The effect of stevia, emulsifier and milk powder on melting rate, hardness and overrun of ice cream formulations during storage

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Abstract

Four types of ice creams were manufactured using stevia (S), milk powder (PP), emulsifier (PS) and UHT whole milk (C), and were investigated for physical, chemical and sensory characteristics. The pH values of ice cream samples ranged from 5.82 to 6.62. The hardness values from textural analyses was around 3.40 and 598.61 N. The highest overrun ratio (29.27 %) was found in PP ice cream during the first week of storage. The substitution of sucrose by stevia powder led to a significant elevation of the hardness of ice cream.

Key words: **texture, melting rate, colour, sensory analysis, microscopic view, fat destabilization, rheology properties**

Introduction

Ice cream is a well-liked dairy product worldwide made by freezing a pasteurised mix of milk, sugar, flavouring, corn syrup, emulsifier, stabilizer and sometimes eggs. The characteristics of ice cream depend mostly upon the components used as well as manufacturing parameters and storage status (Kilara and Chandan, 2007). Adapa et al. (2000) stated that the composition of ice cream changes depending on the processing parameters and trade requests, although the final product quality of ice cream depends mainly on manufacture condition and the components. Ice cream fortification with different kinds of sweetener and sugar replacements can affect various properties of the mix which impact the ice cream texture (Caillet et al., 2003). Ice cream is nourishable food containing valuable nutritients and is extensively consumed by different groups of population. Stevia is a natural sweetener used as sucrose replacement by many food and beverage companies over the world (Ozdemir et al., 2008; Hossain et al., 2010; Goyal et al., 2010). It is perfect for obese people and diabetics due to its natural composition (Lemus-Mondaca et al., 2012). Principally it does not contain glucose or sucrose and it can produce healthy and nutritious foods. Different investigations have reported anti-tumor, anti-hyperglycemic, anti-inflammatory, anti-hypertensive, diuretic and

anti-diarrhea effects of stevia (Chatsudthipong and Muanprasat, 2009). The composition of ice cream affects its hardness and melting capacity although the specific relationships have not been investigated yet (Muse and Hartel, 2004).

Ice cream mixes must be homogenized to obtain maximum benefit from emulsifiers and over emulsification, may cause a curdy meltdown or undesirable greasy mouthfeel (Moeenfard and Tehrani, 2008). Emulsifiers are also useful in the fat emulsion stability during the freezing of ice cream. The objective of this research was to evaluate the effect of the addition of stevia, emulsifier and milk powder on the physical-chemical and sensory properties of ice cream during storage.

Materials and methods

Ice cream manufacture and sampling

Ice cream samples were produced in the Laboratory of Food Production in Food Technology Department, University of Tetova. The ice cream production was done in duplicate. The whole UHT and powder milk used in the production of ice cream was from the Slovenian company "Ljublanske Mlekarne, Alpsko" and "Pomurske Mlekarne", respectively. Other ingredients used in the ice cream mix were sugar, stevia (Vitalia), neutralin emulsifiers (CMC) and vegetable cream. The ice cream was produced with Valmar Snowy 6 freezer. The first stage of an ice cream production was the preparation of the mix of ingredients (Table 1). Whole UHT milk, stevia, milk powder, refined sugar and emulsifier were added to an industrial blender and mixed. This mixture was produced 24 h before the homogenization step. The mixture was homogenized for 10 min and frozen after the period of maturation. The ice creams were stored in a freezer at -18 °C. Composition of mixes was different depending on the type of ice cream intended for production, while the technological process is similar (Table 1). The preparation of the mix was calculated for the production of 5 kg of ice cream. The produced ice cream was stored for six weeks and in the meantime physical-chemical, textural and sensory analyses were carried out in the 1st, 3rd and 6th week. The produced ice cream complies with the requirements for quality standardization of dairy ice cream of the Republic of North Macedonia (Official Gazette No. 96/2011).

Chemical analyses

The ice creams were analyzed in terms of proximate composition, pH, total solids and physical characterization. The value of titration acidity and pH in ice cream is done by the methods as described by Fiol et al. (2016). Fat content was determined according to Gerber's method (Kleyn et al. 2001). Protein content, dry matter and ash content analyses were conducted according to the official methods (AOAC, 1997).

Physical analysis

COLOUR ANALYSES

The colour analyses (L values) of the ice cream mixes were carried out at three different stages of storage (0, 3 and 6 weeks) using a Minolta Chroma Meter (model CR-5, Konica Minolta, Osaka, Japan) with 10° standard observer and D 65 illuminant. Measurements were performed in triplicate for each treatment on non-overlapping areas of the ice creams. The lightness (L^*) colour parameter was determined and was repeated at four randomly selected locations on each sample and average data were reported.

TEXTURE ANALYSES

Textural properties of the ice cream were determined using a texture analyzer (TA-XT2 Texture Technologies Corp., Scarsdale, NY, USA). Detecting of shear force (g) was conducted using a cylindrical probe with 2.5 cm in diameter and 3.5 cm in height. The ice cream sample was filled in a suitable beaker (50 mL) for g force measurement to prevent disturbing its physical and textural states. The speed was set to 2 mm/s as described by Tunick (2000).

Ingridients (%)	Formulation			
	S	PS	PP	C
Stevia powder	8.5	0	0	0
Neutralin	0.3	0.3	0	0.3
Milk powder	16.2	16.2	16.2	0
UHT Milk	0	0	0	76.7
Vegetable cream	0.6	0.6	0.6	0.6
Sugar	0	22.4	22.4	22.4
Water	74.4	60.5	60.8	0

FAT DESTABILIZATION

This parameter was measured by dilution of ice cream (1:500 with water) and measurement of absorbance in a spectrophotometer at 540 nm (Goff and Jordan, 1989).

MELTING PROPERTIES

50 g of ice cream, which was considered as appropriate melting amount, were placed into the on a 0.2 cm wire mesh screen above measuring funnel in which the ice cream melted at room temperature, 20 °C. After 5, 10, 15, 20, 25, 30, 35 and 40 minutes of melting, the melted sample was collected, the portions weighed and compared to the initial weight of the freezed sample (Antepüzümü, 2005).

LINE SPREAD TEST (LST)

The test of the extent of the mass over the lines is a viscosity measurement method for thick liquid products by measuring the sampling distance of the sample on a fair surface. The LST set is made up of a transparent slab under which a measuring plate is placed at intervals of 0.5 cm. An open tube with 2 cm height and 2 cm diameter is filled with 5 mL of sample and placed in the centre of the measuring gauze. Once the tube is raised, the fluid is allowed to flow and the dispersed distance is measured in each 90-degree section of the circle and then averaged.

THE STRUCTURE OF ICE CREAM

The microstructure and the examination of air cells in frozen ice cream samples were measured with a Carl Zeiss Model light microscope (Carl Zeiss Microscopy GmbH 07745 Jena, Germany) as described by Chang and Hartel (2002). An ice cream samples were usually prepared by cutting a thin section and observed in light microscopy at scale bar = 100 μm. The samples were poured onto microscope slides, covered with glass cover slips, and observed under a magnification of ×20. At least 5 replications were prepared for each sample.

SENSORY ANALYSES

The sensory properties of the ice cream were evaluated by ten skilled panellists using a sensory rating scale of 1-9 for appearance, aroma, taste, body and general acceptability as described by Ozdemir et al. (2008). The sensory evaluation was assessed on a scale from 1 for very poor, to 9 for excellent. The ice cream samples were randomly marked and announced to panellists under typical daylight room conditions. The panel of assessors was an external panel of non-smokers who were very familiar with ice cream products.

Statistical analysis

Duncan's multiple comparison tests were used as a guide for paired comparisons of treatment means. The amount of significance of differences between treatments was considered at $P<0.05$. Statistical treatments were carried out using the SPSS version for Windows, version 9.0 (SPSS Inc., Chicago, IL, USA).

Results and discussion

Chemical composition of an ice cream

The physicochemical characteristics of the examined ice cream formulations are presented in Table 2. The titratable acidity (%) of the ice cream samples ranged from 0.16 to 0.23. The acidity results of the fresh produced ice creams manufactured with milk powder and stevia powder were found to be not statistically significant ($P>0.05$). During the storage period of 3 and 6 weeks, the acidity increased or decreased slightly in all samples, respectively, which was non-significant

except for (S) sample. Identical data were found in diabetic ice cream samples by Ozdemir et al. (2003). The use of sugar, emulsifier and milk powder in ice cream production significantly (P<0.05) affected the pH of the ice creams. The increase in pH values of yoghurt ice cream in the first month of storage may result from the degradation of the protein (Guner et al., 2007). Samples of (PS) ice creams presented higher dry matter contents than other formulations during first (44.67 %) and third weeks (45.20 %) of storage. During the sixth week of storage, the (S) samples showed higher values of dry matter than all other presented averages. Ash content in ice creams was with significant differences (P<0.05) and highest value in (S) ice creams during the third and sixth week of storage and lower value in (C) ice cream. In the current study, the data of approximate composition results indicated that the (S) ice cream presented higher contents of protein, total solids and titratable acidity values than other formulations (P<0.05) during the sixth week of storage.

TABLE 2. Acidity, pH, total solids, protein, fat and ash values of ice creamsmanufactured using stevia (S), milk powder (PP), emulsifier (PS), and UHT whole milk (C) during storage at -18±2 °C

Sample	Storage (week)	Acidity (g lactic acid /100 g)	pH	Total solid (g/100 g)	Protein (g/100 g)	Fat (g/100 g)	Ash (g/100 g)
S		0.19±0.01[a,A]	6.06±0.01[d,A]	37.99±0.70[a,A]	2.98±0.06[a,A]	3.30±0.01[a,A]	0.54±0.08[a,A]
PS		0.18±0.01[a,A]	5.82±0.01[a,A]	44.67±0.58[b,A]	2.17±1.03[a,A]	3.74±1.86[a,A]	0.44±0.16[a,A]
PP	1	0.19±0.01[a,A]	5.96±0.01[c,A]	43.57±0.42[b,A]	2.66±0.10[a,A]	3.74±0.31[a,B]	0.39±0.07[a,A]
C		0.16±0.06[a,A]	5.92±0.01[b,A]	39.09±1.41[a,A]	2.42±0.33[a,A]	2.53±0.15[a,A]	0.55±0.07[a,B]
S		0.22±0.06[b,A]	6.62±0.01[d,C]	36.12±0.38[a,A]	N.A	N.A	0.65±0.03[b,A]
PS	3	0.19±0.03[ab,A]	6.49±0.00[b,C]	45.20±2.22[b,A]	N.A	N.A	0.61±0.01[b,A]
PP		0.20±0.05[ab,A]	6.41±0.01[a,B]	44.99±1.03[b,A]	N.A	N.A	0.46±0.04[a,A]
C		0.17±0.01[a,A]	6.52±0.01[c,C]	41.44±0.93[b,A]	N.A	N.A	0.63±0.04[b,B]
S		0.22±0.02[a,A]	6.46±0.01[c,B]	56.62±2.41[c,A]	4.08±0.34[c,B]	3.96±0.31[b,B]	0.60±0.06[b,A]
PS	6	0.19±0.02[a,A]	6.43±0.00[b,B]	44.69±1.18[b,A]	3.65±0.18[bc,A]	3.96±0.00[b,A]	0.61±0.02[b,A]
PP		0.18±0.01[a,A]	6.41±0.01[a,B]	42.57±0.92[b,A]	2.79±0.28[a,B]	2.90±0.46[a,A]	0.45±0.01[a,A]
C		0.18±0.02[a,A]	6.48±0.01[d,B]	38.44±0.16[a,A]	3.09±0.15[ab,A]	3.85±0.15[b,B]	0.34±0.08[a,A]

Different superscript uppercase letters in the same column indicate significant differences (P<0.05) for the same sample on the different week of storage. Different superscript lowercase letters in the same column indicate significant differences (P<0.05) between all the samples on the same week of storage.

Similarly, Pon et al. (2015) achieved a significant increase of total solids by using stevia in ice cream manufacture. Nonsignificant variations were detected in the protein content of the fresh ice creams, but were higher than values obtained from analyses of the (PS) samples. In all fresh combinations, introduced protein contents were almost similar with averages of Lima et al. (2016). The protein content of (S) formulation during the sixth week of storage differed significantly (P<0.05) from other types and was in accordance with the averages determined in the literature, about 4 % (Erkaya et al., 2012).

Physical analyses

Table 3 presents the overrun behaviour of ice cream mixture samples with different formulations. Overrun does not only affect the consistency of the ice cream, but also concerns the quality of the food, its consistency, yield and nutritional value (Aloğlu et al., 2018). Significantly (P<0.05) the highest value of overrun was in (PP) ice cream (29.28 %) and the lowest in (S) ice cream (15.65 %) during the first week. Overrun showed a significant (P<0.05) decrease during the storage in all ice creams, with the highest value in (S) sample. These findings were inconsistent with reports of Alizadeh et al. (2014). These values are in consistent with the investigation of Antepüzümü (2005) and Ozdemir (2015).

The use of powder milk had a positive effect on the volume increase.

The use of stevia significantly affected the fat destabilization in ice cream formulations (Table 3). In the first week of storage, the highest values were detected in (PP) ice cream and the lowest in the (S) ice cream. Values for all ice creams increased during the third week of storage, with the highest one detected in (S) samples. Decrease in the values was found in the sixth week, with the highest values in (PP) and the lowest ones in (S) samples. The destabilization of fats is necessary for giving the structure of ice cream. Fat destabilization refers to the process of accumulation of fatty globules leading to the generation of an extended internal fat network or matrix structure in the product.

TABLE 3. L value, fat destabilization and overrun of ice creams manufactured using stevia (S), milk powder (PP), emulsifier (PS), and UHT whole milk (C) during storage at -18±2 °C

Sample	Storage	L value		Fat destabilization		LST		Overrun	
	(Week)	Mean	SD	Mean	SD	Mean	SD	Mean	SD
S	1	63.95[aA]	2.56	0.38[aA]	0.05	2.80[aA]	0.28	15.65[aC]	0.23
PS		64.36[aA]	2.06	0.47[cA]	0.07	2.55[aA]	0.07	25.20[cC]	0.61
PP		65.41[aA]	0.99	0.46[cA]	0.05	3.39[aB]	0.23	29.28[dC]	0.99
C		71.27[bA]	1.96	0.40[bB]	0.01	2.58[aA]	0.46	15.70[bC]	0.99
S	3	74.67[aB]	1.44	0.81[bB]	0.01	2.84[aA]	0.12	14.21[dB]	0.99
PS		72.90[aB]	3.65	0.60[bB]	0.05	2.45[aA]	0.04	8.09[aA]	1.96
PP		70.50[aA]	2.44	0.48[abA]	0.05	2.58[aA]	0.18	12.31[cB]	0.61
C		72.73[aA]	0.33	0.39[aB]	0.23	2.58[aA]	0.53	9.70[bB]	0.76
S	6	70.61[aB]	0.76	0.36[aA]	0.05	2.68[abA]	0.04	10.83[bA]	0.76
PS		72.51[aB]	0.61	0.41[bA]	0.05	2.35[aA]	0.28	10.96[bB]	2.12
PP		68.71[aA]	2.12	0.43[cA]	0.01	2.48[abA]	0.25	11.70[cA]	1.44
C		73.58[aA]	3.08	0.36[aA]	0.01	2.96[bA]	0.12	3.17[aA]	0.99

DIFFERENT SUPERSCRIPT lowercase letters in the same column indicate significant differences (P < 0.05) between all the samples on the same week of storage. Different superscript uppercase letters in the same column indicate significant differences (P<0.05) for the same sample on the different week of storage.

LST values obtained in the first week showed insignificant (P>0.05) highest value in (PP) ice cream (3.31) and lowest in (S) ice cream (2.44) which may be related to the impact of stevia (Alizadeh et al., 2014). In third and sixth weeks there was a decrease in viscosity which is in consistent with results of Dagdemir et al. (2004). An inverse relationship was found between the overrun and the hardness of ice-creams similarly to findings reported by Wilbey *et al.* (1998). Hartel et al. (2003) reported that an ice cream with high overrun melted slowly than ice creams with low overrun, which showed good melting resistance. According to the results of the first week, the highest (P<0.05) L value was noted in (C) and the lowest in (S) ice cream. In the third week, the (S) samples showed higher values, while the lowest ones were found in (PP) samples. L values decreased from the first week to the sixth week and these results are in accordance with Park et al. (2015). The obtained results are in accordance with the requirements of the state regulations for the quality of ice cream (Official Gazette No. 96/2011). The whiteness of milk products is affected by several factors during product storage that includes light scattering on fat and protein particles (Metzger et al., 2000). Figure 1 shows the results of melting kinetics on the ice cream produced. Sample S showed a lower melting capacity during the three measurements similarly to Alizadeh et al., 2014). All measurements showed slower melting of the (S), (PS) and (C) compared to the (PP) ice creams, that did not contain the emulsifier. Similarly, Goff and Jordan (1989) found that the emulsifier affects the better dispersion of air bubbles and slows the melting kinetics. The hardness values from texture measurement are shown in Figure 2. The results show higher hardness of the (S) ice cream during the storage period. Similar trends were observed by Pon et al. (2015).

Also higher water content of samples affects ice crystal to pack closer to each other. A greater force is required to be used to the surface of the ice cream that is being classified as hard. The size and number of ice crystals formed during the freezing and storage process determine the ice cream hardness (Goff, 1997; Muse and Hartel, 2004).
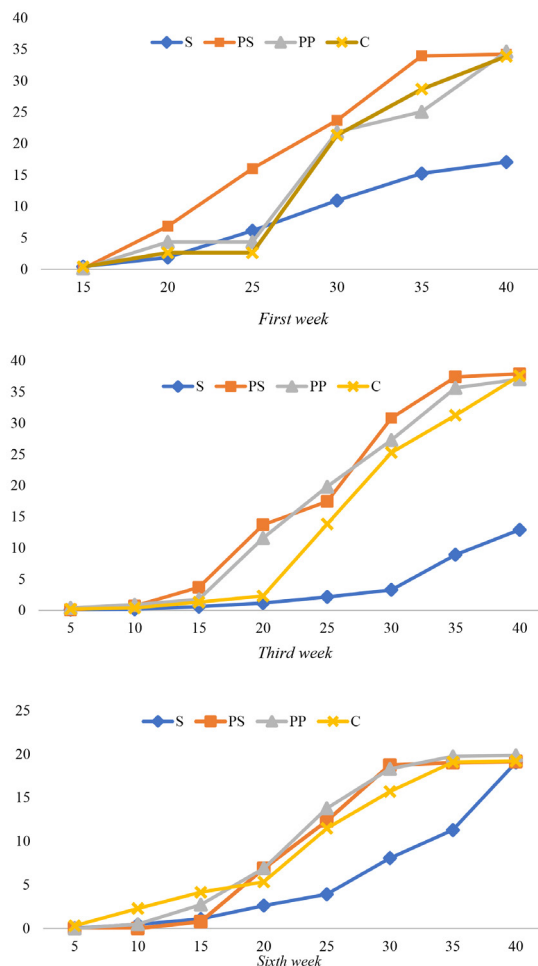
FIGURE 1. Kinetics of melting rate of the ice creams produced with different formulations stevia (S), milk powder (PP), emulsifier (PS), and UHT whole milk (C) during three period of storage
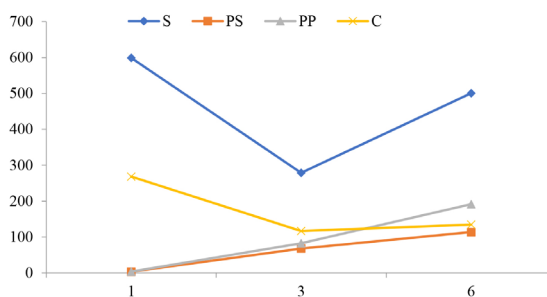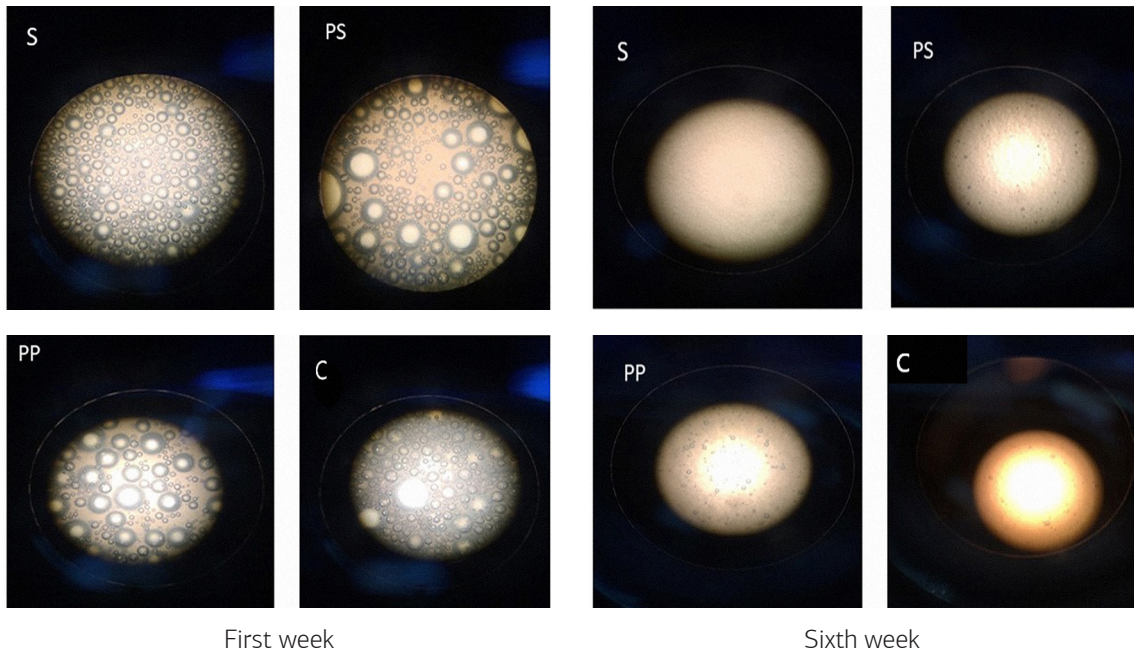

FIGURE 2 Hardness of the ice creams produced with different formulations stevia (S), milk powder (PP), emulsifier (PS), and UHT whole milk (C) during first, third and sixth week of storage

Figure 3 shows the microscopic view of ice cream samples during storage. The size and distribution of air bubbles can be observed during the first week of storage. In the first week (Figure 3a), air bubbles scattered throughout the samples can be clearly observed, which is normal and necessary to incorporate air during the freezing process (Chang and Hartel, 2002a). In the sixth week of storage observed air bubbles were reduced or disappeared completely (Figure 3b).

Chang and Hartel (2002b) found that air bubbles were unstable and tend to disappear during the storage period. During storage in inadequate ice-cream temperatures, air bubbles coalesce leading to a total change in air cell dispersion, which contributes to texture changes of ice-cream (Goff and Hartel, 2013).

First week   Sixth week

FIGURE 3 (a). Microscope view of air bubbles of the ice creams produced with different formulations stevia (S), milk powder (PP), emulsifier (PS), and UHT whole milk (C)

Sensory analysis

The results of the sensory evaluations of the ice creams with different combinations are shown in Table 4.

TABLE 4. Sensory analyses of ice creams manufactured using stevia (S), milk powder (PP), emulsifier (PS), and UHT whole milk (C) during storage at -18±2 °C

Sample	Storage		Appearance	Aroma	Flavour	Body	Acceptability
S	1	Mean	8.13[aB]	5.71[aA]	6.17[aA]	7.58[aC]	8.04[aA]
		SD	0.18	1.47	1.18	0.12	0.41
PS		Mean	8.29[aB]	6.38[aA]	6.50[aA]	8.08[aB]	7.92[aA]
		SD	0.06	1.94	2.12	0.59	0.59
PP		Mean	8.13[aAB]	5.96[aA]	7.00[aA]	7.71[aB]	7.88[aA]
		SD	0.18	1.83	1.41	0.06	0.18
C		Mean	8.54[aA]	6.50[aA]	6.67[aA]	8.08[aA]	7.88[aA]
		SD	0.29	2.12	1.89	0.59	0.18
S	3	Mean	8.58[aB]	6.50[aA]	6.00[aA]	6.25[aB]	8.17[aA]
		SD	0.12	0.71	0	0.35	1.18
PS		Mean	8.58[aB]	7.83[aA]	6.75[abA]	7.83[bB]	7.92[aA]
		SD	0.12	1.18	1.06	0.24	0.59
PP		Mean	8.58[aB]	7.92[aA]	8.58[cA]	8.17[bB]	8.33[aA]
		SD	0.12	0.59	0.12	0.24	0.47
C		Mean	8.42[aA]	8.50[aA]	8.50[bcA]	7.92[bA]	7.92[aA]
		SD	0.12	0.71	0.71	0.82	0.59
S	6	Mean	6.53[aA]	5.45[aA]	5.85[aA]	4.25[aA]	7.05[aA]
		SD	0.39	0.07	1.91	0.35	0.78
PS		Mean	7.30[abA]	6.85[abA]	7.35[aA]	5.65[bA]	7.00[aA]
		SD	0.42	0.49	0.21	0.21	1.41
PP		Mean	7.88[abA]	7.78[bA]	7.80[aA]	6.68[cA]	7.83[aA]
		SD	0.18	1.45	0.28	0.11	0.81
C		Mean	8.38[bA]	8.00[bA]	8.05[aA]	6.78[cA]	8.18[aA]
		SD	0.88	0	0.64	0.04	0.6

Different superscript uppercase letters in the same column indicate significant differences (P<0.05) for the same sample on the different week of storage. Different superscript lowercase letters in the same column indicate significant differences (P<0.05) between all the samples on the same week of storage.

Adding stevia with or without the emulsifier and the added milk powder insignificantly (P>0.05) affected the tested sensory characteristics (Table 4) of ice cream samples during the first week of storage, as well. For instance, during the third week of storage addition of stevia significantly (P<0.05) affected the taste and body attributes of ice cream samples. The results of the sensory assessment of the ice creams were very acceptable, as the points of overall acceptance remained between 7 to 8.

The decrease in the overall score was noticed from the sixth week. In the sixth week, the samples with highest points were (C) 7.8, (PP) 7.6, (PS) 6.8 and (S) 5.8, respectively. Generally, panellists preferred the samples containing sugar whole UHT milk. These analyses are in accordance with previous works that are found in the literature Ozdemir et al. (2015). The results obtained are in accordance with the requirements of the North Macedonia quality standards for the aroma and taste of milk ice cream according to Article 167/3 (Official Gazette No. 96/2011).

Conclusion

This study presented that stevia addition to ice cream is a useful option for reducing the usage of sugar in this category of food products. The samples showed acceptable sensory characteristics and the results of physicochemical analyses were similar for all tested variations, indicating that the analysed properties were not extremely affected by the addition of stevia. Moreover, the texture evaluations of the ice creams confirmed the importance of stevia to obtain a product with longer stability. Results from the sensory examination were favourable, specifying that the panellists endorsed the ice creams with stevia and with substitution of whole milk fat by milk powder. The pH of the ice cream during the storage process showed significant changes and significant differences (P<0.05) during the first to the sixth week. The textural analysis showed an increase in hardness during storage in all ice creams from first to six's week and ice cream with stevia showed higher values. During the sensory evaluation, (S) ice cream achieved the highest scores for appearance. Considering the results of microscopic analysis, the ice cream produced with stevia has maintained well at an adequate temperature for six weeks and has not allowed air bubbles to pool.

Acknowledgements

Utjecaj dodatka stevije, emulgatora i mlijeka u prahu na topljivost, čvrstoću i prihvat zraka različitih sladoleda tijekom skladištenja

Sažetak

U okviru ovog istraživanja proizvedene su četiri različite vrste sladoleda upotrebom stevije (S), mlijeka u prahu (PP), emulgatora (PS) i punomasnog (UHT) mlijeka. Svim uzrocima su određivani fizikalna, kemijska i senzorska svojstva. pH vrijednosti sladoleda kretale su se između 5,82 i 6,62, a čvrstoća od 3,40 do 598,61 N. Najviši stupanj prihvata zraka u sladolednu smjesu (29,27%) pokazao je sladoled oznake PP tijekom prvog tjedna skladištenja. Zamjena saharoze prahom stevije uzrokovao je značajan porast čvrstoće sladoleda.

Ključne riječi: tekstura, topljivost, boja, senzorska analiza, mikroskopiranje, destabilizacija masti, reološka svojstva

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