Gümüşhane University Journal of Science

GUFBD / *GUJS* (2025) 15(2): 486-496 doi: 10.17714/gumusfenbil.1628312 Research Article

Physicochemical, rheological properties, antioxidant activity and mineral amount of the ice cream containing barberry (*Berberis vulgaris* L.)

Karamuk (Berberis vulgaris L.) ilaveli dondurmanın fizikokimyasal, reolojik özellikleri, antioksidan aktivitesi ve mineral içeriği

Bayram ÜRKEK*

Siran Mustafa Beyaz Vocational School, Gumushane University, Siran, Gumushane 25700, Turkey

• Received: 28.01.2025 • Accepted: 02.05.2025

Abstract

Ice cream is classified as a dairy product or frozen dessert. Various fruits have been incorporated into ice cream formulations to enhance their quality and nutritional properties. In this study, ice creams were prepared with barberry at four different concentrations (0%, 5%, 10% and 15%). The physicochemical, rheological characteristics, antioxidant activity, mineral content and sensory properties of the samples were examined. With the addition of barberry, the dry matter (DM), acidity and overrun values increased, while pH and fat content decreased. The viscosity and consistency coefficients were highest in the samples containing 10% and 15% barberry. All samples exhibited pseudoplastic flow behavior. The colorimetric parameters showed significant differences among the samples, except for the *C** value. The sample with 5% barberry had higher levels of Ca, Na, Mg, S, Fe and Zn compared to the other barberry-added samples. The sample containing 15% barberry demonstrated the highest DPPH scavenging activity (22.15 µg/mL) and total phenolic content (TPC) (1474.04 mg GAE/g), while the sample without barberry had the lowest values (143.19 µg/mL and 149.48 mg GAE/g, respectively). Additionally, the control sample received the lowest scores for gumming structure, texture, melting in the mouth, resistance to melting and overall acceptability. These findings suggest that incorporating 10% barberry could enhance the quality and nutritional value of ice creams.

Keywords: Barberry, DPPH, Ice cream, Mineral content, Sensory properties, Viscosity

Öz

Dondurma, bir süt ürünü veya dondurulmuş tatlı olarak tanımlanabilmketedir. Dondurma formülasyonlarına çeşitli meyveler eklenerek besin değeri ve kalite özellikleri artırılabilmektedir. Bu araştırmada, dondurmaya dört farklı oranlarda (0, 5, 10 ve %15) karamuk meyvesi ilave edilmiştir. Dondurma örneklerinin fizikokimyasal, reolojik özellikleri, mineral içeriği, antioksidan aktivitesi ve duyusal özellikleri incelenmiştir. pH ve yağ içeriği karamuk ilavesiyle azalırken, kurumadde (KM), asitlik ve hacim artışı değerleri artmıştır. Viskozite (20 ve 50 rpm'de) ve kıvam katsayısı değerleri en yüksek %10 ve %15 karamuk içeren örneklerde bulunmuştur. Tüm örnekler psödo-plastik akış davranışı göstermiştir. Renk parametreleri bakımında örnekler arasında, C değeri hariç olmak üzere, önemli farklılıklar gözlemlenmiştir. Karamuk oranı %5 olan örnek, diğer karamuklu örneklerden daha yüksek Ca, Na, Mg, S, Fe ve Zn seviyelerine sahip olduğu tespit edilmiştir. Karamuk içeriği %15 dondurma örneği, en yüksek DPPH aktivitesi (22,15 µg/mL) ve toplam fenolik madde içeriğine (TFM) (1474,04 mg GAE/g) sahipken, kontrol örneği en düşüktü (143,19 µg/mL ve 149,48 mg GAE/g). Ayrıca, kontrol örneği en düşük yapışkan yapı, doku, ağızda erime, erimeye direnç ve genel kabul edilebilirlik puanlarını almıştır. Elde edilen sonuçlara göre, dondurma üretiminde %10 karamuk eklemenin dondurmanın kalitesini ve besin değerini artırabileceği sonucuna varılmıştır.*

Anahtar kelimeler: *Karamuk, DPPH, Dondurma, Mineral içeriği, Duyusal özellikler, Viskozite*

*Bayram ÜRKEK bayramurkek@gumushane.edu.tr

1. Introduction

The structure of ice cream is complex, comprising fat, protein, emulsifiers, stabilizers and air (Güven & Karaca, 2002). Some literature defines ice cream as both a dairy product and a frozen dessert (Ürkek et al., 2024). Its nutritional value, derived from its fat, protein and other essential components, makes ice cream a popular choice among people of all ages (dos Santos Cruxen et al., 2017).

Recently, consumer demand for natural and healthy products has increased. However, traditional ice cream tends to be low in dietary fiber, vitamin C and antioxidants. Consequently, there has been a rise in studies exploring the use of natural ingredients in ice cream (Soukoulis et al., 2014; Balthazar et al., 2017). Various forms of fruits and vegetables are incorporated into ice cream as natural ingredients to enhance its nutritional value and quality. Different wild fruits are employed as food additives in ice cream research (Karaman & Kayacier, 2012; Ürkek, 2021), with barberry being one of these potential additions (Arslaner et al., 2016).

Barberry (*Berberis vulgaris* L.) belongs to the Berberidaceae family. The fruits are edible, purple in color and have a sharp flavor. Barberries grow naturally in various regions, including Turkey (Özgen et al., 2012). Due to their tart taste and hard seeds, they are typically consumed as juice, marmalade, or jam (Gundogdu, 2013; Rahimi-Madiseh et al., 2017). Barberry is particularly valued among wild fruits for its high antioxidant capacity, along with elevated levels of alkaloids and organic acids (Özgen et al., 2012; Yildiz et al., 2014). Its significant antioxidant activity is attributed to its content of total phenolics and flavonoids, including anthocyanins and other polyphenolic compounds. Due to these beneficial properties, the use of barberry has increased in both traditional and modern medicinal practices (Akbulut et al., 2009; Özgen et al., 2012). Barberry positively impacts human health, being rich in antioxidants and alkaloids. It has therapeutic effects on the cardiovascular and nervous systems, as well as on conditions such as hypertension, tachycardia, epilepsy, convulsions, fever, cholecystitis, cough, depression, liver disease, hyperlipidemia, hyperglycemia and bleeding (Özgen et al., 2012). Additionally, barberry has a high mineral concentration, particularly with a very high potassium (K) concentration (Akbulut et al., 2009)

The study regarding the use of barberry in dairy products is quately limited (Arslaner et al. 2016). In this research, barberry was used in different ratios (0%, 5%, 10% and 15%) in the ice cream. The goal of this research is to investigate the physicochemical properties (DM, pH, acidity, fat content, overrun, first dripping time (FDT), melting rates, viscosity and colorimetric parameters), rheological properties (consistency coefficient and flow behavior), antioxidant activity (DPPH and total phenolic content (TPC)) and mineral content of ice cream containing barberry.

2. Material and method

2.1. Material

The barberry fruits were collected in October from the Şiran district of Gümüşhane city, Turkey. Raw cow milk was purchased from the local dairy plant (Siran Dairy Products Co). The characteristics of the milk were as follows: DM 12.1%, fat 3.4%, ash 0.71%, acidity 0.17%, pH 6.65 and a somatic cell count of 351,000 cells/mL. Stabilizer (salep), emulsifier, butter and sugar were obtained from supermarkets and patisseries. Milk powder was provided by Aynes Dairy Products Co. (Denizli, Turkey).

2.2. Ice cream manufacture

The barberry fruits were promptly transferred to the laboratory after harvest and stored in a refrigerator for two days before production. They were then washed and blended into small pieces. The crushed fruits were used for ice cream production, which took place at Siran Mustafa Beyaz Vocational School using a Breville BCI600 (Sage BSS, Australia) ice cream machine. Butter was added to adjust the fat content of the mixture to 7%. The mixture contained 16% sugar, 0.6% salep, 0.2% emulsifier and 3.2% skim milk powder. Pasteurization of the mixture was carried out at 85 °C for 25 seconds. After pasteurization, the mix was chilled to +4 °C and held overnight in the refrigerator. The mixture was then divided into four equal parts. The control sample was prepared without barberry, while barberry fruits were added at ratios of 5% (BB5), 10% (BB10) and 15% (BB15). The ice cream machine was used to freeze the mixtures. The ice creams were stored in a deep freezer at -22 °C overnight and then kept at -18 °C until analysis.

2.3. Methods

2.3.1. Physicochemical analysis

Gravimetric methods were used to determine the DM, ash, fat, pH and acidity of the ice creams (Metin, 2012). The overrun value was determined and calculated using the following equation (Akbari et al. 2016):

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

The FDT was determined according to the method reported by Güven and Karaca (2002). Twenty-five grams of weighted ice creams were placed on a wire mesh at room temperature. The FDT was determined in seconds when the first drop fell. The melting amount of samples was measured at the 45th and 60th minutes and the melting rate was calculated as a percentage (%).

Viscosity values were performed using a viscosimeter (Brookfield Model DV-II, Stoughton, MA, USA) with spindle no. 6. Rheological parameters were calculated with the power law model with measurements taken at different rpm. The model is expressed as follows:

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

η (Pa.s), K (Pa.s^n), γ (rpm), n symbols indicate apparent viscosity, coefficient consistency, shear rate and flow behavior index, respectively.

Colorimetric properties (L^*, a^*, b^*, saturation (C^*) and hue angle (H°)) were determined with a Minolta Colorimeter (CR-400, Osaka, Japan). ΔE^* values were calculated using the method reported by Cecchini et al. (2011). White index (WI) values were calculated using the method described by Kurt and Atalar (2018). The calibration used a white plate.

$$\Delta E^* = \sqrt{\Delta L^* + \Delta a^* + \Delta b^*} \quad (3)$$

2.3.2. Mineral content

The mineral analyses of the ice creams were performed at Gümüşhane University (the Central Research and Application Centre for the Central Research Laboratory). The method reported by Güler (2007) was used for the mineral analyses. Ice creams were digested using the wet-burning method. ICP-MS (Agilent 7700, Japan) was used to determine the mineral content

2.3.3. Antioxidant analysis

2.3.3.1. Extraction method

For antioxidant analysis, 25 g of ice cream samples were weighed. Ethanol (90%) was added to the samples and the diluted mixtures were placed in the orbital shaker at 200 rpm for 6 hours. Following this, the mixtures were filtered using the Whatman No. 1 paper (Şengül et al., 2012). Absorbance values were measured using a spectrophotometer (DU 730, Beckman Coulter Inc., Fullerton, CA, USA).

2.3.3.2. DPPH analysis

The antioxidant activity was assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method. The absorbance values of ice cream samples, barberry and reference antioxidants (BHA, BHT, trolox, α-tocopherol) were measured using a spectrophotometer (Gülçin, 2010). Briefly, 0.5 mL of DPPH solution (0.01 mM in ethanol) was mixed with various concentrations (20-100 µg/mL) of the ethanol extracts in a flask. The prepared mixtures were kept in the dark and absorbance was determined against blank samples at 517 nm using the spectrophotometer. IC50 values were calculated from the obtained results.

2.3.3.3. TPC content

The colorimetric method (Folin–Ciocalteu) was used for the determination of the TPC contents. (Gülçin et al., 2002). Briefly, a mixture containing the sample extract (1 mL) and distilled water (46 mL) was prepared. The mixture was allowed to stand for 3 minutes and then sodium carbonate (3 mL) was added. The solutions were shaken on a shaker at 25 °C for 2 hours. After being kept in the dark ambiance for 2 hours, the absorbances were determined at 760 nm with a spectrophotometer (DU 730, Beckman Coulter Inc., Fullerton, CA, USA) in the solutions. Calculations were performed using a linear curve obtained from different concentrations of gallic acid. The results were indicated as µg of gallic acid equivalents (GAE) per mg of sample.

2.3.4. Sensory test

Ten semi-trained panelists evaluated the ice creams based on several criteria: color and appearance, gumming structure, texture, flavor, mouthfeel, resistance to melting and overall acceptability. A hedonic scale was used for the evaluation, with point values ranging from 1 (extremely bad) to 9 (the best) (Drake, 2009). The panelists included six women and four men, aged between 20 and 40 years.

2.4. Statistical analysis

SPSS 17 software (IBM Corp., 2013) was used to analyze the obtained data statistically. Statistical variations were assessed using one-way ANOVA and Duncan's multiple range test was employed to obtain distinctness between the means.

3. Results and discussion

3.1. Physicochemical composition

The DM ($P<0.05$), ash, fat, pH, acidity and melting rates (at 45 and 60 minutes) of the samples were significantly affected by the addition of barberry ($P< 0.01$). However, the FDT was not affected ($P>0.05$).

The dry matter (DM) contents of ice creams BB10 and BB15 were higher than those of samples C and BB5 ($P < 0.05$). The DM of the samples ranged from 30.05% to 31.82% (Table 1). Topdaş et al. (2017) studied the physicochemical and sensory characteristics, as well as the antioxidant activity, of ice creams containing cornelian cherry and found decreasing DM contents in those samples. Similarly, Sayar et al. (2022) reported lower DM values in blueberry-containing samples compared to the sample that did not contain barberry. The results observed in this study were inconsistent with those reported by Sayar et al. (2022) and Topdaş et al. (2017). Arslaner et al. (2016), determined the DM of barberry to be 64.24%, suggesting that the DM values may increase in samples containing barberry in the present study.

The pH and acidity values are presented in Table 1. The pH values of the samples varied from 4.65 to 6.98, while the acidity rates ranged from 0.15% to 0.68%. The pH values significantly decreased with increasing barberry concentration ($P < 0.05$), whereas the acidity values significantly increased ($P < 0.05$). Barberry contains organic acids, including tartaric, ascorbic, malic and citric acids (Özgen et al., 2012; Gundogdu, 2013). The pH values and acidity rates of barberry were reported to be 3.35 and 3.10%, respectively (Yildiz et al., 2014). The discrepancies in pH and acidity values may be attributed to the acidic component content of barberry.

The fat ratio was highest in sample C, while the lowest fat ratio was in sample BB15 (Table 1). The fat content decreased with increasing barberry concentration. Arslaner et al. (2017) found the fat rate of the sample containing 10% barberry to be 3.0%. Ürkek (2021) reported that the fat rates of samples varied from 3.90% to 6.70%, with these results decreasing based on the increase in rosehip concentration. These results were higher than those reported by Arslaner et al. (2017) and similar to those reported by Ürkek (2021). The reduction in fat content may result from the high concentration of fruit in the ice cream formulation.

The overrun rates exhibited a range from 21.79% to 34.73%, as presented in Table 1. The samples containing 10% and 15% barberry exhibited higher overrun rates compared to the other samples ($P< 0.05$). In a related

study, Topdaş et al. (2017) observed an increase in overrun rates with an increase in fruit rate, reporting values between 28.4% and 42.3%. Conversely, El-Samahy et al. (2009) observed a decline in overrun ratios, from 43.11% to 55.71%, with the incorporation of cactus pear pulp. These outcomes were consistent with those reported by Topdaş et al. (2017) but not with those reported by El-Samahy et al. (2009). The overrun values are hypothesized to be affected by various factors, including fat globule size, ice crystal size, the production system and the proportions of protein and emulsifiers (Ürkek, 2021; Sayar et al., 2022).

Table 1. The physicochemical characteristics of ice cream samples

Samples	C	BB5	BB10	BB15
DM (%)	30.05 ± 0.33^{b}	30.85 ± 0.05^{b}	31.67 ± 0.44^{a}	31.82 ± 0.18^{a}
pH	6.98 ± 0.05^{a}	6.10 ± 0.01^{b}	5.00 ± 0.03^{c}	4.65 ± 0.03^{d}
Acidity (% lactic acid)	0.15 ± 0.07^{d}	0.37 ± 0.42^{c}	0.54 ± 0.30^{b}	0.68 ± 2.72^{a}
Fat (%)	6.60 ± 0.28^{a}	5.65 ± 0.21^{b}	5.00 ± 0.14^{c}	4.05 ± 0.07^{d}
Overrun (%)	$21.79\pm1.1b^{a}$	24.75 ± 0.45^{b}	34.73 ± 0.49^{a}	34.38 ± 2.21^{a}
K (Pa.s^{n})	41.00 ± 3.09^{b}	42.05 ± 3.36^{b}	100.73 ± 5.25^{a}	105.91 ± 8.34^{a}
n	0.38 ± 0.04^{a}	0.38 ± 0.01^{a}	0.29 ± 0.02^{b}	0.30 ± 0.04^{ab}
R^2	0.993	0.997	0.991	0.998

a-d letters indicate statistical significance in the same row (P<0.05). The data were shown as the mean ± standard deviation. C: control without barberry, BB5: sample containing 5% (w/w) barberry, BB10: sample containing 10% (w/w) barberry, BB15: sample containing 15% (w/w) barberry

The melting parameters, including the freeze-drying time (FDT) and melting rates at 45 and 60 minutes are shown in Figure 1. The FDT of the samples exhibited both decreases and increases; however, these differences were statistically non-significant (P > 0.05). The FDT ranged from 1520 seconds to 1840 seconds. The melting rates at 45 and 60 minutes were higher in samples C and BB5 compared to samples BB10 and BB15 (P < 0.05). The melting rates at 45 and 60 minutes ranged from 6.66% to 36.83% and from 22.05% to 87.24%, respectively (Figure 1). Ürkek (2021) reported the FDT to be between 1530 seconds and 1830 seconds, while Topdaş et al. (2017) found the highest FDT in ice cream containing 15% cornelian cherry. Şanlıdere Aloğlu et al. (2018) investigated the physicochemical and sensory characteristics of ice creams containing strawberries, determining melting rates (at 45 and 60 minutes) to be between 82.45% and 91.38% and 95.82% and 96.38%, respectively. Karaman et al. (2014), who studied various properties of ice cream containing persimmon puree at five different ratios (8%, 16%, 24%, 32% and 40%), reported that the melting rate (at 30 minutes) of the samples decreased with increasing amounts of persimmon puree.

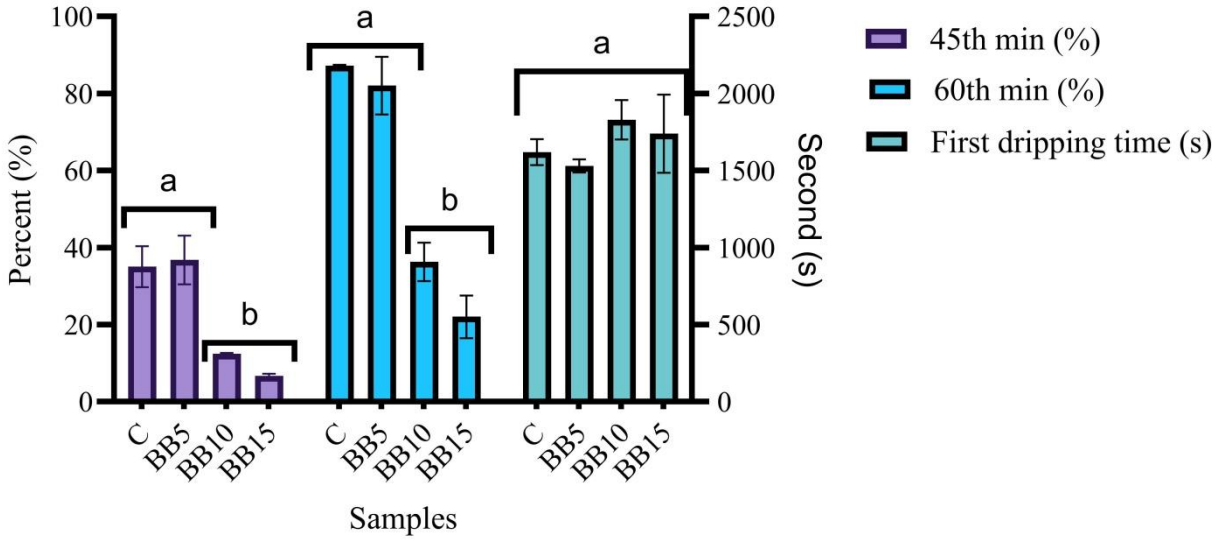

Figure 1. The melting parameters of ice creams (a-d letters indicate statistical significance at P<0.05 level.) C: control without barberry, BB5: sample containing 5% (w/w) barberry, BB10: sample containing 10% (w/w) barberry, BB15: sample containing 15% (w/w) barberry.

The pH, fat amount and destabilization, size of ice crystal, viscosity and overrun could play important roles in the melting parameters (Muse & Hartel, 2004; Sofjan & Hartel, 2004; Favaro-Trindade et al., 2007). A positive correlation has been identified between viscosity and melting parameters (Muse & Hartel, 2004). Similar results were observed in this research (Figures 1 and 2).

3.2. Viscosity and rheological properties

The effect of the addition of barberry was statistically significant on the viscosity and K values of the ice creams (P<0.01). As shown in Figure 2, the viscosity values at 20 and 50 rpm ranged from 6365 to 12781 cP and from 3546 to 6945 cP, respectively. Samples C and BB5 exhibited lower viscosity values than samples BB10 and BB15 (P< 0.05). The differences between samples BB10 and BB15 were statistically insignificant (P>0.05). Topdaş et al. (2017) determined that ice cream samples containing cornelian cherry had decreasing viscosity values. In contrast, Ürkek et al. (2019) found that the viscosity values of ice creams increased with the concentration of sloe berries. The results obtained in this study were consistent with those of Ürkek et al. (2019) but not with those reported by Topdaş et al. (2017). The viscosity values of the samples may be attributed to changes in protein structure due to pH variations and the increase in fiber content related to the fruit composition.

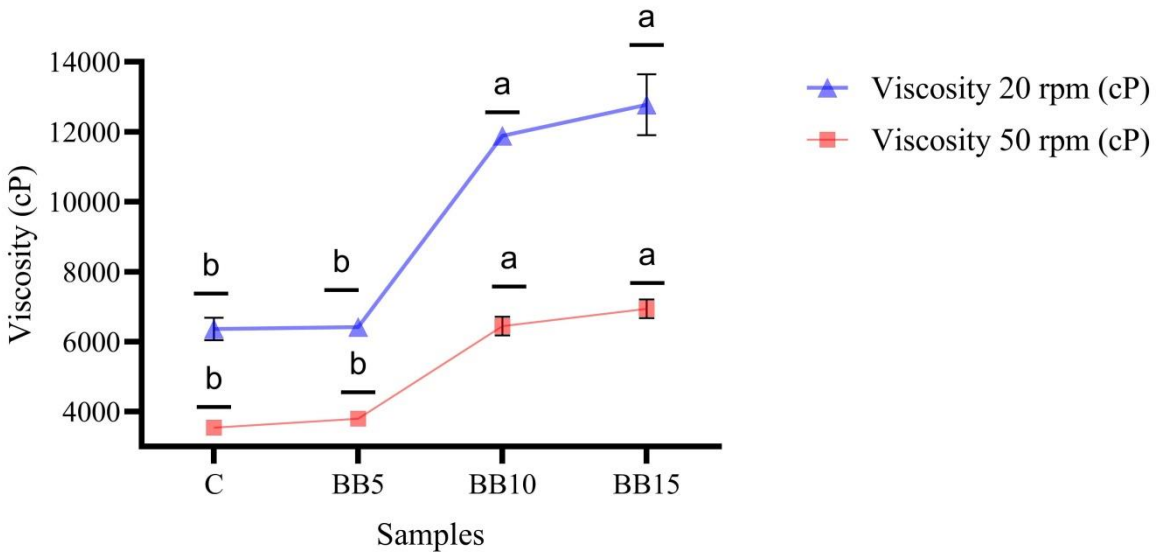

Figure 2. The viscosity values of ice cream samples (a-d letters indicate statistical significance at P<0.05 level). C: control without barberry, BB5: sample containing 5% (w/w) barberry, BB10: sample containing 10% (w/w) barberry, BB15: sample containing 15% (w/w) barberry

The K values are presented in Table 1, ranging from 41.00 Pa·s^n to 105.91 Pa·s^n. Samples C and BB5 showed no significant changes in K values (P > 0.05), although both were lower than those of samples BB10 and BB15. Sayar et al. (2022) reported a decrease in K values for ice creams containing blueberries, while Ürkek (2021) observed an increase in K values with the addition of rosehip. The DM rate plays a crucial role in influencing viscosity and K values (Sayar et al., 2022). The increase in viscosity and K values could be attributed to the higher DM ratio of the fruit-based samples (Table 1).

The n value of the sample containing 10% barberry was the lowest n value (Table 1). The n values varied between 0.29 and 0.38, indicating that the n values of all samples were pseudoplastic. Previous studies have identified the flow behavior of ice cream samples containing various plant materials as pseudoplastic (Soukoulis & Tzia, 2008; Akalın et al., 2018; Sayar et al., 2022; Ürkek et al., 2022).

3.3. Colorimetric parameters

The effect of the addition of barberry was statistically significant on the *L**, *H°* (P<0.01), *b**, *a* and* WI (P<0.05), while only the *C** values were not affected (P>0.05). Table 2 presents the colorimetric parameter values of the samples. The sample not contain barberry exhibited the highest *L**, *b**, *H°* and WI values, whereas these values were the lowest in the sample containing 15% barberry. The lowest and highest a*

values were identified in samples C and BB15, respectively. *C** values did not show a significant change among samples (Table 2). The Δ*E** values indicated clear color differences among the samples.

Table 2. The color parameters of ice creams

Samples	C	BB5	BB10	BB15
*L**	86.22±0.18^{c}	79.82±1.18^{b}	77.58±2.89^{ab}	73.54±1.12^{a}
*a**	-3.66±0.05^{a}	2.70±1.94^{ab}	7.40±4.77^{bc}	11.54±0.42^{c}
*b**	10.66±0.71^{c}	9.58±0.67^{bc}	8.10±0.25^{ab}	6.69±0.71^{a}
H°	108.96±0.94^{c}	74.85±9.75^{b}	50.19±19.60^{ab}	30.04±1.74^{a}
*C**	11.27±0.69^{a}	10.02±1.17^{a}	11.29±2.94^{a}	13.34±0.72^{a}
WI	82.20±0.58^{c}	77.47±1.58^{bc}	74.89±3.90^{ab}	70.36±1.33^{a}
Δ*E**	0.00	9.16±2.10	14.27±5.54	20.23±0.82

a-d letters indicate statistical significance in the same row (P<0.05). The data were shown as the mean ± standard deviation. C: control without barberry, BB5: sample containing 5% (w/w) barberry, BB10: sample containing 10% (w/w) barberry, BB15: sample containing 15% (w/w) barberry

The anthocyanins and flavonoids in the fruits are responsible for the different colors observed (Moyer et al., 2002). Özgen et al. (2012) reported that the *L**, *a**, *b**, *C** and *H*° values of barberry were between 10.91-12.27, 3.28-4.94, 2.37-2.63, 4.11-5.51 and 26.50-40.15, respectively. Thus, the barberry content may affect the colorimetric parameter values of the samples. Similar results have been observed in several previous studies (Şanlıdere Aloğlu et al., 2018; Ürkek, 2021; Ürkek et al., 2019; Sayar et al., 2022).

3.4. Mineral content

The control sample's Ca, Na and S contents (Table 3) were higher than those in BB10 and BB15 (P< 0.05), while the sample C had lower K content (P< 0.05). The Mn, Fe and Zn levels in samples BB10 and BB15 were significantly lower than in sample C (P< 0.05). The P and Ni amounts did not indicate significant change (P>0.05). The Ca and Mg ratio was highest in the sample containing 5% barberry, while the Mn and Fe contents were greatest in sample C.

Table 3. The mineral (mg/kg) contents of ice creams

Mineraller	C	BB5	BB10	BB15
Major elements				
Ca	1629.50±16.98^{b}	1915.73±25.06^{a}	1371.98±29.08^{c}	1273.54±25.94^{d}
Na	487.99±6.89^{a}	517.81±11.03^{a}	378.16±20.73^{b}	362.70±0.74^{b}
Mg	186.79±0.36^{b}	258.25±3.25^{a}	202.78±13.59^{b}	191.24±0.25^{b}
P	849.10±2.89^{a}	831.18±11.99^{a}	868.57±54.73^{a}	870.27±4.80^{a}
S	221.17±3.13^{a}	174.43±2.79^{b}	136.19±12.91^{c}	132.12±0.49^{c}
K	1934.43±28.09^{b}	2048.46±46.32^{b}	2292.05±119.23^{a}	2464.52±12.85^{a}
Minor elements				
Mn	10.47±0.72^{a}	1.10±0.14^{c}	3.45±0.57^{b}	5.10±0.81^{b}
Fe	29.79±1.29^{a}	25.83±0.03^{b}	21.47±0.17^{c}	17.75±0.98^{d}
Ni	0.54±0.07^{b}	0.42±0.01^{b}	0.84±0.01^{a}	0.50±0.08^{b}
Zn	24.19±0.10^{a}	23.37±0.62^{a}	11.60±0.21^{b}	8.55±0.22^{c}

a-d letters indicate statistical significance in the same row (P<0.05). The data were shown as the mean ± standard deviation. C: control without barberry, BB5: sample containing 5% (w/w) barberry, BB10: sample containing 10% (w/w) barberry, BB15: sample containing 15% (w/w) barberry

Previous studies reported that adding fruits resulted in significant differences in the mineral contents of samples (Ürkek et al., 2019; Ürkek, 2021). Barberry contains a high amount of minerals, including Ca (2744.06 ppm), K (12111.19 ppm), Na (2569.33 ppm), Mg (1193.30 ppm) and P (2715.51 ppm). In contrast, its Mn (6.54 ppm), Fe (323.86 ppm), Ni (19.98 ppm) and Zn (7.95 ppm) contents are low (Akbulut et al., 2009). Thus, the mineral content of barberry may contribute to changes in the mineral content of the samples.

3.5. Antioxidant activity

The lowest IC50 value was obtained in the samples that did not contain barberry (143.19 µg/mL), while the IC50 values decreased with increasing barberry content. A high IC50 value indicates low antioxidant activity. The sample containing 15% barberry exhibited higher antioxidant activity (22.15 µg/mL) than BHA, BHT and α-tocopherol; however, this result was lower than that of trolox. The antioxidant activity of all samples was ranked from high to low as follows: trolox > BB15 > BHA > BHT > α-tocopherol > BB10 > BB5 > barberry (fruit) > C (Table 4).

The barberry fruit had the highest TPC value at 4440.08 mg GAE/g, whereas sample C had the lowest TPC at 149.48 mg GAE/g (Table 4). The TPC of the ice creams increased with the addition of barberry. The TPC and IC50 values showed parallel results. Previous studies have determined that ice creams containing different fruits exhibited increased antioxidant activity based on fruit concentration (Karaman & Kayacier, 2012; Ürkek et al., 2019; Sayar et al., 2022).

The antioxidant activity of barberry is high due to anthocyanins and phenolics (Özgen et al., 2012; Yildiz et al., 2014). Therefore, ice cream samples containing barberry might demonstrate high antioxidant activity.

Table 4. TPC and IC_{50} values of barberry, ice creams

Samples	DPPH (IC_{50}; µg/mL)	TPC (mg GAE/g)
BHA	26.51±0.26	-
BHT	25.36±1.26	-
Trolox	18.34±0.22	-
α-tocopherol	20.96±0.38	-
Barberry (fruit)	44.04±1.49	4440.08±62.88
C	143.19±32.49	149.48±73.03
BB5	33.97±0.95	802.82±27.72
BB10	28.41±0.44	1253.01±86.26
BB15	22.15±0.14	1474.04±17.12

C: control without barberry, BB5: sample containing 5% (w/w) barberry, BB10: sample containing 10% (w/w) barberry, BB15: sample containing 15% (w/w) barberry

3.6. Sensory test

The samples containing 10% and 15% barberry received higher scores than the other samples in terms of color and appearance, gumming structure, texture and flavor (Figure 3). The meltdown in mouth score was highest in sample BB5, while sample C had the lowest melting resistance score. Sample BB5 was deemed the least desirable in terms of color, appearance and flavor by the panelists. The highest overall acceptability score was in sample BB10 (7.83), whereas sample C had the lowest score (6.85). Ürkek et al. (2019) reported similar results.

4. Conclusions

The current study found that the addition of BB resulted in increased acidity, dry matter (DM), overrun and viscosity (at 20 and 50 rpm), melting resistance (malting rates at 45 and 60 minutes), along with higher levels of potassium (K), calcium (Ca), sodium (Na), sulfur (S), iron (Fe) and zinc (Zn). Conversely, the pH and fat values decreased. The L^*, a^*, b^*, H°, ΔE^* and white index (WI) indicated significant changes among samples. The antioxidant activity of the samples containing barberry was found to be higher than that of the control sample. Samples BB10 and BB15 received higher scores for all sensory properties, except for mouthfeel and melting resistance. Consequently, barberry could be used to enhance the nutritional and quality characteristics of ice creams.

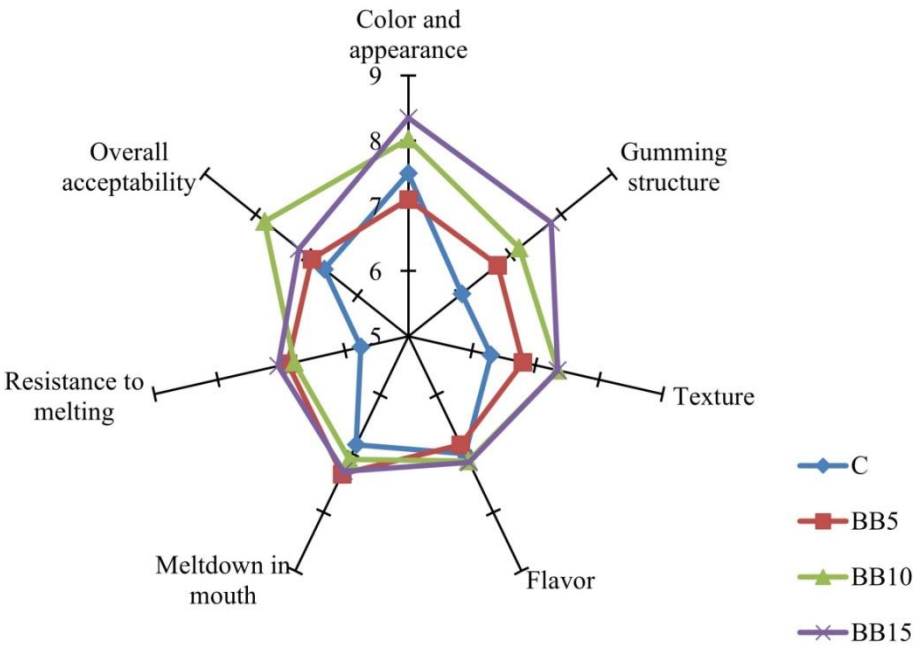

Figure 3. Sensory test of ice creams (C: control without barberry, BB5: sample containing 5% (w/w) barberry, BB10: sample containing 10% (w/w) barberry, BB15: sample containing 15% (w/w) barberry)

Acknowledgment

A part of the article was an oral presentation at the International Agricultural Science Congress and I. International Iğdır Congress on Multidisciplinary Studies and published as an abstract.

Author contribution

The author is responsible for the entire article.

Declaration of ethical code

The author of this article declares that the materials and methods used in this study do not require ethics committee approval and/or legal-special permission.

Conflicts of interest

The author declares that there is no conflict of interest.

References

Akalın, A. S., Kesenkas, H., Dinkci, N., Unal, G., Ozer, E., & Kınık, O. (2018). Enrichment of probiotic ice cream with different dietary fibers: Structural characteristics and culture viability. *Journal of Dairy Science*, *101*(1), 37–46. https://doi.org/10.3168/jds.2017-13468

Akbari, M., Eskandari, M. H., Niakosari, M., & Bedeltavana, A. (2016). The effect of inulin on the physicochemical properties and sensory attributes of low-fat ice cream. *International Dairy Journal*, *57*, 52–55. https://doi.org/10.1016/j.idairyj.2016.02.040

Akbulut, M., Çalişir, S., Marakoglu, T., & Çoklar, H. (2009). Some physicomechanical and nutritional properties of barberry (*Berberis vulgaris* l.) fruits. *Journal of Food Process Engineering*, *32*(4), 497–511. https://doi.org/10.1111/j.1745-4530.2007.00229.x

Arslaner, A., Ali, M., Bayburt, S., Mühendislik, Ü., Gıda, F., & Bölümü, M. (2017). Ceviz Ezmesi ve Dut Kurusu Tozu İlavesiyle Üretilen Düşük Kalorili Dondurmanın Bazı Kalite Niteliklerinin Belirlenmesi. *Atatürk Univ., J. of the*

Agricultural Faculty, *48*(1), 57–64.

Arslaner, A., Çakıroğlu, K., & Çakır, Ö. (2016). Ice-cream with karamuk. *Uluslar Arası Erzincan Sempozyumu*, *2*(September), 825–834.

Balthazar, C. F., Silva, H. L. A., Cavalcanti, R. N., Esmerino, E. A., Cappato, L. P., Abud, Y. K. D., Moraes, J. andrade, M. M., Freitas, M. Q., Sant'Anna, C., Raices, R. S. L., Silva, M. C., & Cruz, A. G. (2017). Prebiotics addition in sheep milk ice cream: A rheological, microstructural and sensory study. *Journal of Functional Foods*, *35*, 564–573. https://doi.org/10.1016/j.jff.2017.06.004

Cecchini, M., Contini, M., Massantini, R., Monarca, D., & Moscetti, R. (2011). Effects of controlled atmospheres and low temperature on storability of chestnuts manually and mechanically harvested. *Postharvest Biology and Technology*, *61*(2–3), 131–136. https://doi.org/10.1016/j.postharvbio.2011.03.001

Drake M.A., (2009). *Modern sensory practices*. In: Clark, S., Costello, M., Drake M.A. and Bodyfelt, F., (eds) The Sensory Evaluation of Dairy Products. New York: Springer, pp. 505–530.

dos Santos Cruxen, C. E., Hoffmann, J. F., Zandoná, G. P., Fiorentini, Â. M., Rombaldi, C. V., & Chaves, F. C. (2017). Probiotic butiá (Butia odorata) ice cream: Development, characterization, stability of bioactive compounds and viability of Bifidobacterium lactis during storage. *LWT*, *75*, 379–385. https://doi.org/10.1016/j.lwt.2016.09.011

El-Samahy, S. K., Youssef, K. M., & Moussa-Ayoub, T. E. (2009). Producing ice cream with concentrated cactus pear pulp: a preliminary study. *J. Pacd*, *11*, 1–12.

Favaro-Trindade, C. S., De Carvalho Balieiro, J. C., Dias, P. F., Sanino, F. A., & Boschini, C. (2007). Effects of culture, pH and fat concentration on melting rate and sensory characteristics of probiotic fermented yellow mombin (Spondias mombin L) ice creams. *Food Science and Technology International*, *13*(4), 285–291. https://doi.org/10.1177/1082013207082387

Gülçin, I. (2010). Antioxidant properties of resveratrol: A structure-activity insight. *Innovative Food Science and Emerging Technologies*, *11*(1), 210–218. https://doi.org/10.1016/j.ifset.2009.07.002

Gülçin, I., Oktay, M., Küfrevioğlu, Ö. I., & Aslan, A. (2002). Determination of antioxidant activity of lichen Cetraria islandica (L) Ach. *Journal of Ethnopharmacology*, *79*(3), 325–329. https://doi.org/10.1016/S0378-8741(01)00396-8

Güler, Z. (2007). Levels of 24 minerals in local goat milk, its strained yoghurt and salted yoghurt (tuzlu yoğurt). *Small Ruminant Research*, *71*(1–3), 130–137. https://doi.org/10.1016/j.smallrumres.2006.05.011

Gundogdu, M. (2013). Determination of antioxidant capacities and biochemical compounds of *Berberis vulgaris* L. Fruits. *Advances in Environmental Biology*, *7*(2), 344–348.

Güven, M., & Karaca, O. B. (2002). The effects of varying sugar content and fruit concentration on the physical properties of vanilla and fruit ice-cream-type frozen yogurts. *International Journal of Dairy Technology*, *55*(1), 27–31. https://doi.org/10.1046/j.1471-0307.2002.00034.x

Karaman, S., & Kayacier, A. (2012). Rheology of ice cream mix flavored with black tea or herbal teas and effect of flavoring on the sensory properties of ice cream. *Food and Bioprocess Technology*, *5*(8), 3159–3169. https://doi.org/10.1007/s11947-011-0713-5

Karaman, S., Toker, Ö. S., Yüksel, F., Çam, M., Kayacier, A., & Dogan, M. (2014). Physicochemical, bioactive and sensory properties of persimmon-based ice cream: Technique for order preference by similarity to ideal solution to determine optimum concentration. *Journal of Dairy Science*, *97*(1), 97–110. https://doi.org/10.3168/jds.2013-7111

Kurt, A., & Atalar, I. (2018). Effects of quince seed on the rheological, structural and sensory characteristics of ice cream. *Food Hydrocolloids*, *82*, 186–195. https://doi.org/10.1016/j.foodhyd.2018.04.011

Meilgaard, M. C., Carr, B. T., & Civille, G. V. (1999). Sensory Evaluation Techniques. In *Boca Raton, FL:CRC Pres, Inc*. (3rd ed.). https://doi.org/10.1017/S1431927611002686

Metin, M. (2012): *Süt ve mamülleri analiz yöntemleri*. Ege Üniversitesi Basımevi, Bornova, İzmir, Turkey

Moyer, R. A., Hummer, K. E., Finn, C. ., Frei, B., & Wrolstad, R. E. (2002). Anthocyanins, phenolics and antioxidants capacity in diverse small fruits. *Journal of Agricultural Food Chemistry*, *50*(5), 519-525.

Muse, M. R., & Hartel, R. W. (2004). Ice cream structural elements that affect melting rate and hardness. *Journal of Dairy Science*, *87*(1), 1–10. https://doi.org/10.3168/jds.S0022-0302(04)73135-5

Özgen, M., Saraçoğlu, O., & Geçer, E. N. (2012). Antioxidant capacity and chemical properties of selected barberry (*Berberis vulgaris* L.) fruits. *Horticulture Environment and Biotechnology*, *53*(6), 447–451. https://doi.org/10.1007/s13580-012-0711-1

Rahimi-Madiseh, M., Lorigoini, Z., Zamani-Gharaghoshi, H., & Rafieian-Kopaei, M. (2017). *Berberis vulgaris* : Specifications and traditional uses. *Iranian Journal of Basic Medical Sciences*, *20*(5), 569–587. https://doi.org/10.22038/IJBMS.2017.8690

Şanlıdere Aloğlu, H., Gökgöz, Y., & Bayraktar, M. (2018). Strawberry tree fruits (Arbutus unedo L) ice cream production, investigation of physical, chemical and sensorial parameters. *Gida / the Journal of Food*, *43*(6), 1030–1039. https://doi.org/10.15237/gida.gd18098

Sayar, E., Şengül, M., & Ürkek, B. (2022). Antioxidant capacity and rheological, textural properties of ice cream produced from camel's milk with blueberry. *Journal of Food Processing and Preservation, October 2021*, 1–8. https://doi.org/10.1111/jfpp.16346

Şengül, M., Erkaya, T., Şengül, M., & Yıldız, H. (2012). The effect of adding sour cherry pulp into yoghurt on the physicochemical properties, phenolic content and antioxidant activity during storage. *International Journal of Dairy Technology*, *65*(3), 429–436. https://doi.org/10.1111/j.1471-0307.2012.00838.x

Sofjan, R. P., & Hartel, R. W. (2004). Effects of overrun on structural and physical characteristics of ice cream. *International Dairy Journal*, *14*(3), 255–262. https://doi.org/10.1016/j.idairyj.2003.08.005

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*(4), 627–655. https://doi.org/10.1111/1541-4337.12083

Soukoulis, C., & Tzia, C. (2008). Impact of the acidification process, hydrocolloids and protein fortifiers on the physical and sensory properties of frozen yogurt. *International Journal of Dairy Technology*, *61*(2), 170–177. https://doi.org/10.1111/j.1471-0307.2008.00385.x

Topdaş, E. F., Çakmakçı, S., & Çakıroğlu, K. (2017). The antioxidant activity, vitamin C contents, physical, chemical and sensory properties of ice cream supplemented with cornelian cherry (Cornus mas L.) paste. *Kafkas Universitesi Veteriner Fakultesi Dergisi*, *23*(5), 691–697. https://doi.org/10.9775/kvfd.2016.17298

Ürkek, B. (2021). Effects of the addition of rose hip on various nutritional and quality properties of ice cream. *Indian Journal of Traditional Knowledge*, *20*(October), 1022–1030. http://op.niscair.res.in/index.php/IJTK/article/view/32564/465479838

Ürkek, B., Aktaş, H., Öztuğ, M. Ö., Yeniçeri, E., & Öztuğ, P. (2024). Physicochemical , sensory and antimicrobial properties of the ice cream containing lavender (Lavandula angustifolia) essential oil. *Ovidius University Annals of Chemistry*, *35*(2), 91–97. https://doi.org/10.2478/auoc-2024-0012

Ürkek, B., Öztürk, F., & Şengül, M. (2022). Farklı bitki tozlarının (üzüm çekirdeği, keçiboynuzu ve çörekotu tozu) dondurma üretiminde kullanım imkanları/Possibilities of using in ice cream production (grape seed, carob and black cumin powder) of differernt plant powders. *ATA-Gıda Dergisi*, *1*(1), 1–5.

Ürkek, B., Şengül, M., Akgül, H. I., & Kotan Erkaya, T. (2019). Antioxidant activity, physiochemical and sensory characteristics of ice cream incorporated with sloe berry (Prunus spinosa L.). *International Journal of Food Engineering*, *15*(11–12), 1–9. https://doi.org/10.1515/ijfe-2018-0029

Yildiz, H., Ercisli, S., Sengul, M., Topdas, E. F., Beyhan, O., Cakir, O., Narmanlioglu, H. K., & Orhan, E. (2014). Some physicochemical characteristics, bioactive content and antioxidant characteristics of non-sprayed barberry (*Berberis vulgaris* L.) fruits from Turkey. *Erwerbs-Obstbau*, *56*(4), 123–129. https://doi.org/10.1007/s10341-014-0216-4