

Effect of Drying Methods and Pre-treatments on Bioactive Potential of Persimmon (*Diospyros kaki* L.)

Elif Yildiz

Uludağ University

Aslihan Yilmaz

Uludağ University

Ozan Gurbuz

Uludağ University

Ilknur Alibas (✉ ilknuralibas@uludag.edu.tr)

Uludağ University

Research Article

Keywords: persimmon, drying, pre-treatments, antioxidant capacity, total phenolics, bioaccessibility

Posted Date: June 29th, 2023

DOI: <https://doi.org/10.21203/rs.3.rs-3112575/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

In this research, persimmon samples (sliced, pureed) were dehydrated by convective (50 and 100°C) and microwave (100 W) drying techniques with different pre-treatment combinations of sugar addition (25%) and blanching (100°C, 5 min). Each pre-treatment consisting of sugar addition, slicing, and blanching resulted in a significant increase in color parameters compared to untreated samples. Color parameters measured at low drying temperatures were lower than high ones. Also, 100 W dried samples were higher in total anthocyanin content, and the pureed samples were 24.80% higher than sliced ones. The bioactive potential was evaluated regarding extractable, hydrolysable, and bioaccessible phenolic fractions (EPF, HPF, BPF) by total phenolic content and ABTS, CUPRAC, and DPPH antioxidant capacity assays. i) 50°C drying prevailed on drying at 100°C and 100 W, especially in terms of EPF and BPFs; ii) Sliced samples were higher for EPF and BPF, while pureed ones were higher in HPFs; iii) Blanching samples were relatively higher than unblanched ones in TPC. For antioxidant capacity assays, EPFs were higher in blanched samples and BPF in unblanched ones (TEAC_{ABTS}, TEAC_{CUPRAC}). iv) Sugar addition negatively affected the bioactive potential in persimmon samples; no-sugar-added samples were higher, especially in BPF ($p < 0.01$; TPC, TEAC_{ABTS}, TEAC_{CUPRAC}). v) The CUPRAC assay was the most appropriate method due to providing a view of more statistical distinction by picturing the same potential.

Introduction

Persimmon (*Diospyros kaki* L.), a fruit that grows in subtropical climate zones such as the Mediterranean region, belongs to the *Ebenaceae* family. The persimmon, whose homeland is China, was first recognized and cultivated by the whole world with the Silk Road trade [1]. It is called Zeus' fruit or divine fruit because of its attractive color, appearance, and nutritious aspect [2]. The high antioxidant capacity, the density of anthocyanin and phenols, richness of protein, carbohydrate, mineral, ascorbic acid, tannin, and vitamin A and E content have caused the consumption of persimmon to increase day by day. In addition to being consumed raw, persimmon has become a fruit frequently used in jams, marmalades, nectars, jellies, meat products, flour and bakery products, ice creams, salads, and healthy drinks in recent years. Persimmon, whose consumption is becoming increasingly popular and a functional product, has significant benefits for human health [3].

Studies have shown that the fruit in question has the feature of lowering cholesterol and blood pressure, strengthening the immune system, supporting eye health, regulating the work of the gastrointestinal system, being effective against fatigue, stress, and depression, delaying aging, preventing cell damage, and cleanses the liver [4]. It has known that the consumption of persimmon helps the prevention of digestive system disorders and cancer diseases that are frequently seen today [5].

The shelf life of persimmon, which is so nutritious and highly beneficial to human health, is minimal due to its physiological and structural features [6]. Many methods are used to extend the product's consumption time and prevent product losses. Drying is the most common method in the world, among these methods [7]. With the drying, the water, which is high in the product and ensures the continuity of the enzymatic activity, is removed from the biomaterial. Thus, the microbial activity is terminated [8]. As a result of drying processes, the product's nutrient content is preserved at a high level, its shelf life is extended, its transportation, packaging, and storage are facilitated, and its commercial value increases. Many drying methods have been used from the past to the present [6, 9].

The oldest known traditional method is natural drying. Although there is no need for energy, it has many disadvantages, such as the need for large areas for drying, the long drying times, the high need for labor, and the adhesion of external pests to the product by the effect of the sun and wind. In order to eliminate all these disadvantages and to obtain higher quality dry products, the trend towards new and technological drying methods has increased [10].

Applying the pre-treatments together with the drying methods has become popular in recent years in maintaining the quality parameters of the dried products. Many pre-treatments such as sulphurate, alkaline solution application, boiling, soaking in sugar, pre-cooking, steaming, salting, and confectionery are applied to agricultural products; thus, color losses, textural, and enzyme-related quality losses are prevented pre-treatments can be used individually as well as in combinations [9].

The aim of the study was to; i) dry sliced and pureed persimmon by applying pre-treatments such as dipping in sugar, blanching, and dipping in sugar + blanching and without pre-treatment by convective and microwave drying methods, ii) determine color parameters of fresh, non-pretreated, and pre-treated dried products, iii) calculation of total color change, whitening, and browning index, iv) specification of antioxidant capacity, total phenolic and anthocyanin content, v) determination of the closest to the fresh product in terms of color, total color change, browning index, whitening index, total phenolic and anthocyanin content, and antioxidant capacity in the pre-treated and dried samples.

Material and methods

Material

Persimmons (*Diospyros kaki* L. var "Thumb") were bought from Bursa Hikmet Şahin City Marketplace (Bursa, Türkiye). Before the drying and pre-treatment, persimmons were washed, then healthy and well-shaped ones were selected for the study. They were stored at $4 \pm 0.1^\circ\text{C}$ and $90 \pm 5\%$ relative humidity. Also, sugar (Torku Co., Konya, Türkiye) used in sugar addition was obtained from local shops in Bursa, Türkiye.

Chemicals

All the chemicals, reagents, and enzymes used for total anthocyanin content, total phenolic content, and antioxidant capacity analyses were purchased from Sigma-Aldrich (St. Louis, MO, USA).

Sample preparation

Two different sample styles, sliced and pureed, were used for persimmon samples. The persimmon was sliced in 5 mm thickness by a slicing apparatus (Nicer-Dicer, Plus, Germany). Pureed ones were laid at a thickness of 5 mm on trays before the drying process.

Pre-treatments

Blanching and sugar addition pre-treatments were applied to sliced and pureed persimmons. For blanching, persimmon samples were blanched for 5 min at 100°C. For sugar addition, persimmon samples were dipped in 25% sugar of their weight (Sample weight: 100 g) for 2 min.

Drying Processes

Persimmons fruit was dried with the convective drying method at 50°C and 100°C microwave drying method at 100 W. The convective and microwave drying methods were used, 100.00 ± 0.10 g sliced and pureed persimmon. Convective drying processes were executed in the convective dryer (Inoksan, FBE 006, Türkiye). The operating conditions of the dryer were 380–400 V~, 3N AC, and 50 Hz, also with a $981.5 \times 760.0 \times 886.0$ mm drying area. Convective drying processes operated at 50°C and 100°C with 400 rpm fan speed. The 410×320 mm-sized Teflon trays were used. Also, the microwave drying processes were operated in the multifunctional microwave dryer (Electrolux, EVY7800AAX, USA) with 230 ± 10 V~, 50 Hz, and 3000 W specifications. The dimensions of the dryer were $800 \times 430 \times 210$ mm.

Color parameters

In the study, color parameters consisting of brightness (L^*), redness (a^*), yellowness (b^*), chroma (C), and hue angle (α°) were measured with a colorimeter (Konica-Minolta, CR10, Japan) working according to CIE-Lab. Also, using L^* , a^* , and b^* , the total color difference (ΔE), browning index (B), and whitening index (W) were determined using the equations specified by Zia and Alibas [11].

Total anthocyanin content

The total anthocyanin content (TAC) of fresh and dried persimmon samples was determined by the pH differential method, according to the procedures of Lee et al. [12]. The TAC results were expressed as cyanidin-3-glucoside equivalent (CDE) in 100 g dry weight.

Antioxidant capacity and total phenolic content

Extraction

Three different extractions of persimmon samples were prepared for antioxidant capacity (AC) and total phenolic content (TPC) analysis: extractable phenolic fraction (EPF), the hydrolysable phenolic fraction (HPF) and the bioaccessible phenolic fraction (BPF). For EPF and HPF, according to the procedure of Vitali et al. [13], a 2 g fresh/ 0.5 g dried sample was mixed with 20 mL methanol/H₂O/HCl (80:10:1 v/v) and kept in a shaker water bath at 20°C (2 h). Then, the mixture was centrifuged (NF 800, Nuve, Ankara, Türkiye; 3500 rpm, 10 min, 4°C), and the supernatant was taken as the EPF. 20 mL H₂SO₄/methanol (1:10 v/v) was added to the residue and kept in a shaker water bath at 85°C (20 h). The mixture was centrifuged (3500 rpm, 10 min, 4°C). The supernatant was kept as the HPF. For BPF, according to the procedure of Bouayed et al. [14], 2 g fresh/ 0.5 g dried sample was mixed with pepsin enzyme (40 mg/mL in 0.1 M HCl; pH:2), kept at 37°C for 2 h, then pancreatin enzyme (2 mg/mL) with porcine bile (12 mg/mL) was added (pH:7.2) and kept at 37°C for 2 h more. After the digestion procedure, the mixture was centrifuged (3500 rpm, 10 min, 15°C) then the supernatant was taken as the BPF. The extracts were kept at -18°C until analyses.

Antioxidant capacity analysis

Three free radical scavenging assay methods were used for estimating the antioxidant capacity (AC) of the fresh and dried persimmon samples: ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid), DPPH (2,2-diphenyl-1-picrylhydrazyl) and CUPRAC (CUPric Reducing Antioxidant Capacity). ABTS and the CUPRAC assays were determined the procedures according to Apak et al. [15] while DPPH assay was applied according to Brand-Williams et al. [16]. The results were given as $\mu\text{mol Trolox}^\circ$ equivalent (TE) g sample, and the triple analyses were presented as mean $\pm$ SEE.

Total phenolic content

TPC was determined as to the procedures of Naczk and Shahidi [17] by the Folin-Ciocalteu method with slight modifications. The results were expressed as mg gallic acid equivalent (GAE) g sample, and the triple analysis were given as mean $\pm$ SEE.

Bioaccessibility %

Based on obtained results of AC and TPC analysis from EPF, HPF, and BPF, the percentage of bioaccessibility of samples was calculated with the following equation [18];

$$B\% = \frac{B}{E + H} \times 100$$

where: B% is the percentage of bioaccessibility, B is the result of BPF, E is the result of EPF, and H is the result of HPF for relevant AC or TPC analyses.

Statistical analysis

All obtained results of the study were evaluated in terms of The Least Significant Difference (LSD) with JMP Pro 14 (SAS Institute, North Carolina, USA). The sample differences were analyzed for statistical significance at $p < 0.01$ and $p < 0.05$. The results were presented as mean values $\pm$ standard error estimation

(*SEE*). Also, the drying processes and the analyses were triplicated. The measurements of color parameters and calculations of the ΔE , BI , and WI were repeated ten times.

Results and Discussion

Color parameters and total anthocyanin content

Table 1 focuses on the color parameters, color difference indices, and TAC of persimmon fruit dried at 50°C, 100°C, and 100 W, which has been subjected to different pre-treatments and has different cutting styles, namely sliced and pureed. Accordingly, the drying method caused a statistically significant difference in all parameters except a^* and BI . The high drying efficiency of both convective drying at 100°C, which is a high-temperature application, and microwave drying at 100 W, which has the effect of shortening the drying time, resulted in higher L^* , b^* , C , a^* , and WI of persimmon samples compared to 50°C, which is the low-temperature application. For similar reasons, the total color differences representing the darkening of the samples, measured at 50°C, were higher than the other two drying techniques. Depending on the shortness of the drying period, 100 W, which has the highest efficiency, ensured the protection of the TAC, followed by 100°C. Contrarily, 50°C, which had low thermal efficiency compared to other techniques used in the study and was famous for prolonging the drying period, caused dramatic reductions in TAC.

Table 1
Color parameters and anthocyanin content of persimmon samples

	<i>L*</i>	<i>a*</i>	<i>b*</i>	<i>C</i>	<i>a°</i>	<i>ΔE</i>	<i>BI</i>	<i>WI</i>	TAC mg CDE/100 g dw
Drying Technique Effects	*	ns	*	*	**	*	ns	*	**
50°C	34.30 ± 1.31 ^b	18.21 ± 0.37	27.85 ± 1.09 ^b	33.64 ± 1.12 ^b	55.60 ± 0.62 ^b	30.93 ± 1.68 ^a	192.10 ± 7.80	24.99 ± 0.69 ^b	81.76 ± 7.68 ^b
100°C	38.64 ± 1.23 ^a	18.92 ± 0.32	31.94 ± 0.96 ^a	37.24 ± 0.95 ^a	58.51 ± 0.53 ^a	24.95 ± 1.51 ^b	203.55 ± 10.19	27.19 ± 0.74 ^a	99.04 ± 6.21 ^{ab}
100 W	37.94 ± 1.05 ^a	19.03 ± 0.30	31.28 ± 0.99 ^a	36.93 ± 0.95 ^a	57.42 ± 0.68 ^a	26.00 ± 1.40 ^b	185.42 ± 4.99	26.90 ± 0.51 ^a	117.39 ± 8.69 ^a
Pre-treatment Effect	ns	**	ns	ns	**	ns	**	**	ns
R	35.64 ± 1.16	17.79 ± 0.25 ^b	30.50 ± 0.89	35.48 ± 0.89	58.32 ± 0.49 ^a	28.27 ± 1.43	217.43 ± 8.32 ^a	25.18 ± 0.67 ^b	102.20 ± 6.50
B	38.28 ± 0.78	19.65 ± 0.27 ^a	30.22 ± 0.79	36.40 ± 0.78	56.03 ± 0.51 ^b	26.32 ± 1.09	169.95 ± 2.47 ^b	27.54 ± 0.35 ^a	96.59 ± 6.73
Cutting Style Effect	**	**	**	**	**	**	**	**	*
S	46.37 ± 0.33 ^a	20.63 ± 0.17 ^a	38.71 ± 0.35 ^a	44.09 ± 0.34 ^a	61.91 ± 0.24 ^a	14.72 ± 0.43 ^b	179.08 ± 1.20 ^b	30.52 ± 0.14 ^a	88.43 ± 6.15 ^b
P	27.55 ± 0.62 ^b	16.81 ± 0.24 ^b	22.01 ± 0.36 ^b	27.78 ± 0.41 ^b	52.43 ± 0.30 ^b	39.86 ± 0.63 ^a	208.30 ± 8.93 ^a	22.21 ± 0.53 ^b	110.36 ± 6.58 ^a
Sugar Addition Effect	**	ns	ns	ns	ns	ns	**	**	ns
WS	34.43 ± 1.06 ^b	18.89 ± 0.28	30.41 ± 0.73	36.01 ± 0.74	57.32 ± 0.43	28.72 ± 1.28	228.02 ± 7.71 ^a	24.22 ± 0.63 ^b	99.91 ± 7.71
WAS	39.49 ± 0.86 ^a	18.55 ± 0.27	30.30 ± 0.94	35.86 ± 0.93	57.03 ± 0.58	25.87 ± 1.25	159.36 ± 2.36 ^b	28.50 ± 0.33 ^a	98.87 ± 5.34
General	**	**	**	**	**	**	**	**	**
Fresh	54.20 ± 0.29 ^a	26.16 ± 0.44 ^a	49.69 ± 0.28 ^a	56.37 ± 0.34 ^a	62.31 ± 0.37 ^{cd}	0.00 ± 0.00 ^p	207.94 ± 2.58 ^{de}	27.52 ± 0.34 ^h	297.77 ± 9.55 ^a
50°C-R-WS-S	43.72 ± 0.29 ^h	17.58 ± 0.13 ^g	33.32 ± 0.18 ⁱ	37.64 ± 0.43 ^j	62.26 ± 0.30 ^{de}	21.34 ± 0.39 ⁱ	155.30 ± 2.17 ^{lm}	32.27 ± 0.29 ^b	55.39 ± 1.11 ^l
50°C-R-WS-P	16.34 ± 0.16 ^t	14.24 ± 0.32 ⁿ	19.93 ± 0.27 ^o	24.31 ± 0.34 ^q	54.48 ± 0.30 ^k	49.66 ± 0.46 ^a	363.65 ± 15.03 ^b	12.82 ± 0.22 ^o	65.38 ± 1.11 ^k
50°C-B-WS-S	40.38 ± 0.25 ^j	21.28 ± 0.49 ^d	32.08 ± 0.22 ^j	38.62 ± 0.33 ⁱ	56.62 ± 0.32 ^j	23.03 ± 0.46 ^h	172.30 ± 2.72 ^{ijk}	29.02 ± 0.32 ^g	17.69 ± 1.11 ^m
50°C-B-WS-P	25.40 ± 0.28 ^r	16.20 ± 0.29 ^{hij}	20.57 ± 0.37 ^{no}	26.38 ± 0.32 ^p	51.17 ± 0.31 ⁿ	42.19 ± 0.66 ^d	183.62 ± 4.36 ^{fghi}	20.92 ± 0.24 ^m	86.75 ± 1.10 ^h
50°C-R-WAS-S	52.41 ± 0.23 ^b	22.81 ± 0.19 ^b	44.97 ± 0.28 ^b	50.46 ± 0.21 ^b	63.10 ± 0.21 ^c	6.22 ± 0.46 ^o	185.51 ± 2.25 ^{fghi}	30.66 ± 0.27 ^{de}	93.12 ± 1.92 ^h
50°C-R-WAS-P	25.60 ± 0.24 ^r	16.32 ± 0.21 ^{hi}	18.38 ± 0.20 ^p	24.59 ± 0.26 ^q	48.36 ± 0.21 ^o	43.56 ± 0.45 ^{bc}	158.91 ± 3.23 ^{kl}	21.64 ± 0.26 ^l	113.46 ± 1.93 ^g
50°C-B-WAS-S	43.84 ± 0.20 ^h	22.34 ± 0.25 ^{bc}	36.71 ± 0.16 ^h	44.39 ± 0.26 ^e	59.82 ± 0.32 ^g	17.10 ± 0.32 ^j	183.66 ± 1.68 ^{fghi}	29.28 ± 0.19 ^g	73.27 ± 1.92 ^{ij}
50°C-B-WAS-P	26.72 ± 0.39 ^q	14.92 ± 0.23 ^{lmn}	16.86 ± 0.37 ^q	22.76 ± 0.37 ^r	48.95 ± 0.18 ^o	44.31 ± 0.42 ^b	133.83 ± 3.96 ⁿ	23.33 ± 0.39 ^k	149.04 ± 1.91 ^{de}
100°C-R-WS-S	42.58 ± 0.28 ⁱ	18.99 ± 0.24 ^f	36.68 ± 0.28 ^h	41.37 ± 0.37 ^h	62.54 ± 0.33 ^{cd}	16.45 ± 0.50 ^{jk}	187.39 ± 2.88 ^{fgh}	29.26 ± 0.26 ^g	132.16 ± 2.22 ^f
100°C-R-WS-P	15.18 ± 0.22 ^u	14.76 ± 0.11 ^{mn}	20.00 ± 0.25 ^{no}	24.86 ± 0.28 ^q	53.42 ± 0.30 ^{lm}	50.36 ± 0.45 ^a	426.08 ± 14.47 ^a	11.61 ± 0.20 ^p	155.76 ± 1.11 ^d

	<i>L*</i>	<i>a*</i>	<i>b*</i>	<i>C</i>	<i>a°</i>	ΔE	<i>BI</i>	<i>WI</i>	TAC mg CDE/100 g dw
100°C-B-WS-S	46.19 ± 0.11 ^f	22.14 ± 0.18 ^{bc}	40.51 ± 0.12 ^e	46.00 ± 0.28 ^d	61.76 ± 0.19 ^{def}	12.92 ± 0.42 ^{lm}	194.23 ± 1.21 ^{efg}	29.10 ± 0.13 ^g	87.70 ± 2.19 ^h
100°C-B-WS-P	31.80 ± 0.22 ⁿ	21.81 ± 0.26 ^{cd}	28.86 ± 0.35 ^k	36.19 ± 0.19 ^k	52.84 ± 0.27 ^m	30.94 ± 0.38 ^{fg}	216.14 ± 2.82 ^d	22.79 ± 0.14 ^k	86.54 ± 1.92 ^h
100°C-R-WAS-S	47.78 ± 0.14 ^{cd}	21.90 ± 0.14 ^{cd}	40.15 ± 0.25 ^{ef}	45.79 ± 0.24 ^d	61.48 ± 0.16 ^{ef}	12.34 ± 0.42 ^m	181.35 ± 1.73 ^{ghi}	30.58 ± 0.18 ^{de}	114.46 ± 1.11 ^g
100°C-R-WAS-P	35.49 ± 0.26 ^l	15.58 ± 0.15 ^{ijkl}	20.69 ± 0.30 ⁿ	25.90 ± 0.24 ^p	53.00 ± 0.53 ^m	36.14 ± 0.46 ^e	115.27 ± 1.73 ^o	30.48 ± 0.25 ^{de}	69.98 ± 1.09 ^{jk}
100°C-B-WAS-S	52.44 ± 0.27 ^b	19.39 ± 0.25 ^f	42.12 ± 0.27 ^d	46.41 ± 0.25 ^d	65.42 ± 0.20 ^a	10.47 ± 0.49 ⁿ	164.60 ± 2.09 ^{ijkl}	33.57 ± 0.28 ^a	72.23 ± 1.11 ^{ijk}
100°C-B-WAS-P	37.63 ± 0.29 ^k	16.82 ± 0.22 ^h	26.53 ± 0.34 ^l	31.43 ± 0.38 ^m	57.61 ± 0.20 ^j	30.00 ± 0.64 ^g	143.39 ± 2.09 ^{mn}	30.15 ± 0.21 ^{ef}	73.45 ± 1.93 ^{ij}
100 W-R-WS-S	48.41 ± 0.27 ^c	20.25 ± 0.25 ^e	43.41 ± 0.20 ^c	48.36 ± 0.16 ^c	63.95 ± 0.23 ^b	10.51 ± 0.48 ⁿ	197.11 ± 1.85 ^{ef}	29.59 ± 0.19 ^{fg}	89.15 ± 1.91 ^h
100 W-R-WS-P	22.53 ± 0.19 ^s	15.73 ± 0.28 ^{ijk}	24.40 ± 0.29 ^m	29.02 ± 0.22 ^o	57.14 ± 0.14 ^{ij}	41.88 ± 0.43 ^d	285.33 ± 4.31 ^c	17.26 ± 0.13 ⁿ	187.56 ± 1.10 ^b
100 W-B-WS-S	47.07 ± 0.25 ^{de}	21.40 ± 0.20 ^d	38.75 ± 0.18 ^g	44.31 ± 0.20 ^e	61.11 ± 0.17 ^f	13.98 ± 0.33 ^l	176.02 ± 1.85 ^{hij}	30.99 ± 0.21 ^{cd}	86.80 ± 1.93 ^h
100 W-B-WS-P	33.56 ± 0.33 ^m	22.34 ± 0.20 ^{bc}	26.46 ± 0.23 ^l	35.09 ± 0.22 ^l	50.53 ± 0.35 ⁿ	31.37 ± 0.25 ^f	179.06 ± 2.98 ^{hi}	25.07 ± 0.29 ^j	148.09 ± 1.90 ^e
100 W-R-WAS-S	46.79 ± 0.24 ^{ef}	17.67 ± 0.30 ^g	39.43 ± 0.35 ^{fg}	43.34 ± 0.21 ^f	65.91 ± 0.25 ^a	15.37 ± 0.32 ^k	177.02 ± 2.77 ^{hij}	31.44 ± 0.29 ^c	71.25 ± 2.90 ^{jk}
100 W-R-WAS-P	30.87 ± 0.32 ^o	17.67 ± 0.27 ^g	24.61 ± 0.37 ^m	30.10 ± 0.27 ⁿ	54.22 ± 0.36 ^{kl}	35.36 ± 0.27 ^e	176.30 ± 4.71 ^{hij}	24.51 ± 0.34 ^j	78.68 ± 1.89 ⁱ
100 W-B-WAS-S	44.85 ± 0.28 ^g	21.77 ± 0.23 ^{cd}	36.38 ± 0.20 ^h	42.43 ± 0.19 ^g	58.99 ± 0.20 ^h	16.93 ± 0.40 ^j	174.47 ± 2.34 ^{hij}	30.43 ± 0.29 ^{de}	167.90 ± 1.90 ^c
100 W-B-WAS-P	29.47 ± 0.27 ^o	15.37 ± 0.15 ^{klm}	16.79 ± 0.22 ^q	22.77 ± 0.20 ^r	47.49 ± 0.45 ^p	42.58 ± 0.42 ^{cd}	118.07 ± 1.89 ^o	25.88 ± 0.24 ⁱ	109.64 ± 1.92 ^g
** <i>p</i> < 0.01, * <i>p</i> < 0.05; ns: non-significant; results are given as mean ± SEE. Column mean values with different superscripts are significantly different. <i>L*</i> : lightness; <i>a*</i> : redness; <i>b*</i> : yellowness; <i>C</i> : chroma; <i>a°</i> : Hue angle; ΔE : Total color difference; <i>BI</i> : Browning index; <i>WI</i> : Whitening index; B: Blanched; R: Raw/unblached; S: Sliced as 10 mm; C: Cubed as 1 cm ³ ; P: Pureed; WAS: With sugar addition; WS: Without sugar addition; TAC: Total anthocyanin content									

On the other hand, the choice of pre-treatment methods consisting of blanching or unblanching (raw) processes had a statistically significant effect merely on *a**, *a°*, *BI*, and *WI* among all parameters. Blanched samples before the drying process reduced *a** and *a°*, compared to raw samples. Similarly, the blanching process led to a fall in *BI*, in other words, *a** decrease in the darkening of the products. It has been confirmed in many studies that blanching has an effect that reduces oxidation in products; that is, it prevents browning. In parallel, *WI* was higher in blanching samples compared to raw samples because of the reduction in browning due to low oxidation levels.

Interestingly, the cutting style had a statistically significant effect on all the parameters in the table. Accordingly, the sliced samples were brighter, yellower, and redder than pureed ones. Also, they had more vivid colors and were on the color wheel closer to the yellow color. High oxidation caused by the contact of all cells with oxygen during the fine grating stage caused browning, which resulted in an increase in the total color difference in pureed samples. For the same reason, compared to sliced samples, the *BI* of the pureed ones increased, but the *WI* decreased. In pureed samples, the amount of TAC, a water-soluble pigment, increased due to the deliquescence caused by the disintegration effect during grating than slices ones.

Strikingly, sugar addition had meaningful statistically for only *L**, *BI*, and *WI* among all parameters. In this context, the sugar addition provided a significant increase in the *L** of the pureed samples than those without sugar. In parallel, the sugar addition caused an oxidation-reducing effect, reducing *BI* but increasing *WI*. From a comparative perspective, the 50°C-R-WAS-S application, in which drying at 50°C, sugar addition, and slicing were applied together, was the most promising of all applications regarding TAC and color parameters.

Just like our results, Zia and Alibas [11] reported that the *L**, *a**, and *C* of cornelian cherry samples dried at 100 W were higher than those dried at 50 and 100°C due to the shorter drying period. In parallel with our findings, Alibas and Yilmaz [19] noted that browning occurred in orange slices dried at 50°C due to the oxidation that developed with the prolongation of the drying time; in other words, ΔE increased compared to 100°C and 100 W. Similar to our study, Zia and Alibas [20] revealed that the TAC of blueberry samples dried at 100 W followed by 90°C and 50°C, respectively. Priyadarshini, et al. [21] emphasized that the Hue angle of mango cubes decreased after conventional blanching compared to fresh ones. Barron-Garcia, et al. [22] stated that the *a°* of raw *Agaricus*

bisporus mushroom samples was higher than the blanching samples. Bozkir and Ergun [23] stated that the L^* , b^* , and a^* values of cube-shaped persimmon samples dried at 60°C after adding sugar were higher than the fresh ones.

The drying technique had statistically significant effect on TAC, microwave dried samples were found to be the highest while conventionally 50°C dried ones were the lowest ($p < 0.01$). Additionally, the pureed persimmon samples were 24.80% higher in TAC comparing to sliced ones ($p < 0.05$). However, there is no statistically significant effect of blanching nor osmotic dehydration (Sugar addition) regarding to TAC. The 100 W-R-WS-P (187.56 ± 1.10 mg CDE/100 g dw) was the highest after fresh persimmons (297.77 ± 9.55 mg CDE/100 g dw) as being 100 W microwaved, raw/unblanched, no sugar added and pureed. Bas-Bellver et al. [24] evaluated the anthocyanin-rich blueberry wastes as a raw material for obtaining functional powder. They associated the anthocyanin content with the drying technique. Zia and Alibas [11] dried cornelian cherries by natural, microwave and convective drying. They determined the highest TAC in fresh fruits, followed by 70°C and 300 W, while the lowest value was obtained in 500 W-50°C. Also, the total TAC loss determined by 42% and 52% for microwave dried samples. It was lower compared to the convective dried samples.

Total phenolic content

Total phenolic content (TPC) results, evaluated by the Folin-Ciocalteu method, are given in Table 2. Drying is commonly used for food products, and retaining the phenolic content is crucial for the bioactive potential due to its health effects [25]. In persimmon samples, EPFs were high 100 W drying (37.96 ± 1.95 mg GAE/ 100g dw), HPFs were high in 100°C drying (12.93 ± 0.70 mg GAE/ 100g dw), and BPFs were high in 100°C drying (15.84 ± 0.91 mg GAE/ 100g dw). Only BPFs were significantly ($p < 0.01$) affected by the drying process, statistically. It is seen that lower temperature was influential in the preservation and release of the bioaccessible phenolic components in persimmon samples. For HPF, 100°C dried samples were conventionally higher than other drying processes. The higher temperature (100°C) in drying was the probable reason for the facilitated release of hydrolysable phenolic compounds. Lavelli et al. [26] associated the increase of TPC for 80°C-dried tomato samples with the release of phenolics from cell-wall, correspondingly the rise of free hydroxyphenols, as well.

Table 2

Total phenolic content of extractable, hydrolysable, and bioaccessible phenolic fractions of persimmon samples and their bioaccessibility %

	Total Phenolic Content			
	Extractable Phenolic Fraction (mg GAE/g dw)	Hydrolysable Phenolic Fraction (mg GAE/g dw)	Bioaccessible Phenolic Fraction (mg GAE/g dw)	Bioaccessibility %
Drying Technique Effects	ns	ns	*	*
50°C	36.06 ± 1.10	12.62 ± 0.62	15.84 ± 0.91 ^a	32.65 ± 1.86 ^a
100°C	36.72 ± 1.42	12.93 ± 0.70	12.87 ± 0.64 ^b	25.91 ± 0.82 ^b
100 W	37.96 ± 1.95	12.84 ± 0.61	13.00 ± 0.68 ^b	25.72 ± 1.17 ^b
Pre-treatment Effect	ns	ns	ns	ns
R	36.25 ± 1.02	12.76 ± 0.54	13.87 ± 0.53	28.40 ± 1.11
B	37.58 ± 1.43	12.83 ± 0.51	13.93 ± 0.88	27.78 ± 1.71
Cutting Style Effect	ns	ns	ns	ns
S	36.50 ± 1.53	12.90 ± 0.57	13.85 ± 0.75	28.18 ± 1.36
P	37.33 ± 0.90	12.69 ± 0.47	13.95 ± 0.71	28.00 ± 1.53
Sugar Addition Effect	ns	ns	*	*
WS	36.65 ± 1.46	12.54 ± 0.58	14.71 ± 0.86 ^a	30.11 ± 1.75 ^a
WAS	37.18 ± 1.02	13.05 ± 0.45	13.09 ± 0.46 ^b	26.07 ± 0.65 ^b
General	*	*	*	*
Fresh	53.06 ± 0.15 ^a	18.42 ± 0.12 ^a	21.85 ± 0.14 ^a	30.57 ± 0.27 ^e
50°C-R-WS-S	30.32 ± 0.99 ^l	11.64 ± 0.05 ^{jk}	15.25 ± 0.04 ^f	36.39 ± 0.92 ^c
50°C-R-WS-P	37.86 ± 0.22 ^e	9.60 ± 0.05 ⁿ	15.89 ± 0.10 ^e	33.47 ± 0.24 ^d
50°C-B-WS-S	40.42 ± 0.33 ^d	12.76 ± 0.60 ^{fg}	20.71 ± 0.01 ^b	38.96 ± 0.34 ^b
50°C-B-WS-P	35.53 ± 0.06 ^h	11.67 ± 0.07 ^{jk}	19.20 ± 0.04 ^c	40.68 ± 0.08 ^a
50°C-R-WAS-S	38.27 ± 0.17 ^e	13.04 ± 0.08 ^f	14.00 ± 0.14 ^{hij}	27.28 ± 0.22 ^{hi}
50°C-R-WAS-P	37.76 ± 0.25 ^e	13.76 ± 0.15 ^e	14.02 ± 0.01 ^{hij}	27.21 ± 0.19 ^{hi}
50°C-B-WAS-S	34.76 ± 0.27 ⁱ	12.64 ± 0.07 ^{fgh}	13.78 ± 0.07 ^j	29.08 ± 0.27 ^f
50°C-B-WAS-P	33.54 ± 0.28 ^j	15.83 ± 0.06 ^c	13.88 ± 0.09 ^{ij}	28.10 ± 0.12 ^g
100°C-R-WS-S	36.04 ± 0.04 ^{fgh}	17.03 ± 0.07 ^b	15.02 ± 0.04 ^{fg}	28.31 ± 0.04 ^{fg}
100°C-R-WS-P	34.46 ± 0.22 ⁱ	12.21 ± 0.09 ^{hi}	11.81 ± 0.01 ⁿ	25.31 ± 0.13 ^k
100°C-B-WS-S	35.56 ± 0.06 ^h	11.82 ± 0.08 ^{ij}	12.08 ± 0.13 ^m	25.49 ± 0.27 ^k
100°C-B-WS-P	34.70 ± 0.14 ⁱ	12.48 ± 0.14 ^{gh}	12.71 ± 0.07 ^l	26.95 ± 0.21 ⁱ
100°C-R-WAS-S	36.41 ± 0.09 ^{fg}	14.08 ± 0.09 ^{de}	14.07 ± 0.22 ^{hi}	27.87 ± 0.36 ^{gh}
100°C-R-WAS-P	44.77 ± 0.23 ^c	13.91 ± 0.03 ^e	15.73 ± 0.02 ^e	26.80 ± 0.10 ^j
100°C-B-WAS-S	31.16 ± 0.20 ^k	10.22 ± 0.08 ^m	10.75 ± 0.09 ^q	25.99 ± 0.27 ^{jk}
100°C-B-WAS-P	40.66 ± 0.12 ^d	11.66 ± 0.08 ^{jk}	10.75 ± 0.10 ^q	20.54 ± 0.20 ⁿ
100 W-R-WS-S	31.65 ± 0.12 ^k	11.57 ± 0.12 ^{jk}	11.48 ± 0.04 ^o	26.57 ± 0.19 ^{ij}
100 W-R-WS-P	36.65 ± 0.12 ^f	12.34 ± 0.04 ^{gh}	16.39 ± 0.06 ^d	33.46 ± 0.24 ^d
100 W-B-WS-S	50.86 ± 0.07 ^b	16.14 ± 0.18 ^c	14.91 ± 0.02 ^g	22.25 ± 0.12 ^m
100 W-B-WS-P	35.68 ± 0.24 ^{gh}	11.23 ± 0.13 ^{kl}	11.03 ± 0.07 ^p	23.52 ± 0.16 ^l

	Total Phenolic Content			
	Extractable Phenolic Fraction (mg GAE/g dw)	Hydrolysable Phenolic Fraction (mg GAE/g dw)	Bioaccessible Phenolic Fraction (mg GAE/g dw)	Bioaccessibility %
100 W-R-WAS-S	34.71 ± 0.22 ⁱ	10.80 ± 0.09 ^l	10.96 ± 0.04 ^{pq}	24.07 ± 0.05 ^l
100 W-R-WAS-P	36.12 ± 0.07 ^{fg^h}	13.11 ± 0.53 ^f	11.85 ± 0.05 ^{mn}	24.08 ± 0.32 ^l
100 W-B-WAS-S	37.85 ± 0.13 ^e	13.03 ± 0.03 ^f	13.19 ± 0.04 ^k	25.92 ± 0.04 ^{ik}
100 W-B-WAS-P	40.19 ± 0.23 ^d	14.48 ± 0.09 ^d	14.16 ± 0.18 ^h	25.90 ± 0.28 ^{jk}
*<i>p</i> < 0.01; ns: non-significant; results are given as mean ± SEE. Column mean values with different superscripts are significantly different. R: raw/unblached; B: Blanched; S: Sliced as 10 mm; P: pureed; WAS: With sugar addition; WS: Without sugar addition.				

Blanching is a common pre-treatment method for vegetables and fruits to reduce volume, inactivate the enzymes, reduce the effectiveness of drying [27]. The rupture of the cell membrane and the cell walls that occurs during the blanching is also supportive of drying effectiveness [28]. For persimmon samples, there is no statistically significant difference in terms of blanching, but blanched samples were higher in EPF, HPF, and BPF compared to raw/unblached ones. So, owing to the rupture of the cell membrane&walls, the release of phenolic fractions was accelerated by blanching in terms of TPC, but without significant change.

Sugar addition is another pre-treatment for promoting drying and maintaining the nutritional value of osmotic dehydration. In this study, there is an insignificant difference in sugar addition regarding phenolic fractions of persimmon samples. Still, it was statistically significant only in BPF and bioaccessibility % and caused an 11.01% decrease in BPF. The EPF and HPF were relatively high in sugar-added samples. Also, there is no significant difference between slicing and pureeing, as cutting style effect as TPC results.

Bioaccessibility represents the phenolic fraction content that could be released in gastrointestinal digestion and available for intestinal absorption. It is essential for evaluating the functionality and bioactive potential of the foods, applied processes, and functional enrichments [29]. The bioaccessibility % was calculated using EPF, HPF, and BPFs from TPC results. In persimmon samples, bioaccessibility % was affected significantly by the drying technique (*p* < 0.01) and the sugar addition (*p* < 0.01). The sugar-added samples reached a 30.11% bioaccessibility ratio average. 50°C-B-WS-P was the highest in bioaccessibility% with 40.68% also high in BPF (19.20 ± 0.04 mg GAE/100g dw) and EPF (35.53 ± 0.06 mg GAE/100g dw) but low in HPF (11.67 ± 0.07 mg GAE/100g dw). It was followed by 50°C-B-WS-S (38.96%) and 50°C-R-WS-S (36.39%). As seen from the relevant samples, conventionally, 50°C dried and no-sugar-added samples were high in the bioaccessible bioactive potential of the persimmon samples.

The blanching resulted in an increase in the TPC of both phenolic fractions in terms of evaluated persimmon samples. Adetoro et al. [30] evaluated the blanching effect on drying pomegranate arils, and the TPC was determined to be higher in blanched ones. They reported that blanched pomegranate arils (30 s, 90°C, 148.80 mg GAE/g dw; 60 s, 100°C, 141.7 mg GAE/g dw) were higher than the unblached ones (102.10 mg GAE/g dw). Also, they explained the related mechanism as follows: the bioactive compounds such as phenolics and anthocyanin are heat-sensitive and thermal processing tends to reduce their stability, but during the blanching treatment, the phenolic-protein complexes that present in chloroplasts increase the extractability of carotenoids and phenols from the matrix structure. For sugar addition, EPF and HPC were increased while BPF and bioaccessibility % were decreased. Bchir et al. [31] reported TPC results of sucrose immersion pre-treated, 60°C dried pomegranate seed samples as 134.58 mg/100 g, while they revealed that TPC was decreased by immersion in sucrose solution with increasing drying temperature. According to Dziki [27], proteins, minerals, and vitamins loss could be occurred during the blanching osmotic dehydration due to the relatively slow mass transfer and influenced cell membranes&cell structure permeability. Loss of phenolic compounds could be occurred, as well.

Antioxidant capacity results

TEAC_{ABTS} results

Table 3 shows the TEAC_{ABTS} results of the persimmon samples' EPF, HPF, and BPF and their %bioaccessibility ratios. In terms of drying technique, drying at 50°C resulted in a statistically significant increase (*p* < 0.01) in EPF and BPF of persimmon samples, compared to drying at 100°C and 100 W. There is no statistical difference in the blanching process, but raw/unblached samples were relatively higher regarding TEAC_{ABTS} results (HPF, BPF). The cutting style was only significant in EPF, and sliced ones were higher than pureed ones. The sugar addition decreased the BPF results; no-sugar-added samples were higher by 8.44% in BPF and 15.61% in bioaccessibility % results. Similarly, in TPC, 50°C-B-WS-S (44.68%) and 50°C-B-WS-S (44.39%) samples were the highest ones as bioaccessibility % in TEAC_{ABTS} results, as well. Also, 50°C-B-WS-S (211.32 ± 0.23 μmol TE/g dw) was the highest in BPF after the fresh one (239.82 ± 1.10 μmol TE/g dw) and relatively high in EPF (437.07 ± 7.85 μmol TE/g dw). Again, 50°C dried and no sugar added samples were higher in bioaccessible bioactive potential same in TPC results. Differences in EPH and BPF were observable and significant (*p* < 0.01) for ABTS assay, and bioaccessibility % was more affected by sugar addition.

Table 3

TEAC_{ABTS} results of extractable, hydrolysable, and bioaccessible phenolic fractions of butternut squash samples and their bioaccessibility % *TEAC: Trolox equivalent antioxidant capacity

	ABTS			
	Extractable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Hydrolysable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessible Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessibility %
Drying Technique Effects	**	ns	*	ns
50°C	410.53 $\pm$ 26.50 ^a	135.05 $\pm$ 19.93	169.53 $\pm$ 7.65 ^a	32.52 $\pm$ 2.93
100°C	378.44 $\pm$ 18.00 ^{ab}	157.37 $\pm$ 12.58	154.62 $\pm$ 7.33 ^b	29.14 $\pm$ 1.32
100 W	347.74 $\pm$ 19.32 ^b	149.79 $\pm$ 20.74	158.38 $\pm$ 6.22 ^{ab}	32.61 $\pm$ 1.76
Pre-treatment Effect	ns	ns	ns	ns
R	370.13 $\pm$ 11.50	156.13 $\pm$ 9.87	162.45 $\pm$ 4.83	31.15 $\pm$ 1.11
B	387.68 $\pm$ 24.08	138.67 $\pm$ 18.33	159.24 $\pm$ 7.02	31.70 $\pm$ 2.25
Cutting Style Effect	**	ns	ns	ns
S	402.15 $\pm$ 19.70 ^a	142.48 $\pm$ 15.60	161.26 $\pm$ 6.51	30.56 $\pm$ 1.95
P	355.67 $\pm$ 15.65 ^b	152.32 $\pm$ 14.11	160.43 $\pm$ 5.53	32.29 $\pm$ 1.54
Sugar Addition Effect	ns	ns	**	**
WS	377.98 $\pm$ 17.47	136.64 $\pm$ 18.69	167.36 $\pm$ 6.49 ^a	33.70 $\pm$ 2.04 ^a
WAS	379.84 $\pm$ 20.50	158.16 $\pm$ 8.70	154.33 $\pm$ 4.85 ^b	29.15 $\pm$ 1.12 ^b
General	**	**	**	**
Fresh	667.41 $\pm$ 6.97 ^a	223.13 $\pm$ 1.36 ^a	239.82 $\pm$ 1.10 ^a	26.93 $\pm$ 0.29 ^{jk}
50°C-R-WS-S	417.79 $\pm$ 2.60 ^f	179.73 $\pm$ 0.58 ^{ef}	173.41 $\pm$ 0.65 ^{de}	29.02 $\pm$ 0.15 ⁱ
50°C-R-WS-P	337.25 $\pm$ 4.10 ^{kl}	158.68 $\pm$ 1.70 ^{hi}	174.94 $\pm$ 1.14 ^{de}	35.28 $\pm$ 0.15 ^d
50°C-B-WS-S	437.07 $\pm$ 7.85 ^e	39.23 $\pm$ 0.72 ^o	211.32 $\pm$ 0.23 ^b	44.39 $\pm$ 0.74 ^a
50°C-B-WS-P	293.09 $\pm$ 7.09 ^{op}	44.67 $\pm$ 3.00 ⁿ	150.87 $\pm$ 0.35 ^{gh}	44.68 $\pm$ 0.46 ^a
50°C-R-WAS-S	405.58 $\pm$ 1.28 ^{fg}	141.21 $\pm$ 0.42 ^j	173.99 $\pm$ 3.11 ^{de}	31.82 $\pm$ 0.53 ^{fg}
50°C-R-WAS-P	446.04 $\pm$ 13.59 ^{de}	161.41 $\pm$ 0.12 ^h	179.98 $\pm$ 1.12 ^{cd}	29.66 $\pm$ 0.67 ^{hi}
50°C-B-WAS-S	554.89 $\pm$ 3.43 ^b	182.80 $\pm$ 0.23 ^e	151.79 $\pm$ 7.06 ^g	20.58 $\pm$ 0.98 ⁿ
50°C-B-WAS-P	392.56 $\pm$ 3.26 ^{gh}	172.64 $\pm$ 1.10 ^g	139.94 $\pm$ 1.46 ^{ij}	24.76 $\pm$ 0.16 ^l
100°C-R-WS-S	386.31 $\pm$ 12.82 ^h	172.85 $\pm$ 0.82 ^g	128.49 $\pm$ 0.51 ^l	23.00 $\pm$ 0.60 ^m
100°C-R-WS-P	347.55 $\pm$ 6.19 ^{ijk}	196.05 $\pm$ 1.99 ^{cd}	169.14 $\pm$ 0.23 ^{ef}	31.12 $\pm$ 0.28 ^{fgh}
100°C-B-WS-S	487.00 $\pm$ 3.37 ^c	176.19 $\pm$ 0.59 ^{fg}	178.84 $\pm$ 1.31 ^d	26.97 $\pm$ 0.34 ^j
100°C-B-WS-P	382.49 $\pm$ 7.44 ^h	193.33 $\pm$ 0.42 ^d	187.05 $\pm$ 2.70 ^c	32.49 $\pm$ 0.38 ^{ef}
100°C-R-WAS-S	363.15 $\pm$ 2.29 ⁱ	143.41 $\pm$ 0.83 ^j	152.96 $\pm$ 5.27 ^g	30.12 $\pm$ 1.14 ^{hi}
100°C-R-WAS-P	315.81 $\pm$ 2.18 ^{mn}	84.70 $\pm$ 2.84 ^m	138.10 $\pm$ 2.45 ^{jk}	34.49 $\pm$ 0.67 ^d
100°C-B-WAS-S	404.92 $\pm$ 8.13 ^{fg}	162.79 $\pm$ 1.99 ^h	143.81 $\pm$ 4.00 ^{hij}	25.32 $\pm$ 0.30 ^{kl}
100°C-B-WAS-P	340.32 $\pm$ 5.03 ^{ijkl}	129.64 $\pm$ 3.23 ^k	138.93 $\pm$ 2.02 ^j	29.56 $\pm$ 0.11 ^{hi}
100 W-R-WS-S	355.03 $\pm$ 2.85 ^{ij}	123.37 $\pm$ 3.30 ^l	146.38 $\pm$ 1.29 ^{ghi}	30.61 $\pm$ 0.52 ^{ghi}
100 W-R-WS-P	326.96 $\pm$ 4.29 ^{lm}	120.08 $\pm$ 1.28 ^l	173.68 $\pm$ 0.93 ^{de}	38.86 $\pm$ 0.58 ^c
100 W-B-WS-S	305.83 $\pm$ 1.91 ^{no}	23.45 $\pm$ 0.35 ^p	136.64 $\pm$ 2.46 ^{jk}	41.50 $\pm$ 0.88 ^b

	ABTS			
	Extractable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Hydrolysable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessible Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessibility %
100 W-B-WS-P	459.35 $\pm$ 4.32 ^d	212.11 $\pm$ 0.54 ^b	177.57 $\pm$ 1.14 ^d	26.45 $\pm$ 0.22 ^{jk}
100 W-R-WAS-S	396.15 $\pm$ 3.25 ^{gh}	191.38 $\pm$ 1.68 ^d	174.66 $\pm$ 3.16 ^{de}	29.73 $\pm$ 0.43 ^{hi}
100 W-R-WAS-P	343.95 $\pm$ 2.61 ^{ijkl}	200.70 $\pm$ 3.36 ^c	164.06 $\pm$ 1.02 ^f	30.12 $\pm$ 0.12 ^{hi}
100 W-B-WAS-S	312.03 $\pm$ 9.50 ^{mn}	173.33 $\pm$ 2.19 ^g	163.19 $\pm$ 2.72 ^f	33.66 $\pm$ 1.04 ^{de}
100 W-B-WAS-P	282.64 $\pm$ 0.88 ^p	153.89 $\pm$ 0.89 ⁱ	130.89 $\pm$ 3.13 ^{kl}	29.98 $\pm$ 0.63 ^{hi}
**$p < 0.01$, *$p < 0.05$; ns: non-significant; results are given as mean $\pm$ SEE. Column mean values with different superscripts are significantly different. R: raw/unblached; B: Blanched; S: Sliced as 10 mm; P: pureed; WAS: With sugar addition; WS: Without sugar addition.				

TEAC_{CUPRAC} results

Table 4 shows the TEAC_{CUPRAC} results of persimmon samples’ EPF, HPF, and BPF and their %bioaccessibility ratios. Same in TPC and TEAC_{ABTS}, according to TEAC_{CUPRAC} results, 50°C dried persimmons were statistically high in EPF ($p < 0.01$) and BPF ($p < 0.05$). Regarding cutting styles, sliced samples were significantly higher in EPF ($p < 0.01$) and respectively higher in BPF compared with the pureed ones. Sugar addition caused to decrease in the bioactive potential of EPF, HPF, and BPFs in persimmons. Blanching increased the bioactive potential in EPF by 14.62% ($p < 0.01$) but reduced it by 3.13% in BPF.

Table 4

TEAC_{CUPRAC} results of extractable, hydrolysable, and bioaccessible phenolic fractions of persimmon samples and their bioaccessibility % *TEAC: Trolox equivalent antioxidant capacity

CUPRAC				
	Extractable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Hydrolysable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessible Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessibility %
Drying Technique Effects	*	ns	*	ns
50°C	118.97 $\pm$ 14.98 ^a	117.94 $\pm$ 15.34	58.84 $\pm$ 9.52 ^a	26.75 $\pm$ 4.83
100°C	101.54 $\pm$ 5.49 ^b	140.79 $\pm$ 14.34	52.82 $\pm$ 1.89 ^{ab}	22.68 $\pm$ 1.71
100 W	95.89 $\pm$ 4.61 ^b	118.77 $\pm$ 7.61	45.87 $\pm$ 5.15 ^b	21.39 $\pm$ 2.30
Pre-treatment Effect	*	ns	ns	ns
R	98.28 $\pm$ 10.50 ^b	126.33 $\pm$ 9.50	53.34 $\pm$ 3.76	24.48 $\pm$ 2.17
B	112.65 $\pm$ 3.95 ^a	125.34 $\pm$ 12.14	51.67 $\pm$ 6.59	22.73 $\pm$ 3.14
Cutting Style Effect	*	ns	ns	ns
S	113.63 $\pm$ 37.07 ^a	125.00 $\pm$ 11.19	54.77 $\pm$ 5.93	24.41 $\pm$ 3.15
P	97.30 $\pm$ 37.89 ^b	126.67 $\pm$ 10.60	50.25 $\pm$ 4.65	22.81 $\pm$ 2.16
Sugar Addition Effect	ns	ns	**	ns
WS	107.50 $\pm$ 6.50	130.09 $\pm$ 11.91	59.14 $\pm$ 5.91 ^a	25.55 $\pm$ 2.82
WAS	103.43 $\pm$ 9.72	121.58 $\pm$ 9.62	45.88 $\pm$ 3.91 ^b	21.67 $\pm$ 2.47
General	**	**	**	**
Fresh	317.41 $\pm$ 3.12 ^a	295.32 $\pm$ 1.52 ^a	128.57 $\pm$ 0.85 ^a	20.98 $\pm$ 0.12 ^h
50°C-R-WS-S	107.65 $\pm$ 1.86 ^f	131.93 $\pm$ 0.88 ⁱ	41.10 $\pm$ 0.22 ^m	17.16 $\pm$ 0.26 ^j
50°C-R-WS-P	89.20 $\pm$ 0.51 ^l	129.79 $\pm$ 1.58 ⁱ	71.96 $\pm$ 0.21 ^c	32.86 $\pm$ 0.28 ^c
50°C-B-WS-S	163.41 $\pm$ 1.01 ^c	59.18 $\pm$ 0.50 ^t	116.23 $\pm$ 0.21 ^b	52.21 $\pm$ 0.06 ^a
50°C-B-WS-P	99.81 $\pm$ 0.83 ^{hi}	70.84 $\pm$ 0.95 ^s	34.23 $\pm$ 0.13 ^p	20.07 $\pm$ 0.28 ⁱ
50°C-R-WAS-S	94.65 $\pm$ 1.03 ^j	93.87 $\pm$ 0.51 ^{pq}	62.90 $\pm$ 0.21 ^e	33.37 $\pm$ 0.20 ^c
50°C-R-WAS-P	95.82 $\pm$ 0.88 ^j	103.12 $\pm$ 0.51 ^o	71.24 $\pm$ 0.22 ^c	35.81 $\pm$ 0.25 ^b
50°C-B-WAS-S	210.82 $\pm$ 1.35 ^b	161.03 $\pm$ 0.88 ^g	37.99 $\pm$ 0.25 ⁿ	10.22 $\pm$ 0.01 ⁿ
50°C-B-WAS-P	90.37 $\pm$ 1.88 ^{kl}	193.79 $\pm$ 0.69 ^c	35.06 $\pm$ 0.17 ^p	12.34 $\pm$ 0.05 ^m
100°C-R-WS-S	124.34 $\pm$ 0.67 ^d	205.04 $\pm$ 0.51 ^b	51.50 $\pm$ 0.36 ^j	15.64 $\pm$ 0.10 ^k
100°C-R-WS-P	122.02 $\pm$ 1.57 ^{de}	180.77 $\pm$ 0.84 ^d	52.42 $\pm$ 0.25 ^j	17.31 $\pm$ 0.07 ^j
100°C-B-WS-S	79.46 $\pm$ 1.21 ^m	145.68 $\pm$ 1.07 ^h	48.13 $\pm$ 0.17 ^k	21.38 $\pm$ 0.14 ^h
100°C-B-WS-P	106.07 $\pm$ 0.19 ^f	172.79 $\pm$ 0.69 ^e	62.97 $\pm$ 0.27 ^e	22.58 $\pm$ 0.15 ^g
100°C-R-WAS-S	88.15 $\pm$ 1.44 ^l	118.25 $\pm$ 0.69 ^l	57.49 $\pm$ 0.51 ^g	27.86 $\pm$ 0.33 ^f
100°C-R-WAS-P	104.16 $\pm$ 0.50 ^{fg}	121.66 $\pm$ 1.19 ^k	44.94 $\pm$ 0.17 ^l	19.90 $\pm$ 0.11 ⁱ
100°C-B-WAS-S	100.66 $\pm$ 1.07 ^{gh}	90.43 $\pm$ 0.67 ^r	54.39 $\pm$ 0.13 ^h	28.47 $\pm$ 0.22 ^e
100°C-B-WAS-P	87.49 $\pm$ 0.83 ^l	91.69 $\pm$ 0.38 ^{qr}	50.68 $\pm$ 0.33 ^j	28.28 $\pm$ 0.27 ^{ef}
100 W-R-WS-S	94.28 $\pm$ 1.06 ^j	104.59 $\pm$ 0.83 ^o	60.56 $\pm$ 0.22 ^f	30.46 $\pm$ 0.18 ^d
100 W-R-WS-P	80.00 $\pm$ 1.17 ^m	122.43 $\pm$ 0.69 ^k	56.83 $\pm$ 0.21 ^g	28.07 $\pm$ 0.22 ^{ef}
100 W-B-WS-S	104.32 $\pm$ 1.33 ^{fg}	111.81 $\pm$ 0.88 ^m	45.51 $\pm$ 0.35 ^l	21.06 $\pm$ 0.10 ^h

	CUPRAC			
	Extractable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Hydrolysable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessible Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessibility %
100 W-B-WS-P	119.42 $\pm$ 1.39 ^e	126.19 $\pm$ 0.84 ^j	68.18 $\pm$ 0.08 ^d	27.76 $\pm$ 0.26 ^f
100 W-R-WAS-S	102.17 $\pm$ 1.02 ^{gh}	109.10 $\pm$ 0.51 ⁿ	44.71 $\pm$ 0.14 ⁱ	21.16 $\pm$ 0.16 ^h
100 W-R-WAS-P	76.96 $\pm$ 1.18 ^m	95.35 $\pm$ 0.89 ^p	24.47 $\pm$ 0.08 ^r	14.21 $\pm$ 0.20 ^l
100 W-B-WAS-S	93.65 $\pm$ 1.02 ^{jk}	169.06 $\pm$ 0.67 ^f	36.67 $\pm$ 0.21 ^o	13.96 $\pm$ 0.07 ^l
100 W-B-WAS-P	96.31 $\pm$ 1.40 ^{ij}	111.60 $\pm$ 0.89 ^m	30.06 $\pm$ 0.32 ^q	14.46 $\pm$ 0.21 ^l
**$p < 0.01$, *$p < 0.05$; ns: non-significant; results are given as mean $\pm$ SEE. Column mean values with different superscripts are significantly different. R: raw/unblached; B: Blanched; S: Sliced as 10 mm; P: pureed; WAS: With sugar addition; WS: Without sugar addition.				

For EPF, the drying technique, blanching, and cutting style were effective on bioactivity ($p < 0.01$). There is no statistically significant effect of applied processes in terms of HPFs. Also, the drying technique ($p < 0.05$) and sugar addition ($p < 0.01$) were effective on bioactivity for the BPF of persimmon samples. Conventionally 50°C dried, unblanched, sliced, and no-sugar-added samples were also higher in bioaccessibility %. 50°C-B-WS-S (116.23 $\pm$ 0.21 $\mu\text{mol TE/g dw}$) was quite close to fresh persimmon samples (128.57 $\pm$ 0.85 $\mu\text{mol TE/g dw}$), and it was followed by 50°C-R-WAS-P (71.24 $\pm$ 0.22 $\mu\text{mol TE/g dw}$) in BPF. Also, 50°C-B-WS-S was the highest in bioaccessibility% with 52.21%, while the fresh one was 20.98%. Conventionally 100°C dried samples were found to be higher again in HPF (averagely 140.79 $\pm$ 14.34 $\mu\text{mol TE/g dw}$). Also, it was observable in TEAC_{CUPRAC} results that sliced and no-sugar-added samples were higher in bioactive potential. Additionally, pureed samples were higher with sugar addition for 100°C drying and 100 W dried samples. Probably, sugar addition could tolerate the loss of the bioactive potential.

TEAC_{DPPH} results

The TEAC_{DPPH} results of EPF, HPF, and BPF extracts and their bioaccessibility % values are given in Table 5. According to statistical evaluation, only the drying technique effect was significant on EPF and HPF results ($p < 0.01$). Same in TPC and other AC assays, conventionally, 50°C dried samples were the highest, again. Different from other AC assays, 100 W-R-WS-S (331.53 $\pm$ 2.63 $\mu\text{mol TE/g dw}$) was the highest after the fresh sample (396.92 $\pm$ 11.95 $\mu\text{mol TE/g dw}$) in HPF and the highest sample in bioaccessibility % (67.37%) for TEAC_{DPPH} results.

Table 5

TEAC_{DPPH} results of extractable, hydrolysable, and bioaccessible phenolic fractions of persimmon samples and their bioaccessibility % *TEAC: Trolox equivalent antioxidant capacity

DPPH				
	Extractable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Hydrolysable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessible Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessibility %
Drying Technique Effects	**	**	ns	ns
50°C	394.60 $\pm$ 40.01 ^a	340.60 $\pm$ 9.33 ^a	214.09 $\pm$ 21.10	29.92 $\pm$ 3.36
100°C	187.57 $\pm$ 18.65 ^b	309.45 $\pm$ 6.03 ^b	192.49 $\pm$ 28.86	37.80 $\pm$ 5.10
100 W	159.10 $\pm$ 12.84 ^b	301.65 $\pm$ 7.53 ^b	180.95 $\pm$ 28.66	38.21 $\pm$ 5.23
Pre-treatment Effect	ns	ns	ns	ns
R	267.67 $\pm$ 42.72	322.99 $\pm$ 9.29	193.96 $\pm$ 22.61	33.32 $\pm$ 3.83
B	266.51 $\pm$ 30.27	311.48 $\pm$ 5.96	197.73 $\pm$ 20.98	37.29 $\pm$ 3.94
Cutting Style Effect	ns	ns	ns	ns
S	251.98 $\pm$ 37.07	316.80 $\pm$ 8.73	209.04 $\pm$ 23.73	37.36 $\pm$ 4.60
P	242.20 $\pm$ 37.89	317.66 $\pm$ 7.16	182.65 $\pm$ 18.95	33.26 $\pm$ 2.99
Sugar Addition Effect	ns	ns	ns	*
WS	276.67 $\pm$ 39.60	322.12 $\pm$ 9.92	183.96 $\pm$ 22.95	31.46 $\pm$ 4.36 ^b
WAS	217.51 $\pm$ 33.11	312.34 $\pm$ 4.99	207.73 $\pm$ 20.03	39.16 $\pm$ 3.04 ^a
General	**	**	**	**
Fresh	623.95 $\pm$ 1.62 ^a	478.10 $\pm$ 2.55 ^a	396.92 $\pm$ 11.95 ^a	36.02 $\pm$ 1.21 ^{fg}
50°C-R-WS-S	475.73 $\pm$ 2.11 ^b	388.50 $\pm$ 0.60 ^b	204.28 $\pm$ 7.38 ^h	23.63 $\pm$ 0.79 ^j
50°C-R-WS-P	473.57 $\pm$ 1.94 ^b	376.69 $\pm$ 0.92 ^c	211.46 $\pm$ 8.20 ^{efgh}	24.87 $\pm$ 0.99 ^{ij}
50°C-B-WS-S	451.84 $\pm$ 1.24 ^c	327.10 $\pm$ 1.24 ^f	215.19 $\pm$ 6.60 ^{efgh}	27.62 $\pm$ 0.76 ^{hi}
50°C-B-WS-P	425.89 $\pm$ 0.91 ^d	311.76 $\pm$ 0.91 ^{hi}	105.19 $\pm$ 2.28 ^{lm}	14.26 $\pm$ 0.31 ^k
50°C-R-WAS-S	457.59 $\pm$ 1.82 ^c	322.88 $\pm$ 1.60 ^e	230.48 $\pm$ 7.37 ^e	29.15 $\pm$ 0.85 ^h
50°C-R-WAS-P	454.65 $\pm$ 1.93 ^c	338.56 $\pm$ 1.20 ^d	309.29 $\pm$ 6.90 ^c	38.99 $\pm$ 0.88 ^{ef}
50°C-B-WAS-S	255.83 $\pm$ 1.83 ^f	332.10 $\pm$ 2.43 ^e	269.35 $\pm$ 10.56 ^d	45.83 $\pm$ 1.99 ^c
50°C-B-WAS-P	161.69 $\pm$ 1.58 ^l	317.23 $\pm$ 2.94 ^g	167.52 $\pm$ 2.66 ^{ij}	34.99 $\pm$ 0.77 ^g
100°C-R-WS-S	105.90 $\pm$ 0.60 ^o	297.96 $\pm$ 2.28 ^{no}	62.03 $\pm$ 2.28 ⁿ	15.36 $\pm$ 0.58 ^k
100°C-R-WS-P	285.94 $\pm$ 2.27 ^e	335.10 $\pm$ 0.60 ^{de}	225.34 $\pm$ 6.97 ^{efg}	36.28 $\pm$ 1.11 ^{fg}
100°C-B-WS-S	218.60 $\pm$ 4.57 ^{gh}	318.87 $\pm$ 1.84 ^g	256.86 $\pm$ 9.45 ^d	47.83 $\pm$ 2.15 ^c
100°C-B-WS-P	195.89 $\pm$ 2.11 ⁱ	319.34 $\pm$ 0.92 ^g	185.05 $\pm$ 4.80 ⁱ	35.91 $\pm$ 0.83 ^{fg}
100°C-R-WAS-S	178.65 $\pm$ 6.87 ^{jk}	305.80 $\pm$ 1.79 ^{kl}	148.08 $\pm$ 5.76 ^k	30.57 $\pm$ 1.15 ^h
100°C-R-WAS-P	138.55 $\pm$ 4.16 ⁿ	275.41 $\pm$ 1.03 ^p	96.95 $\pm$ 3.51 ^m	23.41 $\pm$ 0.75 ^j
100°C-B-WAS-S	213.64 $\pm$ 1.59 ^h	316.31 $\pm$ 0.70 ^g	302.06 $\pm$ 3.94 ^c	57.00 $\pm$ 0.74 ^b
100°C-B-WAS-P	163.39 $\pm$ 0.69 ^l	306.82 $\pm$ 1.03 ^{ikl}	263.51 $\pm$ 9.17 ^d	56.04 $\pm$ 1.87 ^b
100 W-R-WS-S	181.14 $\pm$ 1.82 ^j	311.00 $\pm$ 0.69 ^{ij}	331.53 $\pm$ 2.63 ^b	67.37 $\pm$ 0.81 ^a
100 W-R-WS-P	146.79 $\pm$ 0.92 ^m	300.89 $\pm$ 1.20 ^{mn}	123.42 $\pm$ 4.78 ^l	27.57 $\pm$ 1.05 ^{hi}
100 W-B-WS-S	134.59 $\pm$ 3.17 ⁿ	252.26 $\pm$ 0.92 ^q	59.97 $\pm$ 2.66 ⁿ	15.51 $\pm$ 0.74 ^k

DPPH				
	Extractable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Hydrolysable Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessible Phenolic Fraction ($\mu\text{mol TE/g dw}$)	Bioaccessibility %
100 W-B-WS-P	224.18 $\pm$ 1.85 ^g	326.00 $\pm$ 0.60 ^f	227.17 $\pm$ 6.02 ^{ef}	41.28 $\pm$ 0.94 ^{de}
100 W-R-WAS-S	177.06 $\pm$ 0.92 ^{jk}	303.11 $\pm$ 1.25 ^{lm}	221.48 $\pm$ 9.19 ^{efgh}	46.12 $\pm$ 1.88 ^c
100 W-R-WAS-P	136.45 $\pm$ 0.92 ⁿ	309.92 $\pm$ 1.52 ^{ijk}	163.17 $\pm$ 8.07 ^{jk}	36.55 $\pm$ 1.78 ^{fg}
100 W-B-WAS-S	173.17 $\pm$ 0.92 ^k	315.77 $\pm$ 0.60 ^{gh}	207.15 $\pm$ 2.27 ^{gh}	42.37 $\pm$ 0.52 ^d
100 W-B-WAS-P	99.45 $\pm$ 2.12 ^o	294.22 $\pm$ 3.04 ^o	113.72 $\pm$ 2.29 ^{lm}	28.91 $\pm$ 0.82 ^h
*$p < 0.01$; ns: non-significant; results are given as mean $\pm$ SEE. Column mean values with different superscripts are significantly different. R: raw/unblached; B: Blanched; S: Sliced as 10 mm; P: pureed; WAS: With sugar addition; WS: Without sugar addition.				

Kayacan et al. [32] evaluated the effect of drying with different methods as hot-air drying, freeze-drying, ultrasound-assisted vacuum-drying, and infrared drying, on persimmon bioactivity in terms of TPC, TEAC_{CUPRAC}, and TEAC_{DPPH} by methanol-water (50:50) extraction of samples. They determined the fresh persimmon as 265.10 $\pm$ 1.70 mg GAE/100 g dw, 635.2 $\pm$ 13.5 mg TE/100 g, and 299.70 $\pm$ 3.00 mg TE/100 g, respectively. Also, hot-air dried samples were 77.20 $\pm$ 0.90 mg GAE/100 g dw, 219.20 $\pm$ 9.60 mg TE/100 g dw, 101.10 $\pm$ 6.80 mg TE/100 g dw. Consistent with our results, the fresh persimmon samples were determined to be higher than the dried ones. Including the being susceptible to oxidation and heat treatment of phenolic compounds, they attributed the higher loss of the bioactive content to the longer drying duration. Also, the highest TPC results were obtained in ultrasound-assisted vacuum-dried samples, while the freeze-dried ones were higher in the TEAC_{CUPRAC} and TEAC_{DPPH} results. Bchir et al. [31] determined the %inhibition as 31.17% by the DPPH method for sucrose solution pre-treated and 60°C dried pomegranate seed samples, while untreated ones had 84.23%. They detected a decrease in AC after the samples' osmotic dehydration process, consistent with our study.

In AC assays and TPC determination, together with other spectrophotometric determination methods, detecting changes and interpreting the mechanism behind them is more meaningful and realistic for evaluating the bioactive potential. For studies like this one, sampling creation for an appropriate experimental design to reveal the differences and choosing the most suitable assay are the critical factors because there are various variable factors between conducted studies, even in raw materials, such as geographical location, plant nutrition -based on soil, climate, genotype, maturity, and storage of the raw material, etc. Also, changes in the food matrix, sample preparation, extraction procedures (solvent content, time, temperature, etc.), an indication of the results by different units, and the absence of a universal standard [33] make the comparison and evaluation confusing.

When evaluating all the applied assays on persimmon samples, in terms of effectiveness and picturing their bioactive potential, The TEAC_{CUPRAC} was found to be the most appropriate evaluation method for this research. The CUPRAC assay provided more statistical discrimination together with reflecting the same line with other assays. The methodology of the CUPRAC assay has a more sensitive and selective nature with the chelating mechanism of neocuproine and oxidizing agent mechanism of the Cu²⁺ ions. In addition, this assay can distinguish between different types of antioxidants based on their reducing abilities and less affected by pH changes and other interfering substances [15]. So, the CUPRAC assay prevailed on ABTS and DPPH assays.

The optimum temperature of conventional drying for phenolic compound retention was reported as 60°C by Stojanovic and Silva [34]. An increase in the drying temperature causes the loss of bioactive compounds. Drying of the persimmon samples at 50°C provided higher bioactive potential, while drying at 100°C caused a decrease in bioactive content. Also, comparing the conventional and microwave drying, statistical differences were determined in EPF (TPC, TEAC_{ABTS}, TEAC_{CUPRAC}) and BPF (TEAC_{ABTS}, TEAC_{CUPRAC}) with higher bioactivity of conventional ones. Also, 100 W microwave drying was determined to be lower. Alibas et al. [7] evaluated conventional and microwave drying in basil leaves. They indicated 100 W affected samples negatively compared to other drying methods regarding nutrients and protein content. Prolongation in drying period resulted in a loss in nutrient content. They indicated that longer drying time accelerated the oxidation. Additionally, they compared the drying duration and determined that conventional drying at 50°C was approximately 11 times longer than 900 W and about 2.5 times longer than 100 W [7]. Reduction in the drying period provided protected the samples' nutritional potential. Also, Zhao et al. [5] evaluated the drying of persimmon slices by conventional drying (50°C, 60°C, 70°C) and freeze-drying. They found that 60°C dried samples had higher in TEAC_{DPPH} results and gallic acid content, while 50°C dried ones had the highest β -carotene content among the air-dried samples. In addition, increasing drying temperature led to a decrease in the various bioactive compound contents such as β -carotene, gallic acid, proanthocyanidins, flavonoids, etc. The heat treatment was found to significantly affect the depletion of these bioactive compounds, which can be related to the release of bounded phenolic acids from the matrix by the influence of high temperature.

Sugar addition negatively affected the bioactive potential in persimmon samples. Deng et al. [9] prepared a comprehensive review of the characteristics and quality attributes of applied pre-treatments on drying. It is seen that generally; sugar addition was mainly applied to fruits for osmotic dehydration and generally caused to decrease in bioactive potential. With dietary fiber, sugar, and protein content, the increasing sugar content was tented to reduce bioactive potential as a probable resulting of the Maillard reaction, a non-enzymatic browning involving proteins and sugars, results in toxic and carcinogenic compounds.

In terms of bioaccessibility, BPF reflects a more realistic estimation of nutritional perspective for bioactive potential in favor of mimic extraction. It includes digestion enzymes (pepsin, pancreatin, etc.) and bile salt, also with coequal temperature (37°C) and time of human digestion. In this context, drying at 50°C prevailed on applied drying techniques. In a study by Zhang et al. [35], the influence of digestion on carotenoids was evaluated using *in vitro* digestion on fresh and conventional dried carrot samples. They stated that the cell wall serves as the primary natural barrier that controls the release of carotenoids, with pectin and polysaccharide content affecting bioaccessibility through different interactions with target compounds. When comparing digested fresh and conventional dried samples, it was observed that hot air-drying caused disruption of the cell wall, leading to an expected release of carotenoids and ultimately resulting in higher bioaccessibility values. Bas-Bellver et al. [24] also evidenced the remaining anthocyanins and carotenoids after intestinal digestion and reaching the colon in the anthocyanin-rich blueberry waste powders. Thus, they could be included in the fermentation by the intestinal microbiota and contribute to human health with their enriched bioactivity. Gouw et al. [36] evaluated the effect of the digestion process on dried fruit pomaces in terms of the bioactive compounds. They indicated that bounded phenolics were released during *in vitro* digestion, either through direct solubilization in intestinal fluids or via the action of digestive enzymes. The polyphenols with low molecular weight were found to be partially absorbed in the small intestine. In contrast, the polyphenols with high molecular weight were fermented by microbiota in the colon and partially absorbed by gut epithelial cells. They evidenced that high molecular weight ones act as a counteractant against prooxidants.

The linear correlations of results

Table 6 highlights the linear correlations between quality parameters of persimmon dried at 50°C, 100°C, and 100 W after different pre-treatment and slicing techniques. Expectedly, all of the relationships between color parameters, except a^* and a° , were positively significant. Also, WI, one of the color change markers, showed strong positive correlations with L^* and significant negative correlations with AE and BI, other markers. Strikingly, none of the color parameters had a meaningful relationship with any of the bioactivity components. Conversely, significant relationships among bioactivity components were remarkable.

Table 6

L*: Lightness; a*: Redness; b*: Yellowness; C: Chroma; a°: Hue angle; ΔE: Total color difference; Bt: Browning index; Wt: Whitening index; TAC: Total anthocyanin content (mg CDE / 100 g dw); E: Extractable phenolic fraction; H: Hydrolysable phenolic fraction; B: Bioaccessible phenolic fraction; B%: Bioaccessibility % (%). T: Total phenolic content (mg GAE/g dw); D: TEAC_{DPPH} (μmol TE/g dw); A: TEAC_{ARTS} (μmol TE/g dw); C: TEAC_{CUPRAC} (μmol TE/g dw).

On the other hand, the BPF of ABTS had moderate positive associations with BPF of CUPRAC, HPF of DPPH, or EPF of DPPH, ranging from 70 to 78%. Moderate positive associations of EPF of ABTS with EPF of CUPRAC or HPF of DPPH were exemplary of significant associations between different antioxidant determination methods. Neither the 76% relationship between bioaccessible TPC and bioaccessibility of TPC nor the 74% relationship between BPF of DPPH and bioaccessibility of DPPH was unexpected since BPFs have an essential role in calculating bioaccessibility. The relationship between HBF and EHB of DPPH, along with HBF of ABTS and bioaccessibility of ABTS, was among the significant associations determined in this study.

Like our findings, Alibas et al. [37] and Alibas et al. [7] highlighted a positive association between C and b^* color parameters. Zia and Alibas [11] underlined positive linear relationships between the EPFs of TEAC_{CUPRAC} and TEAC_{ABTS}. They also determined a robust positive association between C and a^* . In parallel with our results, Zia and Alibas [20] mentioned positive correlations between C and b^* or L^* , along with between b^* and L^* . Moreover, they detected a meaningful correlation between the BPFs of TEAC_{CUPRAC} and TEAC_{ABTS}.

Conclusion

In this study, the sliced, cubed, and pureed butternut squash samples were dried by convective drying at 60 and 100°C after the pre-treatments consisting of sugar addition (25%) and blanching (100°C, 5 min). In terms of color parameters (L^* , a^* , b^* , C , a° , B , and W), due to the low thermal efficiency, color parameters measured at 50°C were lower than at 100°C and 100W. All pre-treatments provided a significant increase in color parameters. The colors of the sliced samples were higher than the pureed ones.

The bioactive potential of persimmon samples was evaluated as an extractable, hydrolysable, and bioaccessible phenolic fraction and analyzed by TEAC_{ABTS}, TEAC_{CUPRAC}, TEAC_{CUPRAC}, and TPC. Regarding all assays, drying at 50°C prevailed on drying techniques and provided higher bioactive potential than drying at 100°C and 100 W. Especially EPF and BPFs stood out ($p < 0.01$, $p < 0.05$). Regarding cutting styles, sliced persimmon samples were higher for EPF and BPF in AC assays, while pureed samples were higher for HPFs. For TPC, the blanched samples were relatively higher (EPF, HPF, and BPF) than unblanched ones. For AC, the blanched samples were higher in EPF AC, while BPF was higher in unblanched ones (TEAC_{ABTS}, TEAC_{CUPRAC}). Sugar addition for osmotic dehydration did not work for persimmon samples, and no-sugar-added samples had a significantly higher bioactive potential of BPF ($p < 0.01$; TPC, TEAC_{ABTS}, TEAC_{CUPRAC}). Bioaccessibility% is coming forth with the ratio of the relationship between the phenolic fractions. The drying technique and sugar addition were effective on %bioaccessibility in all assays ($p < 0.01$, $p < 0.05$) compared to other effects. The conventional drying at 50°C and avoiding the osmotic dehydration by sugar resulted in higher bioaccessible bioactive potential. Additionally, among all the assays, the CUPRAC was considered the most appropriate for this study. Together with representing quite close results with TEAC_{ABTS} and TEAC_{DPPH}, TEAC_{CUPRAC} provided more statistical differences between drying technique, sample preparation (cutting styles), and pre-treatments (blanching and sugar addition) on evaluated samples.

Declarations

Acknowledgments

The study was carried out in Bursa Uludag University, Biosystems Engineering, Drying Laboratory (Bursa, Türkiye) under the leadership of Assoc. Prof. Dr. Ilknur Alibas, corresponding author.

Conflict of Interest

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

Author Contributions

Elif Yildiz: Methodology, data curation, writing, reviewing and editing.

Aslihan Yilmaz: Formal analysis, reviewing.

Ozan Gurbuz: Conceptualization, writing, reviewing and editing.

Ilknur Alibas: Conceptualization, drying methodology, visualization writing, reviewing and editing.

Funding

The entire work was personally funded by authors.

Data Availability

The datasets used in the current study are available from the corresponding author on reasonable request.

Consent for Publication

Not applicable.

Competing Interests

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

References

1. Kim J, Chung IK, Kim HY, Kim K (2018) Comparison of the quality of dried persimmon (*Diospyros kaki*) treated with medicinal plant extracts and food additives. Food Sci Nut 6(8):1991–1998. <https://doi.org/10.1002/fsn3.673>
2. Mehra U, Negi M, Awasthi M (2019) Effect of rooting media and indole-3-butyric acid on rooting of cuttings in persimmon (*Diospyros kaki* L.) cv. Fuyu J Pharmacogn Phytochem 8(3):400–403
3. Conesa C, Laguarda-Miró N, Fito P, Seguí L (2020) Evaluation of Persimmon (*Diospyros kaki* Thunb. cv. Rojo Brillante) industrial residue as a source for value added products. Waste Biomass Valorization 11:3749–3760. <https://doi.org/10.1007/s12649-019-00621-0>

4. Matsumoto K, Masuda K, Takekawa K, Koyanagi T (2014) Influence of heat treatment on the bile acid binding ability of persimmon tannin-rich fiber and its application to a food material for breads. *J Japanese Soc Food Sci Technol* 61(11):543–547. <https://doi.org/10.3136/nsk.61.543>
5. Zhao CC, Ameer K, Eun JB (2021) Effects of various drying conditions and methods on drying kinetics and retention of bioactive compounds in sliced persimmon. *LWT Food Sci Technol* 143:111149. <https://doi.org/10.1016/j.lwt.2021.111149>
6. Senadeera W, Adiletta G, Onal B, Di Matteo M, Russo P (2020) Influence of different hot air-drying temperatures on drying kinetics, shrinkage, and colour of persimmon slices. *Foods* 9(1):101. <https://doi.org/10.3390/foods9010101>
7. Alibas I, Yilmaz A, Asik BB, Erdogan H (2021) Influence of drying methods on the nutrients, protein content and vitamin profile of basil leaves. *J Food Compost Anal* 96:103758. <https://doi.org/10.1016/j.jfca.2020.103758>
8. Corrêa JLG, Lopes FJ, de Mello Junior RE, de Jesus Junqueira JR, de Angelis Pereira MC, Salvio LGA (2021) Dried yacon with high fructooligosaccharide content. *J Food Process Eng* 44(12):e13884. <https://doi.org/10.1111/jfpe.13884>
9. Deng LZ, Mujumdar AS, Zhang Q, Yang XH, Zheng ZA, Gao ZJ, Xiao HW (2019) Chemical and Physical Pretreatments of fruits and vegetables: Effects on Drying Characteristics and Quality Attributes-a Comprehensive Review. *Crit Rev Food Sci Nutr* 59(9):1408–1432. <https://doi.org/10.1080/10408398.2017.1409192>
10. Kingsly RP, Goyal RK, Manikantan MR, Ilyas SM (2007) Effects of pretreatments and drying air temperature on drying behavior of peach slice. *Int J Food Sci Technol* 42:65–69. <https://doi.org/10.1111/j.1365-2621.2006.01210.x>
11. Zia MP, Alibas I (2021a) Influence of the drying methods on color, vitamin C, anthocyanin, phenolic compounds, antioxidant activity, and in vitro bioaccessibility of blueberry fruits. *Food Biosci* 42:101179. <https://doi.org/10.1016/j.fbio.2021.101179>
12. Lee J, Durst RW, Wrolstad RE (2005) Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: collaborative study. *J AOAC Int* 88(5):1269–1278
13. Vitali D, Dragojević IV, Šebečić B (2009) Effects of incorporation of integral raw materials and dietary fiber on the selected nutritional and functional properties of biscuits. *J Food Chem* 114:1462–1469. <https://doi.org/10.1016/j.foodchem.2008.11.032>
14. Bouayed J, Deußler H, Hoffmann L, Bohn T (2012) Bioaccessible and Dialysable Polyphenols in Selected Apple Varieties Following In Vitro Digestion vs. Their Native Patterns *Food Chem* 131(4):1466–1472
15. Apak R, Guclu K, Ozyurek M, Celik SE (2008) Mechanism of antioxidant capacity assays and the CUPRAC (Cupric ion reducing antioxidant capacity) assay. *Mikrochim Acta* 4:413–419. <https://doi.org/10.1007/s00604-007-0777-0>
16. Brand-Williams W, Cuvelier ME, Berset CLWT (1995) Use of a Free Radical Method to Evaluate Antioxidant Activity. *LWT Food Sci Technol* 28(1):25–30
17. Naczki M, Shahidi F (2004) Extraction and analysis of phenolics in food. *J Chromatogr A* 1054(1–2):95–111. <https://doi.org/10.1016/j.chroma.2004.08.059>
18. Anson NM, Selinheimo E, Havenaar R, Aura AM, Mattila I, Lehtinen P, Haenen GRMM (2009) Bioprocessing of wheat bran improves in vitro bioaccessibility and colonic metabolism of phenolic compounds. *J Agric Food Chem* 57(14):6148–6155. <https://doi.org/10.1021/jf900492h>
19. Alibas I, Yilmaz A (2022) Microwave and convective drying kinetics and thermal properties of orange slices and effect of drying on some phytochemical parameters. *J Therm Anal Calorim* 1–21. <https://doi.org/10.1007/s10973-021-11108-3>
20. Zia MP, Alibas I (2021b) The effect of different drying techniques on color parameters, ascorbic acid content, anthocyanin and antioxidant capacities of cornelian cherry. *Food Chem* 364:130358. <https://doi.org/10.1016/j.foodchem.2021.130358>
21. Priyadarshini A, Rayaguru K, Biswal AK, Panda PK, Lenka C, Misra PK (2023) Impact of conventional and ohmic blanching on color, phytochemical, structural, and sensory properties of mango (*Mangifera indica* L.) cubes: A comparative analysis. *Food Chem Adv* 100308. <https://doi.org/10.1016/j.focha.2023.100308>
22. Morales-Sánchez E (2022) Ohmic heating blanching of *Agaricus bisporus* mushroom: Effects on polyphenoloxidase inactivation kinetics, color, and texture. *Innov Food Sci Emerg Technol* 80:103105. <https://doi.org/10.1016/j.ifset.2022.103105>
23. Bozkir H, Ergun AR (2020) Effect of sonication and osmotic dehydration applications on the hot air drying kinetics and quality of persimmon. *LWT Food Sci Technol* 131:109704. <https://doi.org/10.1016/j.lwt.2020.109704>
24. Bas-Bellver C, Andrés C, Seguí L, Barrera C, Jiménez-Hernández N, Artacho A et al (2020) Valorization of persimmon and blueberry byproducts to obtain functional powders: in vitro digestion and fermentation by gut microbiota. *J Agric Food Chem* 68(30):8080–8090. <https://doi.org/10.1021/acs.jafc.0c02088>
25. Ozkan K, Karadag A, Sagdic O (2022) The effects of different drying methods on the in vitro bioaccessibility of phenolics, antioxidant capacity, minerals and morphology of black 'Isabel' grape. *LWT Food Sci Technol* 158:113185. <https://doi.org/10.1016/j.lwt.2022.113185>
26. Lavelli V, Hippeli S, Peri C, Elstner EF (1999) Evaluation of radical scavenging activity of fresh and air-dried tomatoes by three model reactions. *J Agric Food Chem* 47(9):3826–3831. <https://doi.org/10.1021/jf981372i>
27. Dziki D (2020) Recent Trends in Pretreatment of Food before Freeze-Drying. *Processes* 8(12):1661. <https://doi.org/10.3390/pr8121661>
28. González-Féslér M, Salvatori D, Gómez P, Alzamora SM (2008) Convective air drying of apples as affected by blanching and calcium impregnation. *J Food Eng* 87(3):323–332
29. Ramírez-Pulido B, Bas-Bellver C, Betoret N, Barrera C, Seguí L (2021) Valorization of vegetable fresh-processing residues as functional powdered ingredients. A review on the potential impact of pretreatments and drying methods on bioactive compounds and their bioaccessibility. *Front Sustain Food Syst* 5:654313. <https://doi.org/10.3389/fsufs.2021.654313>
30. Adetoro AO, Opara UL, Fawole OA (2020) Effect of blanching on enzyme inactivation, physicochemical attributes and antioxidant capacity of hot-air dried pomegranate (*Punica granatum* L.) arils (cv. wonderful). *Processes* 9(1):25. <https://doi.org/10.3390/pr9010025>

31. Bchir B, Besbes S, Karoui R, Attia H, Paquot M, Blecker C (2012) Effect of Air-Drying Conditions on Physico-chemical Properties of Osmotically Pre-treated Pomegranate Seeds. *Food Bioproc Tech* 5:1840v1852. <https://doi.org/10.1007/s11947-010-0469-3>
32. Kayacan S, Karasu S, Akman PK, Goktas H, Doymaz I, Sagdic O (2020) Effect of different drying methods on total bioactive compounds, phenolic profile, in vitro bioaccessibility of phenolic and HMF formation of persimmon. *LWT Food Sci Technol* 118:108830. <https://doi.org/10.1016/j.lwt.2019.108830>
33. Kotha RR, Tareq FS, Yildiz E, Luthria DL (2022) Oxidative Stress and Antioxidants-A Critical Review on In Vitro Antioxidant Assays. *Antioxidants* 11(12):2388. <https://doi.org/10.3390/%20antiox11122388>
34. Stojanovic J, Silva JL (2007) Influence of osmotic concentration, continuous high frequency ultrasound and dehydration on antioxidants, colour and chemical properties of rabbiteye blueberries. *Food Chem* 101:898–906. <https://doi.org/10.1016/j.foodchem.2006.02.044>
35. Zhang Z, We Q, Nie M, Jiang N, Liu C, Liu C et al (2018) Microstructure and bioaccessibility of different carotenoid species as affected by hot air drying: Study on carrot, sweet potato, yellow bell pepper and broccoli. *LWT Food Sci Technol* 96:357–363. <https://doi.org/10.1016/j.lwt.2018.05.061>
36. Gouw VP, Jung J, Zhao Y (2017) Functional properties, bioactive compounds, and in vitro gastrointestinal digestion study of dried fruit pomace powders as functional food ingredients. *LWT Food Sci Technol* 80:136–144. <https://doi.org/10.1016/j.lwt.2017.02.015>
37. Alibas I, Zia MP, Yilmaz A, Asik BB (2020) Drying kinetics and quality characteristics of green apple peel (*Mallus communis* L. var.“Granny Smith”) used in herbal tea production. *J Food Process Preserv* 44(2):e14332. <https://doi.org/10.1111/jfpp.14332>