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Yogurt ice cream sweetened with sucrose, stevia and honey: Some quality and thermal properties

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Abstract: This study investigated the effects of some sweeteners (sucrose, honey and stevia) on the quality and thermal properties of plain (P) and cocoa (C) yogurt ice cream. For this purpose, six different yogurt ice cream samples were prepared with sucrose (control: AP, AC), with honey (BP, BC) and with stevia (CP, CC). The highest values of protein, ash, fat, lactose ratios and lightness (L^*) were measured in samples with stevia. The addition of honey increased the b^* values. The addition of cocoa increased pH and viscosity, but decreased overrun ratios. Although the addition of stevia reduced the lactic acid bacteria (LAB) counts, in all samples the LAB count was above 6 log CFU/g during storage. Results of the thermal and melting analysis showed that the use of stevia had a positive effect on the ice cream stability by increasing the freezing and melting point peak temperatures (T_f, T_m), the enthalpy (ΔH_f, ΔH_m), and the initial ice crystal melting temperatures (T'_m).

Keywords: yogurt ice cream; thermal analysis; stevia; honey; ice cream stability

Yogurt ice cream is considered to be a dessert that combines the nutritious and healthy properties of yogurt combined with ice cream (Ahmadi *et al.* 2014). It is superior to classical ice cream due to its content of partially hydrolysed lactose and the live form of LAB. Lopez *et al.* (1998) stated that LAB remained stable throughout the shelf life in yogurt ice cream samples.

The use of alternative sweeteners to sucrose in the production of ice cream can meet the needs of modern consumers who focus on natural and nutritionally balanced foods (Moriano & Alamprese 2017). *Stevia rebaudiana* Bertoni is a sweet and nutrient-rich plant from the daisy (*Asteraceae*) family. Stevia leaves contain steviol glycosides (stevioside, rebaudioside A to F, steviolbioside and isosteviol) which are on average 250 to 300 times sweeter than sucrose. It is used instead of sugar or artificial sweeteners as a natural and noncaloric sweetener (Peres *et al.* 2018) in foods, beverages, and medicines (Momtazi-Borojeni 2017). It has been listed on the GRAS (Generally Recognized as Safe) list by the FDA (U.S. Food & Drug Administration) since 2009, and EFSA (European Food Safety Authority) determined its ADI (acceptable daily intake) value as 0–4 mg/kg/bw in 2010 and 2016 (JECFA 2016; Amchra *et al*. 2018). It has been reported to increase insulin levels and lower the levels of ALT (alanine aminotransferase) and AST (aspartate aminotransferase) (Shivanna *et al.* 2013).

Previous studies have shown that sweeteners and stabilizers affect the thermophysical properties of ice cream and hence the final product and storage quality (Renaud *et al*. 1992; Hagiwara & Hartel 1996; Flores & Goff 1999; Regand & Goff 2003).

In the literature review performed, no study investigating the use of honey and stevia as a sucrose substitute in yogurt ice cream was found. The aim of this study was to manufacture a novel functional yogurt ice cream using different sweeteners and to measure the effect of stevia and honey on some phys-

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icochemical, microbiological and thermal properties of yogurt ice cream over 28 days at weekly periods and sensory properties on the first day of storage.

MATERIAL AND METHODS

Material. Milk, emulsifier and stevia were supplied by the Atatürk University Research and Application Farm. Sugar (Konya Seker Trade and Industry Co., Turkey) and cocoa (Nestlé Food Industry Inc., Switzerland) were supplied from local markets. Commercial starter culture (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*) was supplied by Chr. Hansen (Istanbul, Turkey), sahlep (flour made from the tubers of the orchid genera) was supplied by Altındal Sahlep World (Burdur, Turkey), and skimmed milk powder was supplied by the Pınar Dairy Products Co. (Istanbul, Turkey). The mean values of some properties of the raw materials used in ice cream production are given Table 1.

Methods

Production of yogurt ice cream. Production was carried out in the Pilot Dairy Factory at the Faculty of Agriculture of Atatürk University. Cream was added to the samples to make up the fat content of 4% to 6%, and skimmed milk powder was added to make up the skimmed milk dry matter content of 8%. The matured mixtures were frozen in a freezing machine after the addition of yogurt (−5°C; Uğur Cooling Inc., Turkey), and stored at −20°C for 28 days (Figure 1). In the study all analyses were performed in duplicate.

Physicochemical analysis. Dry matter, protein and fat content were determined according to the methods of the ISO 3728-2004, ISO 8969-1:2014 and ISO 7327-2008, respectively. Ash content was determined by AOAC 2005. Titratable acidity as lactic acid was determined by a titrimetric method (Bradley *et al*. 1992) and pH was measured with a pH meter (Seven Compact pH/Ionmeter S220; Mettler Toledo, Switzerland). The colour parameters obtained by measuring L^* (brightness, 0: black, 100: white), a^* (+: red, −: green) and b^* (+: yellow, −: blue) values were determined using a chroma meter (CR-300; Konica Minolta, Japan). Viscosity was measured at 4°C using a viscometer (Model DV-II; Brookfield Engineering Laboratories, USA) at 50 rpm. Also, overrun was determined using the method proposed by Ozdemir *et al.* (2015); first dripping and complete melting were detected using the method of Cotrell *et al.* (1979).

Table 1. Physicochemical properties of raw materials (n = 6)

Physicochemical properties	Pasteurized cow milk	Skim milk powder	Cream	Sahlep	*Stevia rebaudiana* powder	Honey
pH	6.69 ± 0.01	6.75 ± 0.00	5.01 ± 0.02	–	–	5.10 ± 0.04
Titratable acidity (%)	0.14 ± 0.00	0.10 ± 0.01	0.25 ± 0.00	–	–	21.82 ± 1.34
Dry matter (%)	13.30 ± 0.06	96.83 ± 0.51	72.62 ± 0.02	91.83 ± 0.67	–	87.81 ± 0.56
Protein (%)	3.40 ± 0.00	36.00 ± 0.00	–	–	0	–
Fat (%)	4.00 ± 0.00	1.25 ± 0.00	70.0 ± 0.00	–	0	–
Total sugar	–	–	–	–	5	–
Glucose (%)	–	–	–	–	0.48 ± 0.09	18.56 ± 0.73
Fructose (%)	–	–	–	–	3.22 ± 0.29	47.93 ± 1.59
Sucrose (%)	–	–	–	–	1.27 ± 0.08	–
Lactose (%)	5.07 ± 0.06	–	–	–	–	–
Fibre (%)	–	–	–	–	81	–
L^*	–	–	–	83.57 ± 1.56	94.76 ± 0.35	56.69 ± 4.56
a^*	–	–	–	0.45 ± 0.04	−1.72 ± 0.03	−1.28 ± 0.37
b^*	–	–	–	11.50 ± 0.27	8.06 ± 0.17	25.26 ± 2.39
Microbiological Analysis (log CFU/g)						
SPC	2.69	4.20	–	–	–	2.93
Yeast and moulds	< 1	< 1	< 1	< 1	< 1	< 1
Coliform	< 1	< 1	< 1	< 1	< 1	< 1

Results are presented as a mean ± s.d.; SPC – standard plate count; L^* (brightness, 0: black, 100: white), a^* (+: red, −: green); b^* (+: yellow, −: blue)

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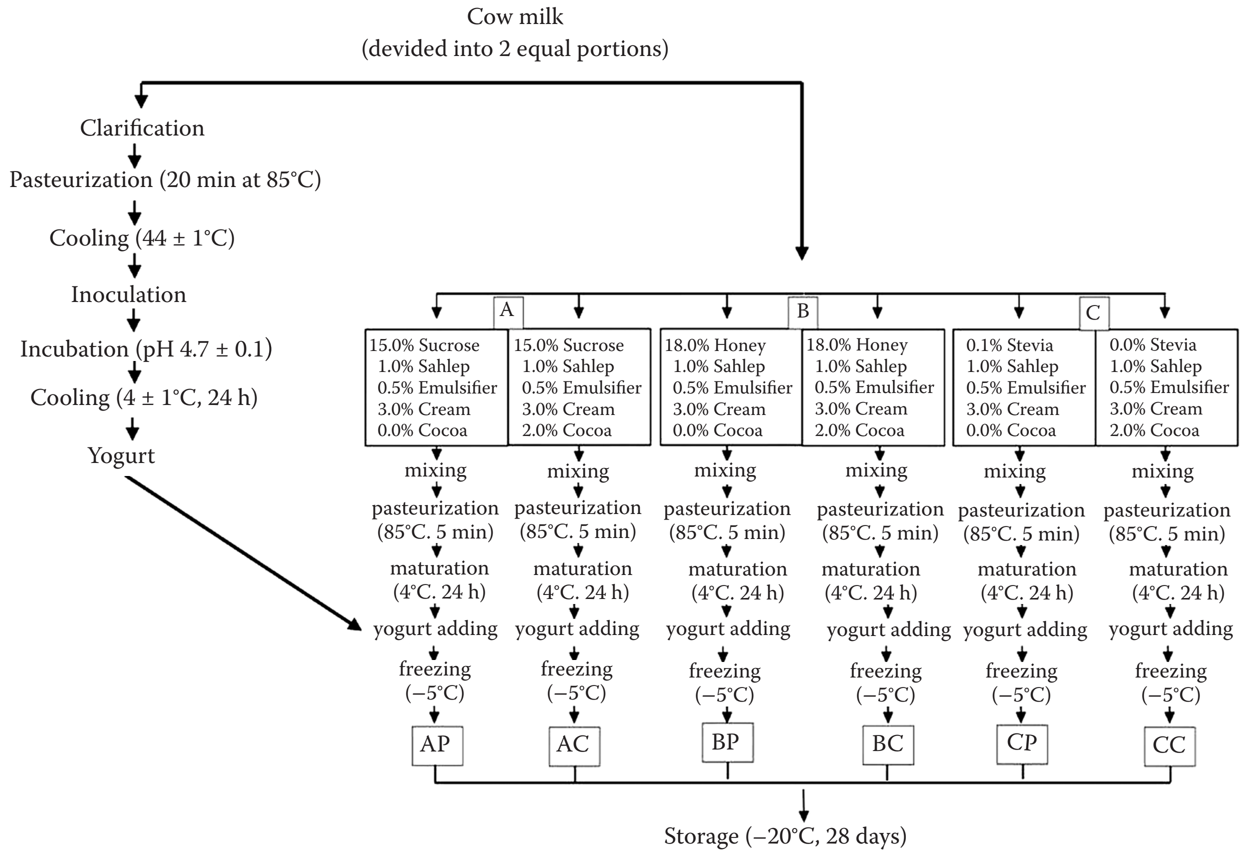

Figure 1. Production process of yogurt ice cream sample

Total calories were calculated by the equation below using conversion factors according to Commission Regulation No 1169/2011; [Carbohydrate (%) × 17 + Fat (%) × 37 + Protein (%) × 17] as defined by Arbuckle (1986).

Sugar profile analysis. The sugar profile analysis was performed according to DIN 10758 (1997) with a minor modification. A 5 g homogenized yogurt ice cream sample was diluted with 20 ml of a methanol-water mixture (25 : 75) and then centrifuged at 5000 *g* at −5°C for 10 minutes. The supernatant obtained was filtered through Whatman No. 1 filter paper and 0.45 µm membrane filter (GE Healthcare Life Sciences, USA), respectively. Extracts prepared for high-performance liquid chromatography (HPLC) analysis were transferred to 2 ml vials and stored at −20°C until analysis. The equipment included the HPLC equipment (LC-10A Series; Shimadzu, Japan), refractive-index detector (RID-10A) and acetonitrile-water mixture which was used as the solvent (80 : 20, v/v; 2 ml/min flow rate). The injection volume was 20 µl and the column oven temperature was 40°C. Monosaccharides were identified by comparing their retention times with sugar standards (glucose, sucrose and lactose).

Microbiological analysis. Standard Plate Count (SPC) on Plate Count Agar (Harrigan 1998), yeast and mould on Potato Dextrose Agar (Koburger & Marth 1984), *Lb. delbrueckii* subsp. *bulgaricus* on De Man, Rogosa and Sharpe agar and *S. thermophilus* on M17 agar (Cruz *et al.* 2012) and numbers of the coliform group bacteria on Violet Red Bile agar (Harrigan 1998) were recorded during storage.

Differential Scanning Calorimetry measurements. Measurements were carried out using a Differential Scanning Calorimeter (DSC-60; Shimadzu Corporation, Japan). The DSC was calibrated for temperature and heat flow using indium (mp = 156.60°C, ΔH_m = 28.45 J/g) and heptane (mp = −91°C, ΔH_m = 140 J/g). Ice cream samples (approximately 10 mg) were weighed into DSC aluminium pans, hermetically sealed, and then loaded onto the DSC instrument at room temperature. An empty pan was used as a reference and liquid nitrogen was used as a coolant. The samples were cooled at a rate of 10°C for 1 min to −80°C, held for 15 min and

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Table 2. General composition and colour values of yogurt ice cream (n = 6)

Sample	Dry matter (%)	Fat (%)	Total protein (%)	Ash (%)	Sugar content (%)				Colour measurements			Calorie** (kJ/100g)
					fructose	glucose	sucrose	lactose	L^*	a^*	b^*	
AP	31.67 ± 0.09^a	4.96 ± 0.08^{bc}	3.24 ± 0.05^d	0.99 ± 0.07^{ab}	0.13 ± 0.02^c	0.12 ± 0.00^c	15.47 ± 0.31^a	3.20 ± 0.10^b	90.70 ± 2.11^c	-2.68 ± 0.17^b	8.890 ± 0.52^c	560.24
AC	31.89 ± 0.25^a	5.18 ± 0.08^b	3.72 ± 0.08^c	1.20 ± 0.11^{ab}	0.25 ± 0.02^c	0.14 ± 0.02^c	14.77 ± 0.0^b	2.88 ± 0.51^b	36.23 ± 2.79^e	8.62 ± 0.40^a	10.70 ± 0.65^b	561.58
BP	29.18 ± 0.47^c	4.86 ± 0.08^c	3.26 ± 0.01^d	0.86 ± 0.04^b	7.33 ± 0.17^a	2.87 ± 0.05^a	0.04 ± 0.01^e	3.03 ± 0.03^b	96.81 ± 2.79^b	-3.52 ± 0.40^c	10.91 ± 1.19^b	460.83
BC	30.35 ± 0.68^b	4.87 ± 0.11^c	3.73 ± 0.06^c	1.25 ± 0.08^{ab}	6.75 ± 0.22^b	2.65 ± 0.10^b	0.01 ± 0.00^e	2.88 ± 0.01^b	44.76 ± 1.98^d	8.41 ± 0.33^a	11.60 ± 0.49^a	452.53
CP	19.76 ± 0.77^d	6.06 ± 0.23^a	3.85 ± 0.01^b	1.22 ± 0.23^{ab}	0.06 ± 0.00^c	0.00 ± 0.00^d	0.68 ± 0.05^c	3.80 ± 0.01^a	102.9 ± 2.20^a	-3.92 ± 0.13^d	8.040 ± 0.67^d	365.83
CC	20.47 ± 0.25^d	6.02 ± 0.07^a	4.22 ± 0.06^a	1.39 ± 0.08^a	0.04 ± 0.00^c	0.00 ± 0.00^d	0.35 ± 0.01^d	3.87 ± 0.05^a	45.74 ± 1.78^d	8.53 ± 0.29^a	10.99 ± 0.40^b	366.90

Results are presented as a mean ± s.d.; mean values followed by different letters in the same column are significantly different ($P < 0.01$); L^* (brightness; 0: black, 100: white); a^*(+: red, –: green); b^*(+: yellow, –: blue); **calculated using the formula: carbohydrate% (over the values given in the table) × 17 + fat% x 37 + protein% × 17; AP – plain yogurt ice cream with sucrose; AC – cocoa yogurt ice cream with sucrose; BP – plain yogurt ice cream with honey; BC – cocoa yogurt ice cream with honey; CP – plain yogurt ice cream with stevia; CC – cocoa yogurt ice cream with stevia

then warmed at a rate of 10°C/min to 20°C. Freezing and melting point peak temperatures (T_f, T_m), enthalpy (ΔH_f, ΔH_m), and ice crystal initial melting temperatures (T'_m) were measured from the thermograms obtained.

Sensory assessment. A modified version of the ADSA (American Dairy Science Association) ice cream score cards was used in sensory evaluation (Bodyfelt *et al.* 1988; Goff & Hartel 2013). The sensory assessments were done by considering the colour and appearance, structure and consistency, taste and smell, icy structure, melting in the mouth and gummy structure properties. Six yogurt ice cream samples (–10°C) were served in the order given in tables (AP, AC, BP, BC, CP, CC) and graded on a scale of 1–5 (defective/excellent) by a group of 10 expert panellists (their genders were about equal and their ages were from 25 to 40) from the Food Engineering Department of Bayburt University, Bayburt, Turkey.

Statistical analysis. The effect of different sweeteners on each parameter was estimated by multiple analysis of variance (ANOVA) tests using SPSS 22 (SPSS Inc., USA) statistical software. Statistically different groups ($P > 0.05$) were determined by Duncan's multiple range test.

RESULTS AND DISCUSSION

General composition and colour values of yogurt ice cream. According to the findings, statistically significant differences were found between the samples in general composition ($P = 0.001$). The highest protein (from 3.85% to 4.2%), ash (from 1.22% to 1.39%), fat (from 6.02% to 6.08%) and lactose (from 3.80% to 3.87%) ratios were found in stevia-sweetened CP and CC samples. When the amount of stevia equivalent to the sweetness of sucrose was added, variations were expected to occur in the total mix volume and thus the fat ratio of the samples. The proportions of all components of the ice cream mix were kept constant except the sweeteners (sucrose, honey or stevia). Thus, the fat ratios of the ice cream samples changed between 4.86 and 6.06%. Similarly, Giri *et al.* (2014) reported a significant increase in fat, protein and ash percentage at higher levels of sugar replacement in the manufacture of *kulfi* (Indian ice cream). Dry matter (from 31.67% to 31.89%) and sucrose (from 15.4% to 14.77%) ratios for the control group (AP and AC) were significantly ($P = 0.001$) higher compared to the others (Table 2). The highest sucrose ratio (15.47%) was detected in the AP sample. The highest glucose

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(2.87%) and fructose (7.33%) ratios were found in the BP sample but the sucrose content of the sample was significantly (P = 0.001) lower than that of the others. Trace amounts of glucose and fructose (from 0.00% to 0.04%) and from 0.35% to 0.68% of sucrose were detected in CP and CC samples (Figure 2). Considering that sucrose has many disadvantages due to its high glycaemic index that facilitates the development of many metabolic diseases, such as diabetes mellitus, metabolic syndrome and obesity (Alizadeh *et al.* 2014), stevia-sweetened yogurt ice cream can be an alternative product for diabetic individuals. The lactose ratios of yogurt ice cream samples ranged from 2.88% to 3.87%. Since lactose is not fully (or only partly) digested in the small intestine, it has a relatively low calorie value and glycaemic index, thus it can be beneficial to people who are sensitive to hyperglycaemia (Schaafsma 2008). As shown in Table 2, the lowest calorie value (365.83 kJ/100 g) was calculated in the CP sample. Similarly, Alizadeh *et al.* (2014) reported that total replacement of sucrose with stevia resulted in a significant reduction in the calorie value from 143.03 Kcal to 105.25 Kcal in soft ice cream.

The effects of stevia and honey on colour values were statistically significant (P = 0.001). Colour measurements showed that the addition of stevia increased the L^* value in the plain sample. The highest L^* value (102.9) belonged to the CP sample and it was found to be statistically different (P = 0.001) from the others. The effects of honey and cocoa addition on the (+) b value of samples were found to be significant (P = 0.001). According to the colour analysis results, the highest (+)b value (11.60) was measured in BC sample. Solayman *et al.* (2016) reported that honey colour may vary from straw yellow to almost black tones depending on the mineral, pollen and phenolic content. Added cocoa decreased the L^* value and increased the (+)a value in AC, BC, CC samples and these were measured to be 36.23, 44.76, 45.74 and 8.62, 8.41, 8.53 respectively (Table 2).

Physicochemical properties of yogurt ice cream. Yogurt ice cream samples with cocoa had a higher pH value than the plain ones (Table 3). This result was mirrored by the findings of Dagdemir *et al.* (2004) and Ozdemir *et al* (2015). Depending on the impact of alkalization in cocoa production, the pH levels of cocoa powders vary between 6.50 and 7.61 (Miller *et al.* 2008). For this reason, the pH of samples with cocoa was higher than that of plain samples. Acidity and pH values did not change significantly during storage. The highest mean viscosity value (6.01 Pa.s) belonged to CC sample. It was found that plain ice cream samples with honey (BP) had the lowest viscosity. Cocoa addition significantly (P = 0.001) increased the viscosity values of all samples. The overrun of plain samples was relatively higher than in the samples with cocoa, but the sample variable did not create any statistical difference in the overrun rates (P = 0.105). CP and CC samples had the highest first dripping (1525 and 1683 sec) and complete melting times (3371 and 3481 sec) (P = 0.001). Added honey decreased first dripping and complete melting time

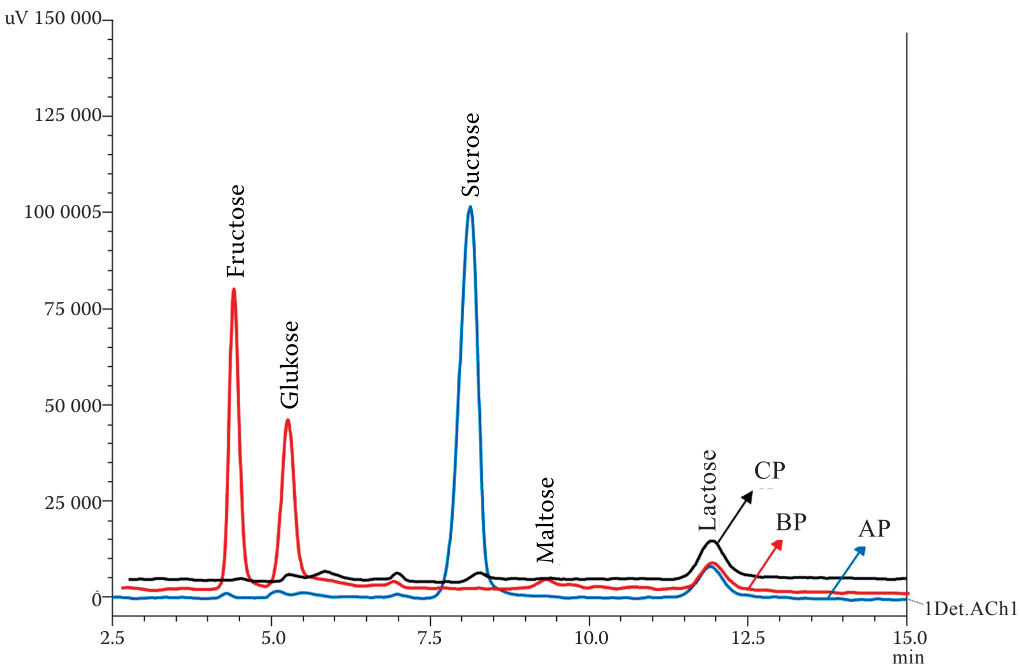

Figure 2. The sugar chromatograms of samples of yogurt ice cream with sucrose (AP), honey (BP) and stevia (CP)

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Table 3. Physical and chemical properties of yogurt ice cream

		Acidity (% LA)	pH	Viscosity (Pa·s)	Overrun (%)	Melting analysis (second)	
						first dripping	complete melting
Samples (*n* = 6)	AP	0.598 ± 0.01[d]	4.72 ± 0.07[d]	5.22 ± 0.32[b]	24.55 ± 14.6	919 ± 20[de]	2343 ± 39[b]
	AC	0.574 ± 0.01[e]	5.11 ± 0.03[a]	5.95 ± 0.22[a]	21.06 ± 9.85	1065 ± 21[c]	2398 ± 37[b]
	BP	0.617 ± 0.03[c]	4.64 ± 0.01[f]	4.16 ± 0.40[c]	18.78 ± 5.62	833 ± 23[e]	2119 ± 55[c]
	BC	0.600 ± 0.02[d]	5.02 ± 0.01[c]	5.20 ± 0.67[b]	17.66 ± 4.63	929 ± 28[d]	2205 ± 59[bc]
	CP	0.732 ± 0.02[a]	4.69 ± 0.02[e]	5.35 ± 0.28[b]	22.53 ± 6.18	1525 ± 51[b]	3371 ± 70[a]
	CC	0.685 ± 0.02[b]	5.08 ± 0.02[b]	6.01 ± 0.54[a]	18.80 ± 4.21	1683 ± 50[a]	3481 ± 73[a]
Storage (day)	1	0.642 ± 0.03	4.85 ± 0.02	5.45 ± 0.03	32.66 ± 0.57[a]	709 ± 19[d]	1994 ± 20[d]
	7	0.636 ± 0.03	4.88 ± 0.02	5.49 ± 0.01	22.92 ± 0.35[b]	999 ± 12[cd]	2281 ± 13[cd]
	14	0.638 ± 0.02	4.86 ± 0.13	5.29 ± 0.01	18.42 ± 0.36[c]	1218 ± 23[bc]	2682 ± 15[bc]
	21	0.631 ± 0.03	4.90 ± 0.02	5.10 ± 0.05	15.99 ± 0.21[cd]	1337 ± 17[ab]	2894 ± 14[b]
	28	0.625 ± 0.02	4.90 ± 0.01	5.23 ± 0,10	12.81 ± 0.28[e]	1531 ± 30[a]	3413 ± 99[a]

Results are presented as a mean ± s.d.; mean values followed by different letters in the same column are significantly different ($P < 0.01$); LA – lactic acid ; for other abbreviations see Table 2

($P = 0.001$). Similarly, various researchers have also reported that the use of fructose as a sucrose substitute reduced the melting resistance in ice cream (Soukoulis *et al.* 2010; Soukoulis 2014).

Microbiological properties of yogurt ice cream. The coliform group bacteria were not found during the storage period in yogurt ice cream samples (<1 log CFU/g) (Table 4). During the storage period the yeast-mould count in the samples was below the maximum value defined in the Turkish Food Codex Microbiological Criteria Communiqué (< 2 log CFU/g). The Standard Plate Counts for the yogurt ice cream samples were found to be in the range between 3.942 log CFU/g and 4.225 log CFU/g and there was no statistical difference between the samples ($P = 0.709$). The SPC in the samples decreased during the storage period ($P < 0.001$). In the USA, standards for the coliform count are almost invariably 10 CFU/g for the finished product. Similarly, the maximum limit for coliforms is 10 CFU/ml in Canada. European Commission Regulation No. 1441/2007 laid down that for ice creams, the maximum limit for *Enterobacteriaceae* is 10 CFU/g. There is no US federal standard for SPC, although most governments at the state level specify either 40.001 CFU/g or 50.001 CFU/g down to as low as 20.001 CFU/g (Clarke 2012).

Table 4. Microbiological properties of yogurt ice cream (log CFU/g)*

		Standard plate count	*Lb. delbrueckii* subsp. *bulgaricus*	*S. thermophilus*	Coliform group	Yeast-moulds
Samples	AP	3.94 ± 0.04	5.02 ± 0.07[a]	5.22 ± 0.09[a]	< 1	< 2
	AC	4.09 ± 0.03	4.27 ± 0.03[b]	4.72 ± 0.02[ab]	< 1	< 2
	BP	4.14 ± 0.05	4.32 ± 0.06[b]	4.87 ± 0.05[ab]	< 1	< 2
	BC	4.22 ± 0.04	3.98 ± 0.05[bc]	4.70 ± 0.06[ab]	< 1	< 2
	CP	3.99 ± 0.03	3.65 ± 0.04[c]	4.52 ± 0.04[b]	< 1	< 2
	CC	4.06 ± 0.03	3.88 ± 0.05[bc]	4.42 ± 0.04[b]	< 1	< 2
Storage (day)	1	5.62 ± 0.02[a]	5.56 ± 0.06[a]	5.76 ± 0.04[a]	< 1	< 2
	7	4.26 ± 0.04[b]	4.11 ± 0.04[b]	4.50 ± 0.04[b]	< 1	< 2
	14	3.48 ± 0.03[c]	3.81 ± 0.03[b]	4.49 ± 0.08[b]	< 1	< 2
	21	3.45 ± 0.04[c]	3.72 ± 0.04[b]	4.41 ± 0.03[b]	< 1	< 2
	28	3.56 ± 0.04[c]	3.73 ± 0.06[b]	4.54 ± 0.03[b]	< 1	< 2

*Results are presented as a mean ± s.d.; mean values followed by different letters in the same column are significantly different ($P < 0.01$); for abbreviations see Table 2

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S. thermophilus and *Lb. delbrueckii* subsp. *bulgaricus* counts (5.222 and 5.023 log CFU/g) for the AP (plain control) sample were significantly (P = 0.001) higher compared to the others (Table 4). The CP sample had the lowest *Lb. delbrueckii* subsp. *bulgaricus* count (3.658 log CFU/g) (P = 0.001). Similarly, Isik *et al.* (2011) stated that the control whole-fat frozen yogurt had significantly more LAB than did control reduced-fat samples, and inulin and isomalt added samples. It was observed that the addition of cocoa decreased *L. delbrueckii* subsp. *bulgaricus* counts in the AC and BC samples. Similarly, in all of the samples the addition of cocoa had a negative effect on *S. thermophilus* count. The lowest *S. thermophilus* count (4.422 log CFU/g) was found in the CC sample and there was no statistical difference between the CP and CC samples. The change in the *S. thermophilus* and *Lb. delbrueckii* subsp. *bulgaricus* counts of the samples after day 7 of storage was statistically insignificant. Although the addition of stevia reduced the lactic acid bacteria (LAB) count, in all samples the total LAB count was above 6 log CFU/g during the storage. Also, Lopez *et al.* (1998) reported slight decreases in LAB counts, which confirmed the fact that the survival rate of LAB under frozen conditions, and after long storage, was totally acceptable.

Thermal properties of yogurt ice cream. The highest T_f values were determined in B (with honey) and C (with stevia) groups (Table 5). In the control group (A), the use of cocoa increased the T_f value (P = 0.001), whereas the value decreased in B and C groups. It was believed that this situation resulted from the interactions between the water and the ingredients and accordingly the varying non-freezing water content was an effective parameter. On the other hand, the highest ΔH_f values were determined in CP sample, and the lowest values were determined in AP and BC samples during the freezing process (P = 0.001). This showed that the use of stevia increased the amount of energy that must be removed during freezing. Ice cream formulation can affect the ice crystallization process by influencing the freezing point and/or the crystallization mechanism (Cook & Hartel 2010). In this study it is thought that the use of stevia in yogurt ice cream production elevated the energy requirements of the freezing process and limited the ice crystal growth.

It was observed that the use of stevia in yogurt ice cream production increased the T_m value but the use of honey decreased it (P = 0.001). Moreover, the cocoa use increased the T_m value in AC sample.

Table 5. Thermal properties of yogurt ice cream samples

		Freezing peak point (T_f) (°C)	Freezing enthalpy (ΔH_f) (J/g)	Melting peak point (T_m) (°C)	Melting enthalpy (ΔH_m) (J/g)	Ice crystal initial melting temperature T'_m		
						onset (°C)	endset (°C)	midpoint (°C)
Samples (n = 6)	AP	–15.17 ± 1.91^a	158.2 ± 6.80^{de}	–1.36 ± 0.40^d	153.0 ± 7.28^{de}	–35.35 ± 2.03^c	–30.53 ± 1.57^b	–33.15 ± 1.79^c
	AC	–13.56 ± 2.20^b	166.8 ± 21.35^c	–0.39 ± 1.13^c	162.9 ± 24.4^c	–33.09 ± 2.29^d	–28.52 ± 1.65^b	–30.78 ± 2.13^d
	BP	–12.35 ± 0.91^c	164.0 ± 12.51^{cd}	–1.69 ± 0.79^{de}	154.5 ± 13.2^d	–39.42 ± 0.47^a	–32.78 ± 2.20^a	–36.65 ± 0.43^a
	BC	–12.41 ± 0.37^c	156.4 ± 6.34^e	–2.06 ± 0.38^e	145.8 ± 5.67^e	–38.56 ± 0.59^b	–32.84 ± 2.64^a	–35.76 ± 0.91^b
	CP	–11.28 ± 0.73^c	208.0 ± 4.97^a	1.47 ± 0.42^a	212.1 ± 5.35^a	–30.86 ± 1.04^e	–23.79 ± 1.59^c	–27.47 ± 0.91^e
	CC	–11.86 ± 2.01^c	193.7 ± 25.8^b	0.71 ± 1.23^b	194.7 ± 29.3^b	–30.61 ± 2.16^e	–25.36 ± 3.13^c	–27.83 ± 2.58^e
Storage (day)	1	–12.69 ± 2.43	171.9 ± 24.9	–0.68 ± 1.42	167.2 ± 30.5	–34.53 ± 3.92	–28.76 ± 3.73	–31.85 ± 3.79
	7	–12.81 ± 2.08	173.6 ± 26.9	–0.55 ± 1.61	169.8 ± 31.3	–34.35 ± 3.79	–29.27 ± 4.01	–31.78 ± 3.62
	14	–12.46 ± 1.22	172.3 ± 23.9	–0.72 ± 1.57	168.6 ± 30.6	–35.30 ± 4.03	–28.84 ± 4.40	–32.37 ± 4.33
	21	–13.00 ± 2.14	179.2 ± 24.4	–0.44 ± 1.53	172.1 ± 30.5	–34.40 ± 4.01	–28.69 ± 3.75	–31.76 ± 4.18
	28	–12.90 ± 1.95	174.5 ± 24.4	0.37 ± 1.66	174.9 ± 28.8	–34.67 ± 3.90	–29.31 ± 5.06	31.94 ± 4.33

Results are presented as a mean ± s.d.; mean values followed by different letters in the same column are significantly different (P < 0.01); for abbreviations see Table 2

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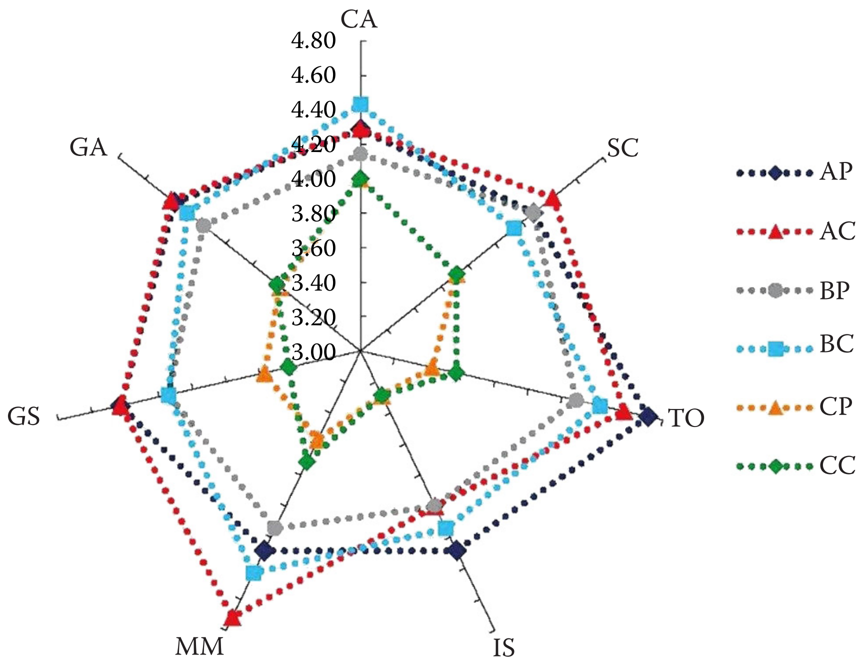

Figure 3. Sensory properties of yogurt ice cream samples

CA – colour and appearance; SC – structure and consistency; TO – taste and odour; IS – icy structure MM – melt in mouth; GS – gummy structure; GA – general acceptability; for other abbreviations see Table 2

Melting, a first-order phase change, is one of the most important parameters affecting the quality of ice cream. Similarly, the highest ΔH_m value was detected in CP and CC samples, while the lowest mean ΔH_m value was detected in AP, BP and BC samples (P = 0.001). The use of cocoa increased the ΔH_m value in AC sample and decreased the value in BC and CC samples. Various researchers have reported that the use of fructose as a sucrose substitute reduces the melting resistance in ice cream (Soukoulis *et al.* 2010; Soukoulis 2014). It is well established that the composition of sweetener in ice cream impacts its colligative properties (Cook & Hartel 2010). However, the use of cocoa in BC and CC samples showed a negative effect on stability.

T'_m values (onset, midpoint, endset) are important quality indicators in terms of stability. It was observed that the use of stevia in yogurt ice cream production increased the T'_m values at a significant level compared to the control (Table 5). The T'_m values were determined to be lower in BP and BC samples compared to the AP and AC samples (P= 0.001). This situation may be due to a higher level of molecular water mobility in the samples. The use of cocoa increased the T'_m values in AC and BC samples. According to these results, it is possible to say that the use of stevia in yogurt ice cream production had a positive effect on the product stability. A similar situation was also reported by Singh and Roos (2010) for the sugar-polymer mixture model systems. However, it is possible to say that the decreased amount of sucrose (342.3 g/mol) contained in the composition for the samples with stevia and its replacement with the stevioside substance that has a higher molecular weight (967 g/mol) were effective on and increased the T'_m value.

Sensory properties of yogurt ice cream. The results of the sensory evaluation of yogurt ice cream samples on a scale from 1 (defective) to 5 (excellent) are shown in a radar plot in Figure 3. As shown in Figure 3, samples with sucrose (AP and AC) had higher scores in terms of general acceptability, but no significant differences were observed between the A and B groups (P = 0.297). In addition, cocoa yogurt ice cream with honey (BC) had the highest colour and appearance scores. Stevia addition in yogurt ice cream production significantly (P = 0.001) affected all sensory properties. According to sensory analysis results, samples with stevia had lower scores than sucrose and honey yogurt ice cream samples. Likewise, Yogiraj *et al.* (2014) reported that the overall acceptability of ice cream samples decreased in samples containing over 2.25% of stevia powder.

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CONCLUSIONS

The study findings suggest that in the production of yogurt ice cream as a sucrose substitute, honey may be used as an alternative sweetener despite the relatively undermining physical properties of the ice cream. Furthermore, no significant differences were detected in general acceptability according to the sensory panel between the samples with sucrose and honey. In addition, yogurt ice cream with honey may be preferred due to its lower-calorie content compared to samples with sucrose. The addition of stevia improved the physical stability of the yogurt ice cream despite its poor sensory characteristics. Stevia-sweetened yogurt ice cream can be suggested as an alternative product for diabetic individuals. However, different studies should be carried out to eliminate the negative effect of stevia on the sensory properties of yogurt ice cream.

References

Ahmadi A., Milani E., Madadlou A., Mortazavi S.A., Mokarram R.R., Salarbashi D. (2014): Synbiotic yogurt ice cream produced via incorporation of microencapsulated *lactobacillus acidophilus* (la-5) and fructooligosaccharide. Journal of Food Science Technology, 51: 1568–1574.

Alizadeh M, Azizi-Lalabadi M., Kheirouri S. (2014): Impact of using stevia on physicochemical, sensory, rheology and glycemic index of soft ice cream. Food and Nutrition Sciences, 5: 390–396.

Amchra F.Z., Al Faiz C., Chaouqi S., Khiraoui A., Benhmimou A., Guedira T. (2018): Effect of *Stevia rebaudiana*, sucrose and aspartame on human health: A comprehensive review. Journal of Medicinal Plant Studies, 6: 102–108.

Arbuckle W.S. (1986): Formulas and industry standards. In: Arbuckle W.S. (eds.): Ice cream. New York, Van Nostrand Reinhold: 405.

Bradley R.L., Arnold E., Barbano D.M., Semerad R.G., Smith D.E., Vines B.K. (1992): Chemical and physical methods. Dairy Products: Standard Methods for the Examination of Dairy Products R.T. Marshall (ed). WA, USA., APHA: 433–529.

Bodyfelt F.W., Tobias J., Trout G.M. (1988): The sensory evaluation of dairy products. New York, AVI Book: 166–226.

Clarke C. (2012): The science of ice cream. Royal Society of Chemistry (2nd Ed.), Thomas Graham House, Science Park, Milton Road, Cambridge CB4 0WF, UK: 201.

Cook K.L.K., Hartel R.W. (2010): Mechanisms of ice crystallization in ice cream production. Comprehensive Reviews in Food Science and Food Safety, 9: 213–222.

Cotrell J.F.L., Pass G., Phillips G.O. (1979): Assessment of polysaccharides as ice cream stabilizers. Journal of the Science of Food and Agriculture, 30: 1085–1089.

Cruz A.G., Castro W.F., Faria J.A.F. (2013): Stability of probiotic yogurt added with glucose oxidase in plastic materials with different permeability oxygen rates during the refrigerated storage. Food Research International, 51: 723–728.

Dagdemir E., Ozdemir C., Celik S., Ozdemir S. (2004): Determination of some properties of caramel cocoa and coffee flavored ice creams. In: International Dairy Symposium, 24–28 May, Isparta, Turkey: 218-221.

Flores A.A., Goff H.D. (1999): Ice crystal size distributions in dynamically frozen model solutions and ice cream as affected by stabilizers. Journal of Dairy Science, 82: 1399–1407.

Giri A., Rao H.G.R, Ramesh V. (2014): Effect of partial replacement of sugar with stevia on the quality of kulfi. Journal of Food Science and Technology, 51: 1612–1616.

Goff H.D., Hartel R.W. (2013): Analyzing Frozen Desserts, Sensory Analyses. In: Goff H.D., Hartel, R.W. (eds): Ice Cream: Springer New York Heidelberg Dordrecht London: 423–431.

Hagiwara T., Hartel R.W. (1996): Effect of sweetener, stabilizer, and storage temperature on ice recrystallization in ice cream. Journal of Dairy Science, 79: 735–744.

Harrigan W.F. (1998): Laboratory methods in food microbiology, San Diego, US., Academic Press: 519.

Isik U., Boyacioglu D., Capanoglu E., Erdil D.N. (2011): Frozen yogurt with added inulin and isomalt. Journal of Dairy Science, 94: 1647–1656.

Koburger J.A., Marth E.H. (1984): Yeast and molds. Compendium of methods for the examination of foods. M.L. Speck (ed). Washington DC, APHA: 197–201.

Lopez M.C., Mendia L.M., Jordano R. (1998): Survival of lactic acid bacteria in commercial frozen yogurt. Journal of Dairy Science, 63: 706–708.

Miller K.B., Hurst W.J., Payne M.J., Stuart D.A., Apgar J., Sweigart D.S., Ou B. (2008): Impact of alkalization on the antioxidant and flavanol content of commercial cocoa powders. Journal of Agricultural and Food Chemistry, 56: 8527–8533.

Momtazi-Borojeni A.A., Esmaeili S.A., Abdollahi E., Sahebkar A. (2017): Review on the pharmacology and toxicology of steviol glycosides extracted from *Stevia rebaudiana.* Current Pharmaceutical Design, 23: 1616–1622.

Moriano M.E., Alamprese C. (2017): Honey, trehalose and erythritol as sucrose alternative sweeteners for artisanal ice cream: A pilot study. LWT-Food Science and Technology, 75: 329–344.

Ozdemir C., Arslaner A., Ozdemir S., Allahyari M. (2015): The production of ice cream using stevia as a sweetener. Journal of Food Science and Technology, 52: 7545–7548.

https://doi.org/10.17221/311/2018-CJFS

Regand A., Goff H.D. (2003): Structure and ice recrystallization in frozen stabilized ice cream model systems. Food Hydrocolloids, 17: 95–102.

Renaud T., Briery P., Andrieu J., Laurent M. (1992): Thermal properties of model foods in the frozen state. Journal of Food Engineering, 15: 83–97.

Peres J., Esmerino E., da Silva A.L., Racowski I., Bolini H. (2018): Sensory profile, drivers of liking, and influence of information on the acceptance of low-calorie synbiotic and probiotic chocolate ice cream. Journal of Food Science, 83: 1350–1359.

Schaafsma G. (2008): Lactose and lactose derivatives as bioactive ingredients in human nutrition. International Dairy Journal, 18: 458–465.

Shivanna N., Naika M., Khanum F., Kaul V.K. (2013): Antioxidant, anti-diabetic and renal protective properties of *Stevia rebaudiana*. Journal of Diabetes and its Complications, 27: 103–113.

Singh K.J., Roos Y.H. (2010): Physical state study of (sugar mixture)-polymer model systems. International Journal of Food Properties, 13: 184–197.

Soukoulis C., Rontogianni E., Tzia C. (2010): Contribution of thermal, rheological and physical measurements to the determination of sensorially perceived quality of ice cream containing bulk sweeteners. Journal of Food Engineering, 100: 634–641.

Solayman M., Islam M.A., Paul S., Ali Y., Khalil M.I., Alam N., Gan S.H. (2016): Physicochemical properties, minerals, trace elements, and heavy metals in honey of different origins: A comprehensive review. Comprehensive Reviews in Food Science and Food Safety, 15: 219–233.

Soukoulis C., Fisk I.D., Bohn T. (2014): Ice cream as a vehicle for incorporating health-promoting ingredients: conceptualization and overview of quality and storage stability. Comprehensive Reviews in Food Science and Food Safety, 13: 627–655.

Yogiraj R.K.D., Anantrao N.S., Piritam K.H., Sharddha S.Z., More K.D. (2014): Preparation of ice cream using natural sweetener stevia. Food Science Research Journal, 5: 30–33

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