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Physicochemical, bioactive, and sensory properties of persimmon-based ice cream: Technique for order preference by similarity to ideal solution to determine optimum concentration

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ABSTRACT

In the present study, persimmon puree was incorporated into the ice cream mix at different concentrations (8, 16, 24, 32, and 40%) and some physicochemical (dry matter, ash, protein, pH, sugar, fat, mineral, color, and viscosity), textural (hardness, stickiness, and work of penetration), bioactive (antiradical activity and total phenolic content), and sensory properties of samples were investigated. The technique for order preference by similarity to ideal solution approach was used for the determination of optimum persimmon puree concentration based on the sensory and bioactive characteristics of final products. Increase in persimmon puree resulted in a decrease in the dry matter, ash, fat, protein contents, and viscosity of ice cream mix. Glucose, fructose, sucrose, and lactose were determined to be major sugars in the ice cream samples including persimmon and increase in persimmon puree concentration increased the fructose and glucose content. Better melting properties and textural characteristics were observed for the samples with the addition of persimmon. Magnesium, K, and Ca were determined to be major minerals in the samples and only K concentration increased with the increase in persimmon content. Bioactive properties of ice cream samples improved and, in general, acetone-water extracts showed higher bioactivity compared with ones obtained using methanol-water extracts. The technique for order preference by similarity to ideal solution approach showed that the most preferred sample was the ice cream containing 24% persimmon puree.
Key words: persimmon, ice cream, bioactivity, technique for order preference by similarity to ideal solution

INTRODUCTION

Ice cream, a sweet dairy product including milk, sweeteners, stabilizers, emulsifiers, and flavorings, is produced by mixing its ingredients, followed by pasteurization and homogenization. Afterward, it is aged at low temperature and finally frozen (Frøst et al., 2005; Karaman and Kayacier, 2012). Ice cream is commonly enjoyed by people of all ages due to its cooling effect and the nutritive value of ice cream is high, as it is a milk-based dessert. Development of new ice cream formulations that are highly enjoyed by consumers is one of the driving forces of ice cream manufacturers. Many kinds of ice cream formulations exist in the market, but new formulations are also required to enlarge the market proportion (Karaman and Kayacier, 2012). Many studies are present in the literature about development of new ice cream formulations (Dervisoglu, 2006; Dervisoglu and Yazici, 2006; Favaro-Trindade et al., 2007; Erkaya et al., 2012; Karaman and Kayacier, 2012).

Fruits are good sources for the fortification of ice creams because of their sweet and desired taste and aroma. Persimmon is a fruit widespread in China, Japan, and Korea and is also traditionally used for medicinal purposes (George and Redpath, 2008; Ferrini and Pennati, 2008; Luo and Wang, 2008). China is ranked first in the production of persimmons in the world, with 1,655,000 t of annual production (Liu et al., 2007), whereas Turkey produces about 20,000 t annually (Ercisli and Akbulut, 2009). It is a popular and widespread fruit because it is a good source of antioxidants, carotenoids, and polyphenols (George and Redpath, 2008). Some scientists have reported that the persimmon is one of the richest fruits containing bioactive components (Daood et al., 1992; Gorinstein et al., 1998). The antioxidant activity of persimmon is reported by many researchers in the literature (Jung et al., 2005; Lee et al., 2008; Fukai et al., 2009; Jang et al., 2010; Veberic et al., 2010; Karaman et al., 2013). The persimmon is consumed in Europe as a fresh fruit because of its positive health effects. The shelf life of

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the matured fruit is rather short (less than 4 wk) and mature fruits should be consumed in a short time after harvesting because of easy deterioration of the fruit. The fruit, even in convenient storage conditions, has a limited shelf life compared with other fruits. Therefore, after harvesting, a significant amount of mature persimmons should be handled and processed into certain products to preserve the fruit's bioactive components. One possible process might be incorporation of persimmon fruit into ice cream. It is possible to improve the nutritional, physicochemical, and textural properties of ice cream in this way.

In the present study, the goal was to improve the quality of ice cream by incorporating different concentrations of persimmon puree into the ice cream. At this point, selection of the optimum persimmon concentration is a difficult task based on 2 selected properties (sensory score and bioactivity), as one sample might display superior bioactivity, whereas the other sample might be the choice because of sensory properties. In these specific conditions, and similar circumstances, the technique for order preference by similarity to ideal solution (**TOPSIS**) might be applied to ease the comparison of the samples based on the results. The TOPSIS is one of the multi-criteria decision-making techniques that provides a decision hierarchy and requires pairwise comparison between criteria (Ballı and Korukoğlu, 2009). Multi-criteria decision making determines the best option among all of the alternatives in the presence of multiple decision criteria (Işıklar and Büyüközkan, 2007). According to the TOPSIS, the alternative that is nearest to the positive ideal solution and farthest from the negative ideal solution is the best alternative (Benítez et al., 2007; Lin et al., 2008). Although the utilization of multi-criteria decision-making techniques has been reported in different areas, to the best of our knowledge, only 1 study (Gurmeric et al., 2013) about this subject in the field of food science exists in the literature.

In the present study, the effect of persimmon puree addition on some physicochemical, textural, sensory, and bioactive properties of ice cream was investigated, and the TOPSIS multi-decision criteria were used for the determination of optimum persimmon puree concentration based on sensory and bioactive properties.

MATERIALS AND METHODS

Materials

Ultra-high temperature-treated milk (Dost; AkGida Co., Sakarya, Turkey) was purchased from a local market in Kayseri, Turkey. Cream (35% milk fat) was obtained from Pinar Dairy Co. (İzmir, Turkey). Stabilizer (salep) and emulsifier (mono- and diglyceride) were provided by Özselamoğlu Food Ing. Co. (Kayseri, Turkey). Table sugar (Panküpü Co., Kayseri, Turkey) was used to sweeten the ice creams. Fresh persimmons were purchased from a local market in Kayseri, Turkey.

Ice Cream Production

Ice cream samples were manufactured according to the process flowchart given in Figure 1. First, milk was heated to 50°C and skim milk powder was added to increase the DM content of the ice cream mix. Cream and table sugar were incorporated at 60 and 70°C, respectively. After addition of the emulsifier and stabilizers, the ice cream mix was pasteurized at 85°C for 5 min and then rapidly cooled to 50°C. At this stage, persimmon puree was obtained by homogenization of fresh persimmons using a Waring blender (Waring Commercial Blender; Waring Products Inc., Torrington, CT). Persimmon puree was added to the ice cream mix at 5 different concentrations: 8, 16, 24, 32, and 40% (wt/wt). The ice cream mixes enriched with persimmon puree were aged at 4°C for 24 h. After the aging process, the samples were frozen using an ice cream maker (Simac II Gelataio GC 6000; Simac, Treviso, Italy), rapidly hardened at −24°C, and stored until the physicochemical, bioactivity, and sensory analyses.

Physicochemical Analysis

Dry matter, ash, and fat analyses were conducted as outlined by official procedures (AOAC International, 2000). Protein content of the samples was determined according to the Dumas method using an automatic nitrogen analyzer (FP 528 LECO, ABD; Leco Corp., St. Joseph, MI). The pH values of samples were determined using a pH meter (inoLab Level 3 Terminal; WTW GmbH, Weilheim, Germany). Viscosity values were measured using an automatic vibrated viscometer (Vibro Viscometer SV-10; A&D Co. Ltd., Tokyo, Japan). The color values of samples were measured using a colorimeter (Lovibond RT Series Reflectance Tintometer; The Tintometer Ltd., Amesbury, UK); L* defines the lightness and a* and b* define the red-greenness and blue-yellowness, respectively. The melting ratio and complete melting time were determined according to the procedure described by Güven and Karaca (2002). A 25-g sample was subjected to melting at a constant temperature (25°C). The melting ratio after 30 min was recorded, and the complete melting time (s) was determined.

Major Sugar Composition of Ice Creams

An HPLC system (Agilent 1100 Series; Agilent Technologies Inc., Santa Clara, CA) equipped with a

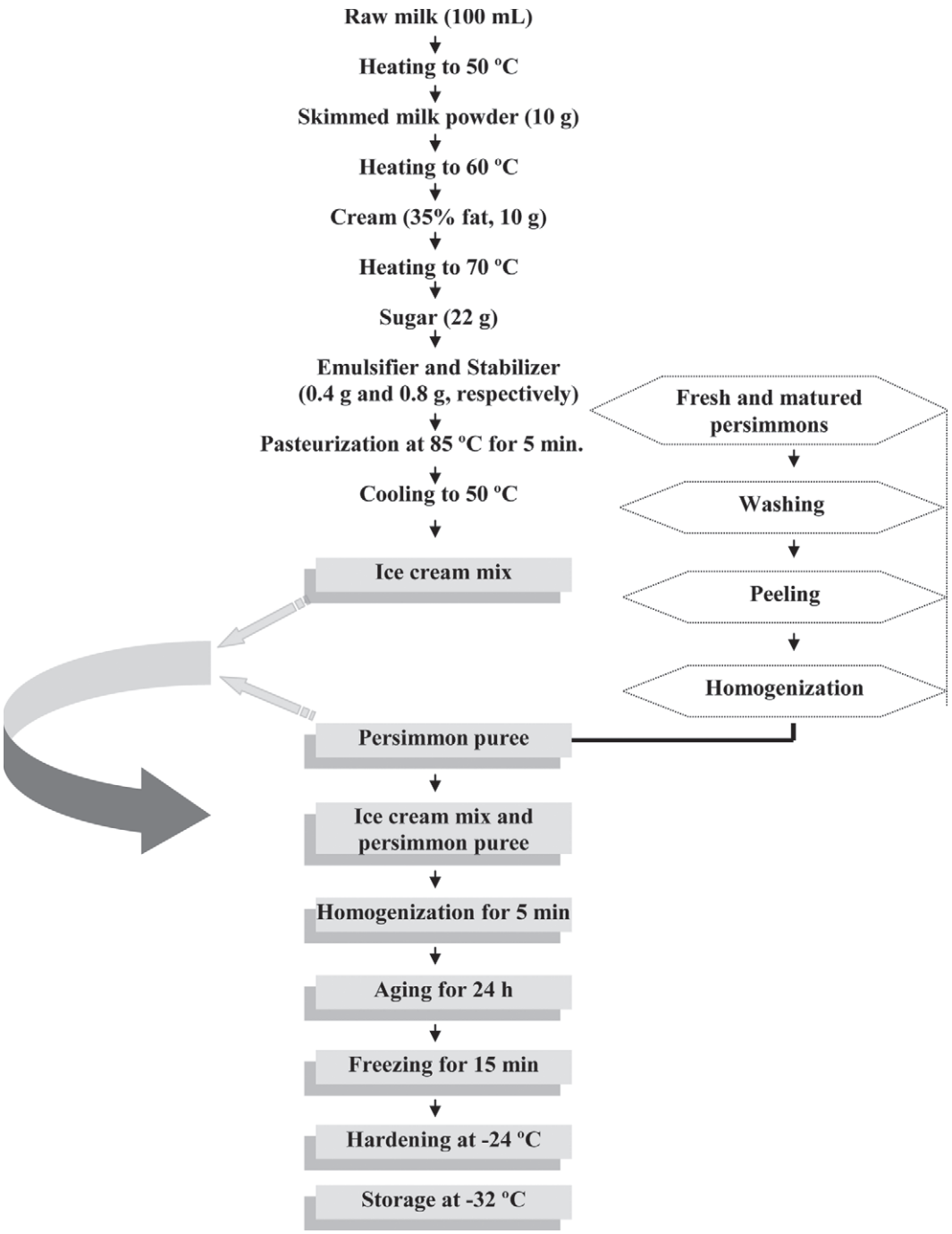


Figure 1. Process flowchart for the production of functional ice cream enriched with persimmon puree.

manual injection quaternary pump, refractive index detectors, and Zorbax carbohydrate column (4.6 × 250 mm, 5-μm particle size), which was thermostated at 25°C, was used for the determination of sugar composition of the ice cream samples. First, ice cream samples (10 g) were subjected to extraction to extract the sugars with the addition of 90 mL of extraction solvent (80:20 methanol:water) and they were kept in the dark at room temperature for 15 h. After the extraction, the sample was taken and centrifuged at 13,680 × g for 10 min at room temperature. The supernatant was filtered using a microfilter (0.45 μm; Sartorius Stedim Biotech GmbH, Göttingen, Germany), and 20 μL of the filtrate was injected to the column. The flow rate of the mobile

phase (80:20 acetonitrile:water, vol/vol) was set to 1.4 mL/min. The major sugar composition (fructose, glucose, and sucrose) was determined by the comparison of retention times with authentic standards. Quantification of the components was based on the external standard method.

Mineral Analyses of Ice Creams

Mineral contents (Ca, Mg, and K) of ice cream samples were determined using an inductively coupled plasma (**ICP**) spectrophotometer (Agilent 7500a series ICP/MS; Agilent Technologies Inc.). A microwave oven (Berghof speedwave; Berghof GmbH, Eningen, Germany) was used for the decomposition of samples. For this aim, about 400 mg of ice cream sample was weighed into the digestion vessels. Seven milliliters of HNO_3 (65%) and 0 to 2 mL of H_2O_2 (30%) were added into the vessels, and the mixture was shaken carefully. The vessels were kept for 20 min with the lids closed. To run the samples in the ICP spectrophotometer, the samples were kept at 145°C for 5 min. The pressure and microwave power were set to be 4,000 kPa and 80%, respectively. The temperature was increased at 2°C/min to 170°C and the samples were kept at this temperature for 10 min. Afterward, the temperature was increased to 190°C and the samples were kept there for 15 min. At the end of the digestion process, the solutions were transferred to a volumetric flask and diluted with distilled water to a suitable concentration, and filtered through a filter paper (Whatman No. 42). All diluted digests were analyzed using ICP-MS. For quality control, internal standards (^{9}Be, ^{45}Sc, ^{103}Rh, and ^{208}Bi) and reference materials were run together with the samples.

Total Phenolic Content and Antiradical Activity of Samples

Total phenolic content of the samples was determined according to the modified method of Singleton and Rossi (1965), and Hwang et al. (2009). Samples were extracted using 2 different solvent types [methanol:water (80:20 vol/vol) and acetone:water (80:20 vol/vol)]. For the extraction process, 10 g of ice cream sample was weighed into a flask and 90 mL of extraction solvent was added. The mixture was stirred for 1 h on a magnetic stirrer (Stuart CC162; Keison Products, Chelmsford, UK) at room temperature, and then kept in the dark for 24 h for effective extraction. After the extraction procedure, samples were centrifuged (Hettich Universal 320; Andreas Hettich GmbH & Co. KG, Tuttlingen, Germany) at 13,680 × g for 10 min at room temperature. The resulting supernatant was collected and filtered through a 0.45-μm filter (Sartorius Stedim Biotech GmbH); 1.5 mL of Folin Ciocalteu phenol reagent was added into a tube containing 0.2 mL of the extract, which was followed by mixing with a vortex for 15 s. After the addition of Na_2CO_3 (20%, wt/vol), the tubes were incubated for 2 h in the dark at room temperature. At the end of the incubation, the absorbances of the samples were measured at 760 nm (Agilent 8453 spectrophotometer; Agilent Technologies Inc.). The total phenolic contents of the samples were calculated as milligrams of gallic acid equivalents (**GAE**) per kilogram of ice cream sample.

The antiradical activity of the samples was determined using 2,2-diphenyl-1-picrylhydrazyl (**DPPH**) free radical. For this aim, 0.1 mL of extract was mixed with 3.9 mL of DPPH solution (0.1 mM in methanol), and the mixtures were incubated for 30 min in a dark place at room temperature. After incubation, the absorbance (Abs) of the samples was measured at 517 nm (Agilent 8453 spectrophotometer; Agilent Technologies Inc.). Antiradical activity of the samples was calculated using the following equation:

$$\%\,\text{Inhibition} = \left(\frac{\text{Abs}^{\text{control}} - \text{Abs}^{\text{sample}}}{\text{Abs}^{\text{control}}}\right) \times 100. \qquad [1]$$

Textural Properties of Ice Creams

Textural characterization of samples was conducted using a texture analyzer (TA.XT Plus; Stable Micro Systems Ltd., Godalming, UK) equipped with a HDP-P/5 attachment (Stable Micro Systems Ltd.) using a 30-kg load cell. Ice cream mixes were filled into the cylindrical plastic cups and the cups were placed on the center of a heavy duty platform. The samples were brought quickly from the freezer one by one for the analysis and the test was started immediately. Pretest speed, test speed, and posttest speed were set to be 1, 0.1, and 5 mm/min, respectively. The deformation type was selected to be distance and the distance was set to be 10 mm. Hardness, work of penetration, and stickiness properties were determined from the time-deformation curve. The average results were obtained from 6 replications.

Sensory Analysis

Sensory properties of ice cream samples were determined by a trained panel comprising 10 members (graduate students and academic staff of the Food Engineering Department at Erciyes University, Kayseri, Turkey). Before starting the tests, panel members were trained regarding the ice cream samples. The training

consisted of a detailed talk for 2 h, presenting the aim of the study and properties of the samples to the panelists. Identification of the ideal persimmon concentration for the desired enriched ice cream in terms of appearance and color, odor, taste and flavor, texture, resistance to melting, and overall acceptance was requested from the panelists. Ice cream samples packaged as 100 g were served to the panelists one by one to avoid melting of samples. Deionized water was used for the cleaning of the panel members' palates before proceeding to the next sample. Ice cream samples were evaluated using a scaling method of descriptive attributes for appearance/color (1 = undesired, 9 = desired), odor (1 = undesired, 9 = desired), taste/flavor (1 = undesired, 9 = desired), texture (1 = undesired, 9 = desired), resistance to melting (1 = undesired, 9 = desired), and overall acceptability (1 = dislike, 9 = like).

TOPSIS for Selection of Convenient Persimmon Concentration

The hierarchy for selection of persimmon concentration is shown in Figure 2. The TOPSIS involved calculations in 6 steps (Ballı and Korukoğlu, 2009).

Step 1. Normalization of the decision matrix was done using the following equation:

$$x_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}}, \quad [2]$$

where x_{ij} is is the normalized value, m is the number of criteria, a_{ij} is the value of the observed data, and a_{kj} is that of the observed data in the same row as a_{ij}.

Step 2. Formation of the normalized decision matrix was done (the weight of each criterion is shown in Figure 2). The weight of each criterion as shown in Figure 2 was determined considering the opinions of different academicians employed in the Food Engineering Department at Erciyes University:

$$v_{ij} = x_{ij} \times w_{ij}, \quad [3]$$

where v_{ij} is the weighted normalized value, x_{ij} is the normalized value, and w_{ij} is the weight of the each criterion.

Step 3. The positive ideal solution (A^*) and negative ideal solution (A^-) was determined:

$$A^* = \{v_{1^*}, v_{2^*}, v_{3^*}, \ldots, v_{n^*}\} \text{ (maximum values)};$$

$$A^- = \{v_1^-, v_2^-, v_3^-, \ldots, v_n^-\} \text{ (minimum values)},$$

where v is the value of each sample.

Step 4. The distance (d) of each alternative from positive and negative ideal solution was calculated:

$$d_i^* = \sqrt{\left(v_{ij} - v_j^*\right)^2}; \quad [4]$$

$$d_i^- = \sqrt{\left(v_{ij} - v_j^-\right)^2}, \quad [5]$$

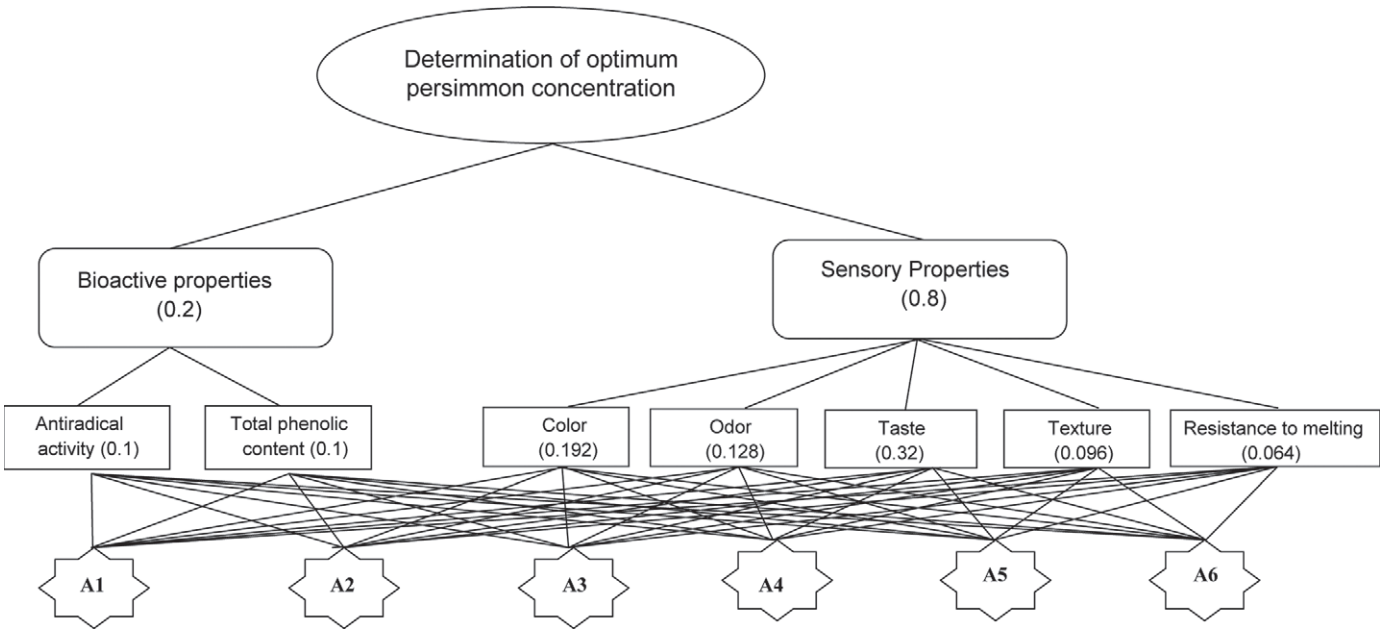


Figure 2. The decision hierarchy of the determination of persimmon concentration of ice cream based on sensory and bioactive properties. A1 = control; A2, A3, A4, A5, and A6 = ice creams including 8, 16, 24, 32, and 40% persimmon puree, respectively.

where v_{ij}, v_j*, and v_j^- are the weighted normalized value and positive and negative ideal solutions, respectively.

Step 5. The closeness coefficient (C) of each alternative was calculated via Equation 6:

$$C = \frac{d_i^-}{d_i^* + d_i^-}. \quad [6]$$

Step 6. The ranking of the alternatives was determined based on the C values.

RESULTS AND DISCUSSION

Physicochemical Properties of Ice Cream Samples

Some physical properties of ice cream samples enriched with persimmon puree at different concentrations are shown in Table 1. It is clear from the table that the addition of persimmon puree caused a significant change in the physicochemical properties of samples. An increase in persimmon puree concentration in the samples caused a decrease in the TS content of the final products ($P < 0.05$). A similar trend was observed for ash, fat, and protein content of the samples, in which the addition of persimmon puree decreased their ratios. The quantity of major constituents in ice cream was diluted with the addition of the puree because it contained 81.03% water. If meeting regulatory guidelines, ice cream with persimmon puree might be considered a low-fat food, good for reducing risk factors of cardiovascular diseases. The pH values of the samples changed with the addition of persimmon puree ($P < 0.05$); it increased to 7.00 with the addition of 24% persimmon puree and decreased from this point, and it was recorded to be 6.76 for the ice cream sample containing 40% persimmon puree. Viscosity, a measure of the resistance of a fluid to flow, is an important quality parameter for liquid and semisolid foods. The viscosity values of ice cream mixes decreased significantly with an increase in concentration of persimmon puree in the formulation of samples ($P < 0.05$). As can be seen from the Table 1, the highest viscosity was recorded to be 479.6 mPa·s for the control sample, whereas it was determined to be 141 mPa·s for the sample containing 40% persimmon puree. Decreases in the viscosity of enriched ice cream samples might be due to the high water content of persimmon purees incorporated into the samples. Table 1 also shows the color properties of the ice cream samples. Incorporation of persimmon puree caused a significant change in the color of the final ice cream products ($P < 0.05$). The L* (lightness) values of samples decreased with an increase in puree concentration. The L* value of control ice cream was 70.11, whereas the color of the sample containing 40% puree was 50.56. The a* (redness between −1.22 and 6.52) and b* (yellowness between 4.83 and 17.09) values decreased significantly ($P < 0.05$) with an increase in puree concentration in the formulation of the products. The melting ratio and complete melting time values of the ice cream samples are illustrated in Figure 3. Addition of persimmon puree provided a very significant reduction in the melting ratio of samples, depending on the time ($P < 0.01$). The melting ratio of the control ice cream was 26.33% after 30 min, whereas the melting ratio of ice cream samples enriched with 40% persimmon puree was 1.61%. Additionally, complete melting time increased with an increase in persimmon puree concentration ($P < 0.05$). The control ice cream sample melted after 3,390 s at 25°C and the sample containing 40% persimmon puree melted after 4,155 s. Erkaya et al. (2012) reported that the complete melting time was found to be longer for the samples containing Cape gooseberry (**CG**) than that of control and it increased with an increase in CG concentration. Dervisoglu (2006) reported that the meltdown amount decreased with the increase in hazelnut flour in the formulation of ice cream. In another study, it was reported that the meltdown amount of ice cream decreased with the increase in citrus fiber concentration (Dervisoglu and Yazici, 2006). Erkaya et al. (2012) stated that the increase in the complete melting time can be due to some components present in the CG that have the ability to absorb water. It can be said that the persimmon puree, which has a high amount of fiber (Gorinstein et al., 2001), absorbed the water and the melting of ice cream was retarded. Favaro-Trindade et al. (2007) reported that the low melting rate of ice cream is especially important for countries with a tropical climate.

Major Sugar Composition of Ice Cream Samples

Table 2 shows the major sugar composition of ice cream samples. Glucose, fructose, sucrose, and lactose were the major sugars in enriched ice creams (Figure 4). Glucose and fructose contents of the enriched samples increased significantly with the increase in persimmon concentration ($P < 0.05$). Unenriched ice cream samples contained no glucose and fructose. The lactose content of the samples decreased with the increase in persimmon puree concentration (i.e., 7.30% in unenriched samples and 3.76% in 40% enriched samples). The major sugar content of persimmon was glucose (6.55%) and fructose (5.08%).

Persimmon is a fruit that generally contains 12.5 g of total sugar/100 g on a fresh weight (**FW**) basis, but the composition can change depending on the cultivar type, climate differences, or maturity (Giordani et al.,

Table 1. Physicochemical properties of ice cream samples enriched with persimmon puree

Ice cream sample	Total DM (%)	Ash (%)	Fat (%)	Protein (%)	pH	Viscosity (mPa·s)	Color value[1]		
							L*	a*	b*
Unenriched	32.505 ± 0.067^{a}	1.077 ± 0.006^{a}	9.03 ± 0.02^{a}	4.660 ± 0.113^{a}	6.663 ± 0.01^{e}	479.6 ± 3.05^{a}	70.11 ± 0.19^{a}	−1.22 ± 0.01^{f}	4.83 ± 0.03^{f}
8%	31.618 ± 0.068^{b}	1.034 ± 0.014^{b}	8.31 ± 0.02^{b}	4.252 ± 0.014^{b}	6.763 ± 0.01^{d}	457.0 ± 2.00^{b}	66.46 ± 0.56^{b}	1.40 ± 0.04^{e}	8.09 ± 0.04^{e}
16%	30.621 ± 0.002^{c}	0.973 ± 0.007^{c}	7.58 ± 0.01^{c}	3.767 ± 0.122^{c}	6.913 ± 0.01^{c}	278.6 ± 4.04^{c}	61.38 ± 0.21^{c}	3.55 ± 0.01^{d}	12.89 ± 0.06^{d}
24%	29.837 ± 0.038^{d}	0.905 ± 0.045^{d}	6.86 ± 0.01^{d}	3.455 ± 0.077^{d}	7.001 ± 0.01^{a}	252.3 ± 3.51^{d}	55.24 ± 1.09^{d}	5.07 ± 0.02^{c}	13.81 ± 0.01^{c}
32%	28.842 ± 0.056^{e}	0.837 ± 0.011^{e}	6.14 ± 0.01^{e}	3.305 ± 0.063^{d}	6.933 ± 0.01^{b}	182.0 ± 0.00^{e}	53.50 ± 0.26^{e}	5.21 ± 0.01^{b}	14.70 ± 0.07^{b}
40%	28.016 ± 0.004^{f}	0.779 ± 0.009^{f}	5.41 ± 0.01^{f}	2.632 ± 0.041^{e}	6.760 ± 0.01^{d}	141.0 ± 4.00^{f}	50.56 ± 0.42^{f}	6.52 ± 0.05^{a}	17.09 ± 0.05^{a}

$^{a-f}$Values within a column with different superscript letters are different ($P < 0.05$).

[1]L* defines the lightness and a* and b* define the red-greenness and blue-yellowness, respectively.

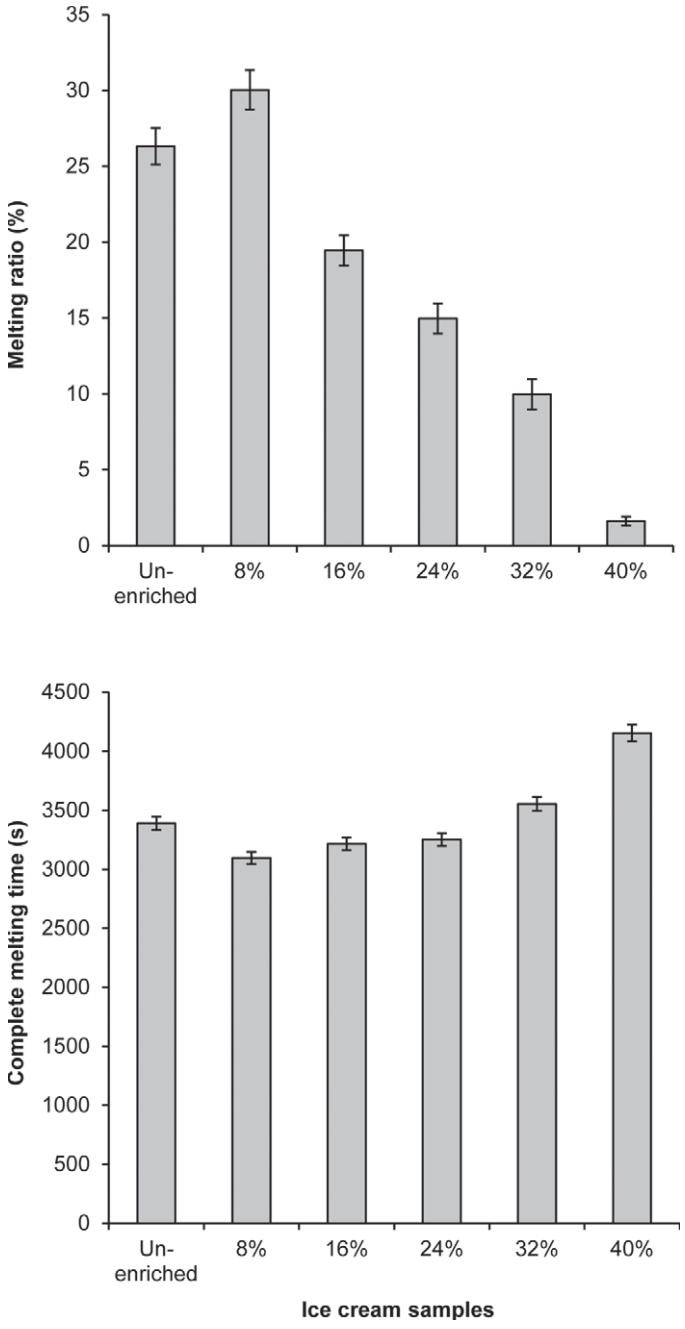


Figure 3. Melting ratio and complete melting time of ice cream enriched with persimmon puree at 0, 8, 16, 24, 32, or 40% (wt/wt). Error bars show SD.

2011). The fructose and glucose content of persimmon fruits were reported to be in the range of 3.8 to 7.78% and 4.78 to 8.79%, depending on the cultivar type. Unenriched samples contained 15.42% sucrose, as expected, as sucrose was an ingredient in ice cream making. Sucrose could not be detected in fresh persimmon puree and the amount of sucrose in enriched ice cream samples decreased gradually with an increase in

Table 2. Major sugar composition (%) of ice cream samples enriched with persimmon puree

Sample	Glucose	Fructose	Sucrose	Lactose[1]
Persimmon puree	6.55 ± 0.04[a]	5.08 ± 0.05[a]	—	—
Unenriched	—	—	15.42 ± 0.49	7.30 ± 0.07[a]
8%	6.93 ± 0.15[f]	6.96 ± 0.08[f]	2.82 ± 0.01[b]	6.72 ± 0.01[b]
16%	7.83 ± 0.02[e]	7.40 ± 0.04[e]	2.71 ± 0.01[b]	5.82 ± 0.08[c]
24%	7.97 ± 0.03[d]	7.55 ± 0.02[d]	2.48 ± 0.01[b]	4.87 ± 0.09[d]
32%	8.15 ± 0.06[c]	7.95 ± 0.11[c]	1.57 ± 0.01[b]	4.43 ± 0.14[e]
40%	8.39 ± 0.01[b]	8.33 ± 0.06[b]	1.55 ± 0.01[b]	3.76 ± 0.38[f]

[a–f]Values within a column with different superscript letters are different ($P < 0.05$).

[1]Lactose content was calculated using the sucrose calibration curve.

persimmon puree concentration. The sucrose content of the ice cream samples decreased rapidly after the addition of persimmon puree. One may expect a linear decrease in sucrose content with the addition of persimmon puree because of the dilution of sucrose in the medium. However, this sharp decrease might have resulted from the effects of invertase enzyme in persimmon puree. It has been reported that the persimmon contains invertase enzyme and its level increases during fruit ripening on the tree (Hirai et al., 1986; Zheng and Sugiura, 1990). Ittah (1993) evaluated the invertase activity and its effect on the sugar composition. That author reported a very different sugar composition for the persimmon, depending on the inhibition of invertase. The sugar composition of the persimmon treated with a preventative immersion using methanol/water (80:20, vol/vol) was determined to be sucrose (10 g/100 g of FW), glucose (2.3 g/100 g of FW), and fructose (1.5 g/100 g of FW). In contrast, Veberic et al. (2010) reported a different sugar composition, with values of 1.2 g/100 g of FW for sucrose, 7.7 g/100 g of FW for glucose, and 6.9 g/100 g of FW for fructose in fresh persimmon. These differences in sugar compositions in the literature might be attributable to both cultivar differences and the activity of invertase enzyme, which significantly affects the final sucrose concentration and, accordingly, the fructose and glucose composition, unless it is strictly controlled. The sugar composition of ice cream samples changed due to the active invertase enzyme. Hirai and Kondo (2002) reported that persim-

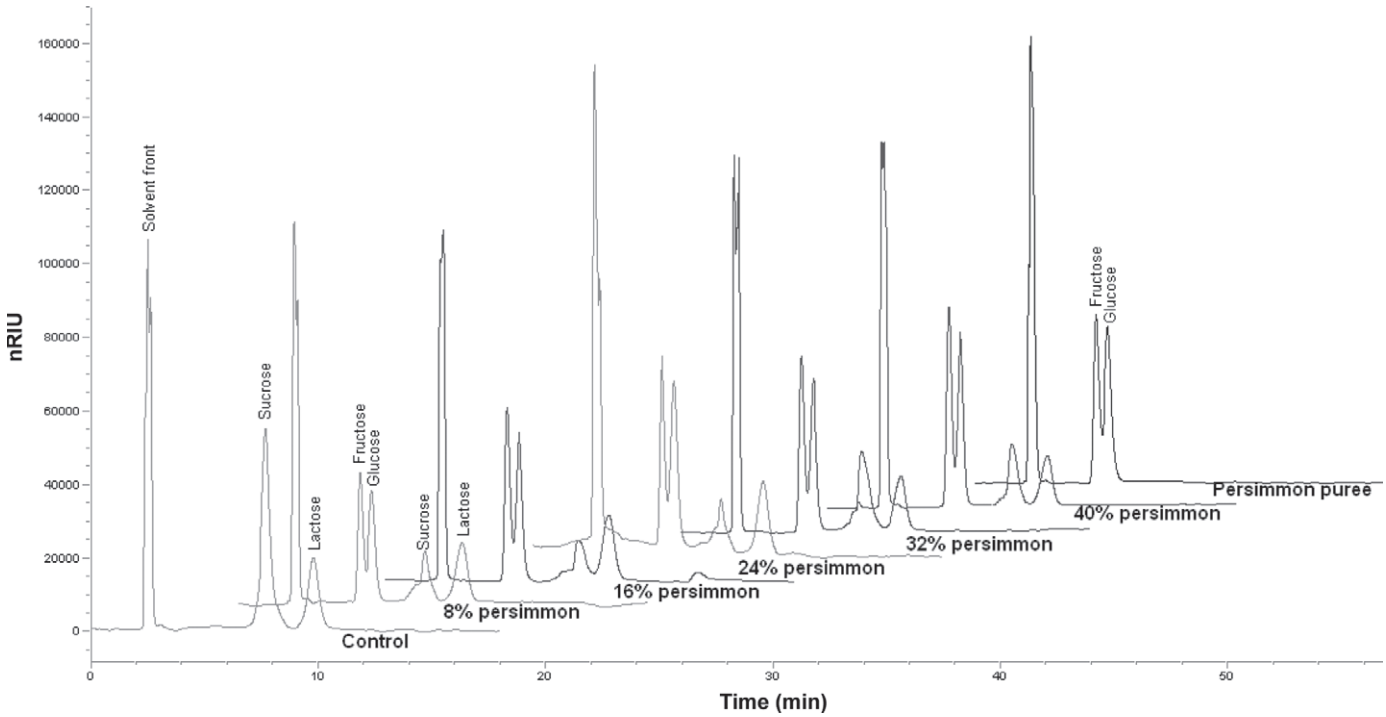


Figure 4. High performance liquid chromatography chromatograms of major sugar composition for ice cream samples containing persimmon puree at different concentrations. nRIU = nano refractive index units.

mon has a much higher invertase activity compared with other popular fruits (e.g., about 2 orders of magnitude higher than apples).

Mineral Contents of Ice Cream Samples

Figure 5 illustrates the major elements detected in the samples. In general, the mineral content of ice cream samples showed statistically significant differences ($P < 0.05$). The Mg and Ca content decreased, whereas K increased in samples enriched with persimmon puree ($P < 0.05$). The Mg, K, and Ca contents of unenriched samples were 134.6, 367.1, and 335.8 mg/kg, respectively; Mg, K, and Ca contents reached levels of 121.8, 483.8, and 205.4 mg/kg, respectively, with the addition of 40% persimmon puree to the ice cream samples. Gorinstein et al. (2001) investigated the mineral composition of persimmon puree and compared the results with the mineral content of apples. They reported that the major element in the whole fruit and pulp is K (2,540 mg/kg) compared with Ca (93.50 mg/kg) and Mg (82.20 mg/kg). The decrease in the concentration of Mg and Ca in the enriched ice cream samples was due to the low Mg and Ca content of the persimmon fruit. On the other hand, the increase in the concentration of K in the enriched ice cream samples was due to the high amount of K in the persimmon fruit. Erkaya et al. (2012) reported that the addition of CG increased the K content of the ice cream samples and the highest mineral was found to be K in all samples. Szefer and Nriagu (2007) reported that K plays a significant role in the physiological functions of the human body. It was also reported that the increase in consumption of K in the daily diet may protect people who are sensitive to high quantities of Na against hypertension (Erkaya et al., 2012).

Bioactive Properties of Ice Cream Samples

Because persimmon fruit is rich in phenolics, addition of the fruit into ice cream may supply phenolic antioxidants in important amounts. Incorporation of persimmon puree provided significant diffusion of phenolic substances into the ice cream ($P < 0.05$) and the total phenolic content values of ice cream samples increased. Two different solvent systems (methanol:water and acetone:water) were used for the extraction of phenolic compounds from the samples, and the total phenolic content and antiradical activity were compared in the resulting extracts. In general, the acetone:water (80:20, vol/vol) extracts showed higher total phenolic content compared with the extracts that were obtained with methanol:water (80:20, vol/vol). The total phenolic content of the samples is shown in Figure 6. Unenriched samples showed the lowest total phenolic content compared with the samples enriched with persimmon puree. Moreover, the total phenolic content of unenriched samples did not change significantly ($P > 0.05$), depending on the solvent used in the extraction. The total phenolic content of the ice cream with 8% persimmon puree was 551 and 427 mg of GAE/kg of ice cream in acetone:water and methanol:water extracts, respectively. As was expected, the higher the degree of persimmon puree incorporation, the more total phenolics were in the enriched samples. Addition of persimmon puree provided a significant increase in the bioactivity of the final ice cream product. Similarly, antiradical activity of samples increased with the increase in persimmon puree concentration in the formulation. Inhibition of DPPH by ice cream samples containing 40% persimmon puree was 42 and 23% in the acetone:water and methanol:water extracts, respectively. The correlation between total phenolic content and antiradical activity was significant, and the correlation coefficient (r) was calculated to be 0.97 and 0.98 for the acetone:water and methanol:water extracts, respectively. A similar correlation (r = 0.998) was determined by Gao et al. (2011) in the total phenolic content and reducing power of persimmons. An increase in total phenolics increases the antiradical activity of the samples (Yıldırım et al., 2001; Sroka and Cisowski, 2003; Paixão et al., 2007). Gao et al. (2011) reported that the highest total phenolic content was found in the water extracts (14.1 mg of GAE/g of dry powder) compared with methanol (3.3 mg of GAE/g of dry powder) and acetone (1.6 mg of GAE/g of dry powder) extracts of persimmon fruit. The variability in the total phenolic content depending on the solvent type is due to the different solubility of the phenolic compounds (Gao et al., 2011). Wang

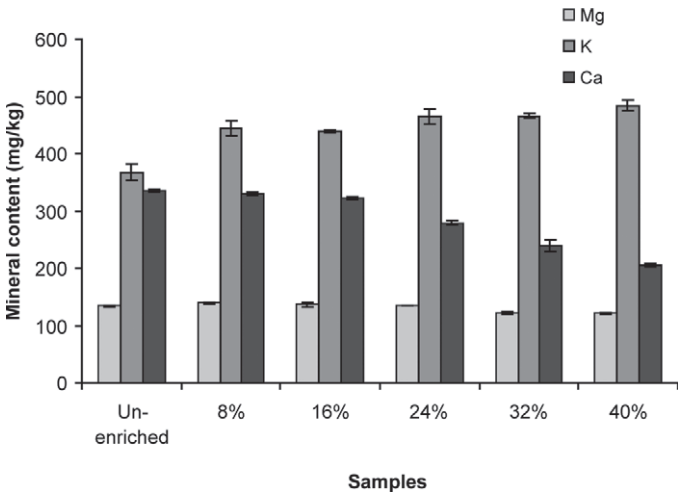


Figure 5. Major minerals in ice cream samples enriched with persimmon puree at 0, 8, 16, 24, 32, or 40% (wt/wt). Error bars show SD.

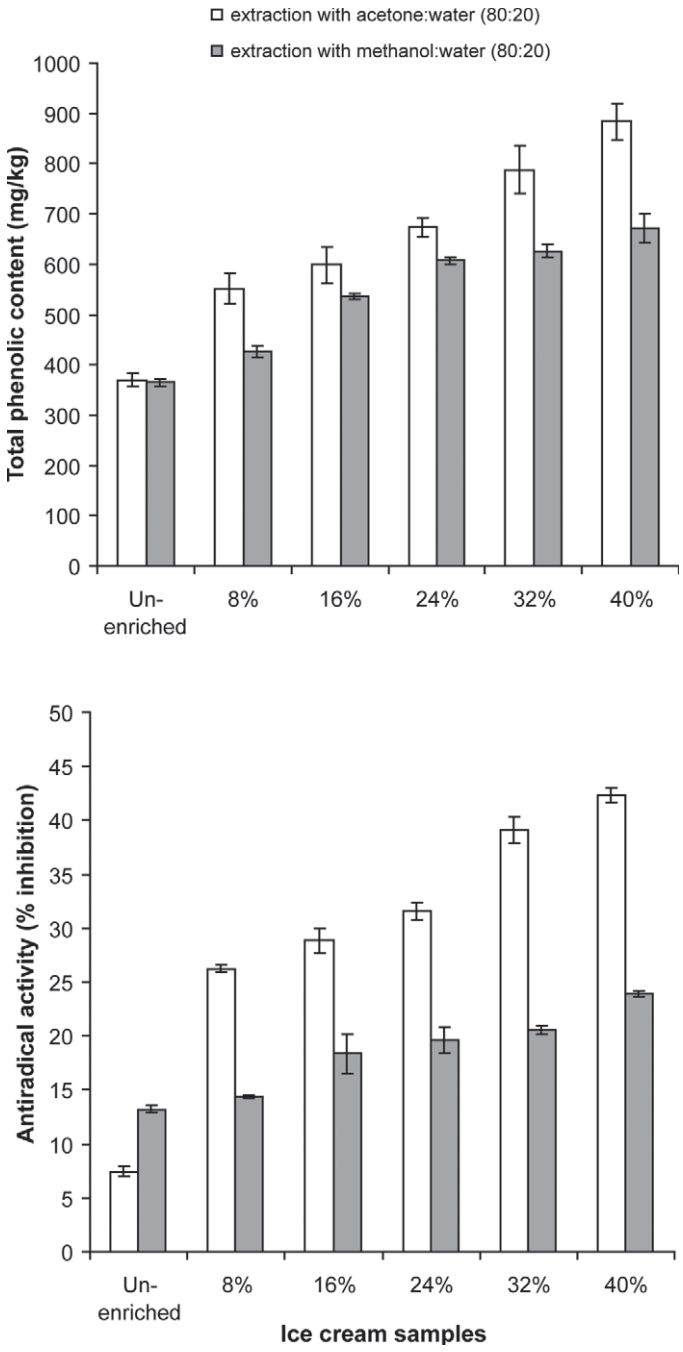


Figure 6. Bioactive properties of ice cream enriched with persimmon puree at 0, 8, 16, 24, 32, or 40% (wt/wt). Error bars show SD.

et al. (2008) suggested that the aqueous mixtures of methanol and acetone are more effective in the extraction of the phenolic compounds from plants compared with their pure state.

Textural Properties of Ice Cream Samples

Figure 7 shows the changes in the textural characteristics of the ice creams samples. The hardest

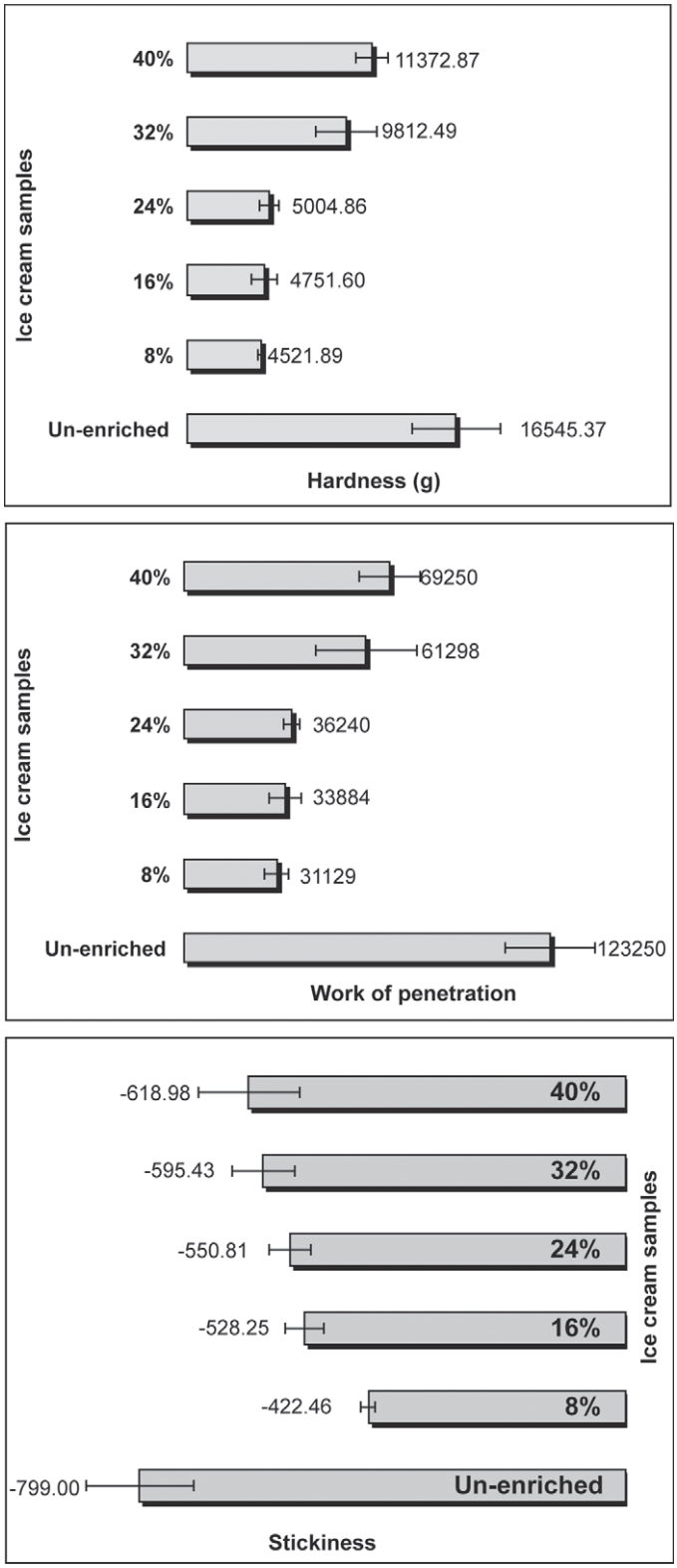


Figure 7. Textural characteristics of ice cream enriched with persimmon puree at 0, 8, 16, 24, 32, or 40% (wt/wt). Error bars show SD.

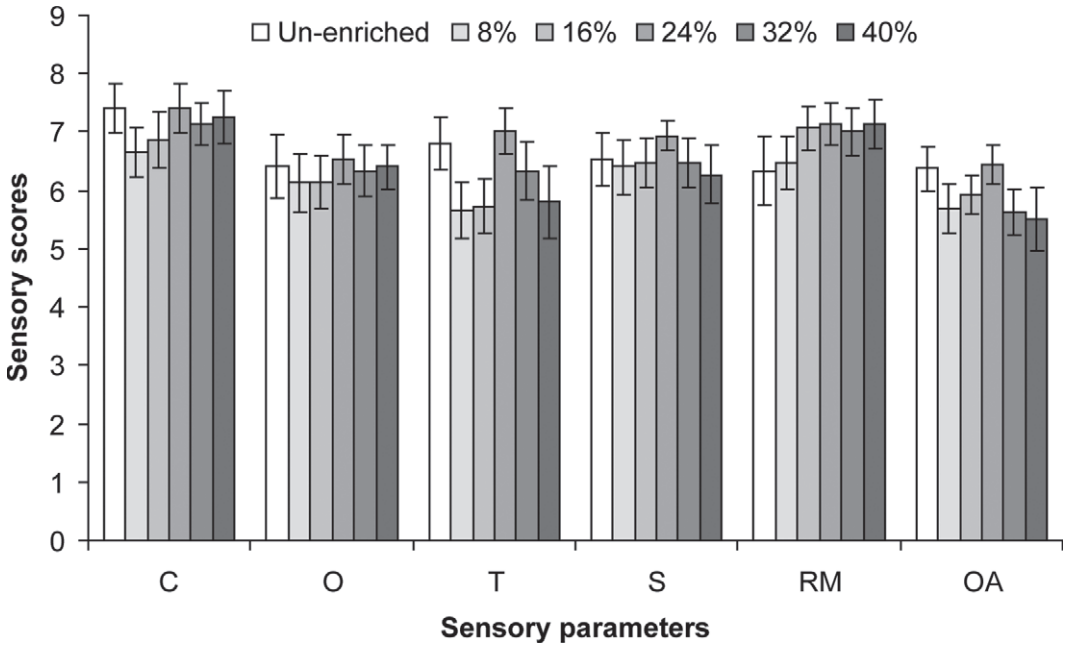


Figure 8. Sensory scores of ice cream enriched with persimmon puree at 0, 8, 16, 24, 32, or 40% (wt/wt). C = color; O = odor; T = taste; S = structure (texture); RM = resistance to melting; OA = overall acceptability. Error bars show SD.

sample was found to be the control ice cream (16.5 kg). The hardness of persimmon-based ice cream samples increased with the increase in persimmon puree concentration among the enriched ice cream samples. Whereas the hardness value of ice cream containing 8% persimmon was 4.52 kg, the hardness value of the ice cream sample containing 40% persimmon puree was 11.37 kg. The differences were found to be statistically significant ($P < 0.05$). A similar trend was observed in the work of penetration. The highest penetration value was observed in the control sample, whereas the lowest was for the ice cream containing 8% persimmon puree. The increase in the persimmon puree concentration increased the work of penetration values. The stickiness values of ice cream samples changed significantly depending on the persimmon puree concentration. The highest adhesive/sticky characteristic was determined in the control sample. An increase in the persimmon puree concentration increased the adhesiveness among the enriched samples. El-Nagar et al. (2002) reported

Table 3. Normalized and weighted normalized decision matrix (calculated by using Equations 2 and 3) for ice creams enriched with persimmon puree at 0 (unenriched), 8, 16, 24, 32, or 40% (wt/wt)

	Bioactivity[1]		Sensory property[2]				
Alternative	TP	AR	C and A	Odor	Taste	Texture	RM
Normalized							
Unenriched	0.227	0.097	0.425	0.407	0.451	0.408	0.351
8%	0.338	0.342	0.382	0.392	0.373	0.398	0.385
16%	0.367	0.376	0.389	0.396	0.374	0.406	0.427
24%	0.413	0.411	0.424	0.424	0.474	0.446	0.432
32%	0.484	0.509	0.414	0.411	0.405	0.405	0.422
40%	0.543	0.551	0.415	0.419	0.359	0.384	0.426
Weighted normalized							
Unenriched	0.034	0.034	0.073	0.050	0.119	0.038	0.025
8%	0.037	0.038	0.075	0.051	0.120	0.039	0.027
16%	0.041	0.041	0.081	0.054	0.152	0.043	0.028
24%	0.048	0.051	0.079	0.053	0.130	0.039	0.027
32%	0.054	0.055	0.080	0.054	0.115	0.037	0.027
40%	0.034	0.034	0.073	0.050	0.119	0.038	0.025

[1]TP = total phenolic; AR = antiradical.

[2]C and A = color and appearance; RM = resistance to melting.

that the stickiness of the ice cream sample increased with an increase in inulin concentration in the formulation of ice cream.

Sensory Properties of Ice Cream Samples

Sensory scores of the ice cream samples are illustrated in Figure 8. Addition of persimmon puree developed the sensory properties of ice cream and increased the acceptability of the product compared with unenriched ice cream sample. The color properties of the samples changed slightly and the color of the samples was desired with an increase in the persimmon puree concentration compared with unenriched samples, due to the significant positive change in the color of the ice cream compared with the color of the control. A significant difference was not determined regarding the odor properties of the samples ($P > 0.05$). The taste score, one of the most important sensory criteria for a product, increased with an increase in the persimmon puree concentration among the enriched samples; however, at a concentration of 40%, it decreased significantly ($P < 0.05$). The texture scores did not change significantly ($P > 0.05$) with persimmon addition to the samples. The increments in persimmon puree concentration provided resistance to melting, which was confirmed by the sensory panel scores. Incorporation of persimmon puree into the samples at concentrations higher than 24% caused a slight decrease in the overall acceptability of the ice cream samples.

Ideal Persimmon Concentration in Ice Cream by TOPSIS

The demand for healthy foods is increasing due to consumer awareness of the relationship between diet and health. Therefore, a combination of bioactive properties and sensory characteristics during selection of a product is crucial, which may be realized by the TOPSIS. The importance ratio of the bioactive and sensory properties was assigned as 20 and 80%, respectively; this means that sensory properties are more important than the bioactive properties of the food. The normalized and weighted normalized matrices were formed by using the real values obtained from analyses (Table 3). The positive (A^*) and negative (A^-) ideal solution values of each criteria were determined using a weighted normalized decision matrix. Table 4 depicts the positive and negative ideal solution values. The distance of each alternative from positive (d_i^*) and negative (d_i^-) ideal solutions were calculated by using Equations 4 and 5 and their values are shown in Table 5. Finally, the closeness coefficient (C) of all alternatives was determined by using Equation 6 to rank the alternatives. The C values of each alternative were determined to be 0.354, 0.380, 0.436, 0.736, 0.685, and 0.601 for unenriched and 8, 16, 24, 32, and 40% enriched ice cream samples, respectively. According to the results, ice cream with 24% persimmon was the best sample when considering preassigned criteria. The results of the TOPSIS were in accordance with the overall acceptability scores. The unenriched sample was determined as the sample with the lowest score due to its lower bioactive properties compared with the other samples. Although the ice cream sample containing 40% persimmon had the highest phenolic content and antiradical activity, the C value of that alternative was lower than ice creams containing 24 and 32% persimmon puree due to lower sensory scores of the sample with 40% persimmon puree. The results of TOPSIS depend on the initial conditions (i.e., weight of the criteria). If the importance ratio is changed, the ranking of the alternatives might be changed. The difference between C values of the unenriched and 40% enriched samples decreases when the importance of the sensory properties is increased. However, as the importance of the bioactive properties is increased, the differences between the C values of the samples are changed; therefore, assigning an importance ratio will eventually affect the final selection of the samples.

Table 4. Positive (A^*) and negative ideal solution (A^-) for the criteria (obtained from Table 3)

Criteria	A^*	A^-
Total phenolic content	0.054	0.023
Antiradical activity	0.055	0.010
Color and appearance	0.082	0.073
Odor	0.054	0.050
Taste	0.152	0.115
Texture	0.043	0.037
Resistance to melting	0.028	0.022

CONCLUSIONS

The findings of this study showed that persimmon is a fruit containing nutritionally important components,

Table 5. Distance from positive (d_i^*) and negative (d_i^-) values of each alternative (calculated by using Equations 4 and 5) for ice creams enriched with persimmon puree at 0 (unenriched), 8, 16, 24, 32, or 40% (wt/wt)

Alternative	d_i^*	d_i^-
Unenriched	0.0562	0.0307
8%	0.0448	0.0274
16%	0.0414	0.0320
24%	0.0191	0.0531
32%	0.0237	0.0514
40%	0.0372	0.0560

and the fruit displayed desired textural improvements in the ice cream formulations. The fruit with the aforementioned properties seemed suitable to exploit for enrichment studies. Enrichment of ice cream samples with certain persimmon concentrations improved the quality of samples in terms of sensory and bioactive properties. Depending on the optimization results, persimmon puree can be used at a concentration of 24% in ice cream formulation. The combination of sensory scores and instrumental values by a suitable objective method (e.g., TOPSIS) might be suitable to make a final decision on a product.

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