

Compositional and Bioactive Compound Analysis of Persimmon and its Use in Functional Ice Cream Production

Trabzon Hurmasının Bileşimsel ve Biyoaktif Bileşen Analizi ve Fonksiyonel Dondurma Üretiminde Kullanımı

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Abstract

This study aimed to analyze the β -carotene and tocopherol levels in persimmons using HPLC and assess their potential as a value-added ingredient in ice cream. Persimmon samples were collected from seven regions in Ordu Province, Türkiye, including Fatsa, Ulubey, Perşembe, Ünye, Gülyalı, İkizce, and Kumru. The analysis included measurements of total phenolic substance, β -carotene, tocopherols and radical scavenging activity. Results showed that β -carotene content ranged from 0.43 to 0.55 mg 100 g⁻¹, α -tocopherol from 0.13 to 0.30 mg 100 g⁻¹, and γ -tocopherol from 0.09 to 0.24 mg 100 g⁻¹. Total phenolic content varied between 30.9 and 673.8 mg GAE 100 g⁻¹, and radical scavenging activity ranged from 0.20 to 11.07 μ g TE mg⁻¹. While β -carotene levels were relatively consistent across samples, two samples (Fatsa and Ulubey) exhibited higher tocopherol content, total phenolics, and radical scavenging activity. Therefore, a combination of these two high-bioactivity persimmon types was used to produce the persimmon purée (PP) incorporated into the ice cream mixes at concentrations of 15, 25, and 35 g 100 g⁻¹. The addition of persimmon puree significantly influenced the ice cream's physicochemical properties and enhanced its antiradical activity compared to the sample without PP addition. Improvements were observed in melting ratio and first dripping time. The acidity level of the ice creams did not increase significantly during storage ($p>0.05$). Neither the ratios nor the storage time had a significant effect on the pH values of the samples. The addition of persimmon puree decreased the *L* color value of the samples while increasing the *a* and *b* color values. The hardness and stickness values of the ice creams have also increased with the increase in persimmon ratio. At the end of storage, the stickness values were similar in ice creams with PP addition. Sensory evaluation revealed that ice creams with 15% and 25% persimmon puree were the most preferred by panelists. These findings suggest that persimmons, being rich in beta-carotene and tocopherols, can enhance the nutritional and sensory qualities of ice cream.

Keywords: *Diospyros kaki*, Antioxidant, Carotenoids, Phenolics, Ice cream texture

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Öz

Bu çalışmanın amacı, HPLC kullanarak Trabzon hurmalarındaki beta-karoten ve tokoferol seviyelerini analiz etmek ve dondurmada katma değerli bir bileşen olarak potansiyelini değerlendirmektir. Trabzon hurması örnekleri Türkiye'nin Ordu ilindeki Fatsa, Ulubey, Perşembe, Ünye, Gülyalı, İkizce ve Kumru olmak üzere yedi bölgeden temin edilmiştir. Analizler toplam fenolik madde, β -karoten, tokoferoller ve radikal temizleme aktivitesi ölçümlerini içermektedir. Sonuçlar β -karoten içeriğinin 0.43 ila 0.55 mg 100 g⁻¹, α -tokoferolün 0.13 ila 0.30 mg 100 g⁻¹ ve γ -tokoferolün 0.09 ila 0.24 mg 100 g⁻¹ arasında değiştiğini göstermiştir. Toplam fenolik içeriği 30.9 ile 673.8 mg GAE 100 g⁻¹ arasında değişirken, radikal süpürme aktivitesi 0.20 ile 11.07 μ g TE mg⁻¹ arasında değişmiştir. Örnekler arasında β -karoten seviyeleri nispeten tutarlı iken, iki örnek (Fatsa ve Ulubey) daha yüksek tokoferol içeriği, toplam fenolik madde ve radikal süpürme aktivitesi sergilemiştir. Bu yüzden bu iki yüksek biyoaktiviteli Trabzon hurması türü birleştirilerek, dondurma karışımlarına 15, 25 ve 35 g 100 g⁻¹ konsantrasyonlarında katılarak üretilmiştir. Trabzon hurma püresi ilavesi, dondurmanın fizikokimyasal özelliklerini önemli ölçüde etkilemiş ve püre ilavesiz örneğe kıyasla antiradikal aktivitesini arttırmıştır. Erime oranında ve ilk damlama süresinde iyileşmeler gözlenmiştir. Dondurmaların asitlik seviyesi depolama sırasında önemli ölçüde artmamıştır ($p>0.05$). Ne oranların ne de depolama süresinin örneklerin pH değerleri üzerinde önemli bir etkisi olmamıştır. Trabzon hurma püresi ilavesi örneklerin *L* renk değerini azaltırken *a* ve *b* renk değerlerini arttırmıştır. Püre oranının artması ile dondurmaların sertlik ve yapışkanlık değerleri de artmıştır. Depolama sonunda, püre ilaveli dondurmalarda yapışkanlık değerleri benzer görülmüştür. Duyusal değerlendirme, %15 ve %25 Trabzon hurması püresi içeren dondurmaların tüketiciler tarafından yüksek beğeni aldığı ortaya koymuştur. Bu bulgular, beta-karoten ve tokoferoller bakımından zengin olan Trabzon hurmasının dondurmanın besinsel ve duyusal niteliklerini geliştirebileceğini göstermektedir.

Anahtar Kelimeler: *Diospyros kaki*, Antioksidan, Karotenoidler, Fenolikler, Dondurma tekstürü

1. Introduction

Fruits and vegetables are crucial part of human nutrition, contributing significantly to overall health. Their positive effects are primarily associated with bioactive compounds, especially phytochemicals, which positively influence human physiology (Manach et al., 2004). Plant carotenoids have garnered significant attention for their provitamin A activity and their role in mitigating oxidative stress through antioxidant effects (Ebadi et al., 2023). Among these, persimmon is particularly notable for its strong antioxidant properties and substantial health benefits (Butt et al., 2015).

Persimmon is a fleshy fiber rich tropical fruit that is widely cultivated in Türkiye and warm regions of the world (Butt et al., 2015). It contains valuable nutrients such as vitamins and minerals in addition to bioactive compounds such as ascorbic acid, tannins, carotenoids, polyphenols and antioxidants. The health benefits of these bioactive compounds mainly depend on their antioxidant properties (Yaquob et al., 2016; Arslan and Bayrakçı, 2016). Among these bioactives, carotenoids and tocopherols stand out as key natural antioxidants with diverse biological activities beneficial to human health. Beta-carotene, a major carotenoid in persimmons, serves as a vitamin A precursor and effectively neutralizes reactive oxygen species (ROS), supporting cognitive and reproductive health, neuroprotection, and lowering the risk of chronic diseases such as cancer and cardiovascular disorders (Miazek et al., 2022; Liu et al., 2025). Tocopherols, including alpha- and gamma-forms, are lipid-soluble antioxidants that protect cell membranes from lipid peroxidation and contribute to cardiovascular, intestinal, and bone health (Ungurianu et al., 2021; Ekeuku et al., 2022; Es-Sai et al., 2025). These compounds also exhibit anti-inflammatory and anticancer effects (Es-Sai et al., 2025). Additionally, tannins and flavonoids present in persimmons significantly enhance its antioxidant capacity, reinforcing its effectiveness in preventing oxidative stress-related diseases (Barba et al., 2006; El Makhzangy et al., 2023). Functional qualities of many fruits and plants have been extensively studied, particularly regarding their potential application as innovative health-promoting ingredients in functional foods (Pehlivanoglu et al., 2024). Recently, the incorporation of certain fruits, prebiotics, probiotics, vitamins, sweeteners, polyunsaturated fatty acids, dietary fibers, and natural antioxidants—ingredients with notable nutritional and physiological benefits—into ice cream production has increased. This trend is driven by growing consumer interest in healthier and more functional food options (Erkaya et al., 2012; Sinan Dayısoylu et al., 2014).

Ice cream is a product consumed by people of all ages because it contains some of the beneficial nutrients of milk, its composition can be easily changed with different types of additives, including various fruits, probiotics and prebiotics. In addition to these features, the number of researches on functionalization of ice cream is increasing due to its beneficial effects on health. The quality of ice cream is largely determined by its mix formulation and processing methods, with studies highlighting the impact of additives on its nutritional and sensory attributes (Cakmakci et al., 2016; Türkmen and Gürsoy, 2017). Despite the variety of formulations available, there is a growing need for innovative, consumer-preferred options, particularly those enriched with bioactive compounds, to expand market share (Karaman and Kayacier, 2012).

The primary aim of this study was to determine the β -carotene, tocopherol, phenolic contents, and antioxidant activity in persimmon fruits collected from Ordu Province, Türkiye, and to compare the carotenoid contents among different persimmon cultivars. Additionally, the study evaluated the physical, chemical, and sensory qualities of ice cream samples made with persimmon puree. Ultimately, this research seeks to promote the use of persimmon—rich in bioactive compounds such as β -carotene and tocopherol—in the food industry by developing new persimmon-based products, such as ice cream, to provide consumers with health-beneficial options during the off-season and increase persimmon consumption.

2. Materials and Methods

2.1. Plant material

In this research, persimmon fruits that had reached the commercial maturity were collected from 7 different regions of Ordu province of Türkiye (Fatsa, Ulubey, Perşembe, Ünye, Gülyalı, İkizce and Kumru). A sub-sample of 10 fruits was selected from each region. After being washed in water, the skin of the fruit was removed and the puree was homogenized using a blender. The resulting puree was used for the analysis of the samples. The extracts obtained from persimmon were analyzed for β -carotene, α - and γ -tocopherol, total phenolic substance and

antiradical scavenging activity. Persimmon fruits collected from different regions were coded as follows: P1; Fatsa, P2; Ulubey, P3; Perşembe, P4; Ünye, P5; Gülyalı, P6; İkizce and P7; Kumru.

2.2. Proximate composition and bioactive properties of persimmon fruits

The study analyzed moisture, ash content, pH, and acidity using AOAC methods (International, 2000). Moisture content was determined by drying approximately 5 g of sample at 105°C until constant weight was achieved. Ash content was measured by incinerating about 1 g of sample at 550°C for 6 hours. Titratable acidity was assessed by titrating the sample with 0.1 N NaOH until the pH reached 8.1, and results were expressed as % citric acid. The pH of the samples was measured directly using a calibrated pH meter at room temperature. To evaluate the bioactive properties of persimmon samples, extracts were prepared for the determination of total phenolic content and antioxidant activity. Ten grams of persimmon pulp were homogenized with 30 mL of acidified methanol (methanol containing 0.1% hydrochloric acid, v/v) using an Ultra-Turrax at 10 000 x g for 2 minutes. The mixture was incubated in a shaking water bath at room temperature for 24 hours in the dark. After extraction, the sample was centrifuged at 4 000 rpm for 15 minutes, and the supernatant was filtered and stored at 4°C until analysis. Total phenolic content was measured with the Folin–Ciocalteu method and calculated as mg gallic acid equivalents (GAE) per 100 g. Diluted extracts were first mixed with 0.1 mL of Folin–Ciocalteu reagent and allowed to react for 5 minutes. Subsequently, 0.3 mL of saturated sodium carbonate solution was added, and the mixture was incubated at room temperature for 2 hours. Absorbance was read at 765 nm using a UV–Vis spectrophotometer. Antiradical activity was evaluated using the DPPH assay, with results expressed as Trolox equivalents. A diluted extract was mixed with a methanolic DPPH solution (1 mM) and kept in the dark at room temperature for 30 minutes. The absorbance at 515 nm was recorded and the antiradical activity was expressed as µg Trolox equivalents per mg weight (Demirkol and Tarakci, 2018).

To determine β-carotene and tocopherol content, five grams of homogenized persimmon sample were placed in a light-protected vessel and extracted with 100 mL of a hexane/acetone/ethanol mixture (50:25:25, v/v/v) using a magnetic stirrer for 30 minutes. After addition of 15 mL ultrapure water, the mixture was transferred to a measuring cylinder to allow phase separation. A 10 mL aliquot of the organic (hexane) layer was evaporated to dryness, and the residue was redissolved in 1 mL of tetrahydrofuran/acetonitrile/methanol (15:30:55, v/v/v). The final solution was filtered through a 0.45 µm PVDF membrane and 20 µL was injected into the HPLC system. The analysis was performed using a Shimadzu HPLC-PDA system (Kyoto, Japan) equipped with an ODS-3V C18 column (250 × 4 mm, 5 µm). The mobile phase consisted of acetonitrile/methanol/dichloromethane/n-hexane (50:40:5:5, v/v/v/v) at a flow rate of 1.0 mL/min. Column temperature was maintained at 30°C, and the autosampler was set at 4°C. Detection was carried out using a diode array detector (DAD) at 470 nm for β-carotene and 292 nm for tocopherols. The analysis time was 30 minutes. The limits of detection (LOD) for β-carotene, α-tocopherol, and γ-tocopherol were 0.004, 0.025, and 0.023 µM, respectively, while limits of quantification (LOQ) were 0.011, 0.076, and 0.070 µM, with correlation coefficients (R²) of 0.98, 0.99, and 0.99, respectively (Choi et al., 2014).

2.3. Ice cream production

Table 3 gives the components (in g 100 g⁻¹ ice cream) of the different treatments of the ice cream mix. The ice cream mix contained 55.33% (w v⁻¹) milk, 13.88% (w w⁻¹) sugar, 4.42% (w w⁻¹) skim milk powder, 0.6% (w w⁻¹) emulsifier/stabilizer and 25.77% (w w⁻¹) cream. The emulsifier and stabilizer in the formulation were commercial products, an equal mix of Supergelmix Turchia and Somix, commonly used in ice cream production. The mixtures were pasteurized at 85°C for 30 seconds, then cooled to 4°C and kept at this temperature for 24 hours for the mix to mature. According to the results of the persimmon analysis, the samples richest in bioactive substances (P1 and P2) were mixed in equal proportions and used for ice cream production. Then 0, 15, 25 or 35% (w w⁻¹) PP was added to each mixture to obtain samples in four different formulations. The mixtures were frozen in an ice cream maker (-5°C) and packaged in 100 mL containers and then kept at -18°C for 24 h. The PP-added ice creams were stored at -18°C until physicochemical and sensory analyses were performed. The dry matter content of the PP-added ice creams with the control sample ranged from 30.44% to 35.56% (Table 3).

2.4. Physical characteristics of the ice creams

To measure the viscosity of the ice cream mix, 30–40 mL of the mix was poured into the appropriate sample container of the device and the viscosity was determined using a sine wave type pulsating viscometer (SV-10, A&D Inc., Japan). Viscosity measurements were performed over 120 seconds under temperature-controlled conditions within the range of 11–12°C. The measurement data were automatically recorded using the instrument's software, and only the values obtained at exactly 12°C were used for analysis. Total acidity was determined as lactic acid by titrimetric technique. A pH meter was used to detect the ice cream's pH (International, 2000). The color of both the PP and ice cream samples was identified using a Minolta CR-200 colorimeter (Osaka, Japan). The *L* (brightness), *a* (redness), and *b* (yellowness) were recorded via color coordinates (Cingöz, 2024).

The melting rate after 30 min and the first drip time of the ice cream were determined according to the method of Güven and Karaca (2002). After the weights of the samples were recorded (at -20°C), they were placed on porous steel wire and kept at ambient temperature (25°C). The melted ice cream was collected from the wire and the melting weight of the ice cream after 30 min was recorded. The first drip time, when the ice cream first started to melt, was also recorded.

2.5. Total phenolic substance and antiradical activity of the ice creams

Methanol with 0.1% HCl was used to extract bioactive components from the ice cream samples. A 20 g of sample and 30 mL of acidified methanol were combined for extraction and the combination was then stored at 4°C overnight. After that, the mixture was filtered via Whatman No. 1 filter paper and the resulting filtrate was collected for further analysis (Demirkol and Tarakci, 2018). The same methods used for PP in Section 2.2 were applied. Total phenolic content was expressed as mg gallic acid equivalents (GAE) per kg of sample, and antiradical activity was reported as the percentage of DPPH radical inhibition (% inhibition).

2.6. Hardness and stickiness values of the ice creams

Hardness and stickiness characteristics of the ice cream were monitored using a Texture Analyzer (TA.XT2.plus, Stable Micro Systems, Surrey, UK) equipped with a cylindrical probe with a diameter of 2.5 mm. Ice creams were stored at -18°C and tempered to -10°C for 24 hours prior to testing. The analysis involved a penetration distance of 10 mm, with forces applied at 3.0 g, and penetration speeds set at 3.3 mm/s and 2.0 mm/s. Each sample was tested twice, and the hardness and stickiness were assessed based on the maximum compression force (N) recorded during penetration.

2.7. Sensory analysis

Ten panelists from Ordu University, Department of Food Engineering performed the sensory analysis of ice cream. Panelists were familiar with ice cream and had previous experience in sensory evaluation. The panelists evaluated various attributes of the ice cream such as appearance, structure, taste, odor and overall acceptability. The scoring was from 1 to 10. A score of 1 depicted the worst sample and a score of 10 depicted the best sample. A score of 5 and above indicates that the samples were considered acceptable.

2.8. Statistical analysis

The study data were statistically compared using Minitab 17.0 software, which included Analysis of Variance (ANOVA). Tukey's multiple range test was employed to determine statistically significant differences ($P < 0.05$) within mean values.

3. Results and Discussion

3.1. Physicochemical characteristics of the persimmon fruits

Table 1 presents the physicochemical properties of persimmon fruits. Accordingly, the pH values of the samples varied between 5.77 and 6.53. Among the samples, the highest pH was observed in P5, while the lowest was recorded in P4 ($p < 0.05$). When the acidity values of the fruits were analyzed, it was observed that P2 sample had the highest acidity with 0.11% and P6 and P7 samples had the lowest acidity. The dry matter content of the samples ranged from 20.89% to 26.4%. No significant differences were observed in ash content ($p > 0.05$). de Ancos et al. (2000) stated that the pH of two different species of persimmons were 5.31 and 5.02, respectively, the acidity

values were 0.14% and 0.12% in terms of citric acid and the dry matter values were between 17.12% and 21.15%. These findings are consistent with the results of the present study.

Table 1. Physicochemical features of the persimmon fruit cultivars

Samples	pH	Titrateable acidity (citric acid, %)	Dry Matter (%)	Ash (%)
P1	6.06 ± 0.005 ^c	0.09 ± 0.001 ^b	21.24 ± 0.05 ^b	0.35 ± 0.12 ^a
P2	5.87 ± 0.020 ^d	0.11 ± 0.005 ^a	21.52 ± 0.79 ^{ab}	0.43 ± 0.04 ^a
P3	6.22 ± 0.015 ^b	0.06 ± 0.002 ^{cd}	21.05 ± 0.44 ^b	0.50 ± 0.02 ^a
P4	5.77 ± 0.015 ^c	0.07 ± 0.000 ^c	26.40 ± 2.84 ^a	0.53 ± 0.03 ^a
P5	6.53 ± 0.025 ^a	0.04 ± 0.002 ^f	20.89 ± 0.01 ^b	0.43 ± 0.02 ^a
P6	6.08 ± 0.005 ^c	0.05 ± 0.001 ^{de}	24.88 ± 0.21 ^{ab}	0.48 ± 0.02 ^a
P7	6.30 ± 0.005 ^b	0.04 ± 0.001 ^{ef}	24.35 ± 0.42 ^{ab}	0.47 ± 0.04 ^a

Samples: P1; Fatsa, P2; Ulubey, P3; Perşembe, P4; Ünye, P5; Gülyalı, P6; İkiizce and P7; Kumru

^{a-c}Means with different letters in the same column differ considerably (p<0.05).

3.2. Phenolic substance, β -carotene, tocopherol and antiradical scavenging activity of the persimmons

Total phenolic contents (TPC) in the different persimmon samples were between 29.70 and 655.8 mg GAE 100g⁻¹. The highest TPC was found in the P2 sample, followed by P1 and P4, respectively. Antiradical activity (AA) values varied from 0.25 to 11.04 μ g TE mg⁻¹. As displayed in Table 2, the P2 sample exhibited the highest AA value with 11.04 μ g TE mg⁻¹ and the P3 sample had the lowest AA value of 0.25 μ g TE mg⁻¹. de Ancos et al. (2000) reported EC₅₀ values of 39.14 g g⁻¹ and 3.07 g g⁻¹ in Sharon and Rojo Brillante persimmon varieties, respectively. Celep et al. (2012) stated that the TPC of Japanese persimmon species was 66.97 mg GAE g⁻¹ extract, antioxidant capacity (DPPH/EC₅₀) was 440 μ g mL⁻¹ and β -carotene content was 75 % (in 1 mg mL⁻¹ extract). According to Jung et al. (2005) dried persimmon residue contained polyphenols ranging from 0.16 to 0.25 g 100 g⁻¹ and carotenoids at a concentration of 0.002 g 100 g⁻¹. Chen et al. (2008) noted that the TPC of Mopan persimmon was 168.15 mg 100 g⁻¹ dw. Persimmons high dietary fiber content is mainly responsible for their health benefits (63.48 g/100 g) and abundant phenolic compounds (1.15 g 100 g⁻¹) (Lee et al., 2006).

β -carotene, α and γ -tocopherol contents of persimmon fruits varied from 0.43 to 0.55 mg 100 g⁻¹, 0.13 to 0.30 mg 100 g⁻¹, 0.09 to 0.24 mg 100 g⁻¹, respectively. Although the β -carotene content of the samples was generally similar, the lowest level was observed in sample P7. Higher levels of tocopherol, total phenolics, and antiradical activity were observed in P1 and P2, which were collected from Fatsa and Ulubey, respectively. de Ancos et al., (2000) stated β -carotene values of 1.63 and 1.24 μ g g⁻¹ in Sharon and Rojo Brillante persimmons, respectively. It was noted that the amount of β -carotene measured by HPLC in Rojo Brillante variety persimmon was 0.1 mg 100 g⁻¹ (Barba et al., 2006). The values obtained in this study are higher than those previously reported.

Table 2. Phenolic substance, β -carotene, tocopherols and antiradical scavenging activity of the persimmon fruits

Sample	Gamma-tocopherol (mg 100 g ⁻¹)	Alpha-tocopherol (mg 100 g ⁻¹)	Beta-carotene (mg 100 g ⁻¹)	Total phenolics (mg GAE 100 g ⁻¹)	Antiradical activity (μ g TE mg ⁻¹)
P1	0.21 ± 0.02 ^{ab}	0.30 ± 0.02 ^a	0.53 ± 0.02 ^{ab}	489.3 ± 10.5 ^b	8.56 ± 0.06 ^b
P2	0.24 ± 0.03 ^a	0.30 ± 0.05 ^a	0.49 ± 0.03 ^{ab}	655.8 ± 18 ^a	11.04 ± 0.04 ^a
P3	0.12 ± 0.02 ^c	0.16 ± 0.01 ^b	0.49 ± 0.01 ^{ab}	29.70 ± 1.20 ^d	0.25 ± 0.05 ^d
P4	0.12 ± 0.02 ^c	0.19 ± 0.01 ^b	0.55 ± 0.03 ^a	285.3 ± 1.50 ^c	4.71 ± 0.21 ^c
P5	0.09 ± 0.02 ^c	0.15 ± 0.02 ^b	0.45 ± 0.05 ^{ab}	39.60 ± 0.60 ^d	0.45 ± 0.05 ^d
P6	0.12 ± 0.01 ^c	0.13 ± 0.02 ^b	0.47 ± 0.03 ^{ab}	60.98 ± 0.68 ^d	0.68 ± 0.02 ^d
P7	0.15 ± 0.02 ^{bc}	0.16 ± 0.04 ^b	0.43 ± 0.04 ^b	43.80 ± 1.20 ^d	0.47 ± 0.03 ^d

Samples: P1; Fatsa, P2; Ulubey, P3; Perşembe, P4; Ünye, P5; Gülyalı, P6; İkiizce and P7; Kumru

^{a-d}Means with different letters in the same column differ considerably (p<0.05).

3.3. Physical characteristics of the ice creams

Some physical characteristics of the ice cream samples to which different ratios of persimmon puree were added are shown in *Table 4*. As shown, the titratable acidity values of the ice cream samples increased with the incorporation of persimmon puree. The acidity level did not increase significantly in the samples with persimmon addition during storage ($p>0.05$). Neither the ratios nor the storage time had a significant effect on the pH values of the samples ($p>0.05$). S. Karaman et al., (2014) found that the pH value in ice cream samples increased by up to 24% with the addition of persimmon, but it decreased again when the persimmon addition reached 40%.

The viscosity values of mixes as presented in Figure 1, ranged between 1.11 cp and 28.85 cp. The addition of up to 25% persimmon did not considerably alter the viscosity values compared to the control sample ($p>0.05$), while the addition of 35% persimmon significantly increased the viscosity of the mix ($p<0.05$). Guner et al. (2007) reported that the viscosity of ice cream mixtures was between 9.76 and 11.6 cP. Cakmakci et al. (2016) found that adding kumquat at 5% and 10% concentrations significantly reduced the viscosity of ice cream samples ($p<0.05$) when compared to the control. However, the viscosity increased when 15% kumquat was added. According to Barba et al. (2006) higher concentrations of mangaba pulp led to an increase in viscosity and dry matter content, while also helping to reduce free water in products such as ice cream. In the study, when the PP concentration was raised to 15% and 25% the viscosity reduced slightly, most likely because of the mixtures lower dry matter content when in compared to the ice cream without added PP.

Table 4 displays the *L*, *a* and *b* color values of the ice creams. The inclusion of persimmon puree considerably altered the color parameters of the ice creams. The brightness value *L* decreased significantly with higher concentrations of the puree ($p<0.05$). While the *L* value of the control sample was 90.47, the *L* value of the sample with 35% puree addition decreased to 78.5. The *a* and *b* values of the samples increased significantly as the puree concentration increased ($p<0.05$). On the first day of storage, *a* value increased from 2.48 to 6.77 and *b* value increased from 3.43 to 12.91. There were no major variations in the *a* and *b* values over the storage period ($p>0.05$). Redness and yellowness values of the samples increased as the fruit ratio increased (*Table 4*). As reported by Sagdic et al. (2012), the addition of phenolic compounds significantly altered the color characteristics of ice creams compared to samples without PP.

Table 4 shows the melting rate and first drip time of the ice creams. The addition of puree significantly decreased the melting rate of the samples in a time-dependent manner. While the melting rate was 56.19% in the control sample, it decreased to 20.28% (sample B) with the addition of puree. Increasing the puree ratio did not affect the melting rate initially. During storage, the melting rate of C and D samples decreased considerably ($p<0.05$). It can be said that persimmon puree, which contains a high content of fiber absorbs water and delays the melting of ice cream (Gorinstein et al., 2001). As shown in *Table 4*, the first dripping time increased notably with the higher puree ratio ($p<0.05$), while the storage period did not considerably affect the first dripping time of the samples ($p>0.05$). Similar to the present study, another study showed that the first drip times increased with increasing fruit content in ice cream samples (Erkaya et al., 2012). Guner et al. (2007) determined the first dripping time of ice creams between 14.33 and 17.66 minutes and the total melting time of ice creams between 82.33 and 87.66 minutes. According to *Table 3*, the dry matter of the ice cream samples varied between 30.44% and 35.56%. Cakmakci et al. (2016) stated that the dry matter of kumquat flavored ice cream samples varied between 37.29% and 41.38%. In agreement with the findings of this research, a rise in the proportion of fruit added to the ice cream mix resulted in a reduction in the dry matter content.

Table 3. Composition of the ice cream mixes (g 100 g⁻¹)

Sample	PP (g)	Milk (g)	Cream (g)	SMP (g)	Sugar (g)	Emulsifier/Stabilizer (g)	DM (%)
A	0	55.33	25.77	4.42	13.88	0.6	35.56 ± 0.28 ^a
B	15	47.03	21.90	3.76	11.71	0.6	33.57 ± 0.01 ^b
C	25	41.57	19.33	3.31	10.19	0.6	30.97 ± 0.29 ^c
D	35	35.96	16.75	2.87	8.82	0.6	30.44 ± 0.40 ^c

Samples include A (control, no PP), B (15% w w⁻¹ PP added), C (25% w w⁻¹ PP added), and D (35% w w⁻¹ PP added). PP; persimmon pree, SMP; skim milk powder, DM; dry matter. Values are mean±standard deviation. ^{a-c}Means with different letters in the same column differ considerably ($p<0.05$).

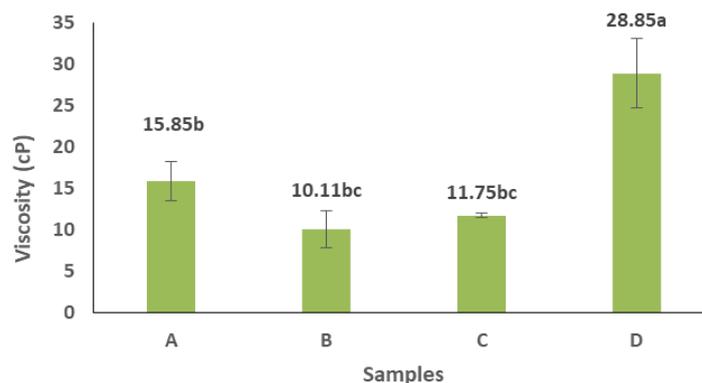


Figure 1. The viscosity values of the ice cream mixes.

Samples include A (control, no PP), B (15% w⁻¹ PP added), C (25% w⁻¹ PP added), and D (35% w⁻¹ PP added). The values are provided as mean ± standard deviation. ^{a-b}Means with different letters are differ considerably (p<0.05). Error bars indicate standard deviation.

Table 4. Physicochemical properties of the persimmon ice creams

Parameter	Sample	Storage time (day)		
		1	30	60
Titratable acidity (%)	A	1.17 ± 0.01 ^{Ba}	1.35 ± 0.06 ^{Ca}	1.22 ± 0.07 ^{Ba}
	B	1.22 ± 0.02 ^{ABb}	1.68 ± 0.04 ^{Ba}	1.38 ± 0.12 ^{Aab}
	C	1.27 ± 0.03 ^{Aa}	1.52 ± 0.07 ^{BCa}	1.38 ± 0.10 ^{Aa}
	D	1.31 ± 0.12 ^{Ab}	2.03 ± 0.01 ^{Aa}	1.42 ± 0.05 ^{Ab}
pH	A	6.95 ± 0.05 ^{Aa}	6.73 ± 0.03 ^{Ab}	6.94 ± 0.00 ^{Aa}
	B	6.9 ± 0.00 ^{Aa}	6.56 ± 0.02 ^{Ab}	6.87 ± 0.03 ^{Aa}
	C	6.85 ± 0.02 ^{Aa}	6.61 ± 0.02 ^{Ab}	6.81 ± 0.05 ^{Aa}
	D	6.85 ± 0.02 ^{Aa}	6.59 ± 0.05 ^{Ab}	6.83 ± 0.04 ^{Aa}
First dripping time (min)	A	12.13 ± 0.12 ^{Ca}	7.89 ± 1.61 ^{Ba}	10.96 ± 1.44 ^{Ca}
	B	14.90 ± 0.65 ^{BCa}	15.64 ± 1.62 ^{Aa}	16.42 ± 3.11 ^{BCa}
	C	20.70 ± 1.55 ^{Aa}	15.66 ± 2.44 ^{Aa}	19.88 ± 0.34 ^{ABa}
	D	19.52 ± 0.51 ^{ABb}	17.26 ± 0.75 ^{Ab}	23.44 ± 0.14 ^{Aa}
Melting ratio (%) (after 30 min)	A	56.19 ± 4.09 ^{Aa}	62.27 ± 2.25 ^{Aa}	66.3 ± 12.3 ^{Aa}
	B	20.28 ± 1.11 ^{Ba}	16.77 ± 1.59 ^{Ba}	14.52 ± 2.9 ^{Ba}
	C	25.63 ± 1.06 ^{Ba}	12.01 ± 1.43 ^{Bb}	11.64 ± 0.74 ^{Bb}
	D	22.59 ± 3.14 ^{Ba}	11.98 ± 0.17 ^{Bab}	8.93 ± 2.66 ^{Bb}
L	A	90.47 ± 0.14 ^{Aa}	90.64 ± 0.39 ^{Aa}	88.69 ± 1.12 ^{Aa}
	B	86.88 ± 0.08 ^{Ba}	79.56 ± 0.2 ^{Bc}	83.83 ± 0.37 ^{Bb}
	C	77.83 ± 0.12 ^{Db}	82.12 ± 1.59 ^{Ba}	81.83 ± 0.43 ^{Bab}
	D	78.5 ± 0.03 ^{DCc}	82.41 ± 0.03 ^{Ba}	81.49 ± 0.15 ^{Bb}
a	A	2.48 ± 0.07 ^{Ba}	2.32 ± 0.06 ^{Ca}	1.8 ± 0.31 ^{Ca}
	B	5.78 ± 0.12 ^{ABc}	8.76 ± 0.24 ^{Aa}	6.93 ± 0.04 ^{Bb}
	C	8.23 ± 0.04 ^{Aa}	7.52 ± 0.22 ^{Ba}	8.1 ± 0.39 ^{ABa}
	D	6.77 ± 1.33 ^{Aa}	7.96 ± 0.11 ^{ABa}	8.72 ± 0.21 ^{Aa}
b	A	3.43 ± 0.13 ^{Cb}	5.49 ± 0.10 ^{Bab}	8.21 ± 1.20 ^{Ba}
	B	9.38 ± 0.90 ^{Bb}	18.95 ± 1.46 ^{Aa}	13.43 ± 1.13 ^{Ab}
	C	17.37 ± 0.29 ^{Aa}	18.73 ± 1.57 ^{Aa}	13.73 ± 1.96 ^{Aa}
	D	12.91 ± 1.6 ^{ABb}	17.97 ± 0.28 ^{Aa}	15.96 ± 0.12 ^{ABb}

Samples include A (control, no PP), B (15% w⁻¹ PP added), C (25% w⁻¹ PP added), and D (35% w⁻¹ PP added). The values are provided as mean ± standard deviation. ^{A-D} Means with different letters in the same column show significant differences (p<0.05). ^{a-c} Means with different letters in the same row differ considerably.

3.4. Bioactive properties of the ice cream samples

In our study, it was noted that persimmons collected from different regions had high bioactive compounds, especially P1 and P2 samples were rich in antiradical activity (RSA) (P1 and P2, 8.56 and 11.04 $\mu\text{g TE mg}^{-1}$, respectively), total phenolic content (TPC) (P1, 489.3 mg GAE 100 g^{-1} and P2, 655.8 mg GAE 100 g^{-1}) and tocopherol. Therefore, P1 and P2 samples were used in the ice cream mixture by blending them in equal proportions.

Table 5 presents the TPC and RSA values of the ice cream samples. The TPC and RSA values of the control ice cream without PP addition indicate the existence of trace levels of phenolic substances, most likely derived from the milk utilized. O'connell and Fox (2001) observed that milk may contain phenolic substances derived from animal feed, amino acids, or environmental pollution. Furthermore, phenolic substances can arise as a result of the Maillard reaction during the pasteurization of ice cream mixtures. The addition of persimmon considerably increased the TPC and RSA values of the samples ($p < 0.05$). TPC ranged from 44.5 mg GAE kg^{-1} to 117.25 mg GAE kg^{-1} on the initial day of storage. After the 30th day of storage, TPC content increased significantly ($p < 0.05$). Similarly, the RSA value of the samples increased as the puree ratio increased. According to the table, RSA values of ice cream samples with puree addition ranged between 28.84 and 43.38 on the initial day of storage. In further research in which different fruit extracts were added, it was reported that the phenolic content increased during storage, similar to the current study (Sagdic et al., 2012). After the 30th day of storage, RSA values increased considerably ($p < 0.05$). At the final stage of the storage, they ranged between 34.64 and 78.48. The data presented show that PP and PP-added ice creams are rich in phenolics and have good radical scavenging activity. In conclusion, persimmon can be easily included in ice cream formulations as a natural source of antioxidants. During the storage period of persimmon ice cream, factors such as tissue degradation, the release of bound phenolic compounds, microstructural damage, and enzymatic transformations may have contributed to the increase in phenolic content. This increase could also positively affect the antioxidant capacity of the product (Sagdic et al., 2012; Akça and Akpınar, 2021).

Table 5. Bioactive properties of the ice creams

Parameter	Sample	Storage time (day)		
		1	30	60
TPC (mg GAE kg^{-1})	A	44.50 \pm 1.50 ^{Cb}	52.00 \pm 1.50 ^{Cab}	72.00 \pm 5.50 ^{Da}
	B	79.00 \pm 3.50 ^{Bc}	127.75 \pm 1.25 ^{Ba}	100.75 \pm 1.25 ^{Cb}
	C	99.00 \pm 4.00 ^{Ab}	118.00 \pm 3.00 ^{Ba}	128.75 \pm 5.75 ^{Ba}
	D	117.25 \pm 3.25 ^{Ab}	185.50 \pm 15.5 ^{Aa}	149.00 \pm 2.00 ^{Aa}
RSA, % Inhibition	A	7.52 \pm 0.26 ^{Da}	5.42 \pm 0.11 ^{Db}	5.42 \pm 0.15 ^{Db}
	B	28.84 \pm 0.3 ^{Cb}	42.72 \pm 0.51 ^{Ca}	34.64 \pm 3.4 ^{Cab}
	C	38.33 \pm 1.3 ^{Bb}	48.70 \pm 0.62 ^{Ba}	50.96 \pm 0.82 ^{Ba}
	D	43.38 \pm 0.7 ^{Ac}	69.92 \pm 1.07 ^{Ab}	78.48 \pm 1.41 ^{Aa}

Samples include A (control, no PP), B (15% w w⁻¹ PP added), C (25% w w⁻¹ PP added), and D (35% w w⁻¹ PP added). Values are mean \pm standard deviation. ^{A-D}Means with different letters in the same column show significant differences ($p < 0.05$). ^{a-c}Means with different letters in the same row differ considerably.

3.5. Hardness and stickiness values of the ice creams

Table 6 displays the hardness and stickiness measurements of ice creams with persimmon puree addition during storage. The addition of puree increased the hardness value of the ice creams. 15% puree addition did not significantly change the hardness value compared to the sample without PP added, while a significant increase in the hardness value was observed after 25% puree addition ($p < 0.05$). As illustrated in Table 6, the hardness values of the samples varied from 1.67 N to 30.51 N on the first day of storage. At the final stage of storage, hardness values increased in samples A and B, while no significant change was detected in samples C and D ($p > 0.05$). Varela et al. (2014) reported hardness values ranging from 25.6 N to 111.5 N in ice creams prepared with various hydrocolloids. Hardness is often used as an indicator of ice crystal development, as the quantity and size of ice crystals generated from water through freezing significantly impact their development and growth throughout storage. In our study, the reason why the samples became hard as the puree ratio increased could be ascribed to the lack of sufficient stabilization against ice crystal growth.

Similarly, as the puree ratio increased, the stickiness measurement of the ice creams also increased ($p < 0.05$). The highest stickiness was found in samples C and D on the initial day of storage. Stickiness values were similar at the end of storage, except for the control sample. Similarly, in another ice cream study using different propolis ratios, the lowest stickiness was found in the control group sample (Mehmetoğlu and Tarakçı, 2023). Increasing the concentration of persimmon puree increased the stickiness among the samples. According to El-Nagar et al. (2002) increasing the concentration of inulin in ice cream formulations led to greater stickiness. Similarly, Karaman et al. (2014) that stickiness values increased with increasing puree ratio. During the storage period, stickiness values increased in samples A and B, while stickiness values decreased in samples C and D.

Table 6. Hardness and stickiness properties of the persimmon ice creams

Parameter	Sample	Storage time (day)		
		1	30	60
Hardness (N)	A	1.67 ± 0.15 ^{Bb}	3.76 ± 0.56 ^{Ca}	4.14 ± 0.30 ^{Ca}
	B	3.05 ± 0.03 ^{Bb}	15.43 ± 1.27 ^{Ba}	14.9 ± 0.75 ^{Ba}
	C	30.51 ± 0.56 ^{Aa}	28.06 ± 0.77 ^{ABa}	22.87 ± 0.78 ^{Ba}
	D	28.49 ± 0.91 ^{Aa}	21.9 ± 0.69 ^{Ab}	25.84 ± 0.02 ^{Aa}
Stickiness (N)	A	-0.20 ± 0.01 ^{Aa}	-0.39 ± 0.06 ^{Aab}	-0.41 ± 0.05 ^{Ab}
	B	-0.26 ± 0.01 ^{Aa}	-0.68 ± 0.05 ^{Bb}	-0.65 ± 0.01 ^{Bb}
	C	-0.93 ± 0.03 ^{Bb}	-0.78 ± 0.04 ^{Ba}	-0.65 ± 0.01 ^{Ba}
	D	-0.86 ± 0.05 ^{Bb}	-0.68 ± 0.03 ^{Ba}	-0.71 ± 0.01 ^{Ba}

Samples include A (control, no PP), B (15% w w⁻¹ PP added), C (25% w w⁻¹ PP added), and D (35% w w⁻¹ PP added). Values are mean ± standard deviation. Hardness and stickiness values were measured using a texture analyzer in Newtons (N). ^{A-C}Means with different letters in the same column show significant differences ($p < 0.05$). ^{a-b}Means with different letters in the same row differ considerably

3.6. Sensory properties of the ice creams

Figure 2 demonstrates the sensory characteristics of the ice creams. In comparison to the control sample, the incorporation of PP had no noteworthy impact on the all sensory characteristics of the ice creams throughout the

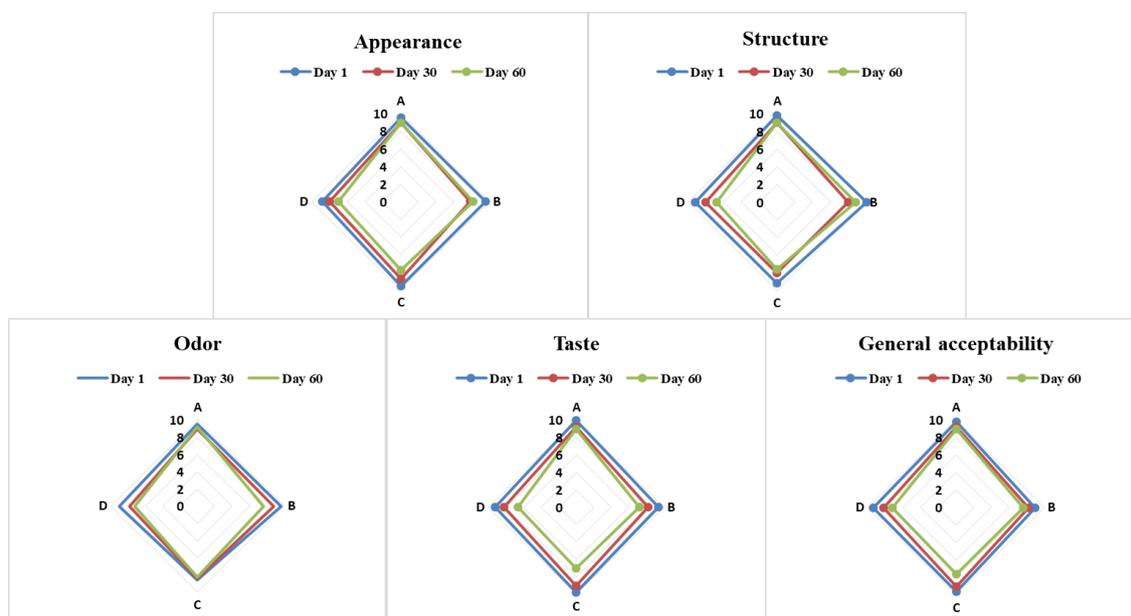


Figure 2. Sensory characteristics of the ice creams

early days of storage. By the end of the storage period, there were noteworthy declines in the average scores of all sensory attributes ($p < 0.05$). Appearance, structure, taste and odor decreased from 9 points to 7, 6.8, 6.6 and 7.2 points, respectively. The most important drop in scores was detected in sample D. The addition of 35% PP negatively impacted the sensory features of the ice cream on the last day of storage. However, after the control sample, the sample with 15% PP addition (B) was the most appreciated ice cream. The panelists found the addition

of up to 25% PP to the ice cream acceptable in terms of sensory acceptability. Panelists noted that the control sample was soft and melted quickly. The use of PP prevented the ice cream from melting easily and samples with PP addition stored for up to 30 days scored similarly the control sample in terms of overall acceptability. However, samples B and C can be recommended to consumers as an ice creams with an overall pleasant taste.

4. Conclusions

The findings indicated that there are similarities besides high variations in the quantities of bioactive substances in persimmons and concluded that bioactive content can be affected by different variables such as fruit species, growing climate and location, harvest time, extraction and analytical methods. Results of this research revealed that persimmon is a fruit with essential components in terms of bioactive properties and that the fruit contributes to the desired physicochemical and sensory improvements in ice cream preparations. Increasing the persimmon concentration in the ice cream samples enhanced their bioactive characteristics. The inclusion of PP enhanced viscosity, extended first drip times and melting durations, and improved sensory qualities. However, the addition of more than 25% PP showed undesirable sensory effects after 30 days of storage. Therefore, it may be recommended to use a concentration lower than 35% in ice cream production to minimize these undesirable consequences. Nevertheless, a sample with 15% or 25% puree addition may be recommended to provide the consumer with a product that is both nutritious and sensory pleasing. Based on these findings, PP, with its nutritional value, appealing aroma, and vibrant color, can serve as a natural component used in ice cream manufacture, enhancing both the nutritional content and physicochemical qualities of the finished product.

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Ethical Statement

This study does not require approval from the ethics committee.

Conflicts of Interest

The authors of this article declare that there is no conflict of interest.

Authorship Contribution Statement

Concept: Melike Demirkol; Design: Demirkol, M., Tarakçı, Z.; Data Collection or Processing: Demirkol, M., Tarakçı, Z., Atmaca, E., Gültekin, K., Akar, S.; Statistical Analyses: Demirkol, M., Tarakçı, Z.; Literature Search: Demirkol, M., Tarakçı, Z., Atmaca, E.; Writing, Review and Editing: Demirkol, M., Tarakçı, Z., Atmaca, E.

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