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Research article

Freeze-dried persimmon peel: A potential ingredient for functional ice cream

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ABSTRACT

The peels are considered part of waste products, which are generally discarded. The use of persimmon peel is associated with its phenolic content, dietary fibers, minerals, and pectins. The main objective of this study was to evaluate changes in antioxidant activity, total phenolic contents (TPC), and color parameters of persimmon peels after freeze drying (−85 °C for 24h), vacuum oven drying (45 °C for 12h), oven drying (50 °C for 12h) and microwave oven drying treatment (900W for 10s). In the next step, the functional ice cream was prepared and studied by adding dried persimmon peel powder (DPPP). Various properties of the resulting ice cream at 4 levels of DPPP addition were investigated. The results showed that the highest value of L*,a*,and b* parameters were in the freeze-dried sample. There was a significant difference in the TPC of samples that dried by different methods ($p < 0.05$). The highest amount of TPC was observed in the freeze-dried sample (673 ± 2.0 mgGAE/100g) and the lowest one was observed in the oven-dried sample (352 ± 0.5 mgGAE/100g). The highest value for IC_{50} (concentration of the antioxidant compound that is necessary for the DPPH radical concentration to reach 50 % of the initial value) was in the sample dried in the oven, following the vacuum oven, microwave, and the lowest value was in the freeze-dried sample. DPPP produced by the freeze-drying method was applied in ice cream formulation at different levels (0–3 %wt.). By increasing the amount of DPPP from 0 to 3 %, the overrun and L* decreased and a*, b*, hardness, and melting resistance of ice cream increased significantly ($p < 0.05$). Based on our findings, DPPP has the potential to be applied as an added-value ingredient in the ice cream industry to improve the functional characteristics of its products.

1. Introduction

Industry and consumers are constantly seeking alternative ingredients as they demand new and healthier food products. As consumers' lifestyles have changed, they have become more aware of plant phenols' protective effects against cancer and cardiovascular disease [1,2]. It can be difficult to find healthy, environmentally friendly ingredients while also developing tasty with high nutritional value food products.

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Phenolics, which are secondary metabolites found in plants, harbor bioactive substances and offer advantageous effects for organisms. Their potential health benefits and impact on human health have sparked substantial interest [3,4]. Categorized into three main groups flavonoids, non-flavonoids, and tannins their biological function primarily hinges on their chemical structure [5]. The recent surge in interest for natural antioxidants in food production over synthetic ones is due to their reduced environmental impact and economic viability. Moreover, natural antioxidants are deemed safer for consumers [5]. Phenolics compounds can help to bind polymeric network as some potential crosslinker due to making some interactions like hydrogen bonds between proteins and create a large network. The protein-phenolic network formation yields a gel that effectively entraps diverse compounds. Incorporating phenolic compounds into the ice cream formulation leads to the development of a robust gel comprising proteins and phenolics. This gel exhibits strength in retaining air bubbles, fat globules, and ice crystals even under elevated temperatures. Consequently, despite complete ice melting, the gel structure can uphold the product's form and attributes. Extensive research in model systems has delved into the interactions between milk proteins and varied phenolic compounds [6], research on the potential usefulness of phenolic compounds and their impact on the characteristics of dairy products like ice cream, still needs comprehensive study. Regarding the antioxidant and radical scavenging properties of phenolic compounds, it can be acknowledged that they play an important role in preserving food products and maintaining human health [7].

Ice cream is a dairy product that is known as a healthy product due to its various nutrients, and at the same time, due to its special food texture, it creates a feeling of happiness and relaxation in consumers. The melting rate of this product is one of its most important properties because it creates a pleasant feeling for the consumer, and it needs to be done within a suitable period of time (Khosrow shahi et al., 2021b). Therefore, investigating the melting time of ice cream and developing it to the optimum level has always been one of the topics of interest for researchers. The ice cream starts to melt when the hot air from its outer layers can penetrate to the inner layers and destroy the crystal ice network. As a result, the contents of the melted water for the ice crystal network flow towards the non-ice viscous phase, and this factor causes the instability of the fat network, air, and the rest of the ice crystal network, and as a result, the structure of the ice cream is completely disintegrated. The rate of ice cream melting depends on various factors, including the air entrapped in the structure, the nature of the ice crystal network, and the structure of the fat during the freezing of the ice cream [8].

Persimmon (*Diospyros kaki*) is a deciduous fruit that is cultivated in different parts of the world. Minerals, bioactive compounds, such as phenolic compounds, terpenoids, steroids, carotenoids, and dietary fibers can be mentioned among the bioactive compounds of persimmon fruit [2]. Fruits of the persimmon tree can be consumed fresh or dried. Specifically, persimmon peel contains more bioactive compounds than persimmon pulp [9]. During the drying process, the antioxidant-rich peel of the persimmon is discarded.

Therefore, in the present study, we first investigated the effect of different drying methods on the color, antioxidant, and total

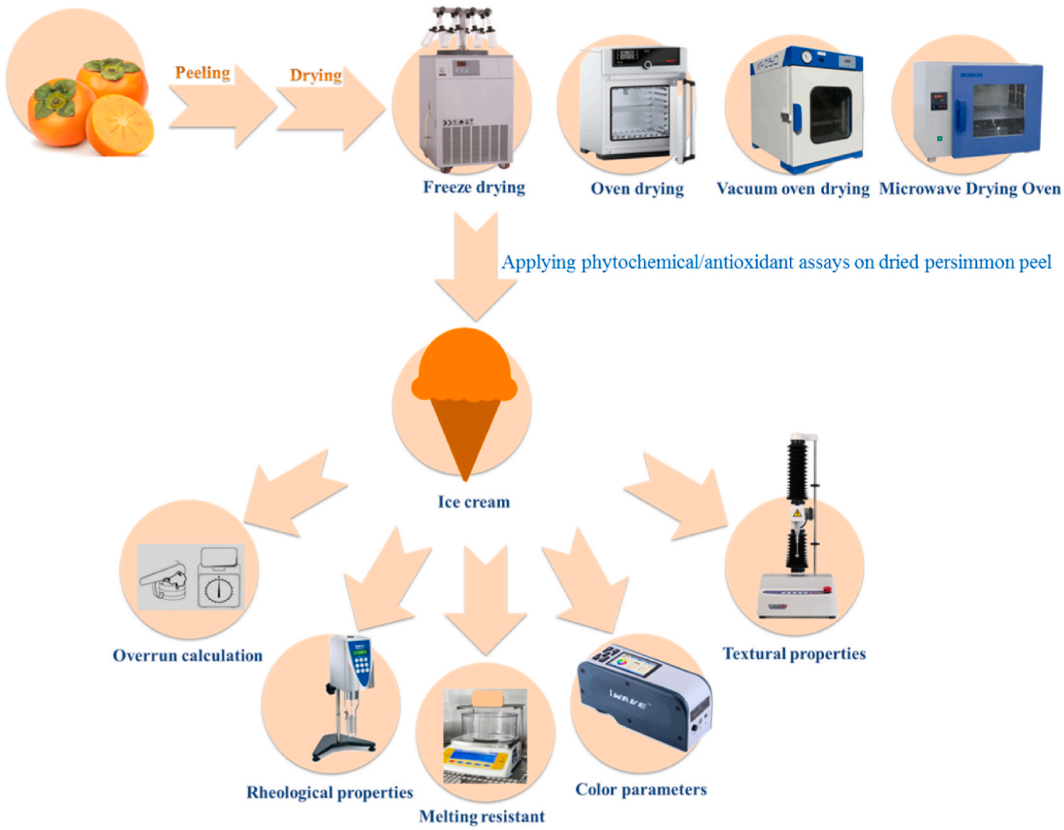

Fig. 1. Steps of study for drying persimmon peel and its use as a natural antioxidant and colorant in functional ice cream.

phenolic content of persimmon peel and then applied the antioxidant-rich persimmon peel powder in the ice cream formulation (Fig. 1). Because of its nutritional value and cooling effect, ice cream is a popular dairy product that can be improved by using natural colors and phenolic compounds to extend its melting time, enhancing its functional and nutritional qualities.

2. Materials and methods

2.1. Materials

Persimmon fruit was purchased from the local market in Mashhad, Iran. Skimmed cow milk powder and cream were obtained from Pegah Co. (Mashhad, Iran). Mono- and diglyceride (E471) was supplied from Guangzhou Cardlo Biochemical Technology Company Ltd. (China). Vanilla, sugar, and salep were purchased from a local supplier. All chemicals and reagents were purchased from Sigma Aldrich.

2.2. Persimmon peel drying

The peel of the persimmon fruit was peeled with a thickness of 2 mm. Persimmon peel contains phenolic compounds oxidase enzyme, which had to be deactivated before drying. In this way, the peel liberated from enzymes for 15–20 min in a water bath at 100 °C (Hai-Feng et al., 2008). The samples were then dried using four methods: freeze drying (−85 °C for 24 h), vacuum oven drying (45 °C for 12 h), oven drying (50 °C for 12 h), and microwave oven drying (900W for 10s). Finally, dried peel were ground and moisture, water activity, solubility, bulk density, particle density, color parameters, total phenolic content, and DPPH radical scavenging activity were determined.

2.2.1. Color parameters

Color parameters (L*, a*, and b*) of dried persimmon peel was determined using a calibrated image processing system. A Color Page HR6X Slim scanner (Genius, Taiwan) was used to scan the samples at 200 dpi in RGB color space with a 24-bit color depth. The images were then cropped to 500 by 500 $pixels^2$ and converted to CIELAB color space [10]. L*, a*, and b* were extracted using ImageJ software (National Institutes of Health, USA).

2.2.2. DPPH radical scavenging activity

Antioxidant activity of persimmon peel powder was determined by DPPH radical scavenging activity method by calculating IC_{50}. In short, 2 mL of freshly prepared DPPH in ethanol (0.15 mol/L) were mixed with 2 mL of peel powder dispersions (100–1000 mg/mL). A thorough shaking of the mixture was followed by 30 min of storage at room temperature in the dark. Using a UV–visible spectrophotometer (UV-160A, Shimadzu, Japan), the absorbance was determined at 517 nm. The following equation was used to estimate the DPPH radical scavenging activity [11]:

$$\text{DPPH radical scavenging activity } (\%) = \left[1 - \frac{A_x - A_{x_0}}{A_x} \times 100\right]$$

Where A_x is absorbance value of control and A_{x0} is the absorbance value of sample at 517 nm.

The IC_{50} value, which is the concentration of the test material that reduces 50 % of the free-radical concentration, was calculated as mg/ml through sigmoidal dose-response curve [12].

2.2.3. Total phenolic content

The Folin–Ciocalteu procedure was applied to determine the total phenolic content. In order to extract phenolic compounds, 0.1 g of peel powders were mixed with 25 mL of water for 2 h at room temperature. A 0.5 mL sample of the filtered extract was mixed with 2.5 mL of 10 % Folin reagent and 2 mL of 7.5 % sodium carbonate after filtering. The absorbance was measured after 30 min with a spectrophotometer (UV–visible, Shimadzu UV-160A, Japan). The calibration curve was created based on the absorbance values of gallic acid, which served as the standard compound [13].

2.2.4. Chemical composition

The freeze-dried persimmon peel powder was subjected to proximate analysis using the methods recommended by AOAC [14].

2.3. Preparation of ice cream samples containing persimmon peel powder

The formulation of ice cream mixes included milk fat at 12 %, milk solids nonfat at 13 %, sugar at 14–17 %, vanilla at 0.1 %, salep at 0.4 %, mono- and diglyceride at 0.15 %, and dried persimmon peel powder at 0, 2, 4, and 6 % for the control, 1DP, 2DP, and 3DP samples, respectively. With an increase in the concentration of dried persimmon peel powder, the sugar content decreased. Specifically, the control sample had 17 % sugar content, while the 1DP sample had 16 % sugar, the 2DP sample had 15 % sugar, and the 3DP sample had 14 % sugar. The ingredients were mixed together for 2 min to create a uniform mixture, then heated to 80 °C for 25 s, and finally homogenized at 18,000 rpm for 2 min using an Ultra Turrax (T25D IKA,Germany). The mixture was then quickly cooled to 4 °C and left to age at that temperature for 6 h. Afterwards, the ice-cream mixtures were placed in a batch ice-cream machine (Model

ICK5000; Delonghi, Italy) and frozen for 15 ± 2 min. The ice creams were kept 24 h in a freezer (−18 °C) to hardened until analysis [15].

2.3.1. *Rheological properties*

We utilized a rotational viscometer (model RVDV-II; Brookfield Engineering Inc., USA) to analyze the rheological properties of ice cream mixture samples at a temperature of 25 ± 0.1 °C. Mixtures were sheared for 800 s at 150 s^{-1} before measurement in order to eliminate time dependence. The viscosity value (mPa.s^n) at shear rate of 50 s^{-1} was determined.

2.3.2. *Overrun*

The overrun was calculated as follows:

Overrun (%) = [(weight of the ice cream mix-weight of the ice cream)/(weight of the ice cream mix)] × 100.

2.3.3. *Color measurements*

Color parameters were obtained in the same way as mentioned before (2.2.1).

2.3.4. *Melting behavior*

Samples weighing 30 g, after hardening in the freezer for 24 h, were placed on a wire rack and the weight of the melted samples was recorded at 25 ± 1 °C every 10 s. The slope of the linear section of the drained mass-time graphs was used to determine the melting rate (g/min).

2.3.5. *Textural analysis*

The penetration test was performed with a penetration depth of 15 mm at a speed of 2 mm/s at room temperature using a texture analyzer (CT3 Texture Analyzer; Brookfield, The USA) equipped with a conical probe (45°). Hardness (maximum compression force during penetration) of the samples was recorded.

2.3.6. *Organoleptic attributes*

During two 3-h training sessions, 10 people, including 5 women and 5 men in the age group of 25–36, defined 6 sensory characteristics for ice cream samples and analyzed them. Then, ice cream samples (30 g, −18 °C) were randomly coded with three-digit numbers and given to the panelists. The evaluation of attributes including oranginess, coldness, hardness, astringent taste and melt resistance was done at room temperature and the people were asked to rinse their mouths with lukewarm water between the evaluation of each sample to eliminate the effect of each sample on the other. The sensory attributes of the ice cream samples were determined through quantitative descriptive analysis. Samples were scored from 1 to 10 based on interest using a 10 cm line scale anchored at its endpoints with the words ‘weak’ and ‘strong’ [16].

2.4. *Statistical analysis*

The study utilized a completely randomized design, with each treatment being replicated three times. The observational data was analyzed using Minitab 16 software, employing analysis of variance with a significance threshold of 5 %.Graphs were drawn using Excel software (ver. 2017).

3. Results and discussion

3.1. *Quality parameters of dried persimmon peel powder*

3.1.1. *Color parameters*

The use of different drying methods causes qualitative changes in the dried product, which strongly affects its marketability and nutritional value [17]. One of the most important quality characteristics in drying agricultural products is color changes [18]. There were significant differences ($p < 0.05$) in L*, a*, and b* values of different drying methods (Table 1). Based on the results of this

Table 1

Quality parameters of dried persimmon peel powder.

Drying method	TPC (mgGalic acid/100 g)	IC_{50} (mg/ml)	Color parameters		
			L*	a*	b*
Freeze drying	673.0 ± 2.0^a	564.0 ± 3.8^d	62.98 ± 2.75^a	25.00 ± 3.23^a	39.20 ± 3.45^a
Oven drying	352.5 ± 0.5^d	768.4 ± 3.4^a	33.36 ± 3.02^c	23.74 ± 1.77^b	26.55 ± 2.45^b
Vacuum oven drying	401.1 ± 0.6^c	728.8 ± 3.6^b	38.95 ± 2.61^c	15.97 ± 1.38^c	24.97 ± 1.93^b
Microwave drying	518.2 ± 0.7^b	648.2 ± 2.5^c	51.79 ± 2.80^b	16.39 ± 1.68^c	25.57 ± 2.67^b

IC_{50} values were determined by nonlinear regression analysis.

Results are mean values ± SD from three experiments.

Values with different letters are significantly different ($P < 0.05$).

research, the highest value of L* was observed for the sample dried with a freeze dryer and the lowest value was observed for the sample dried in the oven. In fact, with increasing drying temperature, the lightness of the samples decreased. This probably due to less pigment decomposition and enzymatic and non-enzymatic browning reactions, which are greatly reduced in the use of freeze drying method [19]. Regarding the a* parameter, its highest value was obtained in the sample dried by the freeze dryer method, which indicates the preservation of the red color in the samples. For the b* parameter, the highest value was obtained in the sample dried by the freeze dryer method, which indicates the preservation of the yellow color in the samples dried by this method [20]. also reported that the freeze dryer method had the highest L*, a*, and b* values of green tea comparing other drying methods (sun drying, shade drying, oven drying at 60, 80, and 100 °C, microwave, and freeze drying) [21]. also stated in the drying of broccoli that the L* values of the dried samples were significantly different in the drying methods. They stated that actually the color changes in the drying processes are attributed to the degradation of the pigment and the browning reaction [21]. They also reported that the freeze-dryer method showed the best drying performance in preserving the color, followed by the microwave and vacuum oven drying methods. In all color parameters, oven drying method showed the weakest color preservation performance (Xu et al., 2019). Other researchers also observed similar results for dried garlic and mint [19,22]. They attributed the reason for the preservation of color in dried samples under freezing and vacuum drying methods to low temperature and vacuum conditions.

3.1.2. *Total phenolic content*

Phenolic compounds derived from plants are significant in their antioxidant activity because of their ability to absorb and counteract free radicals, extinguish singlet and triplet oxygen, and break down peroxides due to their redox properties [23]. Based on the results (Table 1), the total phenolic content in samples dried by different methods had significant differences ($p < 0.05$). The highest value of phenolic compounds was observed in the sample dried by the freeze dryer method (673.0 ± 2.0 mgGAE/100g) and the lowest one in the oven dried sample (352.5 ± 0.5 mgGAE/100g). Throughout the process of desiccation, plants that are metabolically active gradually lose moisture and may perceive this loss as a form of stress. Generally, when plants experience stress, they produce phenolic compounds as a defense mechanism. Studies have shown that various phenylpropanoid compounds such as flavonoids, isoflavonoids, psoralens, coumarins, phenolic acids, lignin, and suberin are synthesized in response to oxidative stress caused by factors such as injury, extreme temperatures, and pathogen attacks [24]. Freeze drying has often been recognized as a suitable method for preserving the quality of plants during processing in numerous previous studies [25–27]. [21] stated that the freeze-dryer method significantly preserved the total phenolic compounds of broccoli compared to other drying methods. The decrease in the total phenolic content in high temperature drying methods can be due to the destructive effect of high temperature on phenolic compounds [28]. Phenolic compounds may associate with other compounds, such as proteins, and due to the limitations of current methods in detecting changes in their chemical composition, this could potentially explain the decrease in phenolic compounds during the drying process [29]. The higher content of total phenolic compounds in freeze-dried samples can be due to the growth of ice crystals in the plant tissue, which can cause more rupture of plant cells. This allows for greater solvent penetration and greater extraction of these compounds [30]. The results of this observation showed that after the freeze-dried samples, the microwave-dried samples had the most phenolic compounds. In this regard, different results have been reported by other researchers [31]. discovered that hot-air drying led to greater oxidation and condensation of phenolic compounds compared to freeze-drying. Similarly [32], found a higher overall phenolic concentration in freeze-dried pomegranate rind. Generally, thermal treatment is known to significantly decrease the phenolic content in food products. Additionally [33], noted a reduction in phenolic compounds in air-dried red pepper, with the concentration decreasing as the drying temperature rose [34]. stated that the rapid and intense heat generated by microwave radiation could result in significant degradation of phenolic compounds. While [35] observed that the phenolic content of ginger improved during the microwave process. In justifying this, it was explained that microwave energy can lead to the breakdown of cellular components and release more phenolic compounds from the tissue. With these findings, we can conclude that the effect of the drying method on the total phenolic content can depend on the drying metods. Freeze-drying eliminates moisture from products by directly converting solid ice into vapor. This approach, conducted under low-temperature and low-pressure conditions, produces high-quality dried goods with improved visual appeal and a higher preservation of nutrients compared to alternative drying methods [36]. Nonetheless, freeze-drying is a time-consuming procedure, which limits its practicality in the food industry. It is important to recognize that small-molecule phenolic acids in plants are chemically linked to other substances such as pectin, cellulose, and proteins. Alterations in structure may occur during the drying process [37]. Our findings, along with previous studies, suggest that freeze-drying is often deemed the most effective technique for preserving temperature-sensitive compounds. This is due to the formation of ice crystals within the plant matrix, which can rupture cellular structures, allowing for the release of cellular components. In the context of our study, freeze-drying appears to be a superior method for maintaining the total phenolic, tannin, and flavonoid concentrations in persimmon peel compared to oven-drying.

3.1.3. *DPPH radical scavenging activity*

The half maximal inhibitory concentration (IC_{50}) is a measure of the potency of a substance to inhibit a specific biological or biochemical function. IC_{50} is a quantitative measure of how much of a specific inhibitor (eg drug or plant extract) is required to inhibit a specific biological process or biological component by 50 % *in vitro*. Considering the diversity of plant phenolic compounds and the existence of different mechanisms for the occurrence of antioxidant activity caused by these compounds, the antioxidant activity of dried persimmon peel powder was evaluated in different ways, according to the DPPH free radical scavenging method. Based on the results (Table 1), the IC_{50} value of persimmon peel powder dried by different methods was significantly different from each other ($p < 0.05$). The freeze-dried sample exhibited the lowest IC_{50} value, indicating a superior antioxidant power compared to the oven-dried, vacuum oven-dried, and microwave-dried samples, which displayed higher IC_{50} values. The increase in the antioxidant power of different samples was in line with the increase in the total phenolic content in the samples. In other words, high content of phenolic compounds causes higher antioxidant activity or lower IC_{50}. It is believed that the high amount of phenolic compounds may contribute to greater antioxidant activity [38]. The decline in antioxidant capacity following drying treatment may be attributed to the degradation of phenolic compounds or the loss of antioxidant components in the dried samples [39]. Studies on strawberry [40], blueberry [41], and apple [39] have reported a reduction in antioxidant levels due to thermal treatment. Conversely, in the thermal drying process, the release of oxidative and hydrolytic enzymes that can degrade antioxidants, along with changes in the chemical structure of phenolics, likely resulted in the decrease in total phenolic content and antioxidant capacity [42]. Comparatively, nonthermal freeze-drying produced notably higher total phenolic content and antioxidant capacity than other drying methods, likely due to poor internal heat transfer in the dry product layer and the absence of air during the freeze-drying process [21]. also reported similar results. They stated that the antioxidant capacity of broccoli dried by freeze-dryer method caused a significant decrease in the value of IC_{50} compared to other drying methods, which indicates more antioxidant power in the powder dried by this method. They reported that thermal drying methods can reduce the antioxidant capacity of the dried product. The reason for this can be attributed to the effect of heat on certain components such as ascorbic acids, flavonoids and phenolic compounds that regulate the antioxidant capacity [21]. [43] deduced that the decrease in antioxidant activity of the samples during the thermal drying could be attributed to the oxidative of phenolic compounds and their thermal breakdown. Therefore, maintaining a low temperature and minimizing drying time would be beneficial for preserving the antioxidant activity in products. Mehrania et al. (2019) in the study of the effect of drying method on the antioxidant properties of *Ficus religiosa* fruit stated that the highest antioxidant activity was related to the sample dried by microwave with a power of 700 W, which can be attributed to less time drying and ultimately less degradation of antioxidant materials [44].

3.1.4. Proximate chemical analysis

Chemical analysis of the freeze-dried persimmon peel showed that it contained 38.97 ± 0.84 % crude fibre, 3.02 ± 0.03 % protein, 8.78 ± 0.54 % moisture, 3.87 ± 0.21 % ash and 1.87 ± 0.09 % fat. Comparison of our results with those of other researchers showed similar chemical compositions. The values of moisture, ash, fat, protein and fibre content of freeze-dried persimmon peel were 7.13, 3.64, 2.30, 3.58 and 39.01 %, respectively, which were reported by Ref. [45]. They also reported values of 19.26 % for cellulose, 1.00 % for hemicellulose and 17.20 % for lignin [45].

3.2. Quality parameters of ice cream containing dried persimmon peel powder

Persimmon peel powder dried in a freeze dryer in four concentrations (0, 1, 2, and 3 %wt) was used in ice cream.

3.2.1. Rheological properties

Viscosity is defined as the fluid's resistance to flow and is considered as a very important parameter in selecting the appropriate transfer pump and designing the required equipment [46]. Viscosity also affects the final texture of the product. On the other hand, viscosity has been introduced as an influencing factor on overrun, creaming rate, mass and heat transfer rate, and flow conditions of milk and dairy products [47]. Due to the complexity of the ice cream mixture, rheology is influenced by many factors such as the composition of the mixture and their concentration (such as fat, polysaccharide and protein), hydration phenomenon during the aging time, protein accumulation, fat crystallization, fat accumulation, etc. [48]. As can be seen, the flow behavior of all the ice cream mixes was of the shear thining (Fig. 2). The results showed that at a constant shear rate of 50 s^{-1}, as the concentration of persimmon peel powder in ice cream mixture increased, the viscosity also increased (Table 2). This increase in viscosity is probably due to the increase in fiber and cellulose and hydrophilic compounds concentration of persimmon peel in the mixture [49]. in the study of persimmon ice cream stated that the viscosity values of the ice cream mixture decreased significantly ($P < 0.05$) with the increase in the concentration of persimmon puree in the formulation of the mixture. They inferred that the decrease in viscosity of the fortified ice cream samples may be due to the high water content of persimmon puree [50]. in the evaluation of ice cream containing *Lippia citriodora* stated that ice cream samples containing extract showed higher viscosity than the control treatment. They also attributed this increase in viscosity to the fiber present in the *Lippia citriodora*, which reduces the movement of free water molecules [50]. Other researchers also reported an increase in the viscosity of the ice cream mixture by adding stabilizing compounds and hydrocolloids [51]. observed an increase in

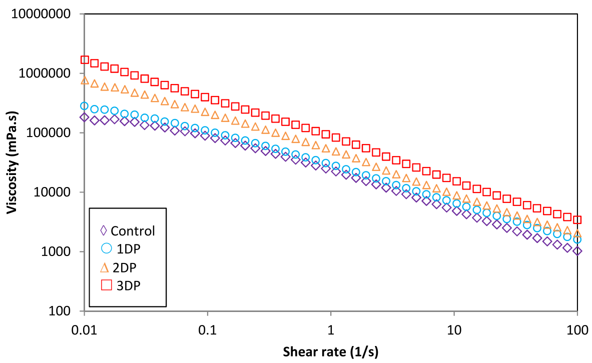

Fig. 2. Rheological curves of ice cream mix at different dried persimmon peel powder contents.

Table 2
Physical properties of ice cream samples.

	Overrun (%)	Hardness (g)	Viscosity at 50 s^{-1} (mPa s)	Melting rate (g/min)	First dipping time (min)	Color parameters		
						L*	a*	b*
Control	95.0 ± 1.0[a]	1825.06 ± 8.74[d]	1628.6 ± 2.6[d]	0.53 ± 0.02[a]	11±0[d]	83.27 ± 0.61[a]	−0.82 ± 0.29[c]	6.63 ± 0.48[c]
1DP	82.7 ± 0.2[b]	1961.23 ± 10.09[c]	2398.3 ± 3.5[c]	0.17 ± 0.02[b]	57±1[c]	73.85 ± 1.08[b]	4.63 ± 1.08[b]	21.14 ± 2.57[b]
2DP	81.0 ± 0.4[b]	2349.34 ± 9.41[b]	3057.5 ± 9.1[b]	–	480±8[b]	71.36 ± 1.34[b]	6.69 ± 1.44[b]	24.58 ± 2.77[b]
3DP	77.6 ± 0.3[c]	2874.31 ± 11.56[a]	5184.1 ± 4.9[a]	–	600 ± 13[a]	66.53 ± 1.30[c]	9.18 ± 1.35[a]	31.99 ± 2.24[a]

Values with different letters are significantly different ($P < 0.05$).

the viscosity of the ice cream mixture containing sodium alginate and xanthan gum and stated that water retention is related to the restriction of the movement of free water molecules by the added hydrocolloids, and as a result, increases the viscosity of the mixture [47]. also stated that with increasing stabilizer concentration, the apparent viscosity also increases. The viscosity of the mixture is related to the reduction of the melting ratio and the increase of the shape retention, both of which are useful for increasing the quality of ice cream [52].

3.2.2. Overrun

In ice cream, overrun refers to the increase in volume due to the introduction of air into the mixture, and it is influenced by various factors, including the type of ingredients in the mixture [53]. The amount of air that enters the ice cream is important for two reasons: 1) its relationship with efficiency and, as a result, profitability, and 2) its effect on the texture, body, and acceptability of ice cream [16]. Too little overrun causes too much coldness in the mouth, lack of creaminess and lack of a pleasant mouthfeel. If the overrun is too high, the ice cream will have a frothy state. Most countries report the allowable overrun range as 100 % [46]. stated that the overrun in soft frozen dairy desserts is usually 50 % and for hard frozen desserts 90–100 % (this difference is related to the total solid matter, which is 30–35 % for soft frozen desserts and for hard frozen desserts are 36–40 %. The results of this research showed that with increasing the dried persimmon peel powder, the overrun decreased significantly ($p < 0.05$) (Table 2). Since in this research, the content of persimmon peel powder is used as the variable factor, therefore, the observed changes in overrun should be justified from the changes caused by applying this ingredient. Therefore, the reduction of overrun can be attributed to the increase in fiber content in ice cream samples with an increase in the persimmon peel powder content [54]. reported that the amount of fiber in different cultivars of persimmon peel is between 8.93 and 15.02 %wt. In addition, the decrease in the overrun of the samples with the increase in the persimmon peel powder content can be attributed to the increase in viscosity in these samples. One of the main roles of stabilizers is to increase overrun by increasing viscosity and maintaining air bubbles [55]. But such a trend was not observed in this study. The reason for such results can probably be attributed to the ineffectiveness of the ice cream maker used in combining air and stirring the mixture and the long time required to freeze the ice cream mixtures. A similar result was also reported by Ref. [47]. [56] has also pointed out the problems of increasing overrun in small amounts for soft and semi-soft ice creams produced in non-continuous ice cream makers.

Fig. 3. Produced ice cream samples; from right to left, respectively: control, 1DP, 2DP, 3DP.

3.2.3. Color measurements

Color is the first sensory characteristic observed by the consumer and the most important qualitative characteristic of food products. Color parameters affect the marketability of products and consumer acceptance, even though functional foods are known as health-enhancing foods, without visual appeal for consumers, they cannot have proper marketability. Therefore, the color of the enriched product is very important [57]. Some pictures of the produced ice cream samples are presented in Fig. 3.

As can be seen (Table 2), with the increase in the persimmon peel powder content in ice cream, the L* parameter decreased, while a* and b*, which respectively express the degree of redness and yellowness of the product, increased ($P < 0.05$). In general, the addition of compounds that affect the consistency of dairy products will change the results of the color evaluation test. Because the presence of persimmon peel powder, in addition to creating a higher consistency and creating a gel-like network, will cause light refraction and decrease the L* index in the final product [49]. also reported in the study of ice cream containing persimmon puree that the addition of persimmon puree caused a significant change in the color of the final ice cream product.

3.2.4. Textural analysis

Texture is one of the main characteristics in foods that affects consumer acceptance [58,59]. The results showed that there was a significant difference in the hardness of the ice cream texture in different treatments ($p < 0.05$) and it increased from 1825.063 g to 2874.316 g by increase in the concentration of dried persimmon peel powder (0–3 %wt) in ice cream formulation (Table 2). Hardness may be a reflection of the constituents of the blend (fat, protein, sweetener, and hydrocolloids) and process conditions (homogenization, freezing, and aging) of the final frozen product. In fact, the compounds that create the network that lead to hardness and also increase the viscosity in the ice cream mixture, will also intensify the cohesion in many cases [60]. In addition, another reason for the hardness of the ice cream may be attributed to overrun. It has been stated that less overrun of ice cream will increase its hardness, because the presence of less air in the continuous network of ice cream makes it more resistant to the penetration of the probe of the texture analyser device and its spoonability decreases [46]. [50] also reported similar results. They have stated that the addition of *Lippia citriodora* to ice cream has led to an increase in the hardness of ice cream.

3.2.5. Melting behavior

The quality of proper melting in ice cream is very important. Because if the ice cream melts too quickly, it loses its ability to eat properly. In addition, such a product is easily exposed to thermal shock. Of course, in contrast to shock, too slow melting is considered a defect in ice cream [61]. The low melting rate of ice cream is especially important for countries with tropical climates (Favaro--Trindade et al., 2007). The results of the ice cream melting test showed that the resistance to melting in ice cream increased with the increase in the concentration of persimmon peel powder (Table 2). So that in the samples containing 2 and 3 % wt persimmon peel powder, the melting of the first drop occurred in 28800 and 36000 s, respectively. The reason for this high melting resistance can be attributed to the presence of compounds that have more water retention and the ability to create viscosity [49]. reported that the addition of persimmon puree caused a significant increase in the melting time of the samples. They stated that the control ice cream sample melted after 3390 s at 25 °C and the sample containing 40 % persimmon puree after 4155 s [62]. also reported that the melting resistance of ice cream samples containing yellow mombin was higher than the control sample [63]. also reported an increase in the melting time of Cape gooseberry ice cream with increasing gooseberry concentration. They stated that the increase in melting time could be due to some components in gooseberry that have the ability to absorb water. It can be said that because persimmon peel has a lot of fiber [9], it can absorb water and delay the melting of ice cream. In a general view, the decrease in melting rate of ice cream can be attributed to the increase in viscosity and stability of mixed ice cream emulsion. Therefore, it can be said that all the mechanisms that increase the viscosity and stability of the emulsion affect the melting rate of ice cream. It is also believed that the solutes increase the stability of the emulsion by increasing its resistance to melting, thus allowing more time for water to flow from the inside to the outside of the ice cream during this phase, and then drip through the metal mesh holes used to test the melting of ice cream (BahramParvar et al., 2011). In the current study, this could be one of the reasons for our ice creams' high melting resistance. Furthermore, a number of proteins interact with phenolic compounds and affect milk product properties [64]. Several studies have demonstrated that proteins can bind to phenolic compounds [65–74]. Protein structure can be altered by phenolic compounds binding to proteins,

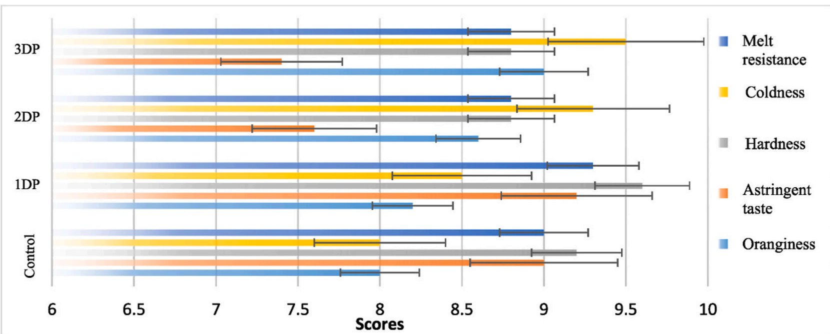

Fig. 4. Sensory characteristics of ice-cream samples.

thus affecting availability of certain amino acids [75]. It has been found that phenolic compounds can function as a bridge between proteins and form large networks. This protein–phenolic network forms a gel that traps some compounds within it. Phenolic compounds also form a gel when added to ice-cream formulations, and this gel is strong enough to hold fat cells, air bubbles, and ice crystals even after high temperatures are applied. The gel structure retains the product properties even after the entire ice portion of the sample melts [76]. As a result, the decrease in the rate of melting when persimmon peel powder is added might also be attributed to the existence of phenolic compounds.

3.2.6. Organoleptic attributes

Undoubtedly, the perception of the texture and taste of ice cream is the biggest factor determining acceptance by consumers [51]. Most people enjoy ice cream because of its sensory attributes, such as sweet taste, smoothness, texture, and a pleasant cold sensation [46]. The results of the sensory evaluation of the ice cream samples in this study showed that regarding the color, the highest score was obtained in the samples containing persimmon peel powder (respectively in the sample containing 3 %, 2 % and 1 % persimmon peel powder) (Fig. 4). The color properties of the samples changed slightly and the color of the samples was favorable with increasing the concentration of persimmon peel powder compared to the non-enriched samples, due to a significant positive change in the color of the ice cream compared to the control color [49]. also stated that the addition of persimmon puree developed the sensory properties of the ice cream and increased the acceptability of the product compared to the non-enriched ice cream sample. Taste score, is one of the most important sensory criteria for a product. As can be seen, by adding persimmon peel powder to the ice cream, the taste desirability score of astringent taste increased (Fig. 4). But it decreased significantly in higher concentrations (2 and 3 %) ($P < 0.05$). In other words, related to the astringent taste item, the sensory evaluators understood well this taste that is created due to the presence of tannins, and in this parameter, the control following 2 % samples got the highest score. Increasing the concentration of persimmon peel powder caused melting resistance, which was confirmed by the scores of sensory evaluators. In terms of hardness and melt resistance, the highest scores were obtained for the sample containing dried persimmon peel. The lack of large differences in many scores in the use of persimmon peel powder in ice cream and even the high score in some parameters indicate the suitability of this combination for ice cream formulation.

4. Conclusion

The results of the present study showed that the drying method has a significant effect on the total phenolic content, antioxidant activity and color of peel persimmons. Based on the results, the highest value of L* parameter, amount of phenolic compounds and antioxidant power was observed in the freeze-dried sample.The results showed that persimmon peel powder can be used well for ice cream formulation. Of course, the important point in using this combination is that due to the astringent taste, its consumption is recommended to the extent that it does not cause adverse effects. By considering the appropriate concentration of persimmon peel, a suitable combination of ice cream with favorable quality characteristics and high melting resistance can be achieved, especially for the residents of tropical regions. So, the persimmon peel has the potential to be used as an added-value ingredient in the ice cream industry to enhance ice cream's functional properties.

Ethics statement

Before enrolling in the study, all participants provided informed consent, and all procedures were conducted in compliance with ethical standards.

Consent for publication

All authors have read and agreed to the published version of the manuscript. All authors read and approved the final manuscript.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

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Sample code: Date: Panelist.

Definition for each attribute

Attribute	Definition
Oranginess	Evaluation of the intensity of a color similar to that of persimmon fruit

(*continued on next page*)

(*continued*)

Attribute	Definition
Coldness	A chilling of the tongue and palate soon after the sample is placed in mouth
Firmness	Resistance against scooping a portion of ice cream
Astringent taste	Taste of tea, tannin, dry-mouthfeel sensation
Melt resistance	The time required for ice cream to turn into liquid

Oranginess.
Weak Strong.

0	1	2	3	4	5	6	7	8	9	10

Coldness.
Weak Strong.

0	1	2	3	4	5	6	7	8	9	10

Hardness.
Weak Strong.

0	1	2	3	4	5	6	7	8	9	10

Astringent taste.
Weak Strong.

0	1	2	3	4	5	6	7	8	9	10

Melt resistance.
Weak Strong.

0	1	2	3	4	5	6	7	8	9	10

☐ I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and without cost.

CRediT authorship contribution statement

Mahdi Yosefiyan: Writing – original draft, Software, Methodology, Investigation. **Elham Mahdian:** Writing – review & editing, Validation, Supervision. **Arefeh Kordjazi:** Writing – original draft, Software, Resources, Methodology, Investigation. **Mohammad Ali Hesarinejad:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Methodology, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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