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QUALITY ASSESSMENT OF CHOKEBERRY FRUIT POWDERS OBTAINED BY CONVECTIVE HOT AIR AND FREEZE DRYING METHODS

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ABSTRACT
In this study, the changes in some quality characteristics of chokeberry (*Aronia melanocarpa* [Michx.] Elliot) fruit powders obtained by freeze drying and convective hot air drying techniques were compared. The moisture (%) and water activity values of powders obtained by hot air and freeze drying were measured as 9.29% and 10.86%, 0.2373 and 0.2963, respectively. Both drying treatments caused significant changes in color properties of the powders, and the highest +a* value (23.30) was detected in the sample obtained by freeze drying (P <0.05). The total phenolic and flavonoid contents of the methanol and water extracts of the powder obtained by freeze drying were higher than the other treatment and were determined as 7231.80 and 4497.34 mg gallic acid equivalent/100 g dry matter, and 5198.98 and 3148.14 mg quercetin/100 g dry matter, respectively. A similar trend was observed in the ABTS and DPPH antioxidant activity analysis results of the samples.
Keywords: Chokeberry, drying, fruit powder, quality

KONVEKTİF SICAK HAVA ve DONDURARAK KURUTMA YÖNTEMLERİYLE ELDE EDİLEN ARONYA MEYVE TOZLARININ KALİTE YÖNÜNDEN DEĞERLENDİRİLMESİ

ÖZ
Bu çalışmada, dondurarak kurutma ve konvektif sıcak hava teknikleri ile elde edilen aronya (*Aronia melanocarpa* [Michx.] Elliot) meyve tozlarının bazı kalite özelliklerindeki değişim karşılaştırılmıştır. Sıcak hava ve dondurarak kurutma tekniği ile elde edilen tozların nem (%) ve su aktivitesi değerleri sırasıyla %9.29 ve %10.86, 0.2373 ve 0.2963 olarak ölçülmüştür. Tozların renk özelliklerinde her iki kurutma işlemi de önemli değişiklikler meydana getirmiş, en yüksek +a* değeri (23.30) dondurarak kurutma işlemi ile elde edilen örnekte tespit edilmiştir (P <0.05). Dondurarak kurutma işlemi ile elde edilen tozun metanol ve su ekstraktlarına ait toplam fenolik ve flavonoid içeriği sıcak hava kurutma ile elde edilen örneğe göre daha yüksek ve sırasıyla 7231.80 ve 4497.34 mg gallik asit eşdeğeri/100 g kuru madde, 5198.98 ve 3148.14 mg kuersetin/100 g kuru madde olarak tespit edilmiştir. Örneklerin ABTS ve DPPH antioksidan aktivite analiz sonuçlarında da benzer bir trend olduğu görülmüştür.
Anahtar kelimeler: Aronya, kurutma, meyve tozu, kalite

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INTRODUCTION

Today, as millions of people suffer from hunger and poverty, decreasing food loss and waste through the food production and consumption chains is very important. In this regard, technological strategies such as different food preservation techniques and/or sustainable food processing/packaging are used to prevent food loss and waste of various fresh products. In the meantime, it is essential to meet the needs of the food industry by protecting perishable products such as fruits and vegetables in a controlled manner with different food processing technologies and increasing their shelf life and market potential (Ravichandran and Krishnaswamy, 2021; Sánchez-Teba et al., 2021).

As is known, fresh fruits and vegetables have high water activity, and therefore they are highly susceptible to mechanical damage, enzymatic reactions, microbial spoilage and environmental conditions. Removing the water in these products by various processes prevents undesirable microbial and physico-chemical reactions, and thus provides a longer storage period. In this sense, drying applications are one of the oldest methods used to remove water for the preservation of these products (Zhang et al., 2017; Pateiro et al., 2022). Drying can greatly reduce or completely neutralize physiological, microbial, and enzymatic degradation, thereby significantly extending the shelf life (Wojdyło et al., 2014). It also reduces packaging, storage and transportation costs by reducing the product mass and volume (Qi et al., 2021).

In this perspective, convective drying using hot air is widely preferred for drying different agricultural products. This process uses air that can be adjusted to a certain temperature and flowing rate, thereby transferring the heat energy to the surface of the moist product and then inside, allowing to obtain a safe dried product (Chandramoha, 2020). Among the advantages of convective hot air drying (HAD) are its easy operation, accurate control of temperature and air flowing rate, low cost, and simple design (Pateiro et al., 2022). However, this method also has some disadvantages related to long drying times depending on the product, degradation of heat-sensitive compounds, enzymatic and non-enzymatic browning reactions, off-flavor generation, and visible shrinkage (Zielinska et al., 2018; Pateiro et al., 2022). Freeze drying (FD), also known as lyophilization, is a gentle drying method that follows the sublimation phenomenon (Ravichandran and Krishnaswamy, 2021). It includes several major steps, such as freezing of the sample, sublimating the frozen water under vacuum during the primary drying process, and then desorption of remaining water during the secondary drying process (Bhatta et al., 2020; Nowak and Jakubczyk, 2020). This drying method preserves the color, flavor and nutrients such as antioxidants, vitamins of the food, causes negligible shrinkage and structure collapse, and thus ensures a product characterized by high porosity and low density (Pateiro et al., 2022). On the contrary, FD necessitates a significant level of energy consumption and installation requirements, as well as a pre-treatment step (initial freezing) and vacuum source (Bustos et al., 2018). It is also a very slow process due to the low drying rates required resulting in relatively low yields (Nireesha et al., 2013). In response to these pros and cons of each method, much focus has been given recently to determining the most effective processing conditions (for instance time, temperature, low energy requirement as possible, etc.) in drying treatments to produce high quality fruits and vegetable powder.

Berry fruits have been the focus of extensive research on their ability to maintain health due to their low calories, high fiber, high antioxidant levels, vitamin and mineral content (Farías-Cervantes et al., 2020). Among the berry groups, black chokeberry (*Aronia melanocarpa* [Michx.] Elliot), also called Aronia, is characterized as having the highest content of total polyphenols, being highly nutritious, and having a pleasant flavor (Bednarska and Janiszewska-Turak, 2020; Ravichandran and Krishnaswamy, 2021). However, these fruits are very sensitive to mechanical damage and deteriorate quickly. Therefore, different food processing applications are widely used to preserve them as unspoiled/raw fruit or value-added products due

to their shorter shelf life and limited seasonal availability (Correia et al., 2017). In this regard, the aim of this study is to obtain high-quality black chokeberry fruit powder that can enrich different formulations in the food industry by using FD and convective HAD techniques. Within this framework, physico-chemical and bioactive component analyzes were made on the fruit powders obtained by both drying treatments.

MATERIALS AND METHODS

In the study, ripe black chokeberry (*Aronia melanocarpa* [Michx.] Elliot) fruits were used in drying treatments. The fruits were collected from Akıncılar village (41.45948 °N, 27.64456 °E) in Vize district of Kirklareli province, which is located in the Northwestern part of Türkiye, and were kept in cooled bags (4 ± 0.5 ℃) for transport to the laboratory. Then, the fruits were cleaned by removing the damaged fruits, all foreign materials and separating of stems by hand. The cleaned fruits were stored in the refrigerator at 4 ℃ for no more than 3 days. All chemicals used in the analyzes were of analytical grade and purchased from Sigma-Aldrich, USA.

Preparation of samples

Before drying treatments, fresh and clean chokeberry fruits (400 g) were homogenized for 2 min at a single speed by using a laboratory blender (Waring laboratory blender, Conair Corporation, 7011G, Stamford, CT, USA). Following that, the homogenized fruit mixture was immediately taken to the drying step. All processes performed within the scope of the study were schematized in Figure 1.

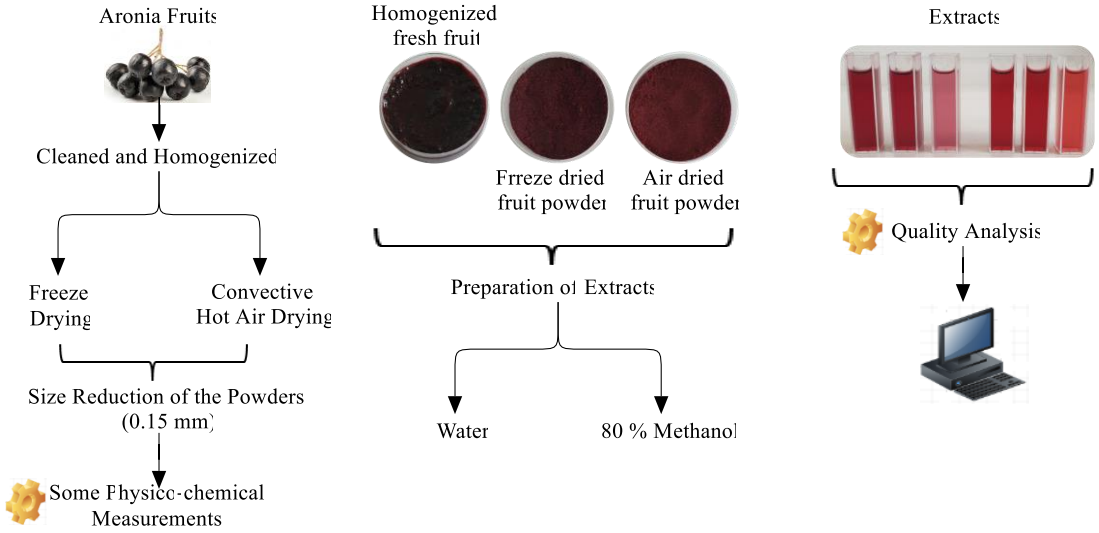

Figure 1. All processes performed within the scope of the study

Convective hot air drying experiment

Before the treatment, 100 g of the homogenized fresh fruit puree (FFP) was uniformly spread on non-stick baking paper with a stainless steel flat rubber spatula and placed in a single layer on the dryer trays. The heat treatment conditions (time and temperature) that could provide the best results in terms of energy consumption and product quality were selected as a result of comprehensive literature review. In this regard, Pachura et al. (2022) and Krzykowski et al. (2023) stated that convective HAD at 40 ℃ gave the best results for preserving the volatile bioactive components of different plant-based materials, taking into account the energy requirements of treatment. Therefore, a very mild convective HAD treatment was carried out at 40 ℃ with 2.0 ± 0.2 m/s airflow (just in front of the meshed sample tray of the fan) for 24 h (Atacama Pro, F77000, Tre Spade, Torino, Italy). At the end of the treatment, dried samples separated from the non-stick baking paper were ground using a coffee grinder (Siemens MC 23200), immediately sieved with a 100 mesh (0.15 mm) stainless steel

flour sifter, and then vacuum packed (100 g each) and stored at 4 °C until further analysis.

Freeze drying experiment

First, the homogenized fruit mixture (30 g) was placed in silicone freeze dryer trays and each tray was shock frozen in a freezer at -40 °C for 5 h. After this process, the trays were immediately transferred into the drying chamber of a freeze dryer device (TRS4-4DS, Teknosem Corp., Istanbul, Türkiye). The FD process was carried out for 24 h (as in convective HAD) with condenser temperature and vacuum chamber pressure equal to -85 °C and 0.01 to 0.004 mbar, respectively (Thuy et al., 2020). At the end of the treatment, freeze dried samples were ground using a closed domestic coffee grinder (Siemens MC 23200), immediately sieved with a 100 mesh (0.15 mm) stainless steel flour sifter, and then vacuum packed (100 g each) and stored at 4 °C until further analysis.

Physico-chemical measurements of the samples

The water activity values of FFP and powder samples were determined using a_w meter (Decagon AquaLab, 4 TE). The moisture content (%) was determined by drying the samples at 70 °C for 24 h without air circulation until a constant mass was achieved. The pH values of all samples were determined using a digital pH meter (Hanna, HI-2211, Romania) at room temperature. The pH value of FFP was measured directly from the homogenized mixture, while the pH values of powder samples were measured by making a 25% (w/v) suspension of the sample in distilled water (Petković et al., 2019). The total ash content was measured by incinerating the samples in a muffle furnace at 550 °C until gray-white ash was obtained using AOAC (2010) method and expressed as g/100 g dry matter (DM). All analyzes were performed in triplicate.

Color analysis of the samples

The color parameters of all samples were determined by using Chromameter CR-400 Konica Minolta (Tokyo, Japan). As a result of the analysis, L* (brightness), a* (redness-greenness), b* (yellowness-blueness), and total color change ΔE_{ab} (between FFP and powder samples) (Eq. 1) values of the samples were recorded. The increase of ΔE_{ab} indicates the greater difference in color between FFP and powder samples (Pathare, Opara & Al-Said, 2013; Altınok et al., 2022). All measurements were done in three replications.

$$\Delta E = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{1/2} \quad (1)$$

Preparation of extracts from the samples

The extraction procedure was performed according to the method described by Gunes et al. (2019) with some alterations. First, 1 g of samples were mixed with 25 mL of methanol (80%) in falcon tubes and the tubes were held in an ultrasonic bath (ISOLAB Laborgeräte GmbH, 621.05.010, Germany) for 30 min at 40 kHz and 25 ± 2 °C. The same application was done with distilled water instead of methanol (80%). Then, the tubes were centrifuged (Beckman Allegra, X-22R Benchtop Centrifuge, United States) at 9500 rpm for 10 min and the supernatants were filtered using a 0.45 µm filter. The application was performed in duplicate and each extract was transferred into dark glass bottles and kept at -18 °C (Arçelik, 2071 MB 7, Türkiye) for further analysis.

Determination of total phenolic content of the extracts

The total phenolic content was measured by the Folin-Ciocalteu method of Singleton et al. (1999) with some modifications. First, 7.5 mL distilled water was pipetted into the test tubes and then, 100 µL of the extracts and 500 µL Folin-Ciocalteu reagent were put into these tubes. The tubes were vortexed (Vortex RS-VA 10, Phoenix Instrument, Garbsen, Germany) thoroughly and left to stand for 3 min and 1 mL saturated Na_2CO_3 solution and 900 µL distilled water were added in order to reach a final volume of 10 mL. Finally, the tubes were left to stand for 1 h at room temperature in the dark and the absorbance was read at 720 nm by using a UV–Vis spectrophotometer (Shimadzu, Tokyo, Japan). The results were expressed as mg gallic acid equivalents (GAE)/100 g DM using the calibration curve of gallic acid (R^2 = 0.9993) and the dilution rates

applied. Each measurement was performed in triplicates and the results were shown as mean values ± standard deviation.

Determination of total flavonoid content of the extracts

Total flavonoid was analyzed using the aluminum chloride colorimetric method with slight modification according to Shraim et al. (2021). In the analysis, the following steps in order were followed; 4.0 mL distilled water followed by a known volume of the flavonoid standard (or 1 mL sample's clear extract), 0.3 mL $NaNO_2$ (1.0 mol/L), vortex mixing (Vortex RS-VA 10, Phoenix Instrument, Garbsen, Germany), and 3.0 min equilibration time, 0.3 mL $AlCl_3$ (10%, w/v), vortex mixing (Vortex RS-VA 10, Phoenix Instrument, Garbsen, Germany) and 3.0 min equilibration time, 2.0 mL NaOH (1.0 mol/L), and the final volume was made to 10.0 mL using distilled water. All solutions were vortex mixed (Vortex RS-VA 10, Phoenix Instrument, Garbsen, Germany) after the last step and the tubes were stored in the dark for 40 min and were read at 420 nm by using a UV–Vis spectrophotometer (Shimadzu, Tokyo, Japan). Quercetin (0, 50, 100, 200, 400, 500, 600, 800, 1000 mg/L in pure methanol) was used to make the calibration curve (R^2 = 0.9981). The results were expressed as mg quercetin equivalents (QE)/100 g DM using this curve and each measurement was performed in triplicates and the results were shown as mean values ± standard deviation.

Determination of total monomeric anthocyanin pigment content of the extracts

Total monomeric anthocyanins (TMA) were quantified using the pH differential method (Giusti and Wrolstad, 2001). Briefly, extracts were diluted with 0.025 M potassium chloride buffer at pH 1 or 0.4 M sodium acetate buffer at pH 4.5. The difference of absorbance at their respective $\lambda_{vis\text{-}max}$ (530 nm) and 700 nm was measured after 15 min using a UV–Vis spectrophotometer (Shimadzu, Tokyo, Japan) versus a blank cell filled with distilled water. The absorbance of the dilute solution was calculated using Eq. 2 and the total amount of monomeric anthocyanin pigment in the original sample was determined using Eq. 3. Cyanidin-3-glucoside (cyd-3-glu) was selected because it is the most common anthocyanin in nature.

$$A = (A_{\lambda vis\text{-}max} - A_{700})_{pH\ 1.0} - (A_{\lambda vis\text{-}max} - A_{700})_{pH\ 4.5} \quad (2)$$

$$TMA\ (mg/100\ g\ DM) = (A \times MW \times DF \times 1000) / (\varepsilon \times 1) \quad (3)$$

where MW (molecular weight) = 449.2 g/mol for cyd-3-glu, DF = dilution factor (previously recorded), l = pathlength in cm; ε = 26900 molar extinction coefficient for cyd-3-glu (L mol^{-1} cm^{-1}), and 10^3 = factor for conversion from g to mg. The results as monomeric anthocyanins were expressed as mg cyd-3-glu equivalents (CGE)/100 g DM. Each measurement was performed in triplicates and results were shown as mean values ± standard deviation.

Determination of antioxidant activity of extracts using DPPH and ABTS methods

The DPPH method was conducted according to the method of Thaipong et al. (2006) with some modifications. Sample extracts (150 µL) were mixed with 2.850 mL 0.1 mM DPPH (prepared with methanol) solution, and then the cuvettes were left in the dark for 30 min at room temperature, and then the cuvettes were measured against the blank (methanol) using the UV–Vis spectrophotometer (Shimadzu, Tokyo, Japan) at 517 nm. A calibration curve (R^2 = 0.9995) was obtained by using Trolox standard solution at concentrations ranging between 50 and 1000 µM. The results were expressed as µmol Trolox/g DM and each measurement was performed in triplicates.

The ABTS method was used according to Xu et al. (2016) with some modifications to determine the ABTS radical scavenging activity of phenolic extracts. Firstly, 1 mL of ABTS stock solution was diluted with methanol to an absorbance of 0.70 ± 0.02 at 734 nm. Then, 20 µL sample extract was mixed with 3.0 mL ABTS solution into spectrophotometer cuvettes. The cuvettes were left in the dark for 6 min at room temperature, and then the cuvettes were measured against the

blank (methanol) with the UV–Vis spectrophotometer (Shimadzu, Tokyo, Japan) at 734 nm. A calibration curve (R^2 = 0.9971) was obtained by using Trolox standard solution at concentrations from 50 to 4000 µM. The results were expressed as µmol Trolox/g DM and each measurement was performed in triplicates.

Statistical analysis

The data obtained as a result of the analysis studies were determined by using the Windows-based SPSS 17.0.1 (SPSS Inc., Chicago, Illinois, USA) statistical package program, and one-way ANOVA & Tukey's test was used to determine whether there was a statistical difference between the groups (P <0.05).

RESULTS AND DISCUSSION

Physico-chemical measurement results of the samples

The physico-chemical properties of the FFP and the powder samples were given in Table 1. As is known, water is the primary component of fresh fruits and vegetables, accounting for approximately 75-95% of the food weight. High water activity may result in shorter product shelf life due to the potential for undesirable biochemical alterations and microbial proliferation. To eliminate these factors, it was stated that the water activity in dried products should be below 0.600 (Samoticha et al., 2016). In the present study, the moisture and water activity values of FFP were found as 70.78% and 0.9127, respectively. However, these values of the hot air dried fruit powder (HADFP) and freeze dried fruit powder (FDFP) samples obtained at the end of the drying process (24 h) were measured as 9.29% and 10.86%, 0.2373 and 0.2963, respectively (P <0.05). According to the results, it can be stated that the dehydrated product obtained after the FD treatment of FFP might absorb moisture during grinding and sieving due to its highly hygroscopic structure, and this might affect the water activity and moisture values of the FDFP sample. In this context, there are studies in the literature that have similar or different results to current values, depending on different drying techniques, temperature and time parameters. For instance, Sadowska et al. (2019) used the convection drying treatment (70 °C, 48 h) to prepare chokeberry fruit powder, and found that the moisture (%) and water activity contents of the powder sample were 2.82% and 0.1625, respectively. Cujic et al. (2016) dried chokeberry fruits at 40 °C using a tunnel dryer before the extraction procedures and found the moisture content as 10.65%. Gorguc et al. (2023) dried chokeberry fruits with HAD treatment (65 °C, 10.7 h, and 1.5 m/s air flow rate) and recorded the moisture (%) and water activity values of the dried fruits were 15.9% and 0.608, respectively. Calín-Sánchez et al. (2015) found the moisture value of the freeze dried (-60 °C, 0.65 mbar, 48 h) chokeberry fruits as 3.31%. In another study, Sadowska et al. (2017) found that the chokeberry fruit powder obtained by FD had a water activity of 0.202.

Table 1. Some physico-chemical properties of the samples.

Sample	Moisture (%)	Water activity	pH	Total Ash*
HADFP	9.29 ± 0.09^{C}	0.2373 ± 0.0035^{C}	3.58 ± 0.03^{A}	3.11 ± 0.08^{A}
FDFP	10.86 ± 0.07^{B}	0.2963 ± 0.0021^{B}	3.55 ± 0.04^{A}	3.09 ± 0.07^{A}
FFP	70.78 ± 0.31^{A}	0.9127 ± 0.0314^{A}	3.42 ± 0.03^{B}	3.06 ± 0.08^{A}

Data represent average values ± standard deviation. There is no statistical difference between the results shown with the same exponential capital letter in the same column (P >0.05). HADFP: Hot air-dried fruit powder. FDFP: Freeze-dried fruit powder. FFP: Fresh Fruit Puree. *: Total ash was expressed as g/100 g DM.

The pH value obtained for the FFP sample was 3.42, while the pH values of the powder samples increased slightly compared to the FFP and were found as 3.58 and 3.55 for HADFP and FDFP samples, respectively. This difference between FFP and powder samples might be due to the increased solids concentration as the free water was rapidly removed by the drying process.

Similar to current results, Taskin (2020) detected that the lowest pH value belonged to the fresh black chokeberry samples and found that there was no significant difference between the pH values of the freeze dried samples in whole, half cut and puree forms of fresh fruits. Petković et al. (2019) determined that the pH values of fresh chokeberry fruits and powders obtained by convective HAD of fresh samples were not affected by the temperature (50, 60, and 70 ℃) of the process. They found the pH values of all samples was 3.41, which was very close to the present results. The total ash (%) values of FFP, HADFP, and FDFP samples were found as 3.06, 3.11, and 3.09, respectively. Considering these results, both drying treatments did not significantly affect the ash content of all samples (P >0.05). Similarly, Sójka et al. (2013) determined that the total ash content in the black chokeberry pomace was between 1.4-3.9% and stated that the seed fractions had a higher content of ash.

Color analysis results

The color characteristics of FFP and the powder samples were given in Table 2, and the surface views of all samples prepared within the scope of the study were depicted in Figure 2. According to the results, both drying treatments caused a significant increase in L* and +a* values, and a decrease in -b* values of FFP (P <0.05) (Table 2). Among both fruit powders, the +a* value of the powder obtained by the HAD treatment was significantly higher, while the -b* value of the powder obtained by the FD treatment was found to be higher than the other sample (P <0.05). Considering the literature, there are studies that show relatively similar or completely different outputs than the present results (Samoticha et al., 2016; Różyło et al., 2019; Sadowska et al., 2019). However, it is not surprising that there are differences in these parameters, as the growing conditions, genetic varieties of black chokeberry, type and amount of color compounds in the fruit, as well as technical preferences and applied parameters in drying affect the color characteristics of the final product. In this framework, higher values of L* and a* color parameters of HADFP indicated that this powder was lighter and had a more intense "red" color than the FDFP, which had a maroon appearance. Therefore, powders produced by both drying techniques can be used as alternatives to each other in order to give a different intensity of red color.

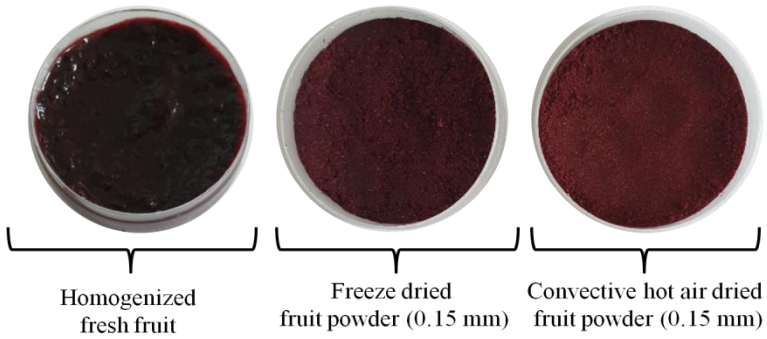

Figure 2. The surface views of all samples prepared within the scope of the study

Table 2. The color characteristics of the samples.

Sample	L*	a*	b*	ΔE
HADFP	24.52 ± 0.12^{A}	23.91 ± 0.30^{A}	-4.57 ± 0.18^{C}	15.39 ± 0.40
FDFP	20.89 ± 0.24^{B}	23.30 ± 0.26^{B}	-7.95 ± 0.26^{B}	10.82 ± 0.28
FFP	10.64 ± 0.42^{C}	21.04 ± 0.38^{C}	-10.55 ± 0.44^{A}	-

Data represent average values ± standard deviation. There is no statistical difference between the results shown with the same exponential capital letter in the same column (P >0.05). HADFP: Hot air-dried fruit powder. FDFP: Freeze-dried fruit powder. FFP: Fresh Fruit Puree.

Recently, the demand for powders of fruit and vegetable juice, puree and various extracts has increased significantly due to the many benefits of applying these products in various food formulations (Shishir and Chen, 2017). In this regard, it is very important that these products obtained by various processes have the natural color of the source from which they are obtained, because color is one of the most important properties that determine the quality and desirability of food products and/or ingredients. However, the color may change due to chemical and biochemical reactions during drying processes (Jia et al., 2020). It is a known fact that the control of these reactions depends greatly on the drying conception, therefore, detecting the changes in the color of the end-product as a result of the applied processes is very important in terms of giving an idea about the most ideal option that can be applied in every respect such as quality, meeting consumer demand, and marketing strategy. In this regard, the ΔE value is quite useful, and the values of powders produced by HAD and FD treatments were found as 15.39 and 10.82, respectively. As is known, the ΔE value is a measurement of the difference between two colors, and the higher ΔE value means the greater difference between the colors being compared. In the literature, differences in perceivable color were analytically classified as very significant ΔE > 3, significant 1.5 < ΔE < 3 and very small difference ΔE < 1.5 (Adekunte et al., 2010). It was stated that the average human eye perceives color differences with a ΔE value of 3 or higher (Chang et al., 2015). In this sense, in the present study, it was observed that both drying treatments caused noticeable color changes, but this occurred relatively less in the FD application in accordance with the literature (Figure 2).

The total phenolic, flavonoid, and monomeric anthocyanin pigment contents of the samples

The analytical data for the total phenolic (TPC), flavonoid (TFC), and monomeric anthocyanin (TMA) pigment contents of the water and methanol (80%) extracts of all samples were given in Table 3. The data clearly showed that for all analysis results, methanol extracts of FFP and powders contained higher amounts of bioactive compounds than the water extracts. Considering the TPC results, there was no significant difference between the methanol extracts of the FFP and FDFP samples ($P > 0.05$), but the results were higher than the HADFP sample ($P < 0.05$). In water extracts, it was determined that the highest TPC was in the FFP sample, followed by FDFP and HADFP, respectively ($P < 0.05$). The same trend was observed in the TFC analysis results. On the other hand, there was no difference between the TMA contents of the methanol extracts ($P > 0.05$), while the results of the water extracts of powder samples were similar to each other but lower than the FFP sample ($P < 0.05$). In the literature, there are similar or different results than those obtained in the current study. For instance, in a study, TPC, TFC, and, TMA values of ethanol (96%) extracts of fresh chokeberry were found as 5222.54 mg GAE/100 g DM, 2346.31 mg catechin equivalents (CE)/100 g DM, and 1764.97 mg CGE/100 g DM, respectively. In the same study, TPC, TFC, and TMA values of ethanol (96%) extracts of chokeberry powder obtained by convective drying at 50 °C until constant weight (37 h) were found as 1918.79 GAE/100 g DM, 1037.19 mg CE/100 g DM, and 376.89 mg CGE/100 g DM. It was stated that higher temperatures of the dehydration process (60 °C, 70 °C) reduced the bioactive components in the chokeberry extracts (Petković et al., 2019). In another study, TPC, TFC, and TMA values of ethanol (80%) extracts of black chokeberry powder obtained by oven drying (60 °C, 12 h) were found as 79230 mg GAE/100 g DM, 5850 mg CE/100 g DM, and 223100 mg CGE/100 g DM (Thi and Hwang, 2016). According to the study of Różyło et al. (2019), the TFC of powder of freeze dried chokeberry fruit was recorded as 51 mg QE/100 g raw material. In a different study, TPC and TMA values of water extracts of chokeberry powders obtained by FD and convective drying (70 °C, 48 h) methods were detected as 2255.86 and 2147.17 mg GAE/100 g DM, 766.59 and 397.71 mg cyanidin-3,5-digalactoside/100 g DM, respectively (Sadowska et al., 2019). Considering all these results, it was inevitable that changes in the chemical composition of black chokeberry fruit, depending

on factors such as growing conditions and genetic diversity, caused changes in TPC, TFC, and TMA values. On the other hand, it is sometimes difficult to compare the results with literature data due to the application of different extraction solvents and conditions or standards to express these values for dried chokeberry fruits or powder samples obtained by different dehydration methods.

Table 3. The total phenolic, flavonoid, and monomeric anthocyanin pigment contents of the samples.

Sample	Extract Type	TPC	TFC	TMA
HADFP	Methanol	6545.58 ± 188.48^{Bb}	4764.50 ± 115.79^{Bb}	1293.87 ± 61.24^{Aa}
FDFP		7231.80 ± 279.50^{Aa}	5198.98 ± 64.36^{Aa}	1313.67 ± 59.76^{Aa}
FFP		7474.09 ± 225.26^{Aa}	5088.91 ± 88.69^{Aa}	1316.21 ± 56.36^{Aa}
HADFP	Water	3700.96 ± 149.06^{Ce}	2499.60 ± 48.04^{Cd}	581.61 ± 17.16^{Bc}
FDFP		4497.34 ± 174.26^{Bd}	3148.14 ± 31.99^{Bc}	621.71 ± 11.23^{Bc}
FFP		5487.92 ± 158.42^{Ac}	4653.23 ± 65.70^{Ab}	767.94 ± 92.87^{Ab}

Data represent average values ± standard deviation. There is no statistical difference between the results shown with the same exponential capital letter in the same column for the same extract group ($P > 0.05$). There is no statistical difference between the results shown with the same exponential lowercase letter in the same column for all samples ($P > 0.05$). HADFP: Hot air-dried fruit powder. FDFP: Freeze-dried fruit powder. FFP: Fresh Fruit Puree. TPC: Total phenolic content (mg gallic acid equivalents (GAE)/100 g DM). TFC: Total flavonoid content (mg quercetin equivalents (QE)/100 g DM). TMA: Total monomeric anthocyanin pigment content (mg cyd-3-glu equivalents (CGE)/100 g DM).

Technological developments in recent years have enabled the development of new drying methods such as vacuum oven drying, microwave drying, freeze drying, and different combined drying treatments (Karabacak et al., 2015; Kursun and Karaca, 2018; Calín-Sánchez et al., 2020; Jia et al., 2020). However, each method has a different effect on the nutritional properties of the final product. In this context, based on the results obtained in the present research, it can be stated that both drying treatments degraded especially water-soluble phenolic compounds in chokeberry fruit. Similarly, Al-Rawahi et al. (2013) found that phenolic compounds of pomegranate peels soluble in water and ethanol were more sensitive compared to the methanol for all drying methods they applied, except FD. Another study determined that the total soluble flavonoid content of hot water extract of immature calamondin peel was severely reduced compared to the hexane and ethyl acetate extracts resulting from heating the peel at 150 ℃ for 1.5 h (Lou et al., 2014). In parallel with the literature, it was found that FD had a minimal effect on the structure of FFP. In the meantime, FD can cause ice crystals to develop in the plant matrix, resulting in further rupturing of the plant cell structure, allowing better solvent access and resulting in higher extraction yields (Nakbanpote et al., 2019). However, it should be noted that HAD is a simple and low-cost technique, so it can be preferred in terms of end-product quality and application performance for the dehydration of chokeberry fruit. To sum up, it would be beneficial to enrich the literature through further studies on drying chokeberry fruit with various treatments and applying different extraction techniques.

The antioxidant activitiy results of the samples

The ABTS and DPPH radical scavenging activities of water and methanol (80%) extracts of all samples were presented in Table 4. As seen, there was no difference between the ABTS radical scavenging activity values of FFP and methanol

extracts of the powder samples (P >0.05). On the contrary, DPPH radical scavenging activity values of methanol extracts were determined as FFP > FDFP > HADFP, respectively (P <0.05). Considering the water extracts, the values obtained for both antioxidant activity analysis results were FFP > FDFP > HADFP (P <0.05). In the meantime, ABTS and DPPH results of methanol extracts were higher than those of water extracts (P <0.05), as were the results of TPC, TFC, and TMA.

Table 4. The antioxidant activitiy results of the samples depending on DPPH and ABTS methods.

Sample	Extract Type	ABTS (μmol Trolox/g)	DPPH (μmol Trolox/g)
HADFP	Methanol	415.28 ± 25.87^{Aa}	217.97 ± 1.64^{Cd}
FDFP		452.43 ± 11.23^{Aa}	232.33 ± 2.15^{Bc}
FFP		427.21 ± 65.64^{Aa}	371.48 ± 9.47^{Aa}
HADFP	Water	212.29 ± 10.38^{Cb}	105.99 ± 1.96^{Cf}
FDFP		257.56 ± 4.34^{Bb}	119.63 ± 0.71^{Be}
FFP		288.01 ± 13.12^{Ab}	257.21 ± 4.78^{Ab}

Data represent average values ± standard deviation. There is no statistical difference between the results shown with the same exponential capital letter in the same column for the same extract group (P >0.05). There is no statistical difference between the results shown with the same exponential lowercase letter in the same column for all samples (P >0.05). HADFP: Hot air-dried fruit powder. FDFP: Freeze-dried fruit powder. FFP: Fresh Fruit Puree.

In this regard, in a study comparing the quality and microstructure of chokeberry powders prepared with different drying methods, Sadowska et al. (2019) determined the antioxidant activity values (ABTS) of water extracts of the powders using FD and convective drying (70 °C, 48 h) applications as 583.6 μmol Trolox/g DM and 489.5 μmol Trolox/g DM, respectively. Oszmianski and Lachowicz (2016) determined the ABTS values of methanol extracts (acidified with 2.0% formic acid) of lyophilized and ground powders made of whole dried fruits (i) and from pomace obtained from whole (ii) and crushed fruits (iii) as 816.6, 816.3, and 599.4 μmol Trolox/g DM, respectively. Samoticha et al. (2016) found that methanol (80%) extracts of fresh chokeberry (i) and its powders obtained by convective drying (50 °C) (ii) and FD (iii) as 2349, 419, and 1147 μmol Trolox/g DM according to the ABTS method, respectively. Considering the DPPH method, Biel et al. (2023) determined of methanol (70%) extract of black chokeberry powder by means of drying at room temperature (18–22 °C, 3–4 days) as 13.36 μM Trolox/g DM. Sady et al. (2019) found that the DPPH value of 75% ethanol extract of FD (-45 °C, 16 h) chokeberry pomace was 429 μM Trolox/g DM. As seen, the results obtained in various studies may differ from each other, and the reason for differences between these studies may be due to the growth conditions and genetic varieties of black chokeberry, as well as the changes applied in the methods. In general, the drying process results in a reduction in naturally occurring antioxidants typically found in raw plant materials (Hsu et al., 2003; Lim and Murtijaya, 2007; Thi and Hwang, 2016), which is valid for all results except ABTS values of methanol extracts in the current study. However, in accordance with the literature, it can be stated that FD treatment preserved the highest levels of bioactive and antioxidant compounds in black chokeberry fruits (Thi and Hwang, 2016; Sadowska et al., 2019). In conclusion, it was clear that chokeberry fruits and powders obtained from these fruits exhibit higher antioxidant activity than many plant based

materials, as summarized by Sidor and Gramza-Michałowska (2019).

CONCLUSION

In this study, fresh black chokeberry (*Aronia melanocarpa* [Michx.] Elliot) fruit puree (FFP) was dried with two different techniques for 24 h and various quality criteria of the obtained fruit powders were examined. According to the results, both convective hot air drying (HAD) and freeze drying (FD) treatments provided suitable results in terms of water activity and moisture value of the powders after 24 h of application. Fruit powders with different color characteristics were obtained with both drying treatments. Considering the effects of drying treatments on the bioactive components of the fresh fruit, it was determined that water and methanol (80%) extracts gave different results. In this regard, FD treatment preserved the highest levels of bioactive and antioxidant compounds in black chokeberry fruits. However, in HAD application, which is a simple and low-cost treatment, it can be stated that it is possible to obtain a powder product rich in phenolic compounds and with high antioxidant activity depending on the drying parameters. Therefore, in order to preserve the beneficial properties of perishable fruits and vegetables, it is recommended to choose the most appropriate dehydration process in terms of cost and performance in line with the intended use.

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CONFLICT OF INTEREST

The author reports no conflict of interest.

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