium, phospholipids, enzymatic hydrolysis and heat denaturation. Emulsion properties of WPC are inferior to those of casein. This may be caused by an imbalance of exposed hydrophilic and hydrophobic groups, similar to the situation in poor foaming properties (Morr 1975). Ice cream mixes containing whey protein had the greatest resistance to heat shocking (Hansen 1979). Heat denatured whey protein globulin had a preventative effect against shrinkage (Nickerson and Tarssuk 1955).

Ice cream mix is basically an oil-in-water emulsion. The continuous phase is an aqueous serum consisting of sugars, serum proteins, mineral salts and calcium caseinate-calcium phosphate micelles (Keeney and Kroger 1974).

The use of preference testing is a very important test in product development and as a tool for predicting a product's ability to survive competition in the market place (Ellis 1969). The theory of signal detection (TSD), for example is a method of differentiating an observer's sensory judgement criteria from his ability to perceive differences in stimuli (Angus and Daniel 1974). Stull et al. (1974) have applied TSD in food product development evaluation by defining and distinguishing rich flavor in ice cream. Young (1978) used TSD in evaluating an ice cream-type frozen dessert made with neutralized, hydrolyzed, fluid cottage cheese whey.

MATERIAL AND METHODS

This research was conducted in The University of Arizona pilot food processing plant. Equipment similar to commercial items was used in every part of the study.

Preparation of Mixes

The experiment was based on a 2^3 factorial design. The control ice cream (Sample No. 9) was based on the use of NFDM and cream as sources of total milk solids. Sucrose was the sweetening agent. All eight experimental ice creams were based on the same percentage formulations, except for different concentrations of three ingredients (Table 1).

Each batch weighed 92 lbs (10 gal). The control had the following formula: 10% fat, 11% MSNF, 15% sucrose, and .33% stablizer/emulsifier. Each experimental mix was formulated to contain 5% corn syrup solids (24 D.E.), and 3.8% WPC. The remaining ingredients (lactose, fructose and sodium caseinate) varied in concentration. The ingredients used in the mixes were: frozen cream (41.2% fat); granulated sugar (California and Hawaiian Sugar Co. San Francisco); corn syrup solids (24 D.E., Hubinger Co.); Low heat, Grade A nonfat dry milk, lactose, WPC (United Dairymen of Arizona, Tempe, AZ); sodium caseinate (Western Dairy Products, Petaluma, Calif); and stablizer/emulsifier (Ultra-Hi, Germantown Manufacturing Co., Broomal, Penn.).

Table 1. Frozen Dessert Formulation
(Constituent %)

Sample	WPC	Caseinate	CSS	Lactose	Fructose	Sucrose	NFDM	S/E	T.S.
A	3.8	2	5	4.5	8.5	--	--	.43	36.34
B	3.8	2	5	4.5	7.5	--	--	.43	35.06
C	3.8	2	5	5.5	8.5	--	--	.43	36.42
D	3.8	2	5	5.5	7.5	--	--	.43	37.42
E	3.8	3	5	4.5	8.5	--	--	.43	34.85
F	3.8	3	5	4.5	7.5	--	--	.43	34.96
G	3.8	3	5	5.5	8.5	--	--	.43	37.87
H	3.8	3	5	5.5	7.5	--	--	.43	38.04
I (Control)	--	--	--	--	--	15	11	.33	38.86

The stabilizer and emulsifier contained carrageenan, guar gum, cellulose gum, locust gum, polysorbate 80 and diglycerides.

Frozen cream was thawed overnight at room temperature and tested for percent fat and rancidity. A reconstitution funnel with a one horsepower sanitary milk pump was used to insure that all ingredients were mixed properly before pasteurization and homogenization. The ingredients were added slowly and in the following order: water, stabilizer/emulsifier, sugars, other solids and cream. The cream was added last to avoid excess foaming due to WPC and caseinate.

In preparation for homogenation, the mix was transferred to a 10 gal, stainless steel milk can and heated to 71.1 C in a starter-sterilizer tank. The mix was homogenized at 71.1 C with a Manton-Gaulin, double stage homogenizer (2000 and 500/lb./sq. in. pressure).

Due to the small volume in each batch, the HTST pasteurization method was not used. The mix was pasteurized by the batch method (79.4 C--15 sec) using a 10-gal milk can in a starter sterilizer water bath.

The mix was cooled by using a modified Cherry-Burrel continuous freezer (85 gal/hr capacity) with only the mix pump operating, no air control valve and with ammonia refrigerant. When the mix reached a temperature of 10 C, it was transferred to a walk-in cooler (1 ± 1 C) and stored less than one week before freezing.

Ice Cream Freezing

The premeasured coloring and flavoring ingredients were added to each mix before freezing in accordance with manufacturer's instructions. The coloring used was annatto cheese color (Hansens Standard of World Cheese Color, Chr. Hansen's Laboratory, Inc., Milwaukee, Wisconsin). A pure, two-fold vanilla flavoring (Consolidated Vanilla Extract, Consolidated Flavor Corp., Brideton, Missouri) was used.

The mix was frozen with a commercial Cherry-Burrel continuous freezer (85 gal/hr capacity) using ammonia as the coolant.

The percent overrun was calculated for each mix by the method described in Arbuckle (1977).

The temperature was recorded as the frozen dessert was drawn from the continuous freezer. When the ice cream reached the proper overrun and temperature it was packaged into either gallon or half gallon paper containers or prelabeled, lidded 3.5-oz plastic cups (Sweet Cup Corp., Chicago, Illinois). The packaged frozen desserts were then transferred to a hardening room at -37 C. After two weeks in the hardening room, some samples were transferred to a commercial storage freezer (-17.8 ± 1.1 C) for various experimental observations.

Sensory Evaluation

Panel and Test Procedure

An untrained panel of eighteen University of Arizona faculty, staff, and graduate and undergraduate students evaluated the acceptability of a frozen dessert using the TSD method (Stull et al. 1974 and

Young 1978). The panel consisted of approximately equal numbers of males and females with an age range of 18-55. The panelists were not familiar with the variables used in the ice creams. The nine ice creams were evaluated using a 10-point (9 to 0) hedonic rating scale (Figure 1).

The panelists evaluated the samples between 10-12 am on three consecutive days. The subjects tasted nine randomly ordered and 3-digit-numbered samples each day.

At each testing session, the panelists were seated at individual booths containing a sample, score sheet, pencil, spoon, glass of water, napkin, stainless steel rinse container and a recording form for scoring (Figure 2). At each session, the panel was given instructions and general information about the test without mentioning specific ingredient variations.

The samples were tempered at -17.8 ± 1.1 C for twenty-four hours before serving. The proctors presented the nine samples at about one minute intervals and communication between panelists was prohibited.

The data from panel testing was coded for computer analysis.

The other sensory evaluation method used in this experiement was a consumer preference test. A 25 gal batch each of control and experimental formulations were processed using almost identical procedures and materials as in the samples for the TSD test (Table 2). The only change made during processing was the use of a 50 gal vat for

Observation #_______________

RATINGS SCORE SHEET

SAMPLE NO.									
PREFERENCE RATING									

Panelist Name______________________ Date___________

Figure 1. Score Sheet Used by Panelists in the Rating Procedure. -- Observation Number, Sample, Number, and Date were all Pre-Coded.

PREFERENCE RATINGS

9 -- Like

8 --

7 --

6 --

5 --

4 --

3 --

2 --

1 --

0 -- Do Not Like

Figure 2. Rating Guidelines Used by Panelists in Scoring Ice Creams. -- These guidelines were Posted in Each Booth.

Table 2. Formulas for Experimental and Control Mixes in lb per 92-lb Batch, and in Percent by Weight of Total Composition.

Ingredient	(lb)	(%)
Experimental Formula--C		
Lactose	5.06	5.5
Fructose	7.82	8.5
CSS 24 D.E.	4.60	5.0
Cream (41.2% fat, 5.6% MSNF)	22.45	24.4
Whey Protein	3.50	3.8
Sodium Caseinate	1.84	2.0
Stabilizer/Emulsifier	.40	.43
Water	46.33	50.37
Total Solids	(33.66)	(36.54)
	92.00	100.0
Control--I		
Sucrose	13.80	15
Cream	22.45	24.4
NFDM	10.12	11
Stabilizer/Emulsifier	.30	.33
Water	45.33	49.27
Total Solids	(34.66)	(37.64)
	92.00	100.0

pasteurization instead of a 10-gal stainless steel can. About two thousand 3.5 oz plastic cups were filled per batch.

The consumer evaluation was conducted in an enclosed, air conditioned shopping mall in Tucson, Arizona. The preference test was assembled among many displays at the 1980 Arizona Food Fair, a community nutrition information program.

Panel members were shoppers and persons attending the Food Fair. The panelists were instructed as to the purpose of the test by a sign which read: "University of Arizona Nutrition and Food Science Department; Frozen Dairy Dessert Taste Test; Taste two vanilla ice creams made with different recipes."

The samples were transferred from the university hardening room to the shopping mall using cardboard boxes and ice chests. The sample cups were kept in a portable freezer (-14 ± 6.7 C) until served.

Most of the panels were adults. Roughly one thousand pairs of ice cream samples were evaluated in less than three hours. The preference test was conducted during two consecutive weekdays. Each panelist was given an information and explanation sheet (Figure 3) along with their samples.

Chemical and Physical Tests

Tests on Ingredients and Mixes

Viscosity. A Brookfield model RVT Synchro-Lectric viscometer was used to measure viscosities of the mix. The rpm was set at five

ICE CREAM PREFERENCE TEST

Please circle the symbol which corresponds to the ice cream you like best.

\# Δ

Comments:

A

ICE CREAM PREFERENCE TEST

One of the desserts you have tasted is made from a common recipe. The other sample is made by using an experimental recipe developed in the Food Science program at The University of Arizona. It contains approved nutritive sweeteners not normally used in ice creams.

It is expected that the results of this research will be included in material submitted to a technical journal for publication consideration. Thank you for participating in this test.

B

Figure 3. Information and Explanation Sheets

and the spinner at four. These settings gave a factor of 400 that was applied to a formula and calculated. The final reading was taken after one minute.

pH. The pH of the mix was measured by a Fisher model 220 pH meter with combination electrode. A standard buffer solution (ph 7.0) was used after the instrument was standardized at room temperature. The measurement of pH was made within a 48 hour period after processing.

Fat. The percent fat of the cream was measured by the modified Babcock method for ice cream described by Arbuckle (1977, pp. 364-365).

Finished Ice Cream Tests

Fats and Solids. Fat and total solids were determined by the Mojonnier method described by Arbuckle (1977, pp. 367-369).

Protein. The percent protein was measured by the Kjeldahl (American Association of Official Analytical Chemists, 1975 sec. 16.253) and formol titration methods (Hill and Stone 1964).

Meltdown. Volume of meltdown was measured by a method described by Nickerson and Pangborn (1961). Meltdown was made at room temperature (23 C) and recorded at five minute intervals on duplicate samples (50 ± 6g). Graduated cylinders (100 ml) were placed under funnels and ¼-inch mesh wire screens. Uniformly scooped ice cream was placed on screens, and the volume of melted ice cream was evaluated every five minutes for 45 min.

Caloric value. Caloric value was determined on dehydrated samples by the use of an adiabatic oxygen bomb calorimeter (Parr Instrument Co., Moline, IL).

Scoring by Expert Panel. Four experienced judges evaluated half-gallon containers of the ice creams monthly. Scores of body, texture, and flavor were recorded utilizing the American Dairy Products Association guidelines (American Dairy Science Association, Champaign, Illinois). Other half gallon containers were examined at the same time for shrinkage. The samples evaluated for scoring and shrinkage were stored in a commercial type freezer at -17.8 ± 1.1 C.

RESULTS AND DISCUSSION

Chemical and Physical Analysis of Ice Cream

Data are reported regarding the properties and composition of ice cream mixes before and after freezing. Many of the government requirements outlined in the Ice cream Standards of Identity are based on mix properties which give importance to these analyses.

Basic Composition

Concentrations of total solids, protein, and fat are of interest with regard to these standards (Table 3).

Solids. Total solids were determined by the Mojonnier method. Solids-non-fat (SNF), which contain solids of non-milk origin (stabilizer-emulsifier, sugar, and corn sugar), were estimated by subtracting the percentage of non-milk solids in the mix from SNF. There is no single laboratory test available to differentiate the solids of milk ingredients (lactose, whey protein, sodium caseinate, protein, and minerals) from those of non-milk origin, therefore, the percent MSNF is an estimation. This calculation is used to check on the mix formulation in which 11% MSNF was desired (Table 3).

Protein. The experimental ice cream exhibited a higher protein level than the control, but the batches were all within the 2.7% minimum amount set in the standards of identity. The variance in percent protein for the experimental batches in this study was 10.05 to 12.66%, with

Table 3. Composition of Ice Cream Mixes

Mix	Fat (%)	Total Solids (%)	SNF[1] (%)	MSNF[2] (%)	Moisture (%)	Protein (%)	Caloric Value (Kcal/gram)	Viscosity (c.ps.)
A	10.39	36.34	25.95	7.52	63.66	10.32	5.29	200
B	8.48	35.06	26.58	9.15	64.94	10.19	5.27	130
C	8.09	36.42	28.33	8.90	63.58	10.10	5.40	140
D	9.53	37.47	27.94	9.51	62.53	10.04	5.38	120
E	9.32	34.85	25.53	7.10	65.15	11.85	5.37	160
F	9.85	35.86	26.01	8.58	64.14	12.66	5.42	120
G	10.87	37.87	27.00	7.57	62.13	10.94	5.28	220
H	10.78	38.04	27.26	8.83	61.96	12.19	5.43	190
I	9.40	38.83	29.46	14.13	61.17	10.75	5.08	100

1. SNF = (Percent Total Solids) - (Percent Fat).
2. MSNF = SNF - (sweeteners) - (S/E).

a mean of 11.0 (Table 3). The main protein contributors in the experimental mixes were whey protein (3.8%) and sodium caseinate (2-3%). The cream contained a calculated 0.5% protein. The common protein contributors in ice cream are fluid milk, cream, and NFDM.

Hansen (1979) stated that if the caseinate level is kept below 20% of the total protein, a high quality ice cream can be produced. In this study, caseinate levels ranged from 34 to 44% of the total protein. All eight experimental mixes contained relatively high levels of caseinate and yet had generally favorable quality.

Fat. The percent fat in the ice creams ranged from 8.09 to 10.87, probably because of small differences in weighing ingredients (Table 3).

Caloric value. The caloric value in the ice creams ranged from 5.27 to 5.43 Kcal/per gram on a dry weight basis. The relatively high values are mainly due to the 10% fat present in the ice cream (Table 4).

Shrinkage. Most of the experimental ice creams were subject to slight shrinkage (Table 4). The usual cause of shrinkage in the present study was weak body due to excessive overrun and partially destabilized protein.

The first sign of shrinkage was after nine weeks of storage at -17.8 ± 1.1 C (Samples B, E, F, G). All experimental batches contained the same amount of WPC. Denatured whey protein globulin is believed to inhibit shrinkage (Nickerson and Tarssuk 1955). The low shrinkage of all experimental ice creams appear to have been retarded by the presence of WPC. All ice creams exhibited relatively high percent overrun, which

Table 4. Expert Panel Criticisms in Flavor, Body and Texture and Shrinkage in Ice Cream Examined at Monthly Intervals for Three Months

Ice Cream	Flavor		Body and Texture		Color	Shrinkage	
	1 Week	5 Weeks	1 Week	5 Weeks		1 Week	5 Weeks
A	Sl. cooked	Sl. cooked	No criticism	Sl. coarse	No criticism	--	None
B	Sl. cooked	Sl. cooked	No criticism	Sl. coarse	No criticism	--	None
C	Sl. cooked	Sl. cooked	No criticism	Sl. coarse	No criticism	--	None
D	Sl. cooked	Sl. cooked	Sl. gummy	Sl. gummy Sl. sandy	No criticism	--	None
E	Sl. cooked	Sl. cooked	Sl. coarse	Sl. coarse	No criticism	--	None
F	Sl. cooked	Sl. cooked	No criticism	Sl. weak	No criticism	--	None
G	Sl. cooked	Sl. cooked	Sl. gummy	Sl. gummy	No criticism	--	None
H	Sl. cooked	Sl. cooked	Sl. gummy	Sl. gummy	No criticism	--	None
I	Sl. cooked	Sl. cooked	No criticism	No criticism	No criticism	--	None
	9 Weeks	13 Weeks	9 Weeks	13 Weeks		9 Weeks	13 Weeks
A	Sl. cooked	Sl. cooked	Sl. coarse sandy	Sl. coarse sandy	No criticism	None	Sl. edges None top
B	Sl. cooked	Sl. cooked	Sl. coarse	Sl. coarse Sl. gummy	No criticism	None edges 1 mm top	None edges 1 mm top

Table 4. Continued

Ice Cream	Flavor		Body and Texture		Color	Shrinkage	
	9 Weeks	13 Weeks	9 Weeks	13 Weeks		9 Weeks	13 Weeks
C	Sl. cooked	Sl. cooked	Sl. coarse Sl. sandy	Sl. coarse Sl. sandy	No criticism	None	None
D	Sl. cooked	Sl. cooked	Sl. coarse Sl. bland	Sl. coarse	No criticism	None	None
E	Sl. cooked	Sl. cooked	Sl. gummy	Sl. coarse Sl. gummy	No criticism	Sl. edges None top	Sl. edges None top
F	Sl. cooked	Sl. cooked	Sl. coarse	Sl. coarse	No criticism	1 mm edges None top	1 mm edges Sl. top
G	Sl. cooked	Sl. cooked	Sl. gummy Sl. sandy	Sl. gummy Sl. sandy	No criticism	Sl. edges None top	Sl. edges None top
H	Sl. cooked	Sl. cooked	Sl. sandy	Sl. coarse Sl. sandy	No criticism	None	1 mm edges 1 mm top
I	Sl. cooked	Sl. cooked carmelized	Sl. coarse weak body	Sl. coarse	No criticism	None	1 mm edges None top

can enhance shrinkage by weakening the air cell structure. The use of sodium caseinate did not appear to disrupt the salt balance but, if an imbalance of salt did occur, it was believed to be partially counteracted by denatured whey protein's stabilizing properties.

Viscosity. The eight experimental frozen desserts had slightly higher viscosities compared to the control. The calculated viscosity values ranged from 100 (Sample I) to 220 centipoises (Sample F) (Table 3).

The normal viscosity of ice cream mix can range from 50 to 300 centiposes (Arbuckle 1977). All of the mix viscosities were within this range.

Overrun. There were slight deviations from the desired overrun values. These ranged from 87 to 102% (Table 5).

Each experimental batch was weighed for calculating percent overrun. Due to differences in mix viscosities, the freezer air control valve was adjusted to give as close to 90% overrun as possible. Conditions that retard overrun are salts, fat content, increased amount of stabilizer, MSNF and poor homogenation.

This study examined the possibility of substituting WPC and sodium caseinate for NFDM or fluid milk in ice cream formulations. The only conventional source of MSNF was from cream. Sodium caseinate is not considered a contributing factor toward MSNF, until a 20% total milk solids (TMS) is achieved. This milk-derived product is not regarded by regulatory agencies as a dairy product, but as a food or chemical ingredient (Nielson 1968). WPC cannot exceed 25% of the total serum

Table 5. Freezing Properties and Computations Relating to Product and Food Solids Weight Per Gallon

Ice Cream	Temperature from Freezer (°C)	Overrun (%)	Wt/Gal Ice Cream (lb)	Wt/Gal Food Solids (lb)
A	-5.3	87	4.92	1.79
B	-5.0	100	4.60	1.61
C	-5.6	100	4.60	1.68
D	-5.6	90	4.84	1.81
E	-4.7	93	4.77	1.66
F	-5.6	102	4.55	1.63
G	-5.3	93	4.77	1.81
H	-5.0	92	4.79	1.82
I	-5.6	92	4.79	1.86

solids in ice cream. This limit is the same as for dried whey, which contains 70% lactose on a dry weight basis, whereas, WPC contains little or no lactose. WPC's strong influence on ease of air incorporation seemed to counteract possible whipping problems due to salt content in caseinate, increased use of stabilizer and use of frozen cream.

Meltdown. Melted ice cream should resemble the original mix with no curdiness, separation, or foaminess (Arbuckle 1977). Protein destabilization is usually the cause of whey leakage and curdy meltdown. This situation can be prevented by the use of proper stabilizers and adequate salt balance. Ice cream that melts slowly is usually an indication of overstabilization or high viscosity levels.

The meltdown appearance of the eight experimental ice creams were superior to the control (Table 6). Foaminess was present in all experimental and control batches. This situation may be due to over emulsification which imparts increased air incorporation (Arbuckle 1977).

Weight per Gallon. Presently, the requirements for ice cream specify minimum weight and food solids per gallon of ice cream of 4.5 and 1.6 lb/gal, respectively. Weight per gallon is related to air incorporation, meeting legal standards, and maintaining consistent quality and profits (Arbuckle 1977). All of the ice creams met the government standards for this criteria (Table 5).

Sensory Quality by Expert Panel and Storage Stability. Flavor, body/texture and color scores were evaluated by the use of The American Dairy Science Association Product Judging Scorecard (Table 7). Perfect

Table 6. Meltdown Characteristics of Ice Cream at Room Temperature (23 C)

Ice Cream	Volume of Melted Ice Cream in 5-Min Intervals (ml/50 ± 6g) 5	10	15	20	25	30	35	40	45	Meltdown Appearance
A	1	5	11	17	25	29	39	50	52	Very little whey-off foamy
B	1	3	7	15	25	35	44	49	52	uniform foamy
C	1	6	13	26	38	53	56	58	58	uniform foamy
D	1	3	8	15	24	33	48	55	61	fairly uniform foamy
E	1	3	8	15	25	32	40	41	47	uniform foamy
F	2	6	9	24	36	48	56	58	58	uniform foamy
G	--	2	8	14	26	40	45	48	50	uniform foamy
H	--	5	11	20	34	44	55	59	59	uniform sl. foamy
I	--	3	7	13	18	23	34	38	42	sl. whey-off foamy sl. curdy

Table 7. Flavor, Body and Texture, and Color as Scored at Monthly Intervals by Expert Panel

Ice Cream	Flavor Scores (Week after Freezing)				Body and Texture Scores (Week after Freezing)				Color Scores (All Evaluations)
	1	5	9	13	1	5	9	13	
A	8	9	9	9	5	4	2	1	5
B	9	9	9	9	5	4	4	4	5
C	9	9	9	9	5	4	2	2	5
D	9	9	9	9	4	3	4	4	5
E	8	9	9	9	4	4	4	4	5
F	9	9	9	9	5	4	4	4	5
G	8	9	9	9	3	3	3	2	5
H	8	8	9	9	4	3	2	2	5
I	9	9	8	8	5	5	3	4	5

scores were 10, 5, and 5 for flavor, body and texture and color, respecitvely. Meltdown of ice creams were checked after eight weeks of storage at -17.8 ± 1.1 C.

The most frequently encountered flavor defect was cooked, probably caused by the batch heat treatment procedure during pasteurization. A less prominent flavor defect was an after taste due to sodium caseinate.

The most prevalent body and texture defects were coarseness and gumminess in the first thirteen weeks of evaluation. The coarseness is due to ice crystal formation and gumminess to the stabilizer and emulsifier.

A moderate degree of sandiness occurred in samples A, C, G and H after nine weeks of storage (-17.8 ± 1.1 C). Lactose crystallization developed in 50% of the experimental ice creams. Lactose crystals were not detected in the control ice cream. Of the four ice creams that exhibited LC, three contained the higher levels of lactose and fructose (Samples A, C and G). The control formulation contained the same percent lactose as in the 5.5% lactose formulation. It is believed, that sucrose, which was the sweetening agent in the control, had an inhibitory effect on LC. The amount of sodium caseinate and stabilizer used in this study was believed to have little or no effect on LC. Sample A had the greatest degree of sandiness. This formulation contained the lower percent lactose and the higher percent fructose. It is a well established that high concentrations of lactose will cause LC, but this study showed fructose to also be a possible factor in lactose crystal formation.

Sensory Evaluation of Ice Creams by Untrained Panel

In the TSD evaluation, the experimental ice creams were compared to the control formulation. All the rating scores for each mix were computated to compare ice cream to the control. The distance metric (dm) is a measure of the degree of discrimination between the control and experimental batches (Angus and Daniel 1974; Stull et al. 1974; and Young 1978). All the dm values in this study were positive numbers, the higher the dm the greater the preference for that sample. A higher dm is an indication of the observer's ability to differentiate between the experimental and control sample (Young 1978).

The most acceptable ice cream according to the dm values, was sample C "(dm = 129)" which contained 5.5% lactose, 8.5% fructose and 2% sodium caseinate (Table 8). The use of TSD computations made it possible to differentiate between the effects of lactose, fructose and caseinate, and associate any of these with day, replication or observer interactions. A factorial design was used in this study to facilitate the statistical analysis.

At a 2% caseinate level (Figure 4) and with 8.5% fructose, increasing the percent lactose from 4.5 to 5.5 raised the degree of preference (Sample A vs. C). As noted previously, Sample C had the highest dm value of all the desserts. At the same caseinate level (2%) and 7.5% fructose, an opposite effect of increasing lactose from 4.5% to 5.5% was observed. In this case, the preference decreased at the higher lactose level (Sample B vs. D).

Table 8. Mean dm Ratings of Experimental Ice Creams

Caseinate (%)	Fructose (%)	Lactose % 4.5	Lactose % 5.5
		--Mean dm--	
2	7.5	103(B)*	89(D)
2	8.5	111(A)	129(C)
3	7.5	67(F)	68(H)
3	8.5	99(E)	65(G)

*Sample letters as shown in Table 3.

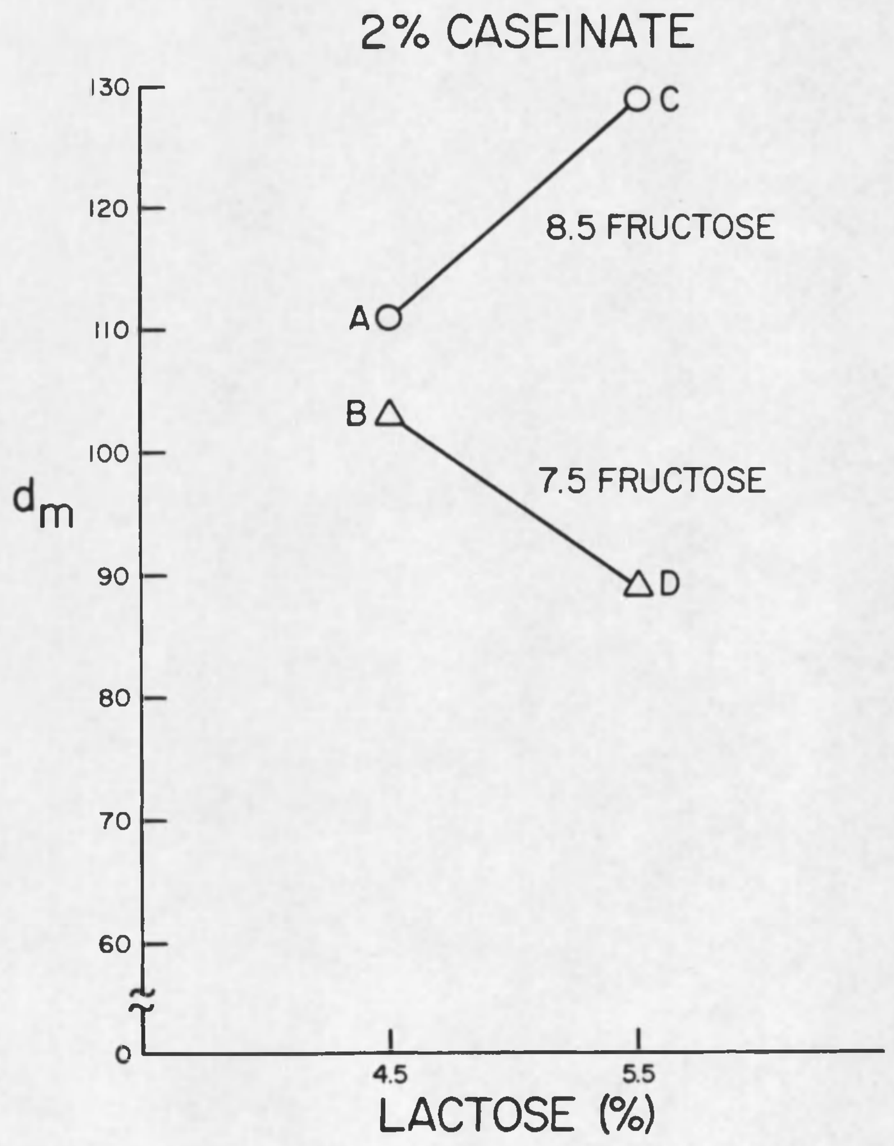

Figure 4. Mean Preference Ratings (in dm) for Ice Creams Related to Levels of Fructose and Lactose Containing 2% Caseinate

With 3% caseinate (Figure 5) and 8.5% fructose an effect is seen which is similar to that in the case of 2% caseinate and 7.5% fructose. Namely, an increase in lactose from 4.5% to 5.5% decreased the dm values (Sample E vs. H) with 3% caseinate and 7.5% fructose increasing lactose from 4.5% to 5.5% had no effect on preference (Sample F vs. G).

Formulations with higher caseinate levels (3% vs. 2%) gave lower dm values, while those with higher fructose levels (8.5% vs. 7.5%) tended to exhibit higher dm values.

The third day of TSD testing showed lower rating scores when compared to the previous two days. This situation was possibly due to the last day of testing occurring on Monday, which gave panelists a two day break from sample evaluation.

TSD is superior to the traditional methods of sensory evaluation because it enables one to interpret more information from the results. Traditional methods can only be evaluated by a calculated raw mean and standard deviation for each ice cream.

Consumer Preference Test Results

The number of persons preferring the experimental product (Sample C) was 355 while 586 indicated a preference for the control (Sample I). The significance of the results was judged by the use of a t-test (American Society for Testing Materials 1968). A t-value of .016 was calculated, which was not statistically significant.

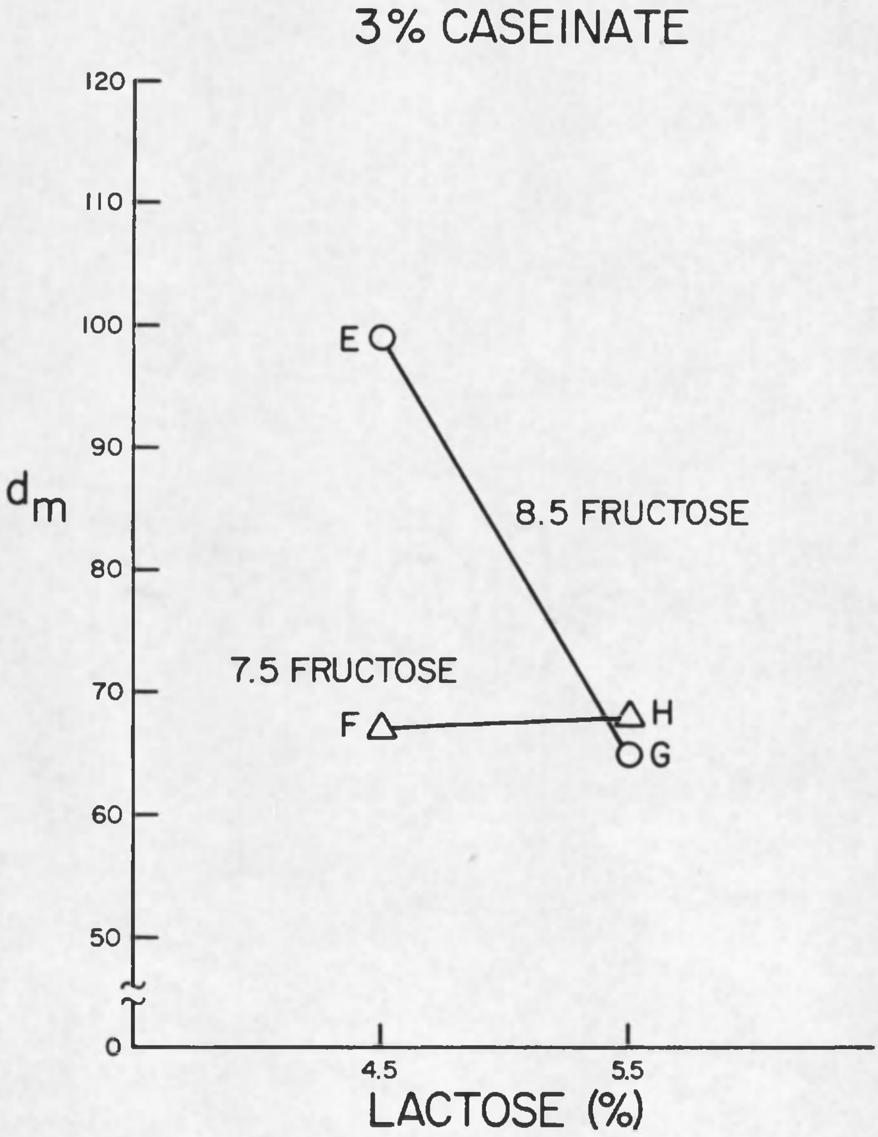

Figure 5. Mean Preference Ratings (in dm) for Ice Creams Related to Levels of Fructose and Lactose Containing 3% Caseinate

CONCLUSIONS

General Conclusions

The goal of this study was to develop and test the acceptability of ice cream-type frozen dairy desserts sweetened with lactose and fructose and utilizing sodium caseinate and whey protein as a MSNF source.

An evaluation of physical, chemical, and sensory data, indicates that the frozen desserts could be considered acceptable. Problems of lactose crystallization can be corrected by reducing percentages of lactose in the mix formulation.

Actual commercial utilization of the products developed in this study involves 1) proper control of crystallization problems; 2) modification of the regulatory status of sodium caseinate and whey protein and 3) considerations of ingredient cost.

Specific Conclusions

1. The experimental ice creams had no meltdown or shrinkage problems.
2. The gummy texture defect could probably be remedied by reducing the amount of stabilizer-emulsifier in the formulation.
3. Reliance on NFDM can be eliminated by a suitable lactose/WPC/caseinate combination.
4. Some of the experimental ice creams exhibited sandiness after three months storage in a commercial-type freezer (-17.8 ± 1.1 C).

5. The experimental desserts contained considerably higher protein than conventional ice cream.
6. The use of fructose and lactose as sweeteners were acceptable based on sensory data, when compared to the control.
7. Carmelized or cooked flavors might be corrected by using high-temperature-short time pasteurization.
8. Based on sensory data from TSD analysis and the consumer preference test, 3% or more sodium caseinate may effect overall acceptability.

LIST OF REFERENCES

Albrecht, T. W. and J. P. Gracy. 1956. Enzymatic Hydrolysis of Lactose to Control the "Sandiness" Defect in Ice Cream. Ice Cream Rev. 40:22.

American Association of Official Analytical Chemists. 1975. Official Methods of Analysis, 12th ed. AOAC, Washington, D.C.

American Society for Testing and Materials. 1968. Manual on Sensory Testing Methods. ASTM, Philadelphia.

Angus, R. C. and T. C. Daniel. 1974. Applying Theory of Signal Detection in Marketing: Product Development and Evaluation. Amer. J. Agric. Econ. 56:573.

Arbuckle, W. S. 1977. Ice Cream, 3rd ed. Avi Publ. Co., Westport, Connecticut.

Arbuckle, W. S. 1979. Whey Solids in Frozen Dessert Formulations. Amer. Dairy Rev. (12):502.

Bates, G.W., J. Boyer, J. C. Hegenauer, and P. Saltman. 1972. Facilitation of Iron Absorption by Ferric Fructose. Amer. J. Clin. Nutr. 25:983.

Craig, T. W. 1975. Food Ingredient Alternatives in Milk Substitutes. Amer. Dairy Rev. 37(2):41.

Doty, T. E. and E. Vanninen. 1975. Crystalline Fructose. Food Tech. 29(11):34.

Ellis, B. H. 1969. Acceptance and Consumer Preference Testing. J. Dairy Sci. 52:823.

Food and Drug Administration. 1960. Frozen Desserts; Definitions and Standards of Identity. Fed. Reg. 25 (145), July 27.

Food and Drug Administration. 1978. Requirements for Specific Standardized Frozen Desserts. Fed. Reg. 43 (4598) Feb. 3.

Gillies, M. T. 1974. Whey Processing and Utilization. Economic and Technical Aspects. Noyes Data Corp.

Guy, E. J., A. Tamsma, A. Kontson, and V. H. Holsinger. 1974. Lactase-Treated Milk Provides Base to Develop Products for Lactose-Intolerant Population. Food Prod. Dev. 8(8):50.

Haase, G. and T. A. Nickerson. 1966. Kinetic Reactions of Alpha and Beta Lactose. I. Mutarotation. J. Dairy Sci. 49:127.

Hansen, A. P. 1979. Using Whey in Ice Cream. Dairy Ice Cream Fld. (7):53.

Hill, R. J. and W. K. Stone. 1964. Procedure for Determination of Protein in Ice Milk or Ice Cream by Formol Titration. J. Dairy Sci. 47:1014.

Keeney, P. G. and M. Kroger. 1974. Frozen Desserts. In B. H. Webb, A. H. Johnson (eds.), Fundamentals of Dairy Chemistry, 2nd ed. Avi Publ. Co. Westport, Connecticut.

Moroz, R. and J. Troy. 1977. Status of Sweeteners for Soft Serve Products. Amer. Dairy Rev. 40(5):36R.

Morr, C. V. 1975. Chemistry of Milk Proteins in Food Processing. J. Dairy Sci. 58:977.

Morr, C. V., P. E. Swenson and R. I. Richter. 1973. Functional Properties of Whey Protein Concentrates. J. Fd. Sci. 38:324.

Nickerson, T. A. 1956. Lactose Crystallization in Ice Cream. II. Factors Affecting Rate and Quality. J. Dairy Sci. 39:1343.

Nickerson, T. A. 1962. Lactose Crystallization in Ice Cream. IV. Factors Responsible for Reduced Incidence of Sandiness. J. Dairy Sci. 45:354.

Nickerson, T. A. 1974. Lactose. In B. H. Webb, A. H. Johnson (eds.), Fundamentals of Dairy Chemistry, 2nd ed. Avi Publ. Co. Westport, Connecticut.

Nickerson, T. A. 1978. Why Use Lactose and its Derivatives in Food? Food Tech. 32(1):40.

Nickerson, T. A. and R. M. Pangborn. 1961. The Influence of Sugar in Ice Cream. III. The Effect on Physical Properties. Food Tech. 15:105.

Nickerson, T. A. and N. P. Tarssuk. 1955. How to Control Shrinkage in Ice Cream. J. Dairy Sci. 38:1305.

Nielson, V. H. 1968. What is Sodium Caseinate? Amer. Dairy Rev. 30(4): 61.

Patel, K. N. and T. A. Nickerson. 1970. Influence of Sucrose on Mutarotation Velocity of Lactose. J. Dairy Sci. 53:1654.

Peeples, M. L. 1965. Control Sandy Ice Cream. Amer. Dairy Rev. 27(12):1019.

Schallenberger, R. S. 1963. Hydrogen Bonding and the Varying Sweetness of Sugars. J. Fd. Sci. 28:584.

Stull, J. W., R. R. Taylor, R. C. Angus, and T. C. Daniel. 1974. Acceptability of a Whey-Based Quiescently Frozen Novelty. J. Food Protection. 40:158.

Thurby, J. A. and O. Sitna. 1976. Lactose crystallization: Investigation of Some Process Alternatives. J. Fd. Sci. 41:43.

Waldrip, E. K. 1975. High Fructose Corn Syrup. Amer. Dairy Rev. 37(6):18.

Whitaker, R. 1933. Some Factors Influencing the Crystallization in Ice Cream. J. Dairy Sci. 16:177.

Young, C. J. 1978. Neutralized, Hydrolyzed, Fluid Cottage Cheese Whey in Frozen Dairy Desserts. M.S. Thesis, University of Arizona, Tucson.

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