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Inhibition activity on alpha-glucosidase of experimental, functional ice cream with the addition of pistachio peel extract

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A B S T R A C T

The aim of this study was to produce the ice cream with potential antidiabetic effects by addition of pistachio peel extract (PPE) (0, 10, 20 and 30% on dry matter basis). The properties of produced ice cream such as physicochemical, rheological, antioxidant, antidiabetic and sensory properties were evaluated. The results indicated that ice creams containing 20 and 30% of PPE provided desired antidiabetic properties (the α-glucosidase inhibition was 79 and 86%, respectively). The DPPH$^{\bullet}$ test results indicated that the antioxidant property of the ice creams containing 30% of PPE was 9.4 times more than the control. All mixes showed non-Newtonian pseudoplastic behavior and by increasing the concentration of PPE, the consistency coefficient (*m*) and viscosity were decreased. Hardness increased as the level of PPE increased but the stickiness decreased. Results of sensory analysis showed that the addition of PPE (up to 20%) had no significant effect on the overall acceptability of product.

Keywords: Antidiabetic, Antioxidant, Ice cream, Enrichment, Pistachio peel, Phenolic compounds

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1. Introduction

According to the American Council on Science and Health, functional foods can be considered to be those whole, enriched or enhanced foods that provide health benefits (Soukoulis et al., 2014). Patients with obesity and diabetes are advised to avoid foods that contain large amounts of carbohydrates, among these foods are white flour bread, white flour paste, ice cream, etc. It should be noted that the costs of treating diabetes are very high mostly due to a chronic consequences and complications (Kumar et al., 2016). Researchers have developed various functional foods for diabetic patients, which include ice cream (Çam et al., 2013), pastry (Ghandehari Yazdi et al., 2015) and pasta (Lalegani et al., 2018). Most research has been on the replacement of sugar with non-nutrient sweeteners, but one of the effective ways to produce such foods is to use enzyme inhibitors in formulation.

One of the useful ways for producing functional food is to apply phenolic compounds (PCs) in the food formulations (Kumar et al., 2016). These compounds act as natural antioxidants, antimicrobial and inhibitor of enzymes (O'Connell & Fox, 2001). PCs can inhibit enzymes activities including: α-glucosidase and α-amylase and prevent the digestion of sugar and carbohydrates (Lalegani et al., 2018). The evidences indicate that PCs may directly influence on the enzyme`s active sites (McDougall et al., 2005). In this regard, Çam et al. (2013) understood that enriched ice creams with pomegranate peel significantly led to increase antioxidant and antidiabetic activities as well as the phenolic content of ice cream. The pistachio peel (PP) is one of the most suitable agricultural byproducts for extracting of the PCs (Goli et al., 2005). According to the reported results, the most PCs of PPE are gallic acid and phloroglucinol (Ghandahari Yazdi et al., 2019). Lalegani et al. (2018), by studying on PP-enriched pasta, found that presence of PCs in the formulation of pasta could prevent the α-amylase and α-glucosidase enzyme activities.

Ice cream is one of the most consumable dairy products in the world which is certainly harmful for diabetic and obese patients. The amount of ice cream calories is high, but it is not generally rich in dietary fibers and some of the natural antioxidants such as vitamin C, natural pigments, and PCs (Sun-Waterhouse et al., 2013) that can be enriched with supplementary substances. In our previous study, the use of PP microcapsules in ice cream formulation was investigated (Ghandahari Yazdi et al., 2020). The results showed that the addition of PP microcapsules improved the antioxidant activity but we found that PP microcapsules had no antidiabetic effect. So, in this study, PPE was used to produce antidiabetic ice cream.

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Due to many beneficial effects of PP, this study was conducted to investigate the a) possibility of producing an antidiabetic ice cream by using PPE, and b) to evaluate the physicochemical properties and sensory attributes of enriched ice creams.

2. Material and Methods

2.1. Plant materials

Pistachio green peel (*Ahmad aghaei* variety) was obtained from the Yazd Agricultural Research Center of Iran. PP dried and then ground to give 40-mesh size powder and until extraction was kept in a freezer at -20°C.

2.2. Chemicals

Methanol was purchased from LOBA Chemie (Mumbai, India). 2, 2′-diphenyl-1-picrylhydrazyl (DPPH), rat intestinal acetone powder (Cat No. I1630) and α-glucosidase from *Saccharomyces cerevisiae* (type I; Cat No. G5003) were purchased from Sigma-Aldrich Chemical Co. (St. Louis, USA). 2, 4, 6-tris (2-pyridyl)-S-triazine (TPTZ) was purchased from Acros Organics Company (Geel, Belgium). Ferric chloride was purchased from Merck Chemical Co. (Darmstadt, Germany). All reagents were analytical grade. Cellulase enzyme obtained from Sigma (St. Louis, MO, USA)**,** tannase enzyme from Kikkoman Biochemifa (Japan, Tokyo), and Pectinex BE color enzyme from Novozymes Ferment (Bagsvaerd, Denmark) were purchased. The soybean lecithin (99%) was obtained from Acros Organics Chemical Co. (New Jersey, USA). Milk, cream, skim milk powder, sugar, salep were purchased from the local market.

2.3. Extraction of PCs from pistachio peel

An enzymatic extraction method was used to increase the extraction yield of PCs from PP. For this purpose, the combination of three enzymes (pectinase, cellulase and tannase) was used according to the following optimized conditions: pectinase (3.8 U/mL), cellulase (2.5 U/mL), tannase (4.0 U/g), time (4 h), particle size (0.4 mm >), solid to liquid ratio (1:80), pH= 4.5 and temperature (40°C) that total PCs content was about 13.79% (Ghandehari Yazdi et al., 2019).

2.4. Preparation of functional ice cream

Ice cream ingredients were obtained from the formulation recommended by Çam et al. (2013). For this purpose, sucrose (37.5 g), cream (42.5 g, fat content 30 %), skimmed milk powder (26.4 g), lecithin (1.05 g) and salep (1.05 g, salep is a flour made from the tubers of the orchid genus *Orchis* (including species *Orchis mascula* and *Orchis militaris*) that grows in Iran and Turkey. These tubers contain a nutritious, starchy polysaccharide called glucomannan which is consumed in beverages and desserts such as coffee and ice cream) were added to milk (180 mL, 1.5 % fat) with continues mixing at 50ºC. The blend was pasteurized at 80ºC for 10 min, and cooled at room temperature. After that the mixture was kept at 4ºC for 24 h. Finally, the mixes were poured into the ice cream maker (Gastroback, Germany) and ice creams were prepared after 30 min. To prepare the functional ice cream, before the pasteurization, the PPE at 0, 10, 20 and 30% on dry matter basis were added to the mixes with continues mixing. Ice creams were kept in a freezer at -20°C until analysis.

2.5. Physicochemical analysis

The pH of samples was measured by a pH meter (Metrohm-780 model made in Swiss). Resistant to melting was evaluated according to modified method described by Akesowan (2008). Thirty g of each sample was placed on a sieve (2 mm wide, rectangular openings) which had been placed above a glass to collect the melted samples. The time of the first drop was recorded as melting temperature. After 15 min, resistance to the melting of ice cream was calculated by the following equation:

$$\mathrm{MR}\ (\%) = \frac{30 - \mathrm{W}}{30} \times 100 \quad (1)$$

where W is sample weight melted after 15 min.

2.6. Color measurement

Color parameters of the samples were analyzed using a colorimeter (Model Hunter Lab Color Flex). The color of ice cream was determined in terms of the L*, a*, b* values, where L* is indicative of lightness on a 0–100 scale from black to white; a* is indicative of red (+) or green (-); and b* is indicative of yellow (+) or blue (-), and total color difference (ΔE) was calculated according to the following equation (Saricoban & Yilmaz, 2010):

$$\Delta \mathrm{E} = \sqrt{(\mathrm{L_0} - \mathrm{L^*})^2 + (\mathrm{a_0} - \mathrm{a^*})^2 + (\mathrm{b_0} - \mathrm{b^*})^2} \quad (2)$$

where subscript “0” refers to the color parameters of control ice cream sample used as the reference.

2.7. Determination of antioxidant properties

2.7.1. Extraction of phenolic compounds from ice creams

The extraction of PCs from ice creams was carried out according to the method of Hwang et al. (2009). The obtained mixture was used for the determination of antioxidant activity ($\mathrm{DPPH}^{\bullet}$ and FRAP assay) and enzymatic analyzes.

2.7.2. Determination of DPPH radical scavenging ability

DPPH radical-scavenging activity was determined according to the method of Hatano et al. (1988). The scavenging capacity of radicals was calculated using the formula described by Abolhasani et al. (2018).

2.7.3. Ferric reducing power (FRAP) assay

The FRAP test was performed in accordance with Benzie and Strain (1996). The antioxidant power expressed as the concentration of antioxidants having a ferric reducing ability equivalent to 1 µM $FeSO_4$.

2.8. Enzyme inhibitory effect of produced ice creams

2.8.1. Determination of α-glucosidase (yeast) inhibitory activity of experimental ice creams (kinetic)

The method described by Apostolidis et al. (2007) was used for evaluating the α-glucosidase (yeast) inhibitory activity of ice cream samples. Results were recorded using the following equation (Lalegani et al., 2018):

$$\%\alpha - \text{glucosidase inhibitory} = \frac{\text{Slope}_{405} \text{ of sample}}{\text{Slope}_{405} \text{ of control}} \times 100 \qquad (3)$$

2.8.2. Inhibitory activity of experimental ice creams on rat intestinal alpha-glucosidase

According to the described method by Connolly et al (2014), rat intestinal acetone powder was prepared. Enzyme solution (100 µL) was pre-incubated with samples extract (50 µL) for 10 min at 25°C. Then, 50 µL of *p*-nitrophenyl α-D-glucopyranoside (as substrate) was added to the mixture. Immediately, the mixture was incubated at 37°C for 30 min and the absorbance of the released *p*-nitrophenyl was measured every 2 min at 405 nm. Then, results were calculated using the formula described in section 2.8.1.

2.9. Rheological properties

Apparent viscosities of the ice cream mixes were evaluated (10- 30 min) using an Anton Paar rheometer (MCR30, CC27-SN16194 spindle, Austria) at 25°C and results fit Power Law model by the following formula:

$$\tau = m y^{n} \qquad (4)$$

where τ = shear stress (pa); *m* = consistency coefficient ($Pa.s^n$); *y* = shear rate (s^{-1}); *n* = flow index.

2.10. Texture analysis

Texture analysis was conducted at room temperature (22 ± 1°C) using a TA.XT plus texture analyzer (Stable Micro System, Reading, UK), equipped with a stainless steel cylindrical probe (with 5-mm diameter). Three measurements were performed for all of the ice cream samples that were tempered to room temperature for 10 min before analysis. The conditions of analysis were as follows: force = 5.0 N, penetration depth = 15 mm, probe speed penetration = 1.0 mm/s. Hardness was determined as the maximum compression force (g) during the testing process of the sample, and adhesiveness as the negative peak force (g) during withdrawal.

2.11. Sensory evaluation

Thirty members' semi trained panels (15 females and 15 males, ages over the range 25-35 years old) were selected for the sensory evaluation using a score test for flavor, texture, aftertaste, color and overall acceptability. The panelists gave scores from 1 to 9 (1: dislike extremely, to 9: like extremely) for each parameter of produced ice creams (Sagdic et al., 2012).

2.12. Statistical analysis

All tests were done in triplicates and the mean ± standard deviation of the data was reported. Least significant difference (LSD) test was used to identify the presence of significant differences at 95% confidence level. For this aim, statistical analysis was accomplished using SPSS 22 software and drawing the related charts using Excel 2013 software.

3. Results and Discussion

3.1. Effect of enrichment with PPE on the color of mixes and ice cream samples

According to Table 1 results, by increasing the amount of PPE, L* value which shows the lightness of the samples decreased significantly ($p < 0.05$). Greenness (a*) of the samples increased by increasing the amount of PPE. Also, yellowness (b*) of ice cream samples and their mixes increased as the level of PPE increased. The results showed that by increasing the amount of PPE, color changes (ΔE) increased as well. Changes on the color properties of ice cream with the addition of PCs have been reported by Sagdic et al. (2012) and Ghandehari Yazdi, et al., (2020). The color changes are probably related to the color of the extract. Due to color of the extract used in this study (which was almost green) the brightness in the mix and ice cream decreased.

Table 1. Effect of enrichment of ice cream with pistachio peel extract (PPE) on the samples color.

Amount of PPE (%)	L *	a*	b*	ΔE
Mixes				
0	87.42±0.09^{a}	-1.70±0.02^{a}	12.93±0.06^{c}	0.00
10	86.03±0.24^{ab}	-2.09±0.02^{b}	13.20±0.04^{b}	0.38±0.04^{a}
20	85.83±0.05^{b}	-2.11±0.03^{b}	13.26±0.12^{ab}	0.60±0.10^{a}
30	85.59±0.14^{b}	-2.26±0.07^{b}	13.48±0.11^{a}	1.13±0.19^{b}
Ice cream				
0	85.53±0.15^{a}	-1.73±0.13^{a}	12.92±0.02^{b}	0.00
10	85.88±0.12^{ab}	-2.06±0.03^{b}	13.21±0.07^{b}	0.48±0.13^{a}
20	86.03±0.13^{bc}	-2.14±0.02^{b}	13.29±0.02^{b}	0.66±0.01^{a}
30	86.29±0.08^{c}	-2.23±0.12^{b}	13.37±0.00^{a}	1.03±0.02^{b}

Note: Data are means ± SD of three replicates. Values with different lowercase letters in the same column are significantly different (LSD, $p < 0.05$).

Table 2. Effect of pistachio peel extract (PPE) on the antioxidant activity of produced ice cream samples.

Amount of PPE (%)	DPPH (inhibition %)	FRAP (mg/100g ice cream)
0	9.26 ± 2.39[d]	2.95 ± 0.75[d]
10	62.65 ± 1.54[c]	142.27 ± 4.19[c]
20	76.57 ± 4.24[b]	174.28 ± 20.27[b]
30	87.41 ± 3.86[a]	215.69 ± 8.10[a]

Note: Data are means ± SD of three replicates. Values with different lowercase letters in the same column are significantly different (LSD, $p < 0.05$).

Table 3. Effect of enrichment of ice cream with pistachio peel extract (PPE) on physicochemical properties.

Amount of PPE (%)	Frist dripping (min)	Meltdown (%)	pH
0	3.75 ± 0.04[a]	28.93 ± 0.61[a]	6.31±0.07[a]
10	3.28 ± 0.06[b]	25.82 ± 1.51[a]	5.98±0.03[b]
20	3.13 ± 0.11[c]	19.22 ± 0.26[b]	5.72±0.04[c]
30	2.84 ± 0.03[d]	17.59 ± 1.23[c]	5.01±0.03[d]

Note: Data are means ± SD of three replicates. Values with different lowercase letters in the same column are significantly different (LSD, $p < 0.05$).

Table 4. Inhibition of α-glucosidase and rat intestinal enzyme activities by pistachio peel extract (PPE) enriched ice cream.

	Enzyme activity (%)	
Amount of PPE (%)	α-glucosidase (yeast)	Rat intestinal (mammalian)
0	0.0 ± 0.0[d]	N. D.
10	70.5 ± 2.8[c]	17.4 ± 2.5[c]
20	79.1 ± 1.4[b]	25.6 ± 1.7[b]
30	86.4 ± 2.6[a]	60.9 ± 1.1[a]

Note: Data are means ± SD of three replicates. Values with different lowercase letters in the same column are significantly different (LSD, $p < 0.05$).

3.2. Determination of antioxidant activities of samples

All ice cream samples fortified by PPE showed an excellent radical scavenging activity as it is presented in Table 2. The DPPH$^{\bullet}$ and FRAP results showed that different levels of PPE in formulation have significant effect on the antioxidant activity of experimental ice cream samples. By increasing the amount of the added extract, the antioxidant activity increased that is related to the presence of PCs (Ghandahari yazdi et al., 2019). At the highest concentration of PPE (30%) in the ice cream, the DPPH antiradical activity was almost 9.4 times higher than control. According to Table 2, addition of PPE to the ice cream increased the FRAP values. The ice cream, that containing 30% of extract had excellent reducing power (215.69 mg/100 g ice cream) while control sample had very low reducing power (2.95 mg/100gice cream). Vital et al. (2018), indicated that the addition of grape juice residue at 10% in ice cream increased antioxidant activity up to 85%. Moreover, Hwang et al. (2009) indicated that addition of 10% of wine lees to the formulations enhanced antioxidant activity of ice cream up to 65 %.

As can be seen in Table 2, the sample without PPE had low antioxidant potential (DPPH antiradical activity: 9.26%, FRAP: 2.95 mg/100g ice cream) due to the presence of furfural compounds produced during pasteurization of ice cream mixes via Maillard reaction (Sagdic et al., 2012). Also, the low amount of PCs in the sample without PPE is probably related to the milk used and the amount of these compounds in the milk depends on animal feeds, amino acid catabolism, and/or contamination from environment (O'Connell & Fox, 2001; Sagdic et al., 2012). The authors found out this radical scavenging is due to the presence of phlorotannins. In fact, the antioxidant properties are related to the number and position of hydroxyl phenolic groups. The ortho position of OH groups acts more efficiently. Furthermore, there is a direct correlation between the number of OH groups in the phlorotannins and the observed antioxidant activity (Li et al., 2009).

3.3. Effect of added PPE on the rheological properties of samples

Viscosity of the ice cream mix is an important quality factor and a certain level of viscosity is essential for proper whipping and retention of air and for creating good body and texture in the final product. Power Law model fitted to the rheological results including flow index (*n*), consistency coefficient (*m*) and correlation coefficient (R^2). Correlation coefficients are over the range 0.963-0.999 which displays the conformity of results with model. The results indicated the non-Newtonian pseudoplastic behavior of samples (n < 1) that has been reported by other researchers (Karaman & Kayacier, 2012; Ghandehari Yazdi et al., 2020). The flow behavior of the mixes containing PPE showed in Fig. 1. By increasing the concentration of extract, viscosity decreased. The viscosities of mixes containing 0, 10, 20, and 30% of PPE were 24.86, 19.38, 13.63 and 11.51 Pa.s, respectively. On the other hand, the consistency index decreased by increasing the amount of PPE. The highest and lowest (*m*) were calculated for the sample containing 0 (2.17 Pa.s^n) and 30% (0.017 Pa.s^n) of PPE, respectively. A similar trend has been reported with the addition of cornelian cherry paste (Topdas et al., 2017). In contrary, increasing the ice cream viscosity has been reported with different compounds such as grape wine lees (Hwang et al., 2009) and PP microcapsules (Ghasndehari yazdi et al., 2020). In this study, due to high water content of PPE, the viscosity of the ice cream mixes decreased.

3.4. Effect of added PPE on texture properties of samples

Effect of PPE on the texture of ice cream is shown in Fig. 2. As seen from Fig. 2, the hardness of samples increased by increasing the amount of extract into the ice cream formulations. The hardness was 1.83 times higher than hardness of control sample. On the other hand, the addition of PPE into ice cream decreased the stickiness of samples. Therefore, the sample containing the highest level of PPE had lowest stickiness value. Muse and Hartel (2004) suggested that different factors could change the hardness of the ice cream such as ice crystal size, fat globulin net, overrun and the rheology of the mix. The obtained results in the present study could be related to the high water content of PPE. In fact, by increasing the amount of PPE, the number and size of ice crystals increased in ice cream samples. These change lead to the increased the hardness of ice cream containing PPE compared to the control.

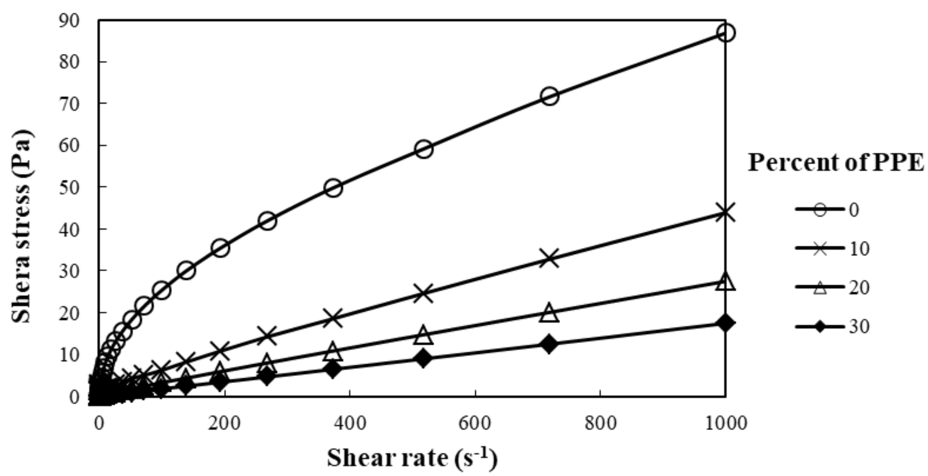

Fig. 1. Effect of added pistachio peel extract (PPE) on the flow behaviour of mixes.

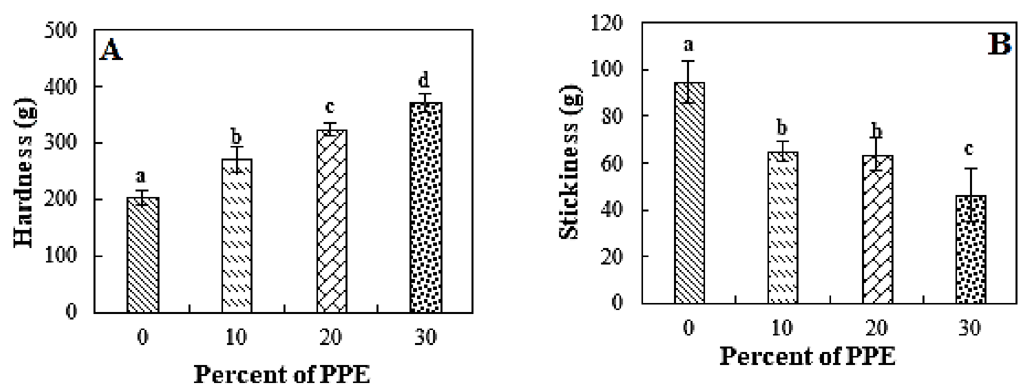

Fig. 2. Effect of added of pistachio peel extract (PPE) on the hardness (A), and stickiness (B) of produced ice creams. Data are means ± SD of three replicates. Values with different lowercase letters in the same column are significantly different (LSD, p < 0.05).

3.5. Determination of pH and melting properties

According to Table 3, addition the PPE decreased the pH of ice creams. Similar results have been reported by others (Hwang et al., 2009; Gabbi et al., 2018). In contrary, in previous study we found that the addition of PP microcapsules did not significantly effect on the pH of ice cream. Sagdic et al. (2012) suggested that the addition of phenolic-rich substances, such as ellagic acid and gallic acid, increased acidity due to acidic nature of these components.

Melting properties are important quality parameters of ice cream because they play key role in sensory properties. As seen from Table 3, the first dripping times of produced ice cream samples ranged from 2.84 to 3.75 min. The first dripping times of samples containing PPE were shorter compared with the control. Also, as shown in Table 3, the samples containing PPE showed lower melting resistance than the control sample which is related to the lack of air in the texture. The melting rate depends on various factors such as ice cream's composition, additives applied, amount of air penetrated into the ice crystals, rheological properties, and the network of fat globules formed during freezing (Moeenfard & Mazaheri Tehrani, 2008). The results obtained in this section also supported the rheological test data. Low melting resistance of samples containing PPE could be a consequence of their lower viscosity compared to control.

3.6. Inhibitory potential of PPE on α-glucosidase (yeast) and rat intestinal (mammalian) enzymes

As mentioned earlier, the PCs inhibit glucosidase enzyme, which is important effect for diabetic patients (type 2). The highest inhibition of α-glucosidase (yeast) and rat intestinal (mammalian) enzyme activity belonged to the sample containing 30% of PPE which inhibited α-glucosidase (yeast) and rat intestinal enzyme (mammalian) activities up to 86.4 and 60.9%, respectively (Table 4). Also, the enriched ice cream by 20% of extract, was able to inhibit α-glucosidase (yeast) and rat intestinal (mammalian) activities by 79.1 and 25.6%, respectively. These results have verified by Boath et al. (2012), the α-glucosidase activity inhibited by the presence of PCs based on their site of action, mechanism and binding affinities. Lalegani et al. (2018) reported PPE as one of the strongest natural inhibitors that can block the glucosidase enzyme so that in the concentration of 76 µg GAE/µ, the enzyme activity reduced up to 90 %. They also showed that this property was due to their non-tannin components of PPE (Lalegani et al., 2018).

However, Imbs and Zvyagintseva (2018) revealed that PCs improves postprandial hyperglycemia in type 2 diabetes and obesity by affecting α-glucosidase activity. Moreover, Silva et al. (2017) showed that PCs influence glucose metabolism by inhibiting carbohydrate digestion. The PCs present in PPE was able to inhibit the enzymes related to carbohydrate digestion because of these compounds probably be able to neutralize free radicals by hydrogen or electron donation, acting as a chelating agent, and denaturing proteins (Bouayed et al., 2012).

Based on the above presented results, the potential antidiabetic effects of experimental ice creams and their categorization as functional food can be provided by the addition of PPE. Similar results were previously described by adding pomegranate peel to ice cream Çam et al. (2014). Their results showed that by adding microcapsules of pomegranate peel to the ice cream sample, α-glucosidase activity decreased. These PCs of plants are generally safe, grass and can act as an enzyme inhibitor. In fact, the PCs act as uncompetitive inhibitor for α-glucosidase (Lalegani et al., 2018). Also, unlike commercial inhibitors that have been used for diabetes treatment, the natural inhibitors are not associated with significant adverse gastrointestinal side effects (Zhang et al., 2011). Therefore, the use of PPE as a rich source of PCs in ice cream can provide beneficial effects for consumers (Jacobs et al., 2011). On the other hand, at the low temperature, phenolics are more stable and easily protect ice cream against the oxidation of fatty acid during storage (Pandey & Rizvi, 2009). Despite these results, as mentioned earlier, in previous study we used PP microcapsules to produce antidiabetic ice cream, but we did not succeed and we found that PP microcapsules did not have antidiabetic properties.

3.7. Sensory evaluation

Addition of PPE had significant effect on the scores of color, flavor, and after taste acceptability features. There were no significant differences in texture scores (up to 20 %) except samples containing 30% of extract. As a result of sensory analysis, the lowest texture scores and overall acceptability were found in ice cream containing 30% of pistachio peel extract. Results of texture evaluation were verified by sensory evaluation results. Similarly, Karaman and Kayacier (2012) showed that by adding of black tea and herbal tea in ice cream, the sensory scores significantly decreased in comparison with control sample. Contrary to these results, Vital et al. (2018) reported that the amount of grape juice residue did not significantly affect the ice creams color, aroma, taste, texture and overall appearance. Also, in our previous research we found that PP microcapsules did not significantly effect on the sensory properties of ice cream (Ghandehari et al., 2020). However, according to the panelists responses, there was no after taste in ice cream which might be due to the presence of sugar in it that covered the taste of the PCs (Çam et al., 2013).

4. Conclusion

Our results indicated that addition of pistachio peel extract, as an enriched source of PCs, into the ice cream can provide functional properties. Adding the PPE into the ice cream increased the hardness, melting speed, color change, antioxidant properties, and enzyme inhibitory activity and decreased the viscosity of samples. According to the results addition of 20% of PPE into the ice cream was appropriate because it improved the functionality without the disadvantages in the overall acceptability. This experimental ice cream could be suitable for the diet of diabetics but it is necessary to do further in vivo tests.

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Conflict of interest

The authors declare that there is no conflict of interest.

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