Foods and Raw Materials. 2024;12(2)

ISSN 2308-4057 (Print)
ISSN 2310-9599 (Online)

Research Article
Open Access

Available online at http://jfrm.ru/en
https://doi.org/10.21603/2308-4057-2024-2-605
https://elibrary.ru/FZWHVH

Effect of drying agents on quality parameters of lyophilized persimmon purée powder

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Received 27.03.2023; Revised 14.08.2023; Accepted 05.09.2023; Published online 20.11.2023

Abstract:
Persimmon juice has good nutritional composition and high antioxidant properties, however it requires more packing space because of large volume and has limited shelf-life. The research objective was to produce persimmon purée powder with prolonged shelf-life by using various concentrations of drying agents (maltodextrin and Arabic gum).

The control sample was persimmon purée powder without drying agents. Experimental samples included powders with maltodextrin (40, 45, and 50%), Arabic gum (25, 30, and 35%), and the mix of maltodextrin (40%) and Arabic gum (10%). All the experimental samples contained 1% of tri-calcium phosphate as an anti-caking agent. Tests were carried out according to the standard techniques.

The samples with 45 and 50% of maltodextrin had lower moisture, ash, redness (*a**), and hygroscopicity values. These powders demonstrated good yield, solubility, density, and color indices (*L**, *b**, C, H). The persimmon purée powders with 30 and 35% of Arabic gum showed an increase in ash content and total acidity. The samples with 30% of Arabic gum obtained the highest sensory evaluation scores.

The optimal results belonged to the samples of lyophilized persimmon purée powder with 45% of maltodextrin, which will have a longer shelf-life due to its low moisture content.

Keywords: Persimmon puree powder, lyophilization, maltodextrin, Arabic gum, chemical and physical indicators, color indicators

Funding: This research is part of a PhD thesis prepared at Damascus University, Syria, which supplied raw materials and laboratory equipment. The study received no support from any funding agencies.

Please cite this article in press as: Saeed AR, Kheir Tahle MA, Tlay RH. Effect of drying agents on quality parameters of lyophilized persimmon purée powder. Foods and Raw Materials. 2024;12(2):256–263. https://doi.org/10.21603/2308-4057-2024-2-605

INTRODUCTION

Fruits and vegetables are an important component of human diet as they are known to reduce the risk of some chronic diseases [1, 2]. Persimmon (*Diospyros kaki* L.) has excellent sensory and nutritional properties, is a source of minerals, carbohydrates, dietary fiber, ascorbic acid, and tannins, not to mention its powerful antioxidant activity [3].

Persimmon fruit contains 76.83% of moisture; its fiber content reaches 13.5% while fats and proteins stay between 0.05% and 1.32%. In addition, 100 g of permon contains 15.60 mg of ascorbic acid [4]. Persimsimmons are a rich source of sugars (12.5 g/100 g wet weight), represented by glucose, fructose, and sucrose [5]. Unfortunately, persimmon fruits have a short shelf-life and require sophisticated preservation techniques to reduce post-harvest losses and develop new products [6]. Nevertheless, persimmons have recently become a popular subject of food science because of their antioxidant, anti-atherosclerosis, and anti-tumor properties [7].

Persimmon juice powder is part of beverage formulations and can serve as a secondary ingredient in confectionary products or baby food. Contemporary studies feature a lot of fruit juice powders, e.g., concentrated apple juice [8]. Modern methods of fruit powder production, e.g., lyophilization, can open persimmon purée powder the way to the global food market.

Lyophilization is currently one of the most important drying methods because it requires low operating temperatures, which reduces thermal damage, thus preserving the flavor and color indicators of the final product [9]. Lyophilization removes water by converting it first into ice crystals and then into steam. This process includes three stages: freezing, primary drying, and secondary drying. During the freezing stage, the fruit mass turns into solid ice crystals. At the primary drying stage, the ice is removed by sublimation. The secondary drying process means removing the bound and residual water until the required moisture content [10].

Lyophilization yields dried products of high nutritional quality, which are easy to transport, consume, and store. This method maintains high standards of reliability and quality, which makes it possible to preserve vitamins and antioxidants [11].

Dubkova *et al*. wrote that lyophilization products can be used in a wide range of food industries and in a variety of ways; e.g., dairy powders can be part of fast-soluble sauces and desserts due to their low weight and the small size of particles [12].

Fruit powders have many economic advantages over fresh juices, e.g., low weight and volume, less packing space, easy logistics, extended shelf-life, etc. [13].

However, the complex chemical composition of fruit juices limits their powdering options. The problem is that fruit juices contain organic acids, e.g., citric acid, malic acid, tartaric acid, etc., as well as low molecular weight sugars, e.g., glucose and fructose. As a result, they have a low glass transition temperature, which leads to high viscosity, extra hygroscopicity, and low solubility of the resulting powder because viscosity directly affects its fluidity and flowability. Drying agents, such as maltodextrin and gum, can solve this problem [14].

Arabic gum is a dried exudate obtained from acacia trees. The substance owes its wide pharmaceutical and industrial uses to its emulsifying properties. Arabic gum is a complex sugar composed of molecules of calcium, magnesium, and potassium with such sugars as arabinose and galactose. It has a mild taste and no smell [15].

Maltodextrin is a product of starch degradation, which consists of β-D-glucose units. It has high solubility and a pleasant flavor. Maltodextrin is cheap and commercially available, which explains its popularity in the food industry [16, 17].

The season of persimmon fruits is as short as three months, and fresh fruits are difficult to preserve [18]. Sucrose, glucose, and fructose have low molecular weight and low glass transition temperature of 62, 32, and 5°C, respectively [19]. These properties make it difficult to convert persimmons into a powder state. This research featured different concentrations of drying agents with a high glass transition temperature and their effect on powder viscosity, productivity, and agglomeration. We also revealed the quality standards of persimmon purée powder prepared by lyophilization method.

STUDY OBJECTS AND METHODS

The study involved fresh persimmons (*Diospyros kaki* L.). Their chemical composition was as follows: 81.31% of moisture, 0.11% total acidity, pH 6.17, 0.72% ash, and 12.64 g total sugar (100 g wet weight). The fruits were purchased at a local market in the city of Damascus. The research was conducted at the laboratories of the Department of Food Sciences, University of Damascus, in November and December during the ripening season of 2022. Each experiment included 2 kg of persimmon fruit.

Pre-treatment. After removing damaged fruits and impurities, we washed the persimmons in plain water and peeled them with a sharp knife. The peeled fruits were mashed in an electric mixer (Starway 4550D, China) for 3 min.

The persimmon purée was divided into several samples. Sample № 1 served as control and involved pure persimmon purée without any drying agents. Sample № 2 contained persimmon purée with maltodextrin at the concentrations of 40, 45, and 50% plus 1% tri-calcium phosphate as an anti-caking agent. Sample № 3 included persimmon purée with Arabic gum at the concentrations of 25, 30, 35% plus 1% tri-calcium phosphate as an anti-caking agent. Each sample was homogenized separately for 3 min using a mixer (Starway 4550D, China) [20, 21].

Freeze-drying. The persimmon purée mixes underwent drying by the freeze-drying method. After adding drying agents, each sample was frozen at –4°C, then processed in the laboratory lyophilization device at –60°C and a pressure of 0.11 mbar [22]. After that, we ground the dried samples in a mixer (Starway 4550D, China) for 3 min and stored the resulting powder in dark glass containers until further analysis.

Moisture content. The moisture content was determined in line with the method described in Article 925.09 of the Official Methods of Analysis of the Association of Official Analytical Chemists [23]. The samples were dried in a drying oven (Memmert D 91126, Germany) at 105°C until constant weight.

Ash content. We estimated the ash content in line with the method described in Article 923.03 of the Official Methods of Analysis of the Association of Official Analytical Chemists [23]. The samples were dried at 550°C until constant weight.

pH. The acidity was estimated using a pH-meter (Precisa PH-900).

Total acidity. The total acidity was measured by titration with 0.1 N sodium water in the presence of a phenolphthalein indicator [23].

Total sugars. Total sugars were defined according to the Lane-Enyon method as in [23].

Color indices. The color indices (L*, a*, b*, C, H) were mapped using a Hunter Lab tool kit (Biobase, China): L* (lightness) – the level of light to dark; a* (red to green) – positive a^+ indicates red; negative a^- indicates green; b* (yellow to blue) – positive b^+ indicates yellow; negative b^- indicates blue; C – color intensity; H (hue angle) – hue angles of 0, 90, 180, and 270° refer to pure red, pure yellow, pure green, and pure blue, respectively [24].

Process yield. The process yield, %, was determined in line with the equation described by Shuen *et al.* [25]:

$$\text{Yield} = \frac{\text{Dried powder}}{\text{Persimmon purée} + \text{Drying agents}} \quad (1)$$

Water solubility index. We defined the water solubility as in [26]: 1 g of persimmon purée and 10 mL of distilled water were mixed and incubated in a water bath at 37°C for 30 min, then centrifuged for 10 min. After that, we placed the floating part of the juice in Petri dishes of known weight and dried in a drying oven (Memmert D 91126, Germany) at 105°C until constant weight. The solubility of the powder was calculated as the difference in weights.

Hygroscopicity. We determined the hygroscopicity according to the method described by Šavikin *et al.* [27]. We put 1 g of persimmon purée in a petri dish with a saturated solution of sodium chloride with a relative humidity of 75.35% and stored the samples at room temperature for 7 days. The hygroscopicity was expressed as 1 g of absorbed moisture per 100 g dry solids.

Bulk and true density. We followed Igual *et al.* to measure the true and bulk density by placing 2 g of powder sample in a graduated cylinder [28]. The bulk density, g/cm^3, was obtained according to the following Eq. (2):

$$\text{Bulk density} = \frac{\text{Powder weight}}{\text{Powder volume}} \quad (2)$$

After determining the bulk density, the cylinder stayed on a vibrating device until the volume of the powder changed. The density (TRUE, g/cm^3) was calculated according to the following Eq. (3):

$$\text{TRUE} = \frac{\text{Powder weight}}{\text{True volume}} \quad (3)$$

Sensory evaluation. The sensory evaluation involved a group of panelists who used a five-point hedonic scale to evaluate the color, taste, aroma, appearance, and overall acceptability of the persimmon juice reconstituted from the powder samples [29]. The sensory tests featured only the samples with 45% of maltodextrin, 30% Arabic gum, and the mix of maltodextrin (40%) and Arabic gum (10%) because they had a better quality from a physical point of view, i.e., degree of solubility, hygroscopicity, yield, and density.

Statistical analysis. The analysis of variance involved the SPSS software, where the results were analyzed using the One-Way ANOVA test followed by the LSD test to determine the significant differences between the means at a 5% confidence level. The results were recorded as means ± standard deviation.

RESULTS AND DISCUSSION

Effect of drying agents on chemical indicators of lyophilized persimmon purée powder. Table 1 demonstrates the data obtained for moisture, ash, pH, total acidity, and content of total sugars. The measurements clearly indicate a significant effect of the drying agents on the moisture content in the powder. The experimental samples with high concentrations of maltodextrin and Arabic gum showed a significant decrease in the moisture content compared to the control. The lowest total moisture values belonged to the powders with 45 and 50% of maltodextrin, 30 and 35% Arabic gum, and the mix of maltodextrin (40%) and Arabic gum (10%). The moisture contents for these samples were as low as 10.36, 9.33, 10.37, 10.00, and 9.41%, respectively. The concentration of the drying agents added to the purée before the lyophilization increased the percentage of solids, which led to a decrease in the total volume of moisture to be evaporated [30]. The results are consistent with those obtained by Cid-Ortega *et al.*, who added Arabic gum and maltodextrin to powdered *Hibiscus sabdariffa* [31].

The samples with Arabic gum were significantly superior to those with maltodextrin in terms of ash content, which was in the range of 4.20–4.42 g/100 g dry weight, respectively. The ash contents in the samples with maltodextrin were from 1.45 to 2.40 g/100 g dry weight, respectively, while the indicator for the control sample was 2.99. Ali *et al.* reported that maltodextrin contained no minerals [32]. However, Kurniadi *et al.* mentioned that adding Arabic gum increased the ash content in the final product because of its high concentrations of calcium, magnesium, and potassium [33].

Table 1 also illustrates a drop in the pH of the powder with Arabic gum: the sample with 35% of Arabic gum had the lowest pH of 5.85. The samples with various

Table 1 Effect of drying agents on chemical indicators of lyophilized persimmon purée powder

Chemical composition		Moisture, %	Ash, g/100 g dry weight	pH	Total acidity, %	Total sugars, g/100 g dry weight
Control		13.49 ± 0.51^{b}	1.59 ± 0.25^{ab}	5.54 ± 0.02^{a}	0.37 ± 0.05^{ad}	78.19 ± 0.23^{f}
Persimmon puree with Arabic gum	25%	12.33 ± 0.33^{b}	4.35 ± 0.29^{c}	6.07 ± 0.01^{b}	0.31 ± 0.02^{ac}	57.07 ± 0.63^{d}
	30%	10.00 ± 0.57^{a}	4.42 ± 0.29^{c}	6.03 ± 0.02^{b}	0.35 ± 0.03^{a}	50.66 ± 0.33^{b}
	35%	10.37 ± 0.31^{a}	4.20 ± 0.19^{c}	5.85 ± 0.08^{c}	0.44 ± 0.03^{d}	47.66 ± 0.66^{a}
Persimmon puree with maltodextrin	40%	12.76 ± 0.24^{b}	2.40 ± 0.15^{ab}	6.35 ± 0.02^{d}	0.19 ± 0.02^{b}	63.06 ± 0.51^{e}
	45%	10.36 ± 0.31^{a}	2.08 ± 0.11^{ab}	6.33 ± 0.03^{d}	0.22 ± 0.03^{be}	55.32 ± 0.45^{c}
	50%	9.33 ± 0.72^{a}	1.45 ± 0.16^{a}	6.27 ± 0.03^{d}	0.28 ± 0.02^{ba}	49.54 ± 0.86^{b}
Persimmon puree with a mix of maltodextrin and Arabic gum	40:10%	9.41 ± 0.30^{a}	2.99 ± 0.27^{b}	6.25 ± 0.02^{d}	0.31 ± 0.06^{ac}	55.19 ± 0.26^{c}

Similar letters in the same column indicate that there were no significant differences at $p > 0.05$

concentrations of maltodextrin and the mix of maltodextrin and Arabic gum demonstrated no significant differences in pH values. In [34], Arabic gum also proved more effective in decreasing pH than maltodextrin because Arabic gum initially had a lower pH (4.64) than maltodextrin (5.16).

The total acidity was higher in the sample with 35% of Arabic gum, reaching 0.44%, while the samples with maltodextrin resulted in 0.19–0.28% total acidity, respectively.

The increasing concentration of both drying agents decreased the values for total sugars. Grabowski *et al.* reported a similar effect of maltodextrin on the total sugars in sweet potato powder [35].

Effect of drying agents on color indicators of lyophilized persimmon purée powder. Table 2 sums up the obtained values of color indicators. Lightness index L^* increased together with the concentration of the drying agent. The samples with high amounts of the drying agents, namely the powders with 50% of maltodextrin and 35% of Arabic gum demonstrated the highest lightness values, 50.33 and 46.56, respectively. The powders with maltodextrin had superior lightness values compared to those with Arabic gum because maltodextrin is white [36]. The obtained results for the lightness value were consistent with those reported by Suravanichnirachorn *et al.* [37].

As for indicator a^* (red to green), Table 2 shows a significant decrease in the samples with high concentrations of the drying agents. In the sample with 50% maltodextrin, a^* equaled 8.62 whereas the sample with 35% of Arabic gum had 9.05. Such results could be explained by the low concentration of persimmon purée [38].

The value of indicator b^* (yellow to blue) increased together with the concentration of maltodextrin: its highest value reached 45.21 in the sample with 50% maltodextrin. No significant differences in the b^* values were recorded for the samples with Arabic gum compared to the control.

Color intensity C increased following the concentration of maltodextrin, its highest value was in the sample with 50% ramaltodextrin (46.22). The C values decreased as the concentration of Arabic gum rose. The results are similar to those reported in [37].

Hue index H increased together with the concentration of the drying agent. The increase in the color gradient angle indicated that the red color of the powders turned yellow. The results were similar to those obtained by Shishir *et al.*, who reported an increase in the hue value at higher concentrations of maltodextrin [39].

Effect of drying agents on some physical parameters of lyophilized persimmon purée powder. The physical properties of powders depend on many factors, i.e., the drying method used, the drying temperature, and the type and concentration of the agent [40].

Table 3, which sums up the physical profiles of the persimmon powders, shows that a higher concentration of the drying agent caused a significant increase in the yield of persimmon purée powder. The highest yield belonged to the sample with 45 and 50% of maltodextrin: 28.93 and 28.86%, respectively. The sample with the mix of maltodextrin and Arabic gum reached a similar value of 29.33. Adetoro *et al.* also reported that maltodextrin had a greater effect on the yield rate than Arabic gum [41]. In general, powder yield is one of the most important physical indicators in terms of production process and economic efficiency [42].

The solubility index is an important property of powders because it is used as a standard to determine the solubility of a powder in water [43].

The solubility index of the powders rose together with the concentration of the drying agent. Its value increased from 90.92% in the control powder sample to 97.71 and 97.66% in the samples with 45 and 50% of maltodextrin, respectively. The samples with maltodextrin had a greater solubility compared to those with Arabic gum because maltodextrin is highly soluble in water [37].

Hygroscopicity is the ability of powder to attract water molecules from the environment. Fruit powders are highly hygroscopic because they contain glucose and fructose, which have polar ends. This property allows them to interact with water molecules, which increases the hygroscopicity of the product. Low hygroscopicity is important to maintain because it increases the stability of the final product [44].

In our case, the hygroscopicity index decreased when the concentration of the drying agent increased. It dropped to 5.19 and 5.51% in the samples with 45 and 50%

Table 2 Effect of drying agents on color indicators of lyophilized persimmon purée powder

Color		L^*	a^*	b^*	C	H
Control		20.51 ± 0.75^{a}	27.31 ± 0.36^{e}	24.39 ± 0.30^{a}	36.49 ± 0.26^{c}	41.55 ± 0.29^{a}
Persimmon puree with Arabic gum	25%	25.73 ± 0.16^{c}	16.64 ± 0.32^{bc}	23.28 ± 0.21^{a}	28.74 ± 0.37^{b}	53.91 ± 0.30^{c}
	30%	25.51 ± 0.33^{c}	17.60 ± 0.30^{c}	24.03 ± 0.57^{a}	29.83 ± 0.45^{b}	53.49 ± 0.36^{c}
	35%	46.56 ± 0.29^{d}	9.05 ± 0.15^{a}	24.89 ± 0.51^{ab}	26.30 ± 0.46^{a}	70.14 ± 0.48^{e}
Persimmon puree with maltodextrin	40%	22.92 ± 0.54^{b}	23.56 ± 0.29^{d}	26.66 ± 0.24^{b}	35.41 ± 0.30^{c}	47.62 ± 0.31^{b}
	45%	47.17 ± 0.59^{d}	17.01 ± 0.54^{bc}	41.52 ± 0.28^{d}	44.93 ± 0.56^{e}	67.72 ± 0.41^{d}
	50%	50.33 ± 0.33^{e}	8.62 ± 0.31^{a}	45.21 ± 0.38^{e}	46.22 ± 0.40^{e}	70.67 ± 0.30^{e}
Persimmon puree with a mix of maltodextrin and Arabic gum	40:10%	41.93 ± 0.58^{f}	15.77 ± 0.22^{b}	35.55 ± 0.33^{c}	38.90 ± 0.34^{d}	66.71 ± 0.25^{d}

Similar letters in the same column indicate that there were no significant differences at $p > 0.05$

Table 3 Effect of drying agents on some physical indicators of lyophilized persimmon purée powder

Physical indicator		Yield, %	Water solubility, %	Hygroscopicity, %	Bulk density, g/cm^3	True bulk density, g/cm^3
Control		10.88 ± 0.20^a	90.92 ± 0.30^a	15.33 ± 0.33^e	0.25 ± 0.02^a	0.33 ± 0.05^a
Persimmon puree with Arabic gum	25%	20.33 ± 0.33^b	94.50 ± 0.28^b	13.14 ± 0.45^d	0.29 ± 0.03^a	0.33 ± 0.03^a
	30%	26.30 ± 0.65^c	93.97 ± 0.20^b	10.33 ± 0.33^c	0.44 ± 0.02^b	0.48 ± 0.01^{ab}
	35%	26.33 ± 0.33^c	94.33 ± 0.33^b	7.33 ± 0.33^b	0.44 ± 0.02^b	0.48 ± 0.02^a
Persimmon puree with maltodextrin	40%	21.33 ± 0.42^b	94.58 ± 0.34^b	8.46 ± 0.29^b	0.27 ± 0.01^a	0.33 ± 0.03^b
	45%	28.93 ± 0.54^d	97.71 ± 0.28^c	5.19 ± 0.42^a	0.47 ± 0.01^b	0.55 ± 0.06^b
	50%	28.86 ± 0.50^d	97.66 ± 0.33^c	5.51 ± 0.28^a	0.46 ± 0.05^b	0.54 ± 0.02^b
Persimmon puree with a mix of maltodextrin and Arabic gum	40:10%	29.33 ± 0.33^d	96.98 ± 0.56^c	4.50 ± 0.28^a	0.43 ± 0.03^b	0.48 ± 0.05^{ab}

Similar letters in the same column indicate that there were no significant differences at $p > 0.05$

Table 4 Effect of drying agents on sensory properties of juices reconstituted from lyophilized persimmon purée powder

	Taste	Color	Aroma	Appearance	Overall acceptability
Control	2.04 ± 0.40^a	1.33 ± 0.33^a	2.03 ± 0.22^a	1.33 ± 0.33^a	1.80 ± 0.19^a
Persimmon puree with 45% maltodextrin	3.34 ± 0.33^{bc}	3.02 ± 0.28^b	3.23 ± 0.42^a	2.42 ± 0.29^b	3.01 ± 0.15^b
Persimmon puree with 30% Arabic gum	4.33 ± 0.33^c	4.57 ± 0.29^c	3.26 ± 0.33^a	4.09 ± 0.20^c	4.42 ± 0.29^c
Persimmon puree with a mix of maltodextrin and Arabic gum (40:10%)	2.71 ± 0.45^{ab}	2.42 ± 0.25^b	2.96 ± 0.50^a	2.33 ± 0.33^b	2.07 ± 0.30^a

Similar letters in the same column indicate that there were no significant differences at $p > 0.05$

of maltodextrin, respectively, and to 4.50% in the mix of maltodextrin and Arabic gum, compared to the control, where it was 15.33%. The powders with maltodextrin had lower hygroscopicity values compared to those with Arabic gum, because maltodextrin has a higher glass transition temperature [41]. In addition, Arabic gum contains free hydroxyl groups that can bind water molecules more easily [45].

Bulk density is one of the most important physical properties for storage, packaging, and transportation of food powders. Powders with high density are more commercially advantageous because they reduce shipping and storage costs [19].

The drying agents had a significant effect on the bulk density of the persimmon powders. The samples with 45 and 50% of maltodextrin had the highest bulk density values, which amounted to 0.47 and 0.46 g/cm, respectively. No significant differences in the bulk density were registered between the samples with 30 and 35% of Arabic gum, 45 and 50% of maltodextrin samples, and the mix of maltodextrin and Arabic gum. The results are consistent with those obtained by Nthimole *et al.* [43].

Table 3 demonstrates a significant effect of the drying agents on the true density values of the persimmon powders. The samples with 45 and 50% of maltodextrin showed the highest true density values.

Effect of drying agents on sensory properties of lyophilized persimmon purée powder. Table 4 summarizes the results of the sensory evaluation of persimmon juice reconstituted from the lyophilized powders. The type of drying agent had a significant effect on the taste of the final product. The juice prepared from the powder with 30% of Arabic gum had the best score for taste, followed by juice samples prepared from the maltodextrin samples. The lowest score belonged to the samples prepared from the powder with the mix of maltodextrin and Arabic gum and the control sample. In terms of color, appearance, and overall acceptability, the juice prepared from powder with 30% of Arabic gum achieved the highest scores for acceptance, followed by the sample with 45% of maltodextrin. The scores for aroma demonstrated no significant differences between the control and the experimental samples: the drying agents had no aroma which could affect the sensory profile of the final product [46].

CONCLUSION

Drying agents with a high glass transition temperature proved effective in the production of high-quality persimmon purée powder.

The lyophilized powders with 45 and 50% of maltodextrin had a much lower moisture content, redness (a*), and hygroscopicity, as well as greater color indicators L*, b*, C, and H. These samples also demonstrated good yield rate, solubility index, and true and apparent density. The samples with 30% of Arabic gum had a high ash content and better sensory characteristics compared to the other samples.

Maltodextrin at a concentration of 45% with 1% anti-caking agent could be recommended for commercial use because it improved the physical properties of persimmon purée powder and reduced its moisture content, thus increasing its shelf-life.

CONTRIBUTION

All authors participated equally to the research and the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interests regarding the publication of this article.

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