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The Effect of Different Culture and Stabilizer Use on the Physicochemical and Sensory Properties of Ice Cream

Ali Yeydem[1], Kurban Yasar[1*]

[1]Department of Food Engineering, Faculty of Engineering and Natural Sciences, Osmaniye Korkut Ata University, 80000, Osmaniye
*Correspondence; Kurban Yaşar
E-mail adress:
kurbanyasar@osmaniye.edu.tr

ORCID No: 0000-0002-6514-2101

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Abstract

This study examined the properties of buffalo milk yoghurt ice creams made with different starter cultures and stabilizers. The starter culture had a significant effect on acidity, pH, and sensorial properties of the samples. Ice creams made with an exopolysaccharide (EPS) producing culture were found to have better structure, taste and overall acceptability. The choice of stabilizer also had a significant impact on acidity, pH and sensory properties. Ice creams made with sahlep as a stabilizer were rated higher in terms of taste, odour, and general acceptability. Overall, ice creams made with the combination of an EPS-producing starter culture and sahlep stabilizer had the best sensory properties.

Keywords: Ice cream, buffalo milk yoghurt, exopolysaccharide (EPS), sahlep, stabilizer

1.INTRODUCTION

Approximately 81% of the world's milk is cow's milk. This is followed by buffalo milk with 15% (OECD/FAO, 2020). Buffalo milk is more intensely white and has superior whitening properties compared to cow's milk due to the greater opacity of casein micelles. It is lower in phospholipids and higher in saturated fatty acids. In addition, buffalo milk contains higher levels of conjugated linoleic acid, protein and fat than cow's milk (Mejares, et al., 2022).

Yoghurt, a dairy product produced by milk fermentation, contains lactic acid bacteria (LAB) that ferment lactose (producing lactic acid) and affect milk peptides and proteins (Gouda et al., 2021). The health benefits of LAB are often attributed to the various metabolites produced by LAB, such as fatty acids, organic acids, bacteriocins and exopolysaccharides (EPS) (Cao et al., 2021). During *Lactobacillus* growth, they secrete extracellular polysaccharides called exopolysaccharides (EPS). EPS has various functions due to exceptional rheological and water-binding properties. It is used in many emulsification applications in the food industry. They also dominate as thickening, gelling, encapsulating and hygroscopic agents (Bibi et al., 2021). To date, a large number of Streptococcus thermophilus strains producing EPS have been isolated and characterized. These exopolysaccharides improve the sensory, rheological and water binding properties of foods such as yoghurt (Cao et al., 2021).

Sahlep is a powder obtained by drying plant tubers belonging to the Orchidaceae family. The tubers extracted from the soil are dried and pulverized in a mill. Sahlep contains a lot of glucomannan (Yaşar and Bozdoğan, 2018). The quality characteristics of sahlep depend on its variety and chemical composition, especially its glucomannan content. Glucomannan in sahlep has good stabilizer properties and gives the ice cream a smooth, hard, flexible, homogeneous structure and stability (Bozdoğan and Yaşar, 2016). Glucomannans are natural, neutral, water-soluble fibers that help normalize blood sugar, alleviate stress on the pancreas, and prevent blood sugar abnormalities such as hypoglycemia (Citil and Tekinsen, 2011).

Carob gum is a hydrocolloid produced from the Ceratonia siliqua tree and is a polysaccharide containing galactomannan (Barak and Mudgil, 2014). It is obtained from the extraction of carob beans with water and aqueous alkaline solution. The molecular size and structure of galactomannan has a great influence on its functional properties (Zhu et al., 2019). Carob gum is widely used in the food industry as a stabilizer. It is also increasingly used for nutritional purposes as it contains antioxidants and is good for anti-cancer, anti-reflux, anti-diabetic diseases (Ikram et al., 2023). Moreover, the gum and fiber of carob gum are beneficial to health in many diseases such as diabetes, intestinal movements, heart diseases, and colon cancer (Zhu et al., 2019).

Guar gum is a stabilizer obtained from the endosperm of Cyamopsis tetragonolobus belonging to the Leguminosae family. It is odourless and white-yellowish powder and is widely used as a raw material in the food industry. It is hydrophilic with high molecular weight and dissolves well in water (Sharma et al., 2018; Theocharidou et al., 2022). Guar gum, serving as a soluble fiber, supports intestinal health by acting as a bulk laxative. Additionally, it exhibits a protective effect against diseases such as cholera and diarrhea. Moreover, through its mechanism of lowering cholesterol, it enhances cardiovascular health by reducing hepatic free cholesterol concentration. Lastly, guar gum and its derivatives prove effective in controlling blood sugar levels, potentially contributing to the prevention of diabetes (Thombare et al., 2016).

Güner et al. (2007) produced ice cream using yoghurt with different acidity (0.7%, 0.8%, 0.9% and 1% lactic acid) and stated that the use of yoghurt instead of milk decreased the viscosity and negatively affected the sensory properties. Dertli et al. (2016) determined that using EPS-producing S. thermophilus strains caused ice creams to have higher viscosity and pseudoplastic non-Newtonian flow properties. In a study by Güven and Karaca (2003) yoghurt ice cream was produced with six stabilizers (karaya gum, guar gum, gelatin, sahlep, carrageenan and carboxy methyl cellulose). It was found that adding different stabilizers affected the titration acidity value, melting time, overrun value, hardness value and viscosity value of yoghurt ice creams. They reported that the sensory scores of ice creams produced by adding guar gum and gelatin were higher.

In this study, buffalo milk yoghurt ice cream was produced using two different starter yoghurt cultures (EPS-producing culture and flavour producing culture) and three different stabilizers (sahlep, carob gum, guar gum). Physical, chemical and sensory properties of the produced ice creams were determined.

2. MATERIALS AND METHOD

2.1. Material

Buffalo milk was obtained from a private farm in Osmaniye (Türkiye). Sahlep (Bucak, Burdur, Türkiye), carob gum and guar gum (Tate & Lyle Istanbul, Türkiye), sugar (Kayseri Şeker Fabrikası A. Ş, Kayseri, Türkiye), direct inoculation yoghurt starter cultures Y 902 and Yo-tech K-41 were obtained from Maysa Gıda (Istanbul, Türkiye) and ice cream containers were obtained from Osmaniye's (Türkiye) bazaar.

Table 1 shows the amounts of raw materials used in the production of buffalo milk yoghurt ice cream according to 100 kg raw buffalo milk. Buffalo milk ice creams are formulated as follows: A: EPS-producing culture and sahlep, B: Flavour-producing culture and sahlep, C: EPS-producing culture and carob gum, D: Flavour-producing culture and carob gum, E: EPS-producing culture and guar gum, F: Flavour-producing culture and guar gum.

Table 1. Amounts of raw materials used in the composition of ice creams

Raw materials	Ice Creams					
	A	B	C	D	E	F
Raw buffalo milk	100 kg	100 kg	100 kg	100 kg	100 kg	100 kg
Sugar	20 kg	20 kg	20 kg	20 kg	20 kg	20 kg
EPS-producing culture (Y 902)	MU/100 L	-	MU/100 L	-	MU/100 L	-
Flavour-producing culture (Yo-tech K-41)	-	MU/100 L	-	MU/100 L	-	MU/100 L
Sahlep	0,8 kg	0,8 kg	-	-	-	-
Carob Gum	-	-	0,8 kg	0,8 kg	-	-
Guar Gum	-	-	-	-	0,8 kg	0,8 kg

MU: Package

2.2. Method

2.2.1. Buffalo Milk Yoghurt Ice Cream Production

After passing through the straining and homogenization process, 9 kg of raw buffalo milk was then pasteurized at 90 °C for 10 minutes. Afterwards, it was cooled to 47 °C and split into two parts. One half was mixed with an EPS-producing direct inoculation yoghurt culture (Y 900) in the amount recommended by the manufacturer (MU/100 L), and the other half was mixed with a flavour-producing direct inoculation yoghurt culture (Yo-tech K-41, MU/100 L) and incubated at 42°C. Incubation was stopped when the pH of the samples reached 4.7. The yoghurts were cooled to 25 °C and then stored overnight at +4 °C.

The 9 kg of raw buffalo milk that has undergone the above-mentioned pre-processing steps was separated into three parts and mixed by adding 20% sugar and 0.8% sahlep, 0.8% carob gum and 0.8% guar gum separately. It was heat processed at 90 °C for 10 min. It was then cooled at room temperature and allowed to develop at +4 °C for 1 day. The matured mixes and yoghurts were mixed 50%-50% and 6 mixtures were prepared.

The buffalo milk yoghurt ice creams were produced by a private company located in Osmaniye Center. Ice cream production was carried out in a -15 °C ice cream machine (UDM 30 L5D Uğur Ice Cream Machines, Nazilli, Aydın, Türkiye). The ice creams were packed in 75 g plastic packages and left to harden in deep freezers at -30 °C. They were stored in deep freezers at -25 °C until analyzed. Ice cream production was carried out in two parallels. The samples were analysed 2 times.

2.2.2. Analysis of Buffalo Milk and Ice Cream

2.2.2.1. Physicochemical Properties of Buffalo Milk and Ice Cream

The titration acidity of buffalo milk and yoghurt ice cream samples was analyzed by titrimetric method (Yasar and Guzeler, 2011). The pH values of buffalo milk and yoghurt ice cream samples were analyzed with a pH meter (Orion Star™ A 211, Thermo Scientific, Waltham, MA).The dry matter content of buffalo milk and yoghurt ice cream samples was analyzed by gravimetric method (AOAC, 2003).The fat content of buffalo milk was analyzed by the Soxhlet method (AOAC, 2003). Nitrogen content in buffalo milk was analyzed by the micro-Kjeldahl method (AOAC, 2003). Lactose content in buffalo milk was analyzed by the Lane-Eynon method (Anon, 1983). The amount of ash in buffalo milk was analyzed by wet incineration method according to the method (AOAC, 2003).

2.2.2.2. Sensory analysis

The panelists (15 persons, 8 females and 7 males, aged between 19 and 50) were trained in sensory analysis of ice cream before starting the analysis. The sensory attributes of the samples were judged using a scoring method (hedonic scale, 1 being very bad and 9 being very good) as described by Meilgaard et al. (1999).

2.2.2.3. Statistical analysis

All data collected from buffalo milk yoghurt ice creams were subjected to variance analysis using the SPSS 20.0 software package. The Duncan test was employed to identify any significant differences.

3. RESULTS AND DISCUSSION

3.1. Composition of Raw Buffalo Milk

The physicochemical properties of buffalo milk are shown in Table 2. The titration acidity value of buffalo milk was 0.25% (% lactic acid), the pH value was 6.59, the dry matter rate was 17.15%, the fat rate was 6.56%, the protein rate was 5.42%, lactose rate was 4.63%, and ash rate was 0.81% (Table 2). The values found by Çelik et al. (2001) and Han et al. (2007) are larger than those obtained in this research.

Table 2. Composition of raw buffalo milk

Composition	**Value**
Titratable acidity (% lactic acid)	0.25±0.02
pH	6.59±0.05
Dry matter (%)	17.15±1.25
Oil (%)	6.56±0.51
Protein (%)	5.42±0.31
Lactose (%)	4.63±0.21

3.2. Physicochemical Properties of Buffalo Milk Yoghurt Ice Cream

The non-statistical data for dry matter, titratable acidity and pH of the ice creams are displayed in Table 3. The dry matter values ranged from 36.75% to 37.40%. Sample (D), produced with a flavour-producing culture and carob gum, demonstrated the highest dry matter value, while sample (E), produced with an EPS-producing culture and guar gum, demonstrated the lowest dry matter value (Table 3). The results of the Duncan test of the ice creams are shown in Table 4. The use of different starter cultures, stabilizers and the interaction between culture and stabilizer did not significantly affect the dry matter values of the ice creams ($p>0.05$) (Table 4).

Table 3. Physicochemical properties of buffalo milk yoghurt ice cream

Ice creams	Dry matter (%)	Titratable acidity (% l.a.)	pH
A	36.76±0.37	0.57±0.01	5.74±0.06
B	37.15±0.49	0.70±0.03	5.45±0.04
C	37.05±0.21	0.69±0.01	5.58±0.02
D	37.40±0.84	0.76±0.03	5.38±0.06
E	36.75±0.35	0.67±0.02	5.52±0.02
F	37.00±1.41	0.75±0.03	5.39±0.07

A: EPS-producing culture and sahlep, B: Flavour-producing culture and sahlep, C: EPS-producing culture and carob gum, D: Flavour-producing culture and carob gum, E: EPS-producing culture and guar gum, F: Flavour-producing culture and guar scale.

Table 4. Duncan test results of physicochemical properties of buffalo milk yoghurt ice cream

	Raw materials	Dry matter (%)	Titration Acidity (% l. a)	pH
Culture	EPS-producing Culture	36.85^{a*}±0.29	0.64^{b*}±0.06	5.61^{a*}±0.19
	Flavour-Producing Culture	37.18^{a}±0.79	0.74^{a}±0.04	5.41^{b}±0.05
Stabilizer	Sahlep	36.96^{a}±0.42	0.63^{b*}±0.08	5.59^{a*}±0.17
	Carob Gum	37.18^{a}±0.54	0.72^{a}±0.04	5.48^{b}±0.11
	Guar Gum	36.88^{a}±0.85	0.71^{a}±0.06	5.45^{b}±0.08

** Means marked with the same letter among each factor are not statistically different from each other.*

Atallah et al. (2022) reported that the dry matter values of buffalo milk ice cream made using different additives instead of sugar varied between 31.95% and 37.98%. Bekiroğlu and Özdemir (2020) found that the dry matter of buffalo milk ice cream made from buffalo milk was 33.12%. In a study conducted by Guler Akın et al. (2016) to investigate certain properties of probiotic yoghurt ice cream containing carob extract and whey powder, as well as the viability of L. acidophilus and Bifidobacterium BB-12 in the ice cream, it was observed that the dry matter value of yoghurt ice cream ranged from 31.11% to 32.84%. In another study by Kırmacı et al. (2014), the dry matter content of probiotic ice cream with added prebiotic fibre and stevia extract ranged from 23.48% to 31.37%.

Table 3 indicates that the titration acidity values of the ice creams ranged from 0.57% to 0.76%. The highest titratable acidity value was obtained in sample (D), produced with the addition of flavour-producing culture and carob gum, and the lowest titratable acidity value was determined in sample (A), produced with the addition of EPS-producing culture and sahlep.

When the results of Duncan's multiple comparison test were examined, it was found that the titration acidity values of ice creams with the addition of flavour-producing culture were higher than those with the addition of EPS-producing culture ($p<0.05$). The titration acidity values of ice creams with sahlep additives were determined to be lower than those with carob gum and guar gum additives ($p<0.05$) (Table 4).

Güven and Karaca, (2003) reported that the addition of different stabilizers statistically affected the titration acidity values of yoghurt ice cream samples. In the production of Maraş type yoghurt ice cream, the titration acidity value of the samples between 0.17% and 0.24% lactic acid. The titration acidity values obtained in this study were higher than those reported by Sezer (2015). Güven et al. (2017) determined that the titration acidity value of yoghurt ice cream produced with the addition of different stabilizers varied between 1.07% and 1.13% in terms of lactic acid and that the use of different stabilizers affected the titration acidity value of yoghurt ice cream. The titration acidity values presented in this study were lower than the titration acidity values found by Güven et al. (2017). This is because cow's milk has lower acidity than buffalo milk.

The pH values of buffalo milk yoghurt ice creams were found to vary between 5.38 and 5.74. The highest pH value was reported in sample (A), produced with EPS-producing culture and sahlep, and the lowest pH value was determined in sample (D), produced with flavour-producing culture and carob gum (Table 3). When the Duncan test results of the average pH values of samples were analyzed, the pH values of samples with EPS-producing culture were detected to be higher than those with flavour-producing culture ($p<0.05$). The pH values of the ice cream with sahlep were found to be greater than those of the ice cream with carob gum and guar gum ($p<0.05$) (Table 4). EPS-producing starter cultures produce less lactic acid the flavour-producing starter cultures. As a result, they have lower titration acidity and higher pH values (Amatayakul et al., 2006).

Güzeler et al. (2018) reported the pH values of yoghurt ice cream between 4.96 and 5.60 in their study. The pH values obtained in present study were close to the pH values examined by Güzeler et al. (2018). Sezer (2015) determined the pH value of Maraş type yoghurt ice cream samples between 6.30 and 6.50. The pH value found in this study was lower than the pH value found by Sezer (2015).

Güven et al. (2017) determined that the pH value of yoghurt ice cream produced using different stabilizers varied between 4.06 and 4.25 and that the addition of different stabilizers did not affect the pH value of the ice cream. The pH values found in present study are higher than the pH values determined by Güven et al. (2017). This is due to the fact that the buffalo milk used contains more lactic acid than cow milk.

3.3. Sensory Properties of Buffalo Milk Yoghurt Ice Cream

The sensory scores of the samples that were not statistically analysed are displayed in Table 5. The color scores of the ice creams varied between 7.05 and 7.50. The highest color scores were obtained in the ice cream with EPS-producing culture and sahlep addition (A), and the lowest color scores were obtained in the ice cream with EPS-producing culture and guar gum addition (E) (Table 5). The Duncan test results of sensory properties of ice creams are given in Table 6. According to the Duncan test data, the use of different cultures and stabilizers did not affect the color scores of the samples ($p>0.05$) (Table 6).

The texture scores of the ice creams ranged between 6.50 and 7.56. It was obtained that the highest texture scores were obtained in ice cream with EPS-producing culture and sahlep addition (A), and the lowest color scores were obtained in ice cream with flavour-producing culture and guar gum addition (F) (Table 5). According to the results of the Duncan multiple comparison test of the texture scores of the samples, it was found that the use of different cultures statistically affected the texture scores of the ice creams ($p<0.05$) (Table 6). Atallah et al., (2022) found the texture scores of fat-free and sugar-free buffalo milk yoghurt ice cream were 9.80 and 9.90, respectively. These values were higher than the present research.

Table 5. Score sensory properties of buffalo milk yoghurt ice cream

Ice creams	Color	Texture	Taste	Odour	General Acceptability
A	7.50±1.50	7.56±0.52	6.89±1.17	7.53±0.71	7.22±0.93
B	7.22±1.86	6.67±1.50	6.11±0.93	7.09±1.43	6.44±0.88
C	7.17±1.84	7.44±1.51	5.88±1.37	6.72±1.48	6.56±1.02
D	7.33±1.41	7.00±1.67	5.55±0.72	6.11±0.92	5.33±1.12
E	7.05±1.13	7.55±1.01	5.78±0.83	6.23±1.09	5.89±1.27
F	7.22±1.20	6.50±1.52	4.72±0.56	6.22±1.48	4.88±0.93

A: EPS-producing culture and sahlep, B: Flavour-producing culture and sahlep, C: EPS-producing culture and carob gum, D: Flavour-producing culture and carob gum, E: EPS-producing culture and guar gum, F: Flavour-producing culture and guar scale.

Table 6. Duncan test results of sensory properties of buffalo milk yoghurt ice cream

Raw materials		Color	Texture	Taste	Odour	General Acceptability
Culture	EPS-producing Culture	7.24^{a*}±1.47	7.52^{a*}±1.05	6.18^{a*}±1.19	6.83^{a*}±1.23	6.55^{a*}±1.18
	Flavour-Producing Culture	7.26^{a}±1.48	6.72^{b}±1.54	5.46^{b}±0.92	6.47^{a}±1.33	5.56^{a}±1.33
Stabilizer	Sahlep	7.36^{a*}±1.64	7.11^{a*}±1.18	6.50^{a*}±1.09	7.31^{a*}±1.13	6.83^{a*}±0.99
	Carob Gum	7.25^{a}±1.59	7.22^{a}±1.56	5.72^{b}±1.07	6.41^{b}±1.23	5.94^{b}±1.21
	Guar Gum	7.14^{a}±1.14	7.02^{a}±1.39	5.25^{b}±0.87	6.22^{b}±1.26	5.39^{b}±1.19

** Means marked with the same letter among each factor are not statistically different from each other.*

The taste scores of buffalo milk yoghurt ice cream samples ranged from 4.72 to 6.89. The highest taste scores were found in the sample with EPS-producing culture and sahlep (A), and the lowest taste scores were found in the ice cream produced with flavour-producing culture and guar gum (F) (Table 5). The taste scores of buffalo milk ice creams produced using sahlep were found to be higher than those produced by adding carob gum and guar gum ($p>0.05$). Panelists gave more points to ice creams produced with EPS-producing culture the flavour-producing cultures ($p<0.05$) (Table 6).

Table 5 shows that the odour scores of the samples ranged from 6.11 to 7.53. The highest odour scores were found in the ice cream with EPS-producing culture and sahlep (A), and the lowest odour scores were found in the ice cream with flavour-producing culture and carob gum (D). Duncan's multiple comparison test results of the odour points of the samples showed that adding different stabilizers affected the odour scores of the ice creams ($p<0.05$) (Table 6). Bekiroğlu and Özdemir (2020) found that the taste and odour scores of buffalo milk yoghurt ice creams ranged from 8.00 to 9.00. The scores in present study are lower than these scores.

The general acceptability scores of the ice creams ranged from 4.88 to 7.22. The highest overall acceptability scores were found in the ice cream with EPS-producing culture and sahlep addition (A), and the lowest overall acceptability scores were determined in the examples with flavour-producing culture and guar gum addition (F) (Table 5). According to the results of the Duncan multiple comparison test of the general acceptability scores of the samples, it was determined that the use of different cultures and stabilizers statistically affected the overall acceptability scores ($p<0.05$) (Table 6). The general acceptability scores of the ice creams produced with EPS-producing starter culture were higher than the ice creams produced with flavour-producing starter culture ($p<0.05$).

Güven and Karaca (2003) produced yoghurt ice cream using different stabilizers. As a result of the panelist evaluation, they reported that the samples to which guar gum and gelatin were added received the highest scores, while the samples to which sahlep and carrageenan were added received the lowest scores. In present study, the sensory properties of the samples produced with sahlep were greater than the sensory properties of the ice-creams produced with sahlep by Güven and Karaca (2003). Sahlep contains different compounds depending on the species, season and region (Turkmen et al., 2021; Arslan et al., 2023).

Güven et al. (2017) examined the sensory properties of yoghurt ice creams made with different stabilizers. They stated that the use of different stabilizers affected the general acceptability scores of the ice creams, and yoghurt ice creams produced with a combination of stabilizers received the highest scores. Güner et al. (2007) determined that sensory properties decreased as acidity increased in yoghurt ice creams produced at different acidity. Dertli et al. (2016) found that the use of EPS-producing starter culture in yoghurt ice cream production improved the sensory properties of their ice creams such as color, mouth solubility, icy texture and cream taste.

4. CONCLUSION

The addition of a flavour-producing starter culture to buffalo milk yoghurt ice cream resulted in higher titratable acidity values compared to samples with an EPS-producing starter culture. Additionally, samples with the EPS-producing starter culture had a higher pH value than those with the flavour-producing starter culture. The texture, taste, and overall acceptability were also better in samples with the EPS-producing starter culture compared to the flavour-producing starter culture. When comparing different stabilizers, the titratable acidity value of buffalo milk ice cream with sahlep was lower than ice cream with carob gum and guar gum, while the pH value with sahlep was higher. Furthermore, buffalo milk ice cream made with sahlep had higher scores for taste, odour, and overall acceptability compared to ice cream made with carob gum and guar gum. It has been concluded that the sensory properties of samples could be better when EPS-producing starter culture and sahlep are used together.

Ethical Approval

None.

Declaration of Interests

The authors of this study declared no conflict of interests.

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Author Contribution

Concept: YA, YK
Design: YK
Data collecting: YA
Statistical analysis: YK
Literature review: YA, YK
Writing: YA
Critical review: YA, YK

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