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Physicochemical, sensory and antimicrobial properties of the ice cream containing lavender (*Lavandula angustifolia*) essential oil

Bayram ÜRKEK*,[1] Haktan AKTAŞ,[2] Miraç Özer ÖZTUĞ,[3] Esra YENIÇERI,[3] and Pınar ÖZTUĞ[3]

[1]*Gumushane University, Siran Mustafa Beyaz Vocational School, 29700, Siran, Gumushane, Turkey*
[2]*Ataturk University, Faculty of Agriculture, Department of Food Engineering, 25240, Erzurum, Turkey*
[3]*Gümüşhane University, Faculty of Engineering and Natural Sciences, Department of Food Engineering, 29100, Gumushane, Turkey*

Abstract. In this study, lavender essential oil (LEO) was added to ice creams as ingredient at 0, 0.02, 0.05 and 0.1% ratios. Some physicochemical, viscosity, rheological, colorimetric, sensory properties, and pathogen inhibition, including *L. monocytogenes* ATCC 7644 and *S. aureus* ATCC 29213, of the ice cream samples with the LEO were investigated. It was determined that the melting rate of the ice creams with the LEO was lower ($P<0.05$) and the overrun values were higher ($P<0.05$) than the control sample. The highest L^* and a^* values were determined in the control samples and the sample with 0.1% LEO, respectively. While C^* value of the sample with 0.02% LEO was higher than the other samples ($P<0.05$), the highest white index (WI) value was determined in the control and the sample with 0.01% LEO. The sample containing 0.01% LEO had the highest viscosity values at 20 and 50 rpm. It was determined that there was no statistically significant difference in the consistency coefficients of the samples ($P>0.05$) and all samples had pseudolplastic flow. The control sample had the highest sensory score, followed by the sample with 0.02% LEO. It was determined that the LEO addition only had a decreasing effect on the count of *S. aureus* ATCC 29213.

***Keywords*:** ice cream; lavender essential oil; physicochemical properties; sensory properties; antagonistic activity.

1. Introduction

Ice cream is a dairy product, also known as frozen dessert, consumed by people of all age groups around the world [1]. Ice cream has a complex structure containing many components such as emulsifier, stabilizer, fat and flavor. With its protein, fat, carbohydrate, mineral and vitamin content, the product is a nutritious with high energy content [2].

The ice cream and frozen dessert market grew by 8.8% in 2022 compared to the previous year and reached a volume of 294.54 billion USD in the global market. Western Europe ranked first in the world market, while Asia-Pacific ranked second [3]. In Europe, Germany ranked first with 614 million litres of ice cream production, followed by France with 459 million litres and Italy with 381 million litres [4]. According to 2022 data, approximately 5 billion kg of ice cream was produced in the USA and per capita ice cream consumption in the USA is approximately 20 kg [5].

Although different flavors stand out in some countries, the most popular flavor in ice cream worldwide is vanilla. For example, strawberry in Turkey, watermelon in the Netherlands, green tea in Japan, banana in Venezuela, chocolate in the UK, and coconut in Thailand are added to ice cream as flavor component [6]. The most preferred ice cream flavors by Americans are chocolate, “Cookies N' Cream”, vanilla, strawberry, chocolate chip, cookie dough, butter pecan, French vanilla, chocolate cookie dough, caramel/salty caramel [5]. On the other hand, different essential oil from plants can also be used as a flavor source in ice cream [7, 8]. Lavender (*Lavandula angustifolia*) is an important medicinal aromatic plant and contains many essential oils. Besides the food industry, the oils are used in soaps, colognes, perfumes, skin lotions and many other cosmetic products [9–11]. In the food industry, lavender essential oil (LEO) can be preferred as a natural flavoring agent in beverages, ice cream, bakery products and chewing gum [9], or it can be used as a preservative [10]. The LEO has an important place in aromatherapy due to its antioxidant, antimicrobial, carminative, spasmolytic, sedative, antiseptic, anti-inflammatory, analgesic properties, antioxidant activity, tonic and antidepressive properties [11, 12]. Moreover, there are no safety hazards associated with the use of lavender and LEO in food [13].

In this study, ice cream samples produced using different ratios of LEO were investigated in terms of some physicochemical and sensory properties. It was aimed to increase the usability of LEO by producing a natural flavored ice cream. On the other hand, ice cream is suitable medium for growth of pathogens because of its high nutrient value, neutral pH, and long storage duration [14]. Moreover, the Turkish Food Codex and the Codex Alimentarius state that *Listeria monocytogenes* (*L. monocytogenes*) and *Staphylococcus aureus* (*S. aureus*) can be dangerous in the ice cream and should not be present in the product. Therefore,

*Corresponding author. *E-mail address:* bayramurkek@gumushane.edu.tr (Bayram Ürkek)

antimicrobial effect of the ice cream samples with the LEO on *L. monocytogenes* and *S. aureus* was also among aim of the study.

2. Experimental

2.1. Materials

Lavender essential oil was obtained from Şiran, Gümüşhane. Raw cow's milk used for ice cream production was obtained from local farms in Şiran, Gümüşhane, and other ingredients including salep, emulsifier, butter, and sugar were bought from local markets. The skim milk powder was supplied by Aynes Dairy Products Co. (Turkey).

2.2. Ice cream production

The raw milk's total solids, fat, acidity and pH values were determined by gravimetric, Gerber, titration methods, and pH meter respectively. The total solids, fat, pH and acidity of the milk used for ice cream production were 11.90%, 3.0%, 6.65 and 0.155%, respectively. The fat content of the ice cream mixture was adjusted to 10% with butter. The ice cream mixture, consisting of 16% sugar, 7% butter, 0.6% salep, 0.2% emulsifier, 3.2% skimmed milk powder, and 73% milk, was pasteurized at 85 °C for 25 s. The pasteurized mixture was then rapidly cooled to +4 °C and kept overnight at the temperature. The mixture was divided into four parts and LEO was added at 0 (Control, C), 0.02 (LI1), 0.05 (LI2), and 0.1% (LI3). Then, the mixtures were frozen using an ice cream machine (Breville BCI600, Sage BSS., Australia) and the frozen samples were kept at -22 °C overnight and then kept at -18 °C until analyses.

2.3. Physicochemical analyses

Total solids (%) and ash (%) rate of the ice cream samples were determined using the gravimetric method [15]. The fat content (%) was determined by a Van Gulic butyrometer in accordance with the Gerber method [15]. The acidity of the ice cream samples was detected with titration method using 0.1 N NaOH, and expressed % lactic acid. pH was measured using a pH-meter (WTW 3110, Weilheim, Germany) [15]. The overrun ratio was calculated by the equation below [16]:

$$\text{Overrun, \%} = \frac{\text{(weight of mix)-(weight of ice cream)}}{\text{weight of ice cream}} \times 100 \quad (1)$$

The first dripping time was determined with the method reported by Güven and Karaca [17]. To determine the melting rate, the melting amounts of 80 g samples were determined for 70 min. The melting rate was calculated by linear regression and expressed in g/min.

2.4. Viscosity and rheological properties

The viscosity of the C, LI1, LI2, and LI3 samples was measured using a Brookfield Viscometer Model DV-II (Stoughton, MA, USA) at 20 and 50 rpm. The rheological properties of the samples were calculated by the power law model based on measurements at 5, 10, 20, 50 and 100 rpm with spindle No. 6. The power law model is shown below:

$$\eta = K \cdot \gamma^{n-1} \quad (2)$$

where: η = apparent viscosity (Pa·s); K = coefficient consistency (Pa·s^n); γ = shear rate (rpm); n = flow behavior index.

2.5. Colorimetric parameters

The colorimetric parameters of the samples were determined by using a colorimeter device (Minolta, CR-400). The saturation (C*) and Hue angle (H) were calculated by using the L*, a*, and b* values according to methods by Cecchini et al. [18] and McLellan et al. [19], respectively. In addition, the method by Kurt and Atalar [20] was used to determine the white index (WI).

2.6. Sensory test

Sensory parameters of the ice cream samples, including color, gumming structure, flavor, meltdown in mouth, resistance to melting and overall acceptability, were scored by 50 semi-trained panelists (26 males and 24 females) aged between 20 and 40 years. A hedonic scale was used to score the samples from extremely bad (1) to extremely good (9) [21]. The required permission for the sensory test was approved by the Research Ethics Committee of Gümüşhane University (date: 05/03/2023 and No: 2023/2).

2.7. Inhibitory effect of LEO on L. monocytogenes and S. aureus

In this study, inhibition effect of LEO on *L. monocytogenes* ATCC 7644 and *S. aureus* ATCC 29213 was investigated. For this purpose, the pathogens were incubated in brain heart infusion (BHI) broth (Merck 110493, Germany) at 37 °C for 24 h. The medium was centrifuged at 3000 × g for 5 min and the supernatant was removed. Then, pathogen concentration was adjusted to 10^8 cfu/mL using phosphate buffered saline (PBS, pH 7.2) and the suspension was added to the C, LI1, LI2, and LI3 at a final concentration of 10^6 cfu/mL. The inhibition effect of LEO on pathogens was investigated with a separate ice cream production and the samples were stored at -18 °C. After serial dilution method, enumeration of *L. monocytogenes* ATCC 7644 was carried out on Palcam agar (Palcam agar base with Palcam selective supplement, Merck) [22] and *S. aureus* ATCC 29213 on Baird-Parker agar (Merck) with egg yolk tellurite [23] during 30 days. Microbial growth was carried out at 37 °C for 24 h and the typical colonies were evaluated for enumeration.

2.8. Statistical analysis

The obtained data were evaluated statistically using SPSS version 20.0 package program (IBM Corp., 2013). Significant differences between the ice cream samples were determined using a one-way analysis of variance (ANOVA) and Duncan's multiple range test at $P<0.05$. The all results from this study were stated as mean ± standard deviation. The study was performed duplicate repeated.

3. Results and discussion

3.1. Physicochemical analyses

The results of the physicochemical analyses on the C, LI1, LI2, and LI3 are given in Table 1. Total solids, ash, fat, pH, acidity and first drip time of ice cream samples were not statistically affected by the addition of LEO (P>0.05), only melting rate was affected (P<0.05).

Table 1. Physicochemical properties of the ice cream samples with lavender essential oil (mean ± standard deviation)

Physicochemical parameters	Ice cream samples			
	C	LI1	LI2	LI3
Total solids (%)	34.67±0.23^{a}	34.36±0.42^{a}	34.06±0.08^{a}	34.27±0.49^{a}
Ash (%)	0.76±0.02^{a}	0.75±0.03^{a}	0.76±0.06^{a}	0.78±0.01^{a}
Fat (%)	10.05±0.35^{a}	10.40±0.28^{a}	10.30±0.14^{a}	10.50±0.42^{a}
Acidity (% lactic acid)	0.23±0.02^{a}	0.21±0.01^{a}	0.22±0.01^{a}	0.20±0.02^{a}
pH	6.75±0.01^{a}	6.75±0.01^{a}	6.75+0.01^{a}	6.76±0.01^{a}
Overrun (%)	32.08±5.36^{b}	46.63±0.16^{a}	46.46±4.10^{a}	43.11±3.98^{a}
First dripping time (s)	1890.00±127.28^{a}	1980.00±169.71^{a}	1920.00±0.00^{a}	2010.00±296.98^{a}
Melting rate (g/min)	0.61±0.06^{a}	0.56±0.01^{ab}	0.47±0.02^{b}	0.47±0.02^{b}

The letters indicate statistically significant differences at level P<0.05; C: Ice cream without lavender essential oil; LI1: Ice cream with 0.02% lavender essential oil; LD2: Ice cream with 0.05% with lavender essential oil; LD3: Ice cream with 0.1% with lavender essential oil.

The ice cream must contain a minimum of 28% total solids according to the legislation [24]. In this study, the total solids of the samples varied between 34.06% and 34.67%. There were not statistically significant between the total solids of the ice cream samples (P>0.05). In addition, all ice cream samples were in accordance with the legal requirements. Nazarewicz et al. [25] studied the use of tomato seed oleo gel in ice cream and found the lowest and highest total solids values of ice cream samples were 36.48% and 36.86%, respectively. However, the changes in total solids values of the samples were not significant. Nadeem et al. [26] reported that the total solids of ice cream with rapeseed oil (1.5-4.5%) were 38.31-38.33% and there were no significant differences between samples. These results were in agreement with the present study.

Considering the ash content of the C, LI1, LI2, and LI3 samples, an increase was observed with increase of LEO concentration (from 0.76 to 0.78), however this increase was not statistically significant (P>0.05). Nazarewicz et al. [25] and Ürkek [27] found no significant changes in the ash content of ice cream samples containing oleogel and chia seed powder, respectively. The results were similar to those of the present study.

The fat content of the C, LI1, LI2, and LI3 samples ranged from 10.05 to 10.50% and there were no significant changes between samples (P>0.05). In the study by Güven et al. [8], the fat content of ice creams containing vegetable oils (olive and hazelnut) was between 11.46 and 12.00%. On the other hand, Nazarewicz et al. [25] stated that the fat content of the samples was 9.85-9.86%. The results from the present study were lower than those reported by Güven et al. [8] and higher than those reported by Nazarewicz et al. [25]. Turkish Food Codex stated that the fat content of the ice creams must be a minimum of 8% and the C, LI1, LI2, and LI3 samples were in accordance with the legal requirement.

The acidity values of the samples changed between 0.20% and 0.23% (Table 1). In this study, the acidity of the LI1, LI2, and LI3 samples were lower than the C samples, but these differences were not statistically significant (P>0.05). Macit et al. [7] determined the acidity of ice creams containing volatile oil of different spices (coconut, lemon crust, clove, and cinnamon) were between 0.25 and 0.26%. Nadeem et al. [26] found that the acidity of ice cream samples was 0.19% and no statistically difference. The results from this study were lower than those by Macit et al. [7], while higher than those by Nadeem et al. [26].

The pH values of the C, LI1, LI2, and LI3 samples varied from 6.75 to 6.76, and there were not no statistically significant differences (P>0.05). Similarly, Macit et al. [7] and Nadeem et al. [26] reported that the pH of the ice cream samples was 6.41-6.47 and 6.70-6.71, respectively.

The overrun values of the C, LI1, LI2, and LI3 samples were between 32.08 and 46.63%. The results showed that the overrun values of the samples with LEO were higher than the control sample (P<0.05). Nadeem et al. [26] determined a decrease in the overrun values based on herbal oil concentration, while Atik et al. [28], Nazaruddin et al. [29] and Nazarewicz et al. [25] reported an increasing in ice cream samples containing oil. The results obtained from the present study were similar with studies by Atik et al. [28], Nazaruddin et al [29], and Nazarewicz et al. [25], but not similar with study by Nadeem et al [26].

The first dripping times of the ice cream samples were between 1890 and 2010 s. The LI1, LI2, and LI3 samples had higher first dripping times than C sample, however these differences were not statistically significant (P>0.05). In the study by Güven et al. [8], the first dripping time value of ice creams with walnut and olive oil was between 894 and 1475 s. Moreover, they reported that the dripping time value decreased with the oil addition. The results reported by Güven et al. [8] were different from the results from the presented study and this situation may have been caused by the low LEO concentration.

The melting rate values of the ice cream samples were between 0.47 and 0.61 g/min (Table 1). The C sample had higher the melting rate compared to other samples (P<0.05). The melting rates of the LI2 and LI3 were lower than the LI1 (P<0.05). Macit et al. [7] found that there was no significant difference between the ice cream samples with spice oil in terms of melting rate. On the other hand, Gowda et al. [30] and Güven et al. [8] reported that the melting rate of ice creams decreased with addition of different oils. On the contrary, Nadeem et al. [26] reported that the melting rate of ice cream increased with the addition of rapeseed oil. The results of the present study were similar to those by Gowda et al. [30] and Güven et al. [8], but were different from those by Macit et al. [7] and Nadeem et al. [26].

The milk fat and herbal oil had effects on first dripping time and melting rate values of the ice cream. Heat transfer decreases as the amount of fat/oil increases [8]. In addition, the type, quantity, application method, and combination with milk fat of oil can affect the initial drip time and melting rate [8, 26, 31]. Furthermore, as in this study, it is known that there is an inverse relationship between the overrun and melting [16].

3.2. Viscosity and rheological properties

Viscosity and rheological properties of the C, LI1, LI2, and LI3 samples are given in Table 2.

Table 2. Viscosity, rheological and colorimetric properties of the ice cream samples with lavender essential oil (mean ± standard deviation)

Parameters	**Ice cream samples**			
	C	**LI1**	**LI2**	**LI3**
*L**	75.20±0.16[a]	74.86±0.01[ab]	74.21±0.49[b]	75.42±0.01[a]
*a**	-3.11±0.03[cb]	-3.08±0.05[b]	-3.17±0.01[c]	-2.98±0.01[a]
*b**	8.38±0.35[a]	8.36±0.04[a]	8.13±0.08[a]	8.10±0.13[a]
*C**	9.51±0.08[b]	9.83±0.06[a]	9.64±0.07[ab]	9.48±0.15[b]
H°	114.18±5.64[a]	109.34±0.18[a]	110.40±0.12[a]	109.37±0.37[a]
WI	73.64±0.25[a]	73.33±0.01[ab]	72.78±0.45[b]	73.95±0.03[a]
Viscosity 20 rpm (cP)	8757.60±27.86[a]	8729.71±83.98[a]	8567.71±125.08[a]	7798.26±110.68[b]
Viscosity 50 rpm (cP)	4729.57±7.87[b]	5356.57±134.56[a]	4721.67±2.04[b]	4317.20±26.22[c]
K (Pa·s^n)	55.21±2.12[a]	58.39±5.72[a]	60.33±1.92[a]	54.58±3.03[a]
n	0.38±0.01[a]	0.37±0.02[a]	0.35±0.01[a]	0.35±0.02[a]
R^2	0.992	0.994	1.000	0.999

The letters indicate statistically significant differences at level P<0.05; C: Ice cream without lavender essential oil; LI1: Ice cream with 0.02% lavender essential oil; LD2: Ice cream with 0.05% with lavender essential oil; LD3: Ice cream with 0.1% with lavender essential oil.

Viscosity values at 20 and 50 rpm were between 7798.26-8757.60 cP and 4317.20-5356.57 cP. The results showed that the LEO had statistically significant on the viscosity at both 20 and 50 rpm (P<0.05), conversely, it did not have significant effect on *K* and *n* values (P>0.05). The viscosity values at 20 and 50 rpm of the LI3 sample were lower than other samples (P<0.05). Moreover, the LI1 sample had the highest viscosity value (5356.57 cP) at 50 rpm. In contrast to the results in the present study, Nazaruddin et al. [29] and Nadeem et al. [26] reported that the viscosity of the samples decreased due to the increase in the herbal oil rate.

The *K* values of the ice cream samples were between 54.58 and 60.33 Pa·s^n. The *K* and *n* values of the samples changed based on the addition of LEO, but these changes were not significant statistically (P>0.05). All *n* values were between 0 and 1, and the flow behavior of the samples was pseudoplastic. Similar results were also found other researchers [28, 31, 32].

3.3. Colorimetric parameters

The colorimetric properties of the C, LI1, LI2, and LI3 samples are given in Table 2. The results revealed that the *L**, *a** and WI values were affected significantly by the addition of LEO (P<0.05), whereas *b**, *C** and *H*° values were not affected (P>0.05). The LD2 sample had the lowest *L** (74.21), *a** (-2.98) and WI (72.78) values. In addition, the *C** value of the LI1 sample was higher than other samples (P<0.05). The only *H*° values did not change significantly based on the concentration of LEO (P>0.05).

The changes in the colorimetric parameters of ice cream with different herbal oil were also determined by other studies [8, 29] and this may be due to the β-carotene content of the vegetable oil used in ice cream production [29].

3.4. Sensory test

The sensory analysis results of the C, LI1, LI2, and LI3 samples are given in Figure 1.

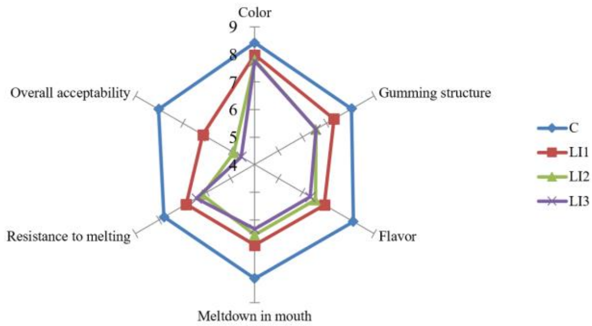

Figure 1. The sensory properties of ice cream samples containing lavender essential oil (C: Ice cream without lavender essential oil; LI1: Ice cream with 0.02% lavender essential oil; LD2: Ice cream with 0.05% with lavender essential oil; LD3: Ice cream with 0.1% with lavender essential oil).

The gumming structure, flavor, resistance to melting (P<0.05) and overall acceptability (P<0.01) of the ice cream samples were affected significantly by the LEO addition, while color and meltdown in melting were not affected (P>0.05). The sensory scores of the LI1, LI2, and LI3 samples for all parameters were lower than the C sample (P<0.05). Flavor and overall acceptability scores decreased with the increase of LEO concentration. The LI1 sample had the highest scores among the samples with LEO. Similarly, Macit et al. [7] and Nadeem et al. [26] reported that ice cream samples with different herbal oils had lower overall acceptability scores than the control samples. These results may indicate that the addition of strong tasting and smelling vegetable oils to ice cream is not well received by consumers.

3.5. Inhibitory effect of LEO on *L. monocytogenes* and *S. aureus*

Inhibition effect results of the ice cream samples with the LEO are given in Figure 2.

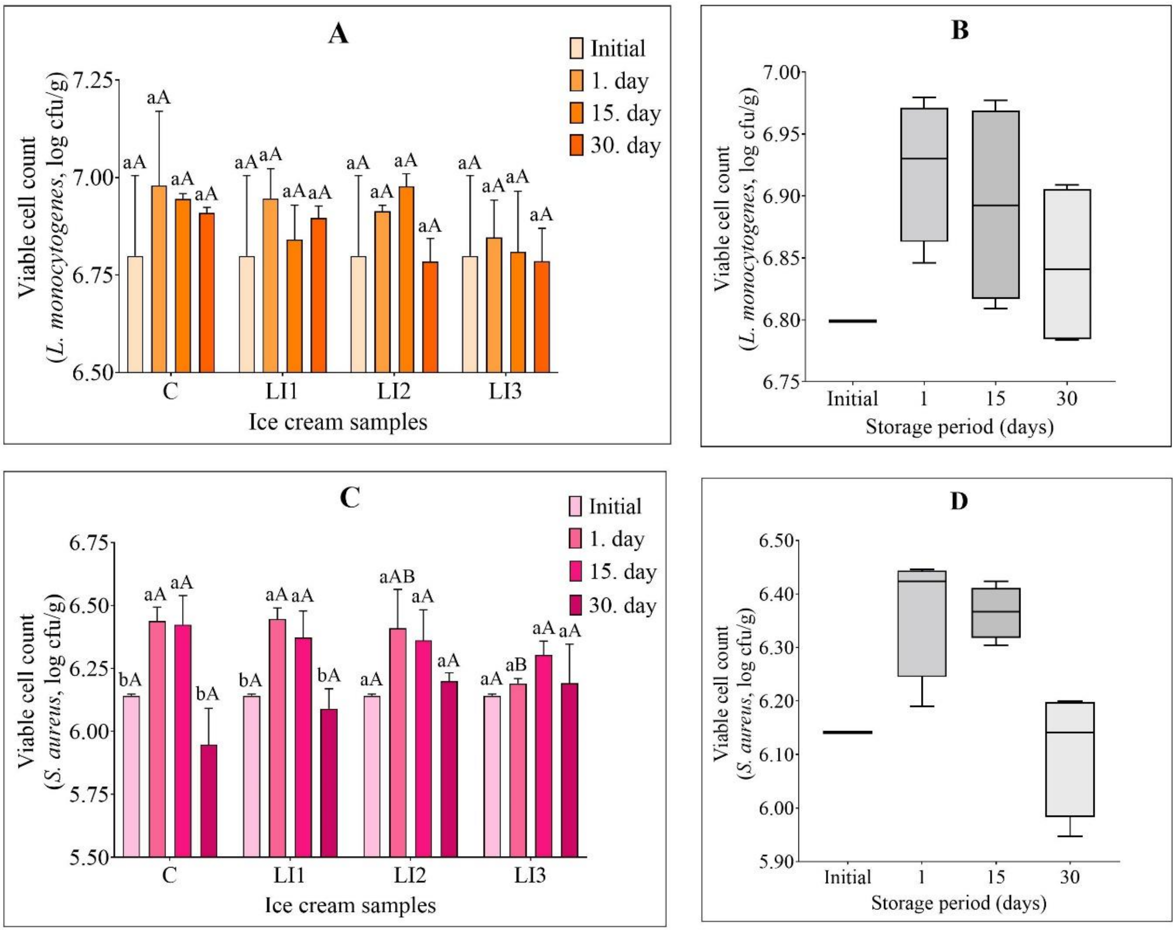

Figure 2. Individual viable cell counts of *L. monocytogenes* ATCC 7644 (A) and *S. aureus* ATCC 29213 (C) in the ice cream samples with the LEO. Viable cell counts of *L. monocytogenes* ATCC 7644 (B) and *S. aureus* ATCC 29213 (D) in all ice cream samples. a, b represented statistical difference during storage period on the same samples, A-B represented statistical difference between the ice cream samples on the same storage day.

The results showed that viable cell count of *L. monocytogenes* ATCC 7644 in all samples varied from 6.78 to 6.98 log cfu/mL and that of *S. aureus* ATCC 29213 varied from 5.95 to 6.45 log cfu/mL. As seen in Figure 2A, while *L. monocytogenes* ATCC 7644 count in the ice cream samples increased at first day of the storage, it did not statically change over storage ($P>0.05$). On the other hand, *S. aureus* ATCC 29213 count in the C and LI1 samples statistically significantly increased at first day of the storage and statistically significantly decreased at end of the storage ($P<0.05$) (Figure 2C). In addition, the increase of LEO concentration inhibited growth of *S. aureus* ATCC 29213 at only first day of the storage. Han et al. [33] reported that 6% solution of the LEO prevented biofilm formation by *L. monocytogenes*. In the study by Perovic et al. [34], LEO at a concentration of 1.4 µg/mL inhibited *L. monocytogenes* and *S. aureus*. In addition, Šarić et al. [35] stated that LEO at a concentration of 5 mg/mL had both inhibition and bactericidal effect on *S. aureus*. Considering the results from the presented study, it is concluded that the LEO addition to the ice cream at a concentration of 0.02, 0.05, and 0.1% is enough for bacteriostatic effect on *L. monocytogenes* ATCC 7644 and *S. aureus* ATCC 29213 but not for bactericidal effect. According to results from our study and above-mentioned studies, increasing the LEO concentration is necessary for the inhibition of the pathogens in ice cream.

Considering *L. monocytogenes* ATCC 7644 and *S. aureus* ATCC 29213 count for all samples, the viable cell count of the pathogens increased at first day of the storage (Figure 2B and 2D). On the other hand, the pathogen content in all samples continuously decreased until end of the storage. It was thought that this decreasing could be relevant with frozen temperature. Similarly, there are many studies stating frozen temperature and conditions can eliminate most pathogenic microorganisms [36, 37].

4. Conclusions

In this study, ice cream was produced containing lavender oil in different rates. Total solids, ash, fat, acidity, pH, first dripping time values of the samples were not observed any a significant changes ($P>0.05$). The overrun values were high at samples containing lavender oil, while the melting rate values were low according to the control sample. Significant changes were determined in the *L**, *a**, WI, viscosity (at 20 and

50 rpm) values of the ice cream samples (P<0.05), while *b**, *C**, H°, *K*, and *n* values did not change significantly (P>0.05). The most desirable ice cream samples were ranked from highest to lowest as C, LI1, LI2 and LI3 samples in terms of color, flavor, meltdown in mouth, and overall acceptability scores. The addition of the LEO into ice cream did not significantly affect *L. monocytogenes* ATCC 7644 and *S. aureus* ATCC 29213 count (P>0.05). Less than 0.02% lavender oil could be added into ice cream as a flavor component.

Conflict of interest

The authors declare that they have no conflict of interest.

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