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Properties of Yogurt Ice Cream Mixes and Resulting Frozen Products Prepared by Various Ratios of Ice Cream Mix to Yogurt

Douglas W. Olson, Charles Boeneke, Kayanush J. Aryana*

School of Nutrition and Food Sciences, Louisiana State University Agricultural Center, Baton Rouge, LA, USA
Email: *KAryana@agcenter.lsu.edu

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Abstract

The effects of varying the ratio of ice cream mix to whole milk yogurt on the characteristics of the mixes and the resulting frozen products including their ice cream and frozen yogurt controls were investigated. Ratios of ice cream mix to yogurt included 100% yogurt for the frozen yogurt control, 25% ice cream mix and 75% yogurt, 50% ice cream mix and 50% yogurt, 75% ice cream mix and 25% yogurt, and 100% ice cream mix for the ice cream control. The resulting mixes were sampled for analysis of total solids content, fat content, pH, and viscosity and then frozen in a batch freezer. The frozen products were analyzed for MRS lactobacilli counts, rate of meltdown at 21˚C (volume after 1 h and time for 15 mL to melt), and sensory properties (flavor and body/texture). The total solids contents ranged from 11.89% to 39.65%, and the fat contents ranged from 2.8% to 12.6% for the 100% yogurt and 100% ice cream mixes, respectively. The pH ranged from 4.55 for the 100% yogurt to 6.77 for the 100% ice cream mix. The 100% yogurt sample had the highest viscosity. As expected, the 100% yogurt and the 75% yogurt samples had the highest MRS lactobacilli counts. The rate of meltdown increased with the increasing proportion of ice cream in the yogurt ice cream. The frozen products consisting of 75% and 100% ice cream received the highest flavor scores and body/texture scores. Yogurt ice cream made from 75% ice cream usually had more desirable meltability and sensory properties than yogurt ice creams made from either 25% or 50% ice cream and provides an opportunity for delivering a desirable product that has a healthy image.

Keywords

Yogurt, Ice Cream, Frozen Desserts, Lactobacilli, Sensory

1. Introduction

Yogurt consumption may provide many health benefits [1] justifying the healthy image of yogurt, and ice cream is a very popular dairy product. Mixing yogurt with ice cream to produce yogurt ice cream should provide an opportunity to improve the healthy image of ice cream and possibly lead to increased utilization of dairy products. Yogurt ice cream has been receiving much attention in Europe and Asia [2] [3] [4].

There are various ingredients and cultures that can be added to yogurt ice cream. Prebiotics such as fructooligosaccharide and chicory root extract and probiotics such as *Lactobacillus acidophilus* can be added to yogurt ice cream [5] [6] [7]. El-Nagar *et al.* [8] produced an acceptable reduced-fat yogurt ice cream by incorporating 5% inulin into the formulation. Otero *et al.* [9] reported that adding a 4% inoculum of 1:1 ratio of *L. acidophilus* and *Bifidobacteria bifidum* during manufacture of yogurt ice cream was adequate to reach levels greater than 10^5 cells per gram. Use of various sweeteners such as sucrose, honey, and stevia in yogurt ice cream has been studied [10]. Gums, including mastic gum, have been added to yogurt ice cream [11]. Various flavors of yogurt ice cream including chocolate, orange, blackberry, raspberry, black mulberry, and strawberry have been prepared [3] [12].

Westerbeek [13] described the procedure for manufacturing yogurt ice cream containing more than 70% yogurt as adding dry ingredients to cold yogurt, pasteurizing and homogenizing the resulting mix, cooling and ripening the mix, adding active cultures and possibly fruits, freezing and whipping within a continuous freezer, packaging and storage. Although the lactic acid bacteria are killed by pasteurization, lactic acid bacteria can be added to the mix immediately after the pasteurization and homogenization steps to obtain active cultures in the frozen product. Improper mix pasteurization and homogenization leads to a relatively low and variable overrun and likely shrinkage in the frozen product [13].

Various ratios of yogurt to ice cream mix have been reported in the literature. Westerbeek [13] claimed that only 5% to 30% of fresh yogurt was typically added to the ice cream mix by most producers in the US, leading to a pH of approximately 5.5 to 6.5 and to the absence of viable lactic acid bacteria after mix pasteurization. However, the required amount of yogurt to obtain a yogurt ice cream with adequate yogurt character is likely 40% to 50% [13]. In an early paper, Dulova [14] described yogurt ice cream as being made by mixing yogurt and ice cream mix in a 1:1 ratio before freezing in an ice cream freezer. Marshed *et al.* [15] reported that up to 50% of fresh milk can be substituted with ABT fermented milk and still obtain an acceptable quality product. Li [16] reported that the optimal formulation for yogurt ice cream as determined by a central composite design combined with response surface analysis was 51% yogurt, 10.8% cream, 15.6% sucrose, and 0.71% stabilizer. Singh *et al.* [4] used between 0% and 60% yogurt in their yogurt ice cream and found the highest overall acceptability scores for products containing 25% yogurt. The entire range of ratios from 0%

yogurt and 100% ice cream mix to 100% yogurt and 0% ice cream mix was used in the present study.

The properties of yogurt ice creams need to be compared to the properties of an ice cream control and a frozen yogurt control to determine which formulations that would lead to a desirable product. The objective of the present study was to compare the mix properties and the microbiological, melting, and sensory properties of yogurt ice creams containing various ratios of ice cream mix and yogurt to each other and to ice cream and frozen yogurt controls.

2. Material and Methods

2.1. Ice Cream Manufacture

Ice cream mixes were made in 7.57 L batches in 17 L stainless steel pails. The formulation is provided in Table 1. Whole milk, heavy whipping cream, instant nonfat dry milk, and sugar were purchased from a local grocery store. Stabilizer CC-452 (Continental Custom Ingredients, Inc., West Chicago, IL) was also used. The dry ingredients were weighed and mixed with the milk and cream mixture. The mixes were heated to 60˚C before homogenizing in a two stage Gaulin homogenizer (Manton-Gaulin Manufacturing Company, Inc., Everett, MA, USA) at 10.34 MPa first stage and 3.45 MPa second stage. Vat pasteurization was performed at 69˚C for 30 min. The mixes were cooled to 4˚C and aged overnight. Ice cream mixes were flavored with 12 mL of double-fold vanilla extract (Virginia Dare, Brooklyn, NY, USA) per 3.785 L (1 gallon) of mix.

2.2. Set-Style Yogurt Manufacture and Storage

Plain yogurt mix was manufactured with 13.25 L whole milk in 17 L pails. The mixes were preheated to 60˚C, homogenized at 10.34 MPa first stage and 3.45 MPa second stage in a Gaulin homogenizer (Manton-Gaulin Manufacturing Company, Inc., Everett, MA, USA), batch pasteurized at 85˚C for 30 min, and cooled to 40˚C. An inoculum of 7.7 mL of the yogurt culture CH-3 (a Redi-Set frozen culture consisting of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*) (Chr. Hansen, Inc., Milwaukee, WI, USA) was added as a direct vat set to each mix. After mixing, yogurt mixes were incubated at

Table 1. Composition of ice cream mix.

Ingredient	(%)
Milk	71.66
Cream	3.65
Nonfat dry milk	3.69
Sugar	20.50
Stabilizer	0.50
Total	100.00

40˚C in the 17 L pails to pH 4.7 to 4.8 before breaking and cooling to 4˚C. The set-style yogurt samples were stored at 4˚C until mixed with ice cream mix.

2.3. Preparation of Yogurt Ice Cream

Yogurt ice cream was prepared by mixing ice cream mix and yogurt in ratios of 0% ice cream mix and 100% yogurt (100% yogurt control), 25% ice cream mix and 75% yogurt, 50% ice cream mix and 50% yogurt, 75% ice cream mix and 25% yogurt, and 100% ice cream mix and 0% yogurt (100% ice cream control) and frozen in a batch freezer (Emery Thompson Machine & Supply Co., Brooksville, FL). Samples were collected into 355 mL containers and stored frozen at −29˚C until analysis.

2.4. Determination of Fat and Total Solids Content

The fat contents of the mixes were measured by the Pennsylvania modified Babcock Method [17]. Total solids contents of mixes were determined by heating the mixes on a steam bath for 12 min and then drying in an oven at 100˚C for 3 h [17].

2.5. Measurements of pH

The pH of the mixes of yogurt ice creams including the controls was measured with an UltraBasic pH/mV Meter (Denver Instrument Co., Arvada, CO, USA) at approximately 5˚C. The electrode was calibrated with pH 7.00 and 4.00 buffer solutions (VWR International, West Chester, PA, USA) prior to use.

2.6. Apparent Viscosity Measurements

The apparent viscosities of the unfrozen mixes were measured by a modification of the procedure of Olson and Aryana [18] at approximately 5˚C in a 946 mL (32-oz) container with a Brookfield viscometer (Brookfield Engineering Labs, Inc., Stoughton, MA, USA) on a helipath stand descending at 0.3875 mm/s. An RV-3 spindle was rotated at 5 rpm. The Wingather program (Brookfield Engineering Labs, Inc., Stoughton, MA, USA) was used to collect the data every 0.3 s and calculate the apparent viscosities. Two hundred measurements were averaged and reported.

2.7. Determination of Lactobacilli Counts

Lactobacilli counts of yogurt ice cream samples diluted to the appropriate dilution with 99 mL of sterilized Butterfield buffer in pre-filled dilution bottles (Weber Scientific, Hamilton, NJ, USA) were performed by the pour plate method using Difco Lactobacilli MRS agar (Becton, Dickinson and Co., Sparks, MD, USA). Petri dishes were placed into BBL GasPaks (BBL, Becton, Dickinson and Co., Cockeysville, MD, USA) and incubated anaerobically at 40˚C for 72 h. A Quebec Darkfield Colony Counter (Leica Inc., Buffalo, NY, USA) was used to assist in enumerating the colonies. The counts were performed at 0, 4, and 8 weeks of storage.

2.8. Meltability

The meltability of the yogurt ice creams was measured as a modification of Aryana and Summers [19]. An approximately 100 g sample of yogurt ice cream or their controls was weighed on a wire gauze containing 6 wires per cm^2. The sample on the wire gauze was placed on a funnel that was set on top of a graduated cylinder and then put into a freezer for 5 min. Next, the samples still on the graduated cylinder were placed into a 21˚C incubator. Both the time needed to collect the first 15 mL of melted product and the volume in mL of melted product collected after1 h were determined. The meltability was determined in duplicate at 0, 4, and 8 weeks of storage.

2.9. Sensory Evaluation

Sensory evaluation of the yogurt ice creams was performed with a five-member expert panel at 0, 4, and 8 weeks of storage. Yogurt ice cream samples were randomly presented to the panelists in the original 355 mL containers, and these containers were coded with a random three-digit number. The official American Dairy Science Association intercollegiate dairy products evaluation contest score card was used. Flavor was evaluated on a 1 to 10 scale where 10 meant no defects, and body and texture were evaluated on a 1 to 5 scale where 5 meant no defects. Defects in flavor and body and texture were recorded on the score cards.

2.10. Statistical Analysis

A one-way analysis of variance for total solids content, fat content, pH, and viscosity of the mixes containing various ratios of ice cream mix to yogurt was performed. The experimental design for log lactobacilli counts and meltability was a split-plot in time design (ice cream to yogurt ratio as whole plots and storage times as subplots) in a randomized block design, and the experimental design for sensory (flavor and body/texture) scores was a split-split-plot in time design (ice cream to yogurt ratio as whole plots, storage times as subplots, and panelists as a sub-sub plot) in a randomized block design. The data were analyzed with SAS version 9.4 for Windows (SAS Institute, Inc., 2002) using PROC MIXED. Replicate was a random factor for log lactobacilli counts and meltability, and replicate and panelist were random factors for the sensory scores. Differences of least squares means were used to determine significant differences at $P < 0.05$ for the main effects (ice cream to yogurt ratio and storage time), for a specific ice cream to yogurt ratio at various storage times, and for a specific storage time for various ice cream to yogurt ratios. Three replications were performed.

3. Results and Discussion

3.1. Fat and Total Solids Content

The fat and total solids contents of the mixes are presented in **Table 2**. Both the fat content and the total solids content were highly significant ($P < 0.0001$). The fat content progressively increased from 2.8% for the 100% yogurt to 12.6% for

Table 2. Composition (fat and total solids contents), pH, and apparent viscosity of the mixes containing various ratios of ice cream mix (icm) and yogurt (yog).

Ratio	Fat Content (%)	Total Solids (%)	pH	Apparent Viscosity (cP)
0 icm:100 yog	2.8[e]	11.89[e]	4.55[e]	12,110[a]
25 icm:75 yog	5.3[d]	18.88[d]	5.03[d]	1098[b]
50 icm:50 yog	7.6[c]	25.87[c]	5.71[c]	594[b]
75 icm:25 yog	10.1[b]	32.69[b]	6.27[b]	456[b]
100 icm:0 yog	12.6[a]	39.65[a]	6.77[a]	702[b]

[abcde]Column means containing a common letter are not significantly ($P < 0.05$) different from each other.

the 100% ice cream with significant ($P < 0.05$) differences between each product. Likewise, the total solids content progressively increased from 11.89% for the 100% yogurt to 39.65% for the 100% ice cream also with significant ($P < 0.05$) differences between each product. The fat content and total solids content for the 100% ice cream in the present study are typical for ice cream that is found on the market.

Composition of ice cream and yogurt ice cream has also been reported in other studies. The total solids content of the ice cream control in the present study was higher than the total solids content (35.51%) of the ice cream control in the Hassan and Barakat study [20]. Mangsi *et al.* [21] prepared yogurt ice cream containing 30% yogurt and reported a mean total solids content of 32.79% and a mean fat content of 4.84%. Ozdemir [12] reported a total solids content of 37.25% and a fat content of 8.10%. Kanta *et al.* [22] manufactured various yogurt ice creams with a total solids content of 33.5% and fat contents ranging from 1.79 to 6.00%.

3.2. The pH

The pH values of the mixes are presented in **Table 2**. Similar to the fat and total solids contents, the pH values were also highly significant ($P < 0.0001$). The pH values progressively decreased from 6.77 for the 100% ice cream to 4.55 for the 100% yogurt and each decrease in proportion of ice cream led to a significant ($P < 0.05$) decrease in pH.

The lower pH values for the formulations with progressively higher yogurt content were caused by lactic acid production during the yogurt formation. Lactose is broken down into lactic acid by the starter cultures during yogurt formation.

The pH values of frozen dairy products were also often found to decrease with increasing content of probiotics or with storage in other studies. Aryana and Summers [19] prepared a probiotic, fat-free, no sugar added ice cream and reported that the pH of their product containing 0.2% probiotic cultures was lower than their control product without probiotics. Özdemir *et al.* [3] reported pH values decreasing from 4.62 at 1 day of storage to 4.06 at 30 days of storage for their plain yogurt ice cream. However, changes in the pH of ice cream type of frozen yogurt during 6 months of storage were small in the Inoue *et al.* [23] study.

3.3. Apparent Viscosity

The apparent viscosities of the mixes are presented in **Table 2**. Similar to the fat and total solids contents and pH values, the apparent viscosities were also highly significant ($P < 0.0001$). Although the apparent viscosity of the 100% yogurt was significantly ($P < 0.05$) higher than the remaining products, there were no significant ($P > 0.05$) differences between the apparent viscosities of any of the remaining products.

The higher viscosity of the 100% yogurt formulation could be explained by the acid coagulation of the casein micelles. Acid coagulation involves formation of new protein particles with a different structure and composition resulting from micellar disaggregation by β-casein release and its reabsorption and by solubilization of colloidal calcium phosphate as described by Heertje *et al.* [24].

Apparent viscosity of frozen dairy product mixes has also been measured in other studies. Aryana and Summers [19] reported that viscosity of their product containing 0.02% and 0.2% probiotic cultures was lower than their control product without probiotics in their probiotic, fat-free, no sugar added ice cream. Özdemir *et al.* [3] reported viscosities of 3150 cP at 20 rpm and 1950 cP at 50 rpm for their plain yogurt ice cream. Şimşek *et al.* [11] reported that their yogurt ice cream mixes exhibited a pseudoplastic flow behavior and higher apparent viscosities in formulations containing mastic gum compared to their control.

3.4. MRS Lactobacilli Counts

The log MRS lactobacilli counts at 0, 4, and 8 weeks of storage are shown in **Table 3**. Although the formulation as a main effect was highly significant ($P < 0.0001$) and age as a main effect was not significant ($P > 0.05$), their interaction

Table 3. Log MRS lactobacilli counts of the yogurt ice creams containing various ratios of ice cream mix (icm) and yogurt (yog) and the yogurt control determined at 0, 4, and 8 weeks of storage.

Ratio	Age (Weeks)		
	0	4	8
0 icm:100 yog	9.38^{a}	9.26^{a}	9.22^{a}
25 icm:75 yog	9.22^{b}	9.24^{a}	9.26^{a}
50 icm:50 yog	9.09^{c}	9.07^{b}	9.05^{b}
75 icm:25 yog	8.74^{d}	8.63^{c}	8.69^{c}

^{abcd}Column means containing a common letter are not significantly ($P < 0.05$) different from each other.

was significant (P = 0.0137). The log MRS lactobacilli counts for the 100% yogurt formulation as a main effect was not significantly (P = 0.1975) different from the log MRS lactobacilli counts for the 25% ice cream and 75% yogurt formulation as a main effect. Although week 0 log MRS lactobacilli counts for the 100% yogurt formulation were significantly (P = 0.0025) higher than the corresponding log MRS lactobacilli counts for the 25% ice cream and 75% yogurt formulation, the weeks 4 and 8 log MRS lactobacilli counts for the 100% yogurt formulation were not significantly (P > 0.05) different than the corresponding log MRS lactobacilli counts for the 25% ice cream and 75% yogurt formulation. The remaining log MRS lactobacilli counts for a given storage time significantly (P < 0.005) decreased as the percent of ice cream in the formulation increased.

MRS lactobacilli and probiotic counts have also been measured in other studies. Özdemir *et al.* [3] reported lactic acid bacteria log counts of 3.87 for their plain yogurt ice cream. Rao *et al.* [7] found probiotic counts of 2.54×10^8 cfu/g in their yogurt ice cream containing 1% fructo-oligosaccharides. Şimşek *et al.* [11] found a gradual reduction in *L. bulgaricus* and *S. thermophilus* counts in their yogurt ice cream samples during 60 days of storage. Inoue *et al.* [22] found that lactic acid bacteria counts decreased during 6 months of frozen storage, especially during the first week, in ice cream type frozen yogurt. Likewise, Hekmat and McMahon [25] reported decreases in *Lactobacillus acidophilus* and *Bifidobacterium bifidum* counts in probiotic ice cream during 17 weeks of frozen storage. Although decreased lactobacilli counts were not shown in the present study, De Angelis and Gobbetti [26] reported that lactobacilli counts could decrease during storage with a decrease in pH because acid is an environmental stress to lactic acid bacteria.

3.5. Meltdown Rate

The meltdown rate (both the volume of meltdown after 1 h and the time for the first 15 mL of melted product to be collected) of each product at 0, 4, and 8 weeks of storage are presented in **Table 4**. The formulation for both measures of meltdown rate as a main effect was highly (P < 0.0001) significant. The time required for the first 15 mL to melt at 21˚C decreased as the percent of ice cream mix increased since the required time ranged from 104.5 min to 115.2 min for the 100% yogurt formulation to 33.9 min to 44.8 min for the 100% ice cream formulation. This faster rate of meltdown for formulations with increasing contents of ice cream mix can also be shown by no melting for the 100% yogurt after 1 h to 37.2 mL to 51.3 mL for the 100% ice cream formulation. Age as a main effect was close to significance for both time for the first 15 mL of melted product to be collected (P = 0.0827) and for the volume of meltdown after 1 h (P = 0.0518). There was a slight, but non-significant, tendency for a faster melt as the products aged.

Various properties affect rate of ice cream meltdown. Ice cream meltdown is affected by its ice cream mix viscosity [27]. The slow meltdown rate of the 100%

Table 4. Rate of meltdown (volume (mL) after 1 h and time (min) for the first 15 mL to melt) of the yogurt ice creams containing various ratios of ice cream mix (icm) and yogurt (yog) and the controls determined at 0, 4, and 8 weeks of storage.

Ratio	Parameter	Age (Weeks)		
		0	4	8
0 icm:100 yog	Volume (mL) after 1 h	0.0[d]	0.0[c]	0.0[c]
25 icm:75 yog	Volume (mL) after 1 h	5.4[cd]	6.7[c]	7.8[c]
50 icm:50 yog	Volume (mL) after 1 h	13.8[bc]	19.1[b]	30.3[b]
75 icm:25 yog	Volume (mL) after 1 h	18.7[b]	26.8[b]	23.8[b]
100 icm:0 yog	Volume (mL) after 1 h	37.2[a]	43.3[a]	51.3[a]
0 icm:100 yog	Time (min) for the first 15 mL	115.2[a]	109.2[a]	104.5[a]
25 icm:75 yog	Time (min) for the first 15 mL	72.7[b]	72.4[b]	70.7[b]
50 icm:50 yog	Time (min) for the first 15 mL	61.4[c]	55.2[c]	44.5[d]
75 icm:25 yog	Time (min) for the first 15 mL	57.1[c]	50.6[c]	55.5[c]
100 icm:0 yog	Time (min) for the first 15 mL	44.8[d]	38.7[d]	33.9[e]

[abcde]For a given parameter, column means containing a common letter are not significantly ($P < 0.05$) different from each other.

yogurt formulation in the present study might be related to its high mix viscosity. Muse and Hartel [28] found the largest effects on melting rate were extent of fat destabilization and ice crystal size, and a lesser effect due to the consistency coefficient of the ice cream mix.

Meltdown rates and effect of added ingredients have also been reported in other studies. The yogurt ice cream in the Mangsi *et al.* [21] study melted quicker than the yogurt ice creams in the present study as 93.19% of their yogurt ice cream was melted after 50 min. Aryana and Summers [19] did not find differences in time for 15 mL to melt or with meltdown volume after 60 min with various levels of probiotics added to their probiotic, fat-free, no sugar-added ice cream. Kumar *et al.* [6] delayed the first dripping time and complete melting time in their synbiotic yogurt ice cream by adding 3% and 6% chicory root extract. Şimşek *et al.* [11] was able to delay the first dripping time in their yogurt ice cream by increasing the mastic gum concentration in their formulation. Hassan and Barakat [20] reported that ice cream melting resistance can be increased by adding pumpkin pulp and carrot pulp.

3.6. Sensory Evaluation

The sensory (flavor and body and texture) scores of each product at 0, 4, and 8 weeks of storage are shown in Table 5. The formulation as a main effect was highly significant ($P < 0.0001$) for both flavor scores and body and texture scores. Sensory scores normally increased as the ice cream content increased within the formulation, indicating that ice cream was more desirable than yogurt

Table 5. Sensory evaluation (flavor and body/texture) scores of the yogurt ice creams containing various ratios of ice cream mix (icm) and yogurt (yog) and the controls determined at 0, 4, and 8 weeks of storage.

Ratio	Parameter	Age (Weeks)		
		0	4	8
0 icm:100 yog	Flavor	4.65^{c}	4.73^{d}	5.10^{d}
25 icm:75 yog	Flavor	5.48^{bc}	5.86^{c}	5.76^{cd}
50 icm:50 yog	Flavor	6.24^{b}	6.35^{bc}	6.31^{bc}
75 icm:25 yog	Flavor	7.19^{a}	7.45^{a}	7.32^{ab}
100 icm:0 yog	Flavor	8.06^{a}	7.12^{ab}	7.61^{a}
0 icm:100 yog	Body/Texture	1.12^{c}	1.04^{c}	1.36^{b}
25 icm:75 yog	Body/Texture	1.55^{c}	1.40^{c}	1.53^{b}
50 icm:50 yog	Body/Texture	2.31^{b}	2.51^{b}	2.11^{b}
75 icm:25 yog	Body/Texture	3.91^{a}	3.86^{a}	3.76^{a}
100 icm:0 yog	Body/Texture	4.48^{a}	4.39^{a}	4.46^{a}

^{abcd}For a given parameter, column means containing a common letter are not significantly ($P < 0.05$) different from each other.

in this type of frozen product. Yogurt frequently suffered from high acetaldehyde and high acid flavors. Low body and texture scores (1.04 to 1.36) for the formulations containing 100% yogurt were likely due to the low total solids content of the yogurt, leading to a course and icy texture. Unlike formulation, age (weeks) as a main effect did not significantly affect the flavor scores ($P = 0.8538$) or the body and texture ($P = 0.9821$) scores of the products.

The normally higher flavor scores and body and texture scores for the formulations containing higher percentages of ice cream mix were likely caused by their higher fat contents. Similar to the present study, Inoue *et al.* [23] also found that the ice cream type of frozen yogurt had a richer sensory character than the normal frozen yogurt. Also, Venkateshaiah *et al.* [29] reported that flavor scores of frozen yogurts containing 1%, 2%, or 3% fat increased with increasing fat content. Fat provides a desirable flavor and body and texture to dairy products. A major goal of developing nonfat and reduced fat products is to try to maintain the desirable properties provided by the fat [30], but this was not achieved in the present study. Attempts to improve the sensory properties of the frozen dairy products containing lower fat contents could include use of fat replacers within the formulation [31] or certain processing procedures such as microfluidization of the mixes [32].

Other studies have also reported results from sensory analysis for their frozen dairy products. Soukoulis *et al.* [33] blended probiotic yogurt at levels of 25% and 50% of the total into ice cream mix and found that the higher yogurt level imparted coarseness and wateriness, increased hardness, and decreased gumminess and creaminess perception of the product. Otero *et al.* [9] found that yogurt ice cream manufactured with a 4% inoculum of a 1:1 ratio of *L. acidophilus* and *B. bifidum* and flavored with lemon, orange, or strawberry had excellent sensory properties. Aryana and Summers [19] reported lower sensory scores in fat-free, no sugar-added ice cream containing 0.02% and 0.2% probiotic cultures compared to their control product without probiotics. Product at a pH of 5.5 was judged as having superior sensory properties compared to products at other pH values in both the Hekmat and McMahon [25] and Inoue *et al.* [23] studies. Mangsi *et al.* [21] found that each of the sensory scores (appearance/color, taste/flavor, body/texture, and melting quality) increased from the time of being fresh to 3 months of storage.

4. Conclusion

This study examined how high of a level in which yogurt can be incorporated into ice cream mix and still obtain a desirable frozen product throughout 8 weeks of storage. Although the 100% ice cream control had the most desirable meltdown and sensory properties, yogurt ice cream containing 75% ice cream mix and 25% yogurt still had desirable sensory properties. Except for high MRS lactobacilli counts, the 100% yogurt control and the yogurt ice cream containing 25% ice cream and 75% yogurt did not have desirable sensory properties and suffered from a slow melting defect. Therefore, incorporating high amounts of yogurt into ice cream mix to enhance the healthy perception of the resulting yogurt ice cream is not recommended due to sensory and meltability problems.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Aryana, K.J. and Olson, D.W. (2017) A 100-Year Review: Yogurt and Other Cultured Dairy Products. *Journal of Dairy Science*, **100**, 9987-10013. https://doi.org/10.3168/jds.2017-12981

[2] Cais-Sokolińska, D. and Danków, R. (2002) Yoghurt Ice Cream—An Example of Probiotic Food (Foreign Title: Lody jogurtowe przykladem żywności prozdrowotnej). *Prace i Materialy Zootechniczne. Zeszyt Specjalny*, **14**, 39-46.

[3] Özdemir, C., Demirci, M., Özdemir, S. and Sagdic, O. (2005) Production and Some Properties of Yoghurt Ice Cream in Turkey. *Milchwissenschaft*, **60**, 419-422.

[4] Singh, J., Minhas, K.S. and Bajwa, U. (2006) Studies on Preparation and Shelf-Life of Yoghurt Ice Cream. *Journal of Food Science and Technology* (*Mysore*), **43**, 656-661.

[5] Ahmadi, A., Milani, E., Madadlou, A., Mortazavi, S.A., Mokarram, R.R. and Salar-

bashi, D. (2014) Synbiotic Yogurt-Ice Cream Produced via Incorporation of Microencapsulated *Lactobacillus acidophilus* (la-5) and *Fructooligosaccharide*. *Journal of Food Science and Technology*, **51**, 1568-1574. https://doi.org/10.1007/s13197-012-0679-y

[6] Kumar, D., Rai, D.C., Alam, T., Rai, D. and Bhardwaj, A. (2019) To Study the Effect of Chicory Root Extract on Physico-Chemical Properties of Synbiotic Yoghurt-Ice Cream. *Milchwissenschaft—Milk Science International*, **72**, 25-29.

[7] Rao, X., Tu J.L., Hu, J.S., Zhao, S., Liao, S.M., Chen, B. and Liu, D.M. (2021) Effects of *Fructooligosaccharides* and *Stachyose* on the Quality of Probiotic Yogurt Ice Cream. *Food Research and Development*, **42**, 19-24.

[8] El-Nagar, G., Clowes, G., Tudorica, C.M., Kuri, V. and Brennan, C.S. (2002) Rheological Quality and Stability of Yog-Ice Cream with Added Inulin. *International Journal of Dairy Technology*, **55**, 89-93. https://doi.org/10.1046/j.1471-0307.2002.00042.x

[9] Otero, M., Rodríguez, T., Fernández, M., González, J. and Lima, L.B. (1996) Yoghurt Ice Cream. *Alimentaria*, **34**, 113-115.

[10] Arslaner, A., Salik, M.A., Özdemir, S. and Akköse, A. (2019) Yogurt Ice Cream Sweetened with Sucrose, Stevia and Honey: Some Quality and Thermal Properties. *Czech Journal of Food Sciences*, **37**, 446-455. https://doi.org/10.17221/311/2018-CJFS

[11] Şimşek, B., Aksoy, A., Kirhan, S. and Topçu, D.S. (2019) Effects of Mastic Gum (*Pistacia lentiscus*) on Chemical, Rheological and Microbiological Properties of Yogurt Ice Cream. *Journal of Food Processing and Preservation*, **43**, e13945. https://doi.org/10.1111/jfpp.13945

[12] Ozdemir, C. (2019) Yogurt Ice Creams Produced by Adding Different Fruits: Production and Characteristics. *Advances in Food Sciences*, **41**, 66-72.

[13] Westerbeek, J.M.M. (1995) Fermented Ice Cream Products—A Healthy Challenge to the Ice Cream Industry. *Scandinavian Dairy Information*, **9**, 29-31.

[14] Dulova, V. (1975) Yoghurt Ice Cream. *Prumysl Potravin*, **26**, 344.

[15] Marshed, S.M.A., Abdel-Ghaffar, E. and El-Abbassy, M. (1999) Some Characteristics of Probiotic Ice Cream. *Annals of Agricultural Science*, *Moshtohor*, **37**, 1793-1803.

[16] Li, S.L. (2012) Optimization of the Formula of the Yogurt Ice Cream by Response Surface Method. *Food Research and Development*, **33**, 130-133.

[17] Bradley, R.L., Arnold, E., Barbano, D.M., Semerad, R.G., Smith, D.E. and Vines, B.K. (1992) Chapter 15: Chemical and Physical Methods. In: Marshall, R.T., Ed., *Standard Methods for the Examination of Dairy Products*, American Public Health Association, Washington DC, 433-529.

[18] Olson, D.W. and Aryana, K.J. (2008) An Excessively High *Lactobacillus acidophilus* Inoculation Level in Yogurt Lowers Product Quality during Storage. *LWT-Food Science and Technology*, **41**, 911-918. https://doi.org/10.1016/j.lwt.2007.05.017

[19] Aryana, K.J. and Summers, M. (2006) Probiotic, Fat-Free, No Sugar-Added Ice Cream. *Milchwissenschaft*, **61**, 184-187.

[20] Hassan, M.F.Y. and Barakat, H. (2018) Effect of Carrot and Pumpkin Pulps Adding on Chemical, Rheological, Nutritional and Organoleptic Properties of Ice Cream. *Food and Nutrition Sciences*, **9**, 969-982. https://doi.org/10.4236/fns.2018.98071

[21] Mangsi, A.S., Soomro, A.H., Baloch, M.H., Khaskheli, M., Nizamani, A.H. and Khaskheli, G.B. (2011). Production and Evaluation of Yoghurt Ice Cream. *Pakistan*

Journal of Nutrition, **10**, 955-958. https://doi.org/10.3923/pjn.2011.955.958

[22] Kanta, A., Soukoulis, C. and Tzia, C. (2018) Eliciting the Sensory Modalities of Fat Reformulated Yoghurt Ice Cream Using *Oligosaccharides*. *Food and Bioprocess Technology*, **11**, 885-900. https://doi.org/10.1007/s11947-018-2064-y

[23] Inoue, K., Shiota, K. and Ito, T. (1998) Preparation and Properties of Ice Cream Type Frozen Yogurt. *International Journal of Dairy Technology*, **51**, 44-50. https://doi.org/10.1111/j.1471-0307.1998.tb02506.x

[24] Heertje, L., Visser, J. and Smits, P. (1985) Structure Formation in Acid Milk Gels. *Food Microstructure*, **4**, 267-277.

[25] Hekmat, S. and McMahon, D.J. (1992) Survival of *Lactobacillus acidophilus* and *Bifidobacterium bifidum* in Ice Cream for Use as a Probiotic Food. *Journal of Dairy Science*, **75**, 1415-1422. https://doi.org/10.3168/jds.S0022-0302(92)77895-3

[26] De Angelis, M. and Gobbetti, M. (2004) Environmental Stress Responses in *Lactobacillus*: A Review. *Proteomics*, **4**, 106-122. https://doi.org/10.1002/pmic.200300497

[27] Wu, B., Freire, D.O. and Hartel, R.W. (2019) The Effect of Overrun, Fat Destabilization and Ice Cream Mix Viscosity on Entire Meltdown Behavior. *Journal of Food Science*, **84**, 2562-2571. https://doi.org/10.1111/1750-3841.14743

[28] Muse, M.R. and Hartel, R.W. (2004) Ice Cream Structural Elements that Affect Melting Rate and Hardness. *Journal of Dairy Science*, **87**, 1-10. https://doi.org/10.3168/jds.S0022-0302(04)73135-5

[29] Venkateshaiah, B.V., Atmaram, K. and Kempanna, C. (1994) Influence of Fat Levels and Added Flavours on Acceptability of Frozen Yoghurt. *Indian Journal of Dairy and Biosciences*, **5**, 51-54.

[30] White, C.H. (1993) Chapter 12: Low-Fat Dairy Products. In: Altschul, A.M., Ed., *Low-Calorie Foods Handbook*, Marcel Dekker, Inc., New York, 253-271.

[31] Akbari, M., Eskandari, M.H. and Davoudi, Z. (2019) Application and Functions of Fat Replacers in Low-Fat Ice Cream: A Review. *Trends in Food Science & Technology*, **86**, 34-40. https://doi.org/10.1016/j.tifs.2019.02.036

[32] Olson, D.W., White, C.H. and Watson, C.E. (2003) Properties of Frozen Dairy Desserts Processed by Microfluidization of Their Mixes. *Journal of Dairy Science*, **86**, 1157-1162. https://doi.org/10.3168/jds.S0022-0302(03)73698-4

[33] Soukoulis, C., Lyroni, E. and Tzia, C. (2010) Sensory Profiling and Hedonic Judgement of Probiotic Ice Cream as a Function of Hydrocolloids, Yogurt and Milk Fat Content. *LWT-Food Science and Technology*, **43**, 1351-1358. https://doi.org/10.1016/j.lwt.2010.05.006