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Evaluation of Beverage Powder Produced from Apricot Puree and Carrot extract by Foam-Mat DryingMethod

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ABSTRACT

The purpose of this research was to produce a beverage powder from apricot puree and carrot extract using the foam mat method and to investigate the physicochemical and sensory properties of the produced powder. First, a mixture of carrot extract, apricot puree and cardamom extract was prepared and then some chemical properties of the resulting mixture were measured. To prepare foam from this mixture, apricot, carrot and cardamom extracts were combined with each other with a ratio of 68:28.5: 0.5%. 3% albumin was used as a foaming agent and maltodextrin was used at 0, 10 and 20% levels as a foam stabilizer. The prepared foams were dried by two methods, freezing and hot air. The physicochemical and sensory characteristics of the prepared powders were measured. The drying method had a significant effect on the moisture content, antioxidant capacity, total phenol, beta-carotene content and sensory characteristics. While powder solubility, browning index were not affected by the drying method. Powders dried by foam mat-freezing method had more moisture content, beta-carotene compared to powders dried by hot air method. In samples dried by hot air method, phenol content, antioxidant capacity, and sensory characteristics were higher than samples of powders dried by foam mat freezing method. With increasing maltodextrin concentration, browning index, beta-carotene content, phenol content, antioxidant capacity and sensory characteristics decreased. Maltodextrin concentration had no significant effect on powder solubility. In addition, the 0% hot air maltodextrin treatment has relative superiority in sensory evaluation. In general, the results indicated that the powder produced by both foam mat freezing and hot air methods had acceptable physicochemical characteristics.

1- Introduction

Apricot (*Prunus armeniaca*) belongs to the Rosaceae subfamily Prunoideae [1]. Apricots contain abundant antioxidant compounds, including carotenoids, flavonoids, and lycopene. The phenolic compounds in apricots include catechin, epicatechin, p-coumaric acid, caffeic acid, ferulic acid, and their esters [2]. Apricots contain organic acids like malic and citric acid and serve as a rich source of beta-carotene, which acts as a precursor to vitamin A [3]. Dark orange apricots contain higher levels of beta-carotene. Due to their beta-carotene content, apricots help reduce the risk of heart disease, stroke, cataracts, and certain cancers. They also protect the skin from UV radiation, promoting rejuvenation [4].

The carrot (*Daucus carota L.*) is an edible root vegetable and biennial plant from the Apiaceae family that historically grew wild in Asia and Europe [5]. The edible part of the carrot is its fleshy storage root, which comes in various colors, including yellow, red, orange, purple, and white. Orange carrots typically contain 45-80% beta-carotene and some alpha-carotene. Red carrots contain significant amounts of lycopene and tiny amounts of beta-carotene. Purple carrots have a carotenoid composition similar to orange carrots, but dark anthocyanins mask orange. White carrots lack any pigmentation [6].

Cardamom (*Elettaria cardamomum*) belongs to the ginger family and is a tropical plant. It originates from Southeast Asia and the mountainous forests of India and Sri Lanka. Cardamom grows wild and cultivated in mountainous regions under tree shade [7]. Cardamom essential oil primarily contains monoterpene compounds that offer therapeutic benefits, including antioxidant, anti-cancer, anti-diabetic, anti-inflammatory, antifungal, antiviral, and digestive protective properties [8].

Most fruits and vegetables contain high amounts of water and sugars, making them susceptible to spoilage. Several methods exist to prevent spoilage and extend the shelf life of these products [9]. Drying is one of the oldest food preservation methods and shelf-life extension methods [10]. When we dry food, we reduce unwanted chemical reactions and extend product durability. Converting food into powder through drying reduces weight, volume, and packaging costs while making transportation and storage more efficient [11].

Freeze-drying or lyophilization ranks among the most beneficial and suitable methods for drying heat-sensitive compounds like fruit extracts and natural pigments [12]. In freeze-drying, we first freeze the material and then reduce the system's pressure to convert the frozen water directly into vapor (sublimation process) [13]. Food scientists also use freeze-drying to microencapsulate heat-sensitive compounds like plant extracts and bioactive components such as anthocyanins [14].

Hot air convective drying represents the most common food drying method [15]. However, this method has drawbacks despite its simplicity and ease of use, including high energy consumption and lengthy drying times due to food's low thermal conductivity. It also causes significant shriveling through cellular collapse as water leaves the food [16].

We can speed up the drying process by converting food materials into foam. Foam consists of gas bubbles dispersed in a liquid or solid matrix, creating a two-phase system with a dispersed phase (usually air) and a continuous phase. A thin liquid film, lamella (bubble wall), separates the dispersed and continuous phases [17]. Foam-mat drying transforms liquid and semi-liquid food by adding foaming agents and foam stabilizers to create relatively stable foam, which dries in thin layers [18]. This method offers advantages like simplicity and cost-effectiveness [19]. Foam-mat drying also allows food to dry at low temperatures in shorter periods [18].

Previous research on foam-mat drying includes Carvalho Tavares et al.'s (2020) examination of the effect of time and temperature on jambolana fruit powder characteristics. No significant difference in flavonol content was observed among the various samples, while anthocyanin content decreased slightly. The jambolana powder was exceedingly stable concerning anthocyanin and flavonol content at every storage temperature [20].

Brar et al. (2020) also optimized foam-mat drying conditions for peaches. From their findings, a higher foam thickness enhanced drying time, while higher temperatures and concentrations of foaming agents reduced drying time. Their research reported that peach powder dried with chickpea protein isolate contained more significant bioactive contents than powder produced with soy protein isolate [21].

Haji Aghaei and Sharifi (2020) examined the physical characteristics of red beetroot extract powder obtained via hot air and foam-mat freeze-drying processes. The research revealed that hot air foam-mat drying is economically viable for producing beverage powders with suitable physical characteristics [22].

Haji Ali Asghari and Sharifi (2021) investigated the application of carrier agents on the physicochemical properties of borage flower powder produced through foam-mat freeze-drying. Their investigation discovered that gum Arabic and maltodextrin-type carriers enhance the functionality of the powder, and foam-mat freeze-drying offers satisfactory physical characteristics in beverage powder [23].

2. Materials and Methods

This research used Mahnshan apricots (Prunus armeniaca), carrots (Daucus carota L), cardamom, egg albumin, and maltodextrin (DE=18) as primary materials. We bought Mahnshan apricots in the Zanjan market, carrots in the Abhar market, cardamom extract in the Amitida Company (Iran), and maltodextrin in the Zarmakaron Company (Iran). We supplied the required chemicals from Merck Germany.

2.1. Puree and Foaming Preparation

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We washed fruits and removed foreign material. In each experiment, we pureed apricots well in a food processor (Moulinex, France) of 800g and passed it through a sieve (mesh No. 30) to obtain an even particle size. Then, we filled the resultant pulp in polyethylene bags. Carrot extract was prepared from a home juicer (Rotel, Switzerland) and filtered twice to remove suspended material. Then, at last, apricot puree, carrot extract, and cardamom extract in a ratio of 68:28.5:0.5 weight/weight according to initial sensorial analyses were mixed, and experiments were performed using this blend.

Egg white albumin was used as a foaming material at a constant concentration of 3%. Here, maltodextrin was used as a stabilizer of the foam in different ratios of 0%, 10%, or 20% (T1: oven 0% maltodextrin, T2: oven 10% maltodextrin, T3: oven 20% maltodextrin, T4: freeze-drying 0% maltodextrin, T5: freeze-drying 10% maltodextrin, T6: freeze-drying 20% maltodextrin). The extract quantity was constantly maintained in all treatment groups. Then, a mechanical blender (IKA LABORTECHNIK, Germany) was used at a maximum of 788 rpm for 8 minutes at ambient temperature to mix the mixture, forming a stable and acceptable foam [22].

2.2. Drying Process

Both freeze-drying and hot-air drying methods dried the obtained foams. In the freeze-drying process, we loaded 1cm-thick foam samples onto plates and exposed them to a deep freezer at -70°C (Faratak, Iran) for 24 hours. Afterward, frozen samples were dried in a freeze-dryer (Zist Farayand Tajhiz Sahand SBPE, Iran) at -65°C and 190 mtorr pressure for 24 hours. Afterward, dry samples were removed and placed in a desiccator. Dried foam was scraped from the plate and ground.

For hot air drying, Petri dish samples of 3mm foam thickness were dried in a batch cabinet dryer (SH-Scientific, Republic of Korea) at a flow rate of 1.5 m/s of air for 6 hours at 60°C to constant weight [22].

2.3. Tests Carried Out on Apricot, Carrot, and Cardamom Puree Mixture

2.3.1. pH Analysis

pH was analyzed in accordance with Iranian National Standard No. 1249 [24].

2.3.2. Brix Test

Brix measurement was conducted in accordance with Iranian National Standard No. 1249 [24].

2.3.3. Measurement of Antioxidant Capacity

Antioxidant capacity was measured using Kalantari et al.'s (2020) DPPH free radical scavenging analysis method. One milliliter of methanolic DPPH solution was added to 30μL of the mixture of apricot puree, carrot, and cardamom extracts. Then, it was shaken using a vortex (Classic, VELP, Italy) for

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one minute and kept in darkness at ambient temperature for 30 minutes. Finally, a measurement of the absorbance of the solution was taken using a spectrophotometer (Lambda 35 UV/VIS Spectrometer, PerkinElmer, USA) at a wavelength of 517nm [25].

(1)

$$\%AC = \left[1 - \frac{\text{Sample A}}{Control\ A}\right] \times 100$$

In equation (1), A represents absorbance at 517nm wavelength.

2.3.4. Measurement of Total Phenol Content in Extract

The total phenol content was determined by the Folin-Ciocalteu method. In this method, one milliliter of extract was mixed with 1 milliliter of distilled water and one milliliter of Folin-Ciocalteu reagent. After 5 minutes, 10 milliliters of 7% sodium carbonate was added to the mixture and maintained at room temperature for one hour. After one hour, the absorbance of the mixture was read at 760 nanometers wavelength using a spectrophotometer against a blank. Phenol content was determined as milligrams of gallic acid per gram of extract [26].

2.3.5. Beta-carotene Measurement

Beta-carotene was extracted using the AOAC method. To this end, 10 grams of sample was mixed with 50 milliliters of 95% ethanol in an Erlenmeyer flask and placed in a 70°C water bath for 20 minutes. Then, by adding 15 milliliters of distilled water, the ethanol percentage was diluted to 85% and placed in an ice water bath for five minutes. The mixture was poured into a separatory funnel, adding 25 milliliters of petroleum ether and mixing thoroughly. The supernatant layer was discarded, and the sedimentary layer was returned to the separatory funnel, which was added and shaken well with another 25 milliliters of petroleum ether. The top layer was discarded, and the bottom layer was transferred back to the separatory funnel. The extraction process was repeated another five times, with 10 milliliters of petroleum ether, until a somewhat yellow extract was obtained. Lastly, all the petroleum ether phases were gathered in an Erlenmeyer flask, and extraction was again carried out with 50 milliliters of 80% ethanol to get the final extract utilized for the beta-carotene determination. The optical density of the upper phase of the solution, which is caused by beta-carotene extraction, was determined using a spectrophotometer at 452 nanometers wavelength. Petroleum ether served as the blank solution for the test.

(2)

$$\mathrm{C}\left(\frac{\mu g}{l}\right) = \frac{A}{EL}$$

Parameter C in formula (2) is a carotene concentration, and A is the optical absorbance of the sample at wavelength 452nm. E is the extinction coefficient of

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beta-carotene in petroleum ether medium, and L is the optical path length of the cuvette, maintained constant at one centimeter for standardization.

2.4. Analysis of Produced Beverage Powder

2.4.1. Moisture Content Measurement of Produced Beverage Powder

We followed Affendi et al.'s (2017) method [27].

2.4.3. Solubility of Produced Beverage Powder Determination

Solubility was determined by dissolving 1 g of powder in 100 mL of distilled water. The solution was centrifuged (HERMLE Z 323 K, HermleLaborTechnik GmbH, Germany) at 7500 rpm for 10 minutes to allow sedimentation of insoluble particles. Twenty-five mL of supernatant was heat treated in an oven (BINDER model, USA) at 105°C for 5 hours. The percentage solubility was determined using equation(3) [28].

(3)

$$\%S = \frac{m_2 - m_1}{0/25} \times 100$$

In equation (3), S represents percentage solubility, m_1 for empty plate mass, and m_2 for plate mass with post-oven sample residue.

2.4.4. Browning Index

A spectrophotometric analysis was undertaken to identify the browning index of the powders obtained. One gram of the sample powder was added to a water-methanol solution in the volume ratio 1:3 and centrifuged at 8500 rpm for 10 minutes. The optical density of the clear supernatant solution as an index of the degree of browning was read using a spectrophotometer at a wavelength of 420 nanometers [29].

2.4.5. Beta-Carotene Content of the Beverage Powder Obtained

The beta-carotene extraction procedure commenced with the homogenization of 5g beverage powder, 10 mL acetone, and anhydrous sodium sulfate crystals. The supernatant was transferred doubly in sequence to a beaker. The supernatant transferred to a separatory funnel was treated with 10-15mL petroleum ether following complete homogenization. After removing the lower phase, the upper phase was transferred to a 100mL volumetric flask with further standardization to volume using petroleum ether. Beta-carotene content was estimated by spectrophotometric measurement at 452nm wavelength with beta-carotene content expressed as milligrams per 100 grams of sample [30].

2.4.6. Assessment of Total Phenolic Content in Beverage Powder

Total phenolic content was determined using the Folin-Ciocalteu colorimetric method described by Zarei et al. (2019). A 20-gram beverage powder was mixed in 100 milliliters of distilled water and

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homogenized using a magnetic stirrer (VELP SCIENTIFICA, Italian manufacturer). Thereafter, centrifugation for 15 minutes was performed on the mixture, followed by using the supernatant to assess the phenolic content. 0.3 milliliters of the extracted solution was combined with 2.5 milliliters of 10% Folin-Ciocalteu reagent and vortexed (Classic, VELP made in Italy) for 15 seconds. It was then placed at room temperature in the dark for 5 minutes. Two milliliters of sodium carbonate were added and placed at room temperature for 90 minutes. Finally, a spectrophotometer read the absorption at 725 nanometers wavelength [26].

2.4.7. Evaluation of Antioxidant Potential of Beverage Powder

The antioxidant activity of beverage powder was evaluated using 2,2-diphenyl-1-picrylhydrazyl (DPPH). For the preparation of methanolic extract, one gram of the developed beverage powder was mixed with 10 milliliters of methanol; the solution thus obtained was centrifuged using a refrigerated centrifuge at 4000 rpm for 20 minutes. The measurement process was as follows: 600 microliters of centrifugation supernatant was mixed with 600 milliliters of ready DPPH solution and kept in the dark at room temperature for 30 minutes. After that, absorption was read at 517 nanometers. Antioxidant activity was calculated using the following equation [31].

(4)

$$\%AC = \left[1 - \frac{\text{Sample A}}{\text{Control A}}\right] \times 100$$

A is the absorption measured at a wavelength of 517 nanometers.

2.4.8. Sensory Evaluation

The sensory evaluation of the produced beverage powder was conducted according to the method of Soleimani et al. (2016). The powder was mixed with water in specific ratios, and the beverage was reconstituted. The produced beverage was then given to 10 trained evaluators, and the product was assessed using a 5-point hedonic scale. In this method, the scores included 1 (very poor), 2 (poor), 3 (average), 4 (good), and 5 (excellent) [29].

2.5. Statistical Analysis

SAS software version 14 was used to analyze the obtained data. One-way ANOVA at a 5% probability level was used to determine significant differences between data means. All samples were analyzed in triplicate. Graphs were created using Excel 2019 software.

3. Results and Discussion

In this research, some physicochemical properties of the mixture of apricot puree, carrot extract, and cardamom were measured, and the results are shown in Table (1).

Table 1 Average pH, Brix, antioxidant capacity, total phenol and beta-carotene content of apricot and carrot puree

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SAMPLE	PH	BRIX (٪)	ANTIOXIDANT CAPACITY (٪)	TOTAL PHENOL CONTENT (MG GAE/100G)	BETA-CAROTENE CONTENT (MG*100G)
APRICOT AND CARROT PUREE MIXTURE	3.94±0.05^{a}	16±2^{a}	50.93±1.95^{a}	0.509±0.05^{a}	0.862±0.20^{a}

*Different Latin letters above the numbers indicate a significant difference (p < 0.05) and the same letters indicate a non-significant difference (p > 0.05) between the data

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3.1. Powder Moisture

As shown in Figure 1, the drying method significantly affected the moisture percentage of powder samples (p<0.05). Freeze-dried samples had significantly higher moisture content compared to hot air-dried samples. Additionally, maltodextrin content had a significant effect on the moisture content of the produced powders (p<0.05). In the freeze-drying method, moisture decreased with increasing maltodextrin concentration. However, moisture increased with increasing maltodextrin content in the hot air drying. The decrease in powder moisture content with increasing maltodextrin concentration in the freeze-drying method can be attributed to the increase in carbohydrate concentration. The increase in moisture is mainly due to the hydrophilic and hygroscopic properties of maltodextrin and the presence of low molecular weight sugars in its structure [32]. Similarly, it was reported that with increasing maltodextrin percentage, the moisture content of foam-mat dried beetroot extract powder produced by hot air and freeze-drying methods decreased [22]. An investigation of maltodextrin's effect on the physicochemical properties of freeze-dried mulberry leaf extract powder showed that the moisture content of the powders produced decreased with increasing maltodextrin. Researchers attributed this moisture reduction to increased carbohydrate concentration [33]. In another study, it was reported that increasing maltodextrin had a significant effect (p<0.05) on the moisture content of spray-dried barberry powder, and increasing maltodextrin content led to decreased moisture [34].

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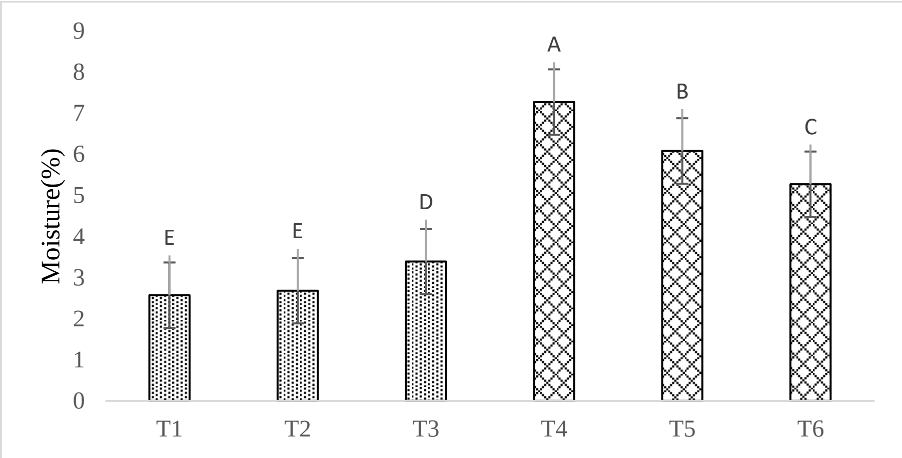

Figure 1 The effect of different proportions of maltodextrin on the moisture content of mixed powder of apricot puree, carrote and cardamom essence Produced by Foam-Mat Freeze Dyring and hot air drying method

*Different Latin letters above the numbers indicate a significant difference ($p < 0.05$) and the same letters indicate a non-significant difference ($p > 0.05$).

3.2. Powder Solubility

The analysis of variance results showed that the drying method had no significant effect ($p>0.05$) on the solubility of powders prepared by both foam-mat freeze-drying and hot air-drying methods (Figure 2). Additionally, maltodextrin concentration had no significant effect ($p>0.05$) on the solubility of powder prepared from the mixture of apricot, carrot, and cardamom (Figure 2). In powders dried by both freeze-drying and hot air methods, solubility slightly increased with maltodextrin concentration up to 10%. However, when maltodextrin content increased to 20%, powder solubility decreased. However, the difference between samples was not statistically significant.

In spray-drying barberry powder, increasing maltodextrin concentration, arabic gum, and temperature had no significant effect on barberry powder solubility. The sample prepared at 180°C using only maltodextrin as a carrier had the lowest solubility percentage, which could be due to the formation of a hard surface layer on powder particles at high temperatures that prevents the diffusion of water molecules into the particle [35]. Findings from another study showed that adding maltodextrin increased date powder solubility, and the control date powder had significantly lower solubility than powders containing maltodextrin and Arabic gum carriers [36].

The solubility of food powders depends on multiple factors, including initial sample composition, formulation components, production method and conditions, and particle size distribution of the resulting powder [37]. In the freeze-drying process, due to creating a porous structure entirely of cavities, the produced samples absorb water like a sponge. Additionally, some non-frozen water is bound to proteins and

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carbohydrates through hydrogen bonding, which evaporates during the freeze-drying process. When exposed to water, these samples rapidly absorb water to compensate for the lost hydrogen bonds. Therefore, this process creates an open structure and high surface area for water absorption [38].

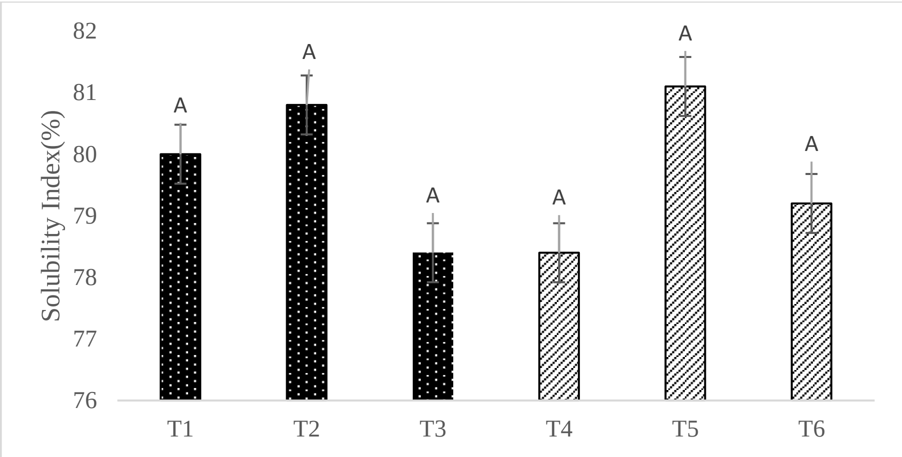

Figure 2 The effect of different ratios of maltodextrin on the solubility of mixed apricot, carrot and cardamom powder produced by Foam-Mat Freeze Dyring and hot air drying methods

*Different Latin letters above the numbers indicate a significant difference ($p < 0.05$) and the same letters indicate a non-significant difference ($p > 0.05$).

3.3. Powder Browning Index

A comparison of powders produced by foam-mat freeze-drying and hot air methods showed that the browning index in the control powder sample (without maltodextrin) dried by the hot air method was significantly higher than in other samples ($p<0.05$). There are two reasons for this: first, higher temperatures are used for drying oven-dried samples compared to freeze-drying; additionally, the control sample lacks maltodextrin, as drying aids form a thin layer and film around particles acting as a barrier, preventing direct contact between hot air and particles [39]. However, no significant difference was observed between other powder samples ($p>0.05$).

With increasing maltodextrin concentration, the browning index of carrot, cardamom, and apricot mixture powder samples decreased, and this decreasing trend was significant in samples dried by foam-mat hot air method ($p<0.05$). However, in samples dried by foam-mat freeze-drying method, despite the decrease in browning index due to increased maltodextrin concentration, no statistically significant difference was observed between samples ($p>0.05$).

Investigating drying conditions in cabinet dryers and various pre-treatments on grape drying intensity and raisin quality characteristics showed that increasing drying temperature was associated with an increased browning index. Given the effect of temperature on browning reaction intensity, the increased browning index of raisins with

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increased drying air temperature is not unexpected [40]. Researchers studying non-enzymatic browning indices in Sardasht black grape concentrate using response surface methodology concluded that the browning index increases with increasing brix and storage temperature of concentrate.

Researchers studying the effect of pre-treatment and different drying methods on the drying process, texture, color, amount, and rate of water reabsorption of button mushroom slices concluded that longer drying time results in a higher browning index, therefore the browning index for hot air drying is higher compared to other methods as it occurs over a more extended period [41]. Results from measuring the browning index of banana milk powder produced by hot air foam-mat drying, microwave, and freeze-drying methods showed that the browning level of powder by hot air dryer was higher than the microwave method [42]. Moreover, results from examining different apple drying methods showed that the browning index in the freeze-drying method was lower than other methods because the freeze-dryer temperature is -18 degrees. Therefore, no particular change was observed in the browning index [43].

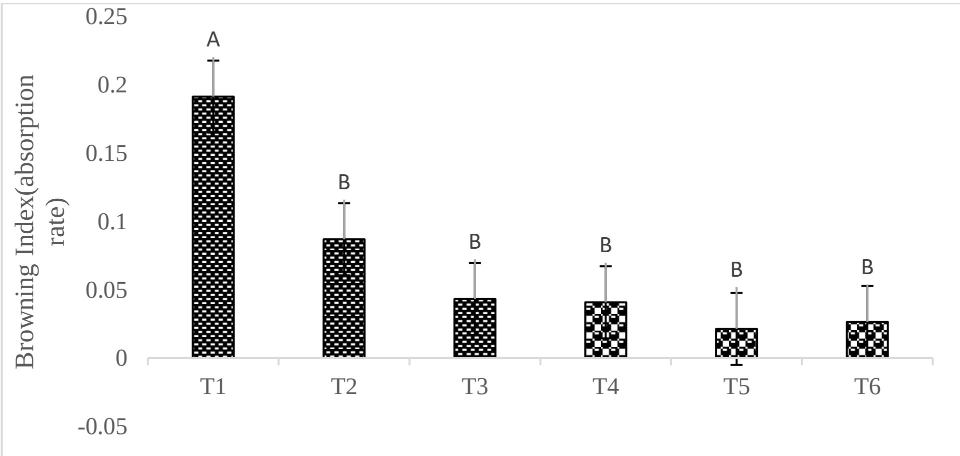

Figure 3- The effect of different proportions of maltodextrin on the browning index of mixed apricot, carrot and cardamom powder produced by Foam-Mat Freeze Dyring and hot air methods

*Different Latin letters above the numbers indicate a significant difference ($p < 0.05$) and the same letters indicate a non-significant difference ($p > 0.05$).

3.4. Antioxidant Capacity of Powder

Analysis of variance showed that different samples had significant differences in antioxidant activity ($p<0.05$) (4). Results indicate that the drying method significantly affected the antioxidant activity of carrot, apricot, and cardamom mixture powder ($p<0.05$). Samples dried by the foam-mat hot air method showed higher antioxidant activity than those dried by the freeze-drying process. Additionally, maltodextrin concentration significantly affected the antioxidant activity of carrot, apricot, and cardamom mixture powder ($p<0.05$). In powders produced by foam-mat hot air and freeze-drying methods, antioxidant activity decreased with increasing maltodextrin concentration.

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In hot air-dried samples, the antioxidant activity of the control sample was 44.44±3 percent. With the addition of 10% and 20% maltodextrin, antioxidant activity decreased to 14.86±2 and 13.23±0.95 percent respectively. In samples dried by foam-mat hot air method, the antioxidant activity of the control sample was 16.1±0.9%, which declined to 7.46±1 and 5.34±0.9% with 10% and 20% maltodextrin, respectively.

The harmful effects of free radicals can be reduced by antioxidants because these substances trap and inhibit free radicals, thereby preventing potential diseases caused by free radicals [44]. In a similar study, adding maltodextrin and Arabic gum significantly affected the antioxidant activity of borage flower powder dried by foam-mat freeze-drying method. In this research, the highest antioxidant activity was observed in the control powder, and the antioxidant activity of borage flower powder decreased with increasing concentrations of maltodextrin and Arabic gum [23]. Furthermore, it was reported that the ratio of maltodextrin to Arabic gum did not affect the antioxidant activity of microencapsulated grape extract [45]. Increasing carrier amount decreases antioxidant activity due to the dilution effect [46].

The freezing stage causes the formation of ice crystals and the rupture of cellular structures, including cell walls, leading to the release of antioxidant compounds from the cellular network. On the other hand, some internal antioxidants in a sample may be destroyed and eliminated with heat application and temperature increase. Additionally, investigation of temperature and drying method effects on antioxidant activity of grape pomace powder showed that increasing oven temperature from 80°C to 100°C led to increased antioxidant activity, attributed to the formation of Maillard reaction products or release of cellular compounds with antioxidant properties [47]. Investigation of microencapsulation effects of ginger extract using maltodextrin and Arabic gum as encapsulating agents on six effective ginger genes showed that microencapsulation causes a reduction in the amount of ginger's active compound gingerol and consequently decreases phenol content and antioxidant activity [48].

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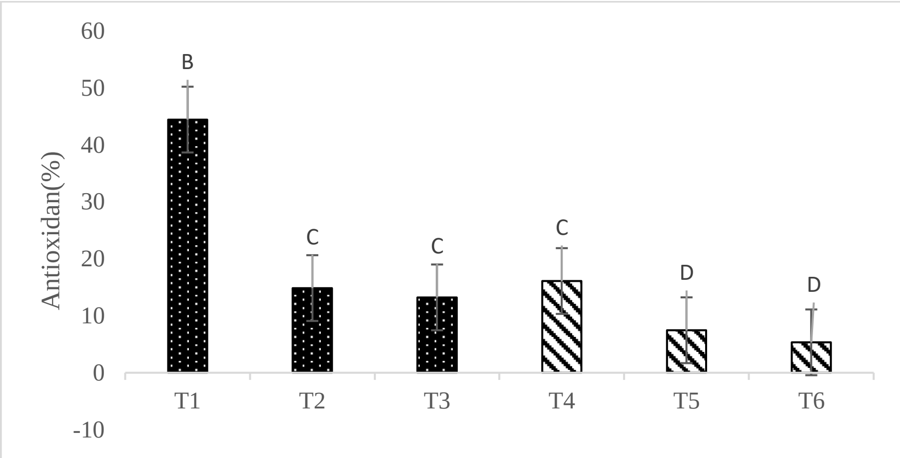

Figure 4 The effect of different proportions of maltodextrin on the antioxidant capacity of mixed apricot, carrot and cardamom powder produced by Foam-Mat Freeze Dyring and hot air methods

*Different Latin letters above the numbers indicate a significant difference ($p < 0.05$) and the same letters indicate a non-significant difference ($p > 0.05$).

3.5. Total Phenol Content of the Powder

The drying method significantly affected the phenolic content of the apricot, carrot, and cardamom powder mixture ($p<0.05$). The phenolic content was considerably higher in foam-mat hot air drying than in the freeze-drying method. The reduction in total phenol content during drying can be attributed to irreversible oxidative reactions and thermal decomposition during prolonged heating [49]. It is hypothesized that one reason for the increase in phenolic compounds due to heating is the breakdown of heavy-weight polyphenols into lower molecular weight varieties. Phenolic compounds are released from their precursors through non-enzymatic reactions caused by heating, thus increasing their quantity [50].

The control powder dried by hot air method had the highest phenolic content of 0.787±0.04 mg GAE/100g. The lowest phenolic content belonged to the powder containing 20% maltodextrin dried by the freeze-drying method. Results also showed that maltodextrin concentration significantly affected the phenolic content of the apricot, carrot, and cardamom powder mixture ($p<0.05$). As maltodextrin concentration increased in hot air-dried powders, the phenolic content decreased. This may be attributed to the addition of carrier agents, which might dilute the phenolic content, reducing total phenol content [36].

In samples dried by foam-mat hot air method, the phenolic content of the control sample was 0.787±0.04 mg GAE/100g, which decreased to 0.496±0.05 mg GAE/100g with the addition of 10% maltodextrin. With a further increase in maltodextrin concentration to 20%, the phenolic content decreased to 0.323±0.03 mg GAE/100g. In freeze-dried samples, as maltodextrin concentration increased to 10%, the phenolic content initially increased slightly but then decreased with a further increase to 20%.

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The reduction in phenolic content in maltodextrin-containing powders compared to the control sample could be related to the addition of maltodextrin and albumin. Maltodextrin is a carrier and protective shield for bioactive compounds during powder storage [23]. Maltodextrin has high water solubility, creates stable emulsions, and retains volatile compounds well. Therefore, increasing maltodextrin can improve phenolic properties [37]. The increase in phenolic compounds at 60°C (hot air drying) can be mainly attributed to the inactivation of phenolic-degrading enzymes [51].

Researchers reported that increasing maltodextrin concentration by up to 13% increased the phenolic content of barberry powder. Still, with a further increase in maltodextrin concentration, the phenolic content of barberry powder slightly decreased [34]. In another study, results from examining the effect of carrier agents (maltodextrin and Arabic gum) on phenolic compounds of foam-mat freeze-dried borage powder showed that the control sample had higher total phenols compared to powders containing carriers [23].

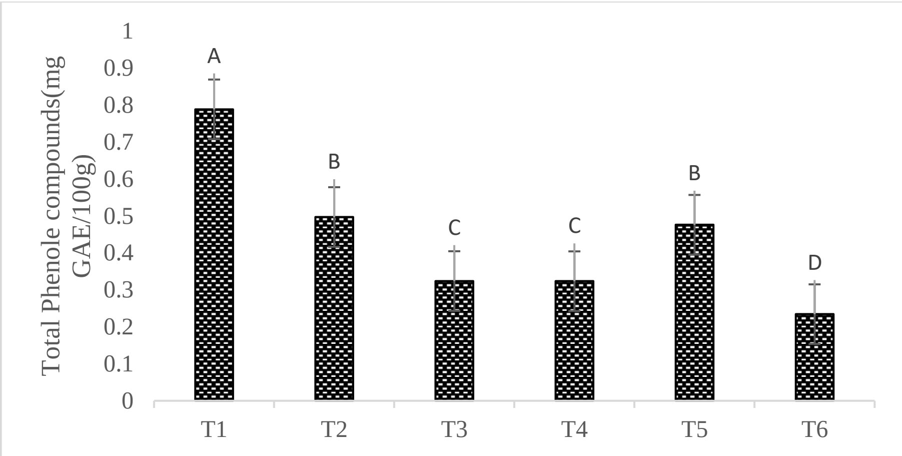

Figure 5 The effect of different proportions of maltodextrin on the total phenol of mixed apricot, carrot and cardamom powder produced by Foam-Mat Freeze Dyring and hot air drying method

*Different Latin letters above the numbers indicate a significant difference ($p < 0.05$) and the same letters indicate a non-significant difference ($p > 0.05$).

3.6. Beta-carotene Content of Powder

Analysis of variance results showed that the drying method significantly affected the beta-carotene content of the carrot, apricot, and cardamom powder mixture ($p<0.05$). The beta-carotene content in powders dried using the foam-mat freeze-drying method was higher than those dried using the foam-mat hot air method. The highest beta-carotene content (0.953±0.04) belonged to the control sample dried using the foam-mat freeze-drying method. The sample containing 20% maltodextrin dried using the foam-mat hot air method had the lowest beta-carotene content. Results also showed that increasing maltodextrin concentration significantly affected the beta-carotene content of the apricot, carrot, and cardamom powder mixture ($p<0.05$). Beta-carotene content decreased with increasing maltodextrin concentration in powder samples dried using the hot air method. The beta-carotene content of the control sample was 0.785±0.02, and as maltodextrin concentration increased to 10% and 20%, the beta-carotene content of powders decreased to 0.630±0.03 and 0.223±0.03, respectively. In powder samples dried using the foam-mat freeze-drying method, the beta-carotene content slightly reduced and increased as maltodextrin concentration increased. However, this trend was not statistically significant. The beta-carotene content in the control sample dried using the freeze-drying method was 0.953±0.04, and with growing maltodextrin concentration to 10% and 20%, it reached 0.868±0.02 and 0.903±0.05, respectively. Results from studying the foaming behavior and foam-mat drying of cantaloupe pulp showed that cantaloupe powder produced with a thickness of 3 millimeters and drying temperature of 40°C had the highest beta-carotene content. Beta-carotene content decreased with increasing drying temperature to 55°C and 70°C [52]. In spray drying of watermelon, the researchers observed that the pigments known to impart the red color to this product, namely anthocyanin, beta-carotene, and lycopene, significantly decreased with a rise in the drying temperature [53]. Again, in papaya powder production by the foam-mat process, it was noticed that the beta-carotene content in papaya powder decreased significantly with thicker foam, increased temperature, and time extension [54]. Beta-carotene degradation is affected by various factors, namely drying temperature, drying time, and oxygen content [34].

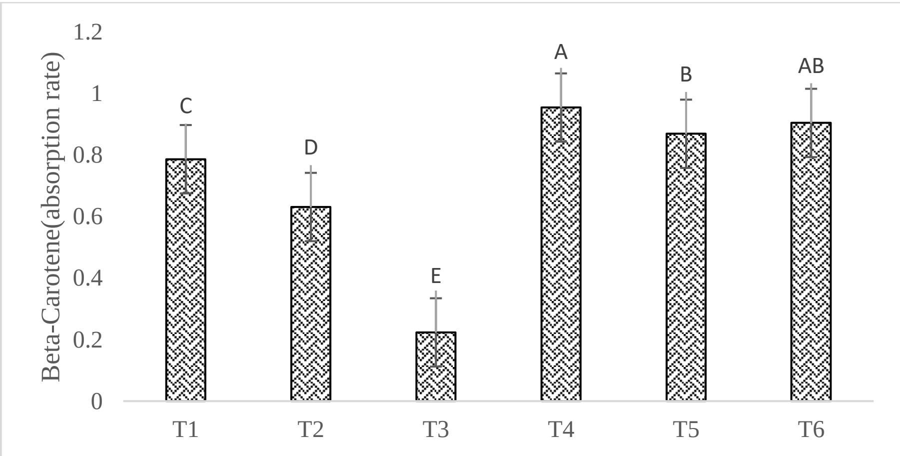

Figure 6 The effect of different proportions of maltodextrin on the amount of beta-carotene in apricot, carrot and cardamom mixed powder produced by Foam-Mat Freeze Dyring and hot air method

*Different Latin letters above the numbers indicate a significant difference ($p < 0.05$) and the same letters indicate a non-significant difference ($p > 0.05$).

3.7. Sensory Evaluation

As shown in Figure 7, overall, powders produced using the foam-mat hot air method were preferred by evaluators more and received higher scores. Analysis of variance also revealed that the drying method significantly affected the sensory characteristics of the powders ($p<0.05$). Powders produced using the foam-mat hot air method were

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better than samples made using the foam-mat freeze-drying method in terms of sensory characteristics, including appearance, color, taste, aroma, and mouthfeel. Additionally, in both powders dried using hot air and freeze-drying methods, control samples were better regarding sensory characteristics and received higher scores. Sensory characteristics decreased with increasing maltodextrin concentration. Regarding color characteristics, evaluators gave the highest score to the control sample (without maltodextrin) dried using the foam-mat hot air method. The lowest color scores were given to samples containing 10% and 20% maltodextrin dried using the freeze-drying method. Regarding aroma, control powder samples and those with 10% maltodextrin dried using the hot air method were better than other samples, and the powder sample containing 20% maltodextrin dried using the freeze-drying method had the least aroma. Regarding taste characteristics, evaluators gave the highest scores to the control powder sample and 10% maltodextrin dried using the foam-mat hot air method. In contrast, all three samples dried using the freeze-drying method received minimum scores. Regarding appearance and mouthfeel, the control powder sample dried using the foam-mat hot air method was better than the other samples, and the three samples dried using the foam-mat freeze-drying method received the lowest scores.

In studying the sensory characteristics of orange beverage powder prepared using the foam-mat method, it has been reported that the powder sample dried at 60°C obtained the highest overall acceptance score. Researchers stated that thermal processing can cause the degradation of flavor-producing compounds. Therefore, non-thermal methods such as freeze-drying and spray-drying can produce more desirable powders [55].

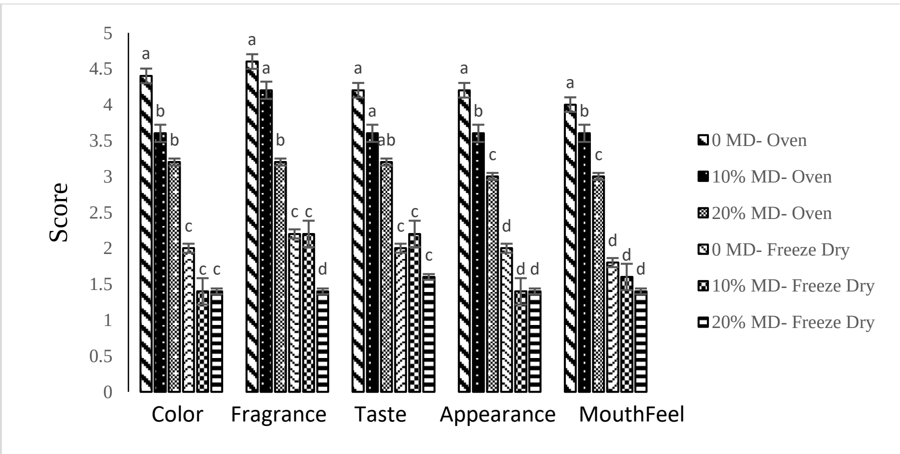

Figure 7 Sensory characteristics of mixed apricot, carrot and cardamom powder samples produced by Foam-Mat Freeze Dyring and hot air drying method (MD: maltodextrin, FD: freeze drying, Oven: oven)
*Different Latin letters above the numbers indicate a significant difference ($p < 0.05$) and the same letters indicate a non-significant difference ($p > 0.05$).

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4. Conclusion

Given the abundance of antioxidant compounds in apricots and the significant impact of these compounds on human health, coupled with the limited fresh consumption of this fruit, apricot is considered a valuable product. Various methods, such as drying, can increase its shelf life and enable year-round consumption. Therefore, in line with producing health-promoting food products, the extract or puree of this fruit can be used to make an instant beverage. The powder's physicochemical properties analysis showed that the drying method significantly affected moisture content, antioxidant capacity, total phenols, beta-carotene content, and sensory characteristics. However, the drying method did not affect powder solubility and browning index. Powder samples dried using the foam-mat freeze-drying method had higher moisture and beta-carotene content than powders dried using the foam-mat hot air method. Additionally, in samples dried using the hot air method, phenol content, antioxidant capacity, and sensory characteristics were higher than in powder samples dried using the foam-mat freeze-drying method. Results of studying the effect of maltodextrin on physicochemical properties of the carrot, apricot, and cardamom beverage powder mixture prepared using foam-mat freeze-drying and foam-mat hot air methods showed that in the freeze-drying method, moisture decreased with increasing maltodextrin concentration. In contrast, in the hot air method, moisture increased. Furthermore, with growing maltodextrin concentration, browning index, beta-carotene content, phenol content, antioxidant capacity, and sensory characteristics decreased. Study results indicated that powder containing 10% maltodextrin and dried with hot air could be introduced as the optimal sample. Overall, results demonstrated that the carrot, apricot, and cardamom beverage powder mixture produced by both foam-mat freeze-drying and foam-mat hot air methods had acceptable physicochemical properties, and the produced product could be used as a beverage powder throughout all seasons.

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ارزیابی ویژگی‌های فیزیکوشیمیایی و حسی پودر نوشیدنی تولید شده از پوره زردآلو و عصاره هویج، با روش خشک کردن کف‌پوشی

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چکیده

هدف از این پژوهش، تولید پودر نوشیدنی از پوره زردآلو و عصاره هویج به روش کف‌پوشی و ارزیابی ویژگی‌های فیزیکوشیمیایی و حسی پودر تولید شده بود. ابتدا مخلوط عصاره هویج، پوره زردآلو و عصاره هل تهیه و سپس برخی خصوصیات شیمیایی مخلوط حاصل اندازه‌گیری شد. برای تهیه کف از این مخلوط، عصاره هویج و پوره زردآلو و هل با نسبت ٦۸: ۲۸/۵: ۰/۵ درصد با یکدیگر ترکیب شدند. از آلبومین به مقدار ۳ درصد به عنوان ماده کف‌کننده و از مالتودکسترین در سطوح صفر، ۱۰ و ۲۰ درصد به عنوان پایدار کننده کف استفاده شد. خشک کردن کف‌های تهیه شده به دو روش انجمادی و هوای داغ انجام گرفت. خصوصیات فیزیکوشیمیایی و حسی پودرهای تهیه شده اندازه‌گیری شد. روش خشک کردن تاثیر معنی‌داری بر روی درصد رطوبت، ظرفیت آنتی‌اکسیدانی، فنول کل، محتوای بتاکاروتن و ویژگی‌های حسی داشت. در حالی که حلالیت پودر و شاخص قهوه‌ای شدن تحت تاثیر روش خشک کردن قرار نگرفتند. پودرهای خشک شده به روش کف‌پوشی– انجمادی محتوای رطوبت، بتاکاروتن بیشتری در مقایسه با پودرهای خشک شده به روش کف‌پوشی– هوای داغ داشتند. در نمونه‌های خشک شده به روش هوای داغ، محتوای فنول، ظرفیت آنتی‌اکسیدان، و ویژگی‌های حسی بیشتر از نمونه پودرهای خشک شده به روش کف‌پوشی– انجمادی بود. با افزایش غلظت مالتودکسترین، شاخص قهوه‌ای شدن، محتوای بتاکاروتن، محتوای فنول، ظرفیت آنتی‌اکسیدانی و ویژگی‌های حسی کاهش پیدا کردند. علاوه بر این، تیمار صفر درصد مالتودکسترین هوای داغ در ارزیابی حسی برتری نسبی دارد. پودر تولید شده به هر دو روش کف‌پوشی– انجمادی و کف‌پوشی– هوای داغ ویژگی‌های فیزیکوشیمیایی قابل قبولی داشت.