EJONS International Journal on Mathematic, Engineering and Natural Sciences | ISSN 2602 - 4136

Article Arrival Date 18.03.2023 | Article Type Research Article | Article Published Date 20.06.2023

MICROWAVE-HOT AIR HYBRID DRYING: THE IMPACT OF PRE-TREATMENT SOLUTION ON SOME QUALITY CHARACTERISTICS OF WHITE CHERRY FRUIT

Şenel Ecem BERK
Research Assistant, Hacettepe University, Faculty of Engineering, Food Engineering Department, Ankara/Turkey, ORCID: 0000-0002-5432-2174

Hüseyin DEMİRCAN
Research Assistant, Bursa Technical University, Faculty of Engineering and Natural Sciences, Food Engineering Department, Bursa/Turkey, ORCID: 0000-0003-3375-8777

Gökçen YILDIZ
Associate Professor, Bursa Technical University, Faculty of Engineering and Natural Sciences, Food Engineering Department, Bursa/Turkey, ORCID: 0000-0002-6637-7666

Gülçin YILDIZ
Associate Professor, Iğdır University, Faculty of Engineering, Food Engineering Department, Iğdır/ Turkey, ORCID: 0000-0001-6229-7338

Onur TAŞKIN
Associate Professor, Bursa Uludağ University, Faculty of Agriculture, Biosystem Engineering Department, Bursa/Turkey, ORCID: 0000-0002-5741-8841

Rasim Alper ORAL
Associate Professor, Bursa Technical University, Faculty of Engineering and Natural Sciences, Food Engineering Department, Bursa/Turkey, ORCID: 0000-0001-7530-7478

Sorumlu Yazar/ Corresponding Author: Gökçen YILDIZ
Adres/Adress: Bursa Technical University, Faculty of Engineering and Natural Sciences, Food Engineering Department, Bursa/Turkey.

ABSTRACT

White cherry (*Starks gold*) is a very valuable and delicious fruit that can be produced in rare regions in Turkey and the world**.** The short harvest time and high production make the necessity of white cherries even more important. Both its economic value and its contribution to nutrition can be increased by drying the white cherry. In current study, the effects of three different (microwave, hot air and microwave-hot air hybrid) drying methods on the water activity, rehydration ratio, color parameters, total phenolic content and antioxidant capacity of pre-treated and non-pretreated white cherry fruits were investigated. 200W microwave power, two different drying temperatures (70 and 80 ºC) and two different microwave-hot air combinations (200W+70ºC and 200W+80 ºC) were applied by using a laboratory microwave-hot air oven. It was observed that the applied drying parameters and pre-treatment affect significantly the product quality. In particular, more successful results were obtained in terms of color, antioxidant capacity and total phenolic compounds of pre-treated white cherry fruit samples dried by the microwave-hot air hybrid drying especially at 200W+80 ºC in comparison with the hot air and microwave alone drying methods.

Keywords: White cherry fruit, Microwave-hot air hybrid drying, Pre-treatment, Total phenolic content, Antioxidant capacity.

1. INTRODUCTION

Fruits have an important place in human nutrition and health thanks to the nutritious elements they contain. The importance of fruits in human health arise from phenolic compounds found in fruits. Phenolic compounds found in all fruits and vegetables play a crucial role in color, taste, antioxidant and antimicrobial activities. Due to the antioxidant effect of phenolic compounds, it is believed that they have a defensive impact on many diseases including cardiovascular diseases, cancer and diabetes, and have positive effects such as delaying aging. In addition, antimicrobial and antioxidant activities of phenolic compounds have made them natural alternatives to synthetic food additives. In recent years, the consumer's tendency to seek healthy nutrition and natural food has led to an increase in the use of fruits in human diets and the development of alternative products in which they are processed in different ways. Dried fruits are one of those food products and are added into different mixtures straightly or by soaking in water. The long shelf life, the reduction in volume and weight during transportation, and being ready to use at any time increase the demand for the use of dried foods. It has been determined that there are many studies on drying various vegetables and fruits in the literature with or without pretreatments (Rajkumar et al., 2017; Wang et al., 2018; İzli and Yildiz, 2021; Yildiz, 2021). However, this is the first effort to explore the effect of 2% Ethyl oleate + 5% K_2CO_3 pre-treatment on dried white cherries.

White cherry (Starks Gold) is a very valuable and delicious fruit that can be produced in rare regions in Turkey and the world. Turkey is one of the few growers of this fruit in the world. Most of the white cherry production in our country is done in Ereğli, Konya. White cherries, which are exported after processing, are used in the cake, pastry and fruit juice industry (Budak, 2017). The short harvest time and high production make the necessity of white cherries even more important. Both its economic value and its contribution to nutrition can be increased by drying the white cherry. It is of great importance to know and apply the conditions that will preserve the characteristics of the fruit. Within the scope of this research, the influences of microwave, hot air and microwave-hot air hybrid methods on the water activity, rehydration ratio, color parameters, total phenolic components and antioxidant capacity values of pretreated and non-pretreated white cherry fruits will be determined.

2. MATERIALS AND METHODS

2.1. Sample Preparation

The white cherry fruits used as material in the experiments were bought from a local producer in Ereğli district in Konya and were kept at 4 ± 0.5 ºC until the experiments were completed. White cherry fruit samples to be taken for drying trials were prepared in two different forms as pre-treated and untreated white cherries, after washing process. Initial moisture content of white cherry fruit samples was found as 79.7% as a result of drying 5 g of white cherry fruit samples in an oven at 105±5°C (Memmert UN55, Germany) before the reaching stable weight.

Pre-treatment was applied by immersing the white cherry fruits with seeds in an alkaline solution (2% Ethyl oleate + 5% K_2CO_3) at room temperature for a minute. Drying experiments were carried out after the surfaces of the pretreated white cherry fruit samples were dried.

Drying trials of prepared fresh white cherry fruit samples were carried out using a microwave-hot air oven (Arçelik KMF 833, Turkey) with 5 different combinations at 70ºC, 80ºC, 200W, 200W-70ºC, and 200W-80ºC. The drying times of white cherry fruit samples were provided in Table 1. 150 g of white cherry fruit was used for each drying trial. The drying application was ended when the final moisture of white cherry fruits arrived at approximately 20%.

2.2. Physicochemical Properties of Fresh White Cherry Fruits

For the determination of the average size of the white cherry fruit samples, 2 linear dimensions, particularly length (L) and diameter (D), were calculated by the assist of digital caliper with an accuracy of 0.01 mm. 100 g of white cherry fruits were randomly selected. The geometric mean diameter D_g (mm) was determined according to the below Eq. (Mohsenin, 1986):

$$D_g = (LD^2)^{1/3} \quad (1)$$

The sphericity, S_p (%), described as the ratio of surface area of a sphere having the same volume as that of white cherry fruits to the surface area of the white cherry fruit, was calculated using the below equation (Mohsenin, 1986):

$$S_p = 100\left(D_g \middle| L\right) \quad (2)$$

In addition, the surface area and aspect ratio of the white cherry fruits were calculated by using the below equation (Mohsenin, 1986):

$$S = \pi D_g^2 \quad (3)$$

Table 1. Drying times of white cherry fruits

	Drying methods	Drying Time (min.)
Non-pretreated	70°C	1140
	80°C	1050
	200W	980
	200W+70°C	760
	200W+80°C	625
Pretreated	70°C	890
	80°C	820
	200W	695
	200W+70°C	560
	200W+80°C	510

Hardness measurement of white cherry fruit was determined by a texture analyzer (TA XT Plus, Stabe Micro System Ltd., Surey, UK). The cylinder penetrometer probe (5mm diameter) was gone through the white cherry fruits with the test variables organized as: 2 mm/s of pre-speed, 0.5 mm/s of both post-speed and test speed parameters as well as 10 g trigger. In the penetration measurement, hardness was defined as the max force (N) needed to puncture the white cherry fruits.

The chemical characteristics (moisture, water activity, total soluble solids, ash, protein, oil, titratable acidity, pH, total & reducing sugar) of the white cherries were figured out by following the steps in the procedure stated by Cemeroğlu (2010). The dry matters of white cherry fruits were found out by drying process (ED115 Binder, Tuttlingen, Germany) at 105±5 °C until they have arrived at a stable weight. Total soluble solids (°Brix) of white cherry fruit samples was figured out by a refractometer (Kyoto-Kem, RA-600, Japan) at 20 °C. The ash content was detected in a muffle furnace (Protherm PLF 110/8, Turkey) at 550°C to a white color. Protein content was figured out by the Kjeldahl method and the calculation was made by using the conversion factor as 6.25. The total oil content of white cherry fruit samples was extracted with n-hexane (60 °C) for about 8 hours by using a Soxhlet extractor. In addition, the titratable acidity of white cherry fruit samples was found out by titration with the use of 0.1 N NaOH solution, using phenolphthalein as an indicator, until observing pink color and the findings were described in terms of malic acid. pH values of the white cherry fruit samples were detected by pH meter (Ohaus ST 3100-F, USA). On the other hand, both the total & reducing sugar levels of white cherries was found by the Luff-School technique. Lately, the carbohydrate content of the white cherry fruit samples was determined by the change between 100 and the sum of moisture, ash, proteins, and oil ratios (Rodrigues et al., 2009). The white cherry fruits were analyzed in 3 replications. The results of physicochemical properties of fresh white cherry fruits were tabulated in Table 2.

2.3.Water Activity (a_w)

The a_w level of dried white cherry fruit was measured by the assistance of a water activity meter (Novas Lab master, Switzerlan).

2.4.Rehydration Ratio (RR)

The rehydration ratios (RRs) of white cherry fruits were obtained by weighing approximately 2.5 g of dried white cherry fruits in glass which contains deionized H_2O in a percent of 1:30 (w/w) at 100 ^oC for about 10 minutes. Right after the soaking step, the extra water was eliminated with an absorbent paper, and white cherry fruit was weighed, and the rehydration values of pretreated and non-pretreated samples were determined based on Equation 4 (Rajkumar *et al.*, 2017)

$$\text{RR}\ (\%) = \frac{R_2}{R_1} \times 100 \qquad (4)$$

where R_1 and R_2 are first weigh (g) and weigh subsequently to water absorption (g) of the white cherry fruits, subsequent.

Table 2. Physicochemical properties of fresh white cherry fruit

Parameters	Number of replications	
Length (mm)	100	20.07 ± 1.60
Diameter (mm)	100	23.31 ± 0.95
Geometric mean diameter (mm)	100	22.17 ± 1.05
Sphericity (%)	100	110.89 ± 6.75
Surface area (cm^2)	100	1.55 ± 0.14
Mass of fruit (g)	25	6.56 ± 0.66
Fruit hardness (N)	25	8.05 ± 1.14
$L*$	10	60.57 ± 2.82
$a*$	10	5.35 ± 1.00
$b*$	10	24.93 ± 2.75
C	10	22.50 ± 2.88
$\alpha°$	10	77.98 ± 1.23
Moisture (%)	3	79.70 ± 0.73
Water activity	3	0.96 ± 0.00
Total soluble solids (°Brix)	3	18.27 ± 0.65
Ash (%)	3	4.63 ± 0.07
Protein (%)	3	1.06 ± 0.04
Oil (%)	3	0.18 ± 0.02
Carbohydrate* (%)	3	14.44 ± 0.69
Titratable acidity (%) (as malic acid)	3	1.05 ± 0.04
pH	3	3.66 ± 0.02
Total sugar (g/kg)	3	136.86 ± 1.21
Reducing sugar (g/kg)	3	110.70 ± 1.78
Antioxidant capacity (µmol Trolox/g dw)	3	4.47 ± 0.37
Total phenol content (mg GA/100g dw)	3	458.52 ± 11.18
Ascorbic acid content (mg/100 g)	3	49.56 ± 0.94

2.5.Color Measurement

By using a colorimeter (PCE-CSM 3, USA), classification of $L*$ parameters (stand for lightness index), $a*$ parameters (stand for redness or greenness index) and $b*$ parameters (stand for yellowness or blueness index) of both pretreated and non-pretreated dried white cherry fruits were determined by means of 10 different readings at casual spots on the surface of white cherry fruit samples.

Additionally, the Chroma (C), hue angle (α) and total colour changes (ΔE) were determined as follows:

$$C = \sqrt{(a^2 + b^2)} \quad (5)$$

$$a = \tan^{-1}\left(\frac{b}{a}\right) \quad (6)$$

$$\Delta E = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \quad (7)$$

where, subscript ''$_0$'' stands for the color of untreated white cherry fruit sample.

2.6.Sample Extract Preparation

500 mg of pretreated and non-pretreated dried white cherry fruit samples were weighed in test tubes and extracted three times with 10 mL of methanol: water (80:20, v/v) and mixed well for 10 minutes in all steps. After that, the tubes were centrifuged at 3500 rpm for about 3 minutes (Hettich Universal 320 R, Germany) to collect a clear white cherry extracts and they were blended in different tubes. The measurements of total phenolics and ATC were performed by utilizing the white cherry fruit extract.

2.7.Total Phenolic Content (TPC)

The TPCs of white cherry fruit samples by following the method declared by Singleton et al (1999) with a small alteration were determined. In a short way, a part of extract was filtered through 0.45 µm nylon filter and 1.6 mL of Folin-Ciocalteu's reagent was blended with 0.4 mL of filtered white cherry fruit extracts respectively diluted by methanol: H_2O (80:20, v/v) in test tubes. The content was blended by vortexing and waited for 5 min. Later on, 1.6 mL of 20% Na_2CO_3 was added into the blend and vortexed, the test tube was remained at room temperature for about 90 min. Afterwards, the mix was exposed to centrifugation at 3500 rpm for about 3 min and delivered immediately in a cuvette. The measurements were accomplished by a UV-VIS spectrophotometer (Mecasys Optizen Pop, Korean) at the wavelengths of 765 nm and quantification was investigated by a gallic acid calibration curve, built change from 0 to 30 µg/mL. The results were displayed as mg GAE/100 g of dry weight of white cherries.

2.8.Antioxidant Capacity (ATC)

ATC of white cherry fruit samples was determined according to the DPPH methodology (Brand-Williams et al 1995) with slight changes. Buffer solution of DPPH was organized by mixing 10 mg of DPPH in 25 mL of ethanol and diluted by 25 mL of distilled water. From on, the dispersion of DPPH was organized by approximately 400 mL of water: ethanol (1:1, v/v) mix having absorbance ranges nearby 0.75-0.80 at the wavelengths of 525 nm. A 0.2 mL of white cherry fruit extracts were added into test tubes and blended with 4.0 mL of DPPH solution. The tubes were placed in an orbital shaker and they were blended for approximately 30 minutes at 350 rpm in a dark under ambient temperature. Subsequent to centrifugation step achieved under 3500 rpm during 3 minutes, the transparent supernatants were collected, and the absorbance of samples were read at the wavelengths of 525 nm using a spectrophotometer (Korea). Each and every measurement was taken at 30 min after showing a reaction with white cherry fruit extracts and DPPH solutions. The antioxidant capacity was shown as µmol of Trolox equivalent (TE) per 1 g dry weight of white cherry fruit samples.

2.9.Statistical Analysis

The analyzed variables were performed in 3 replications. The findings were examined by JMP (Version 7.0, SAS Institute Inc., Carry, NC, USA). Mean changes were evaluated for significance with a least significant difference (LSD) test at a 5% significance value.

3. RESULTS AND DISCUSSIONS

3.1. Water Activity and Rehydration Ratios of Dried White Cherry Fruits

As presented in Table 3, rehydration ratios of white cherry fruit samples dried with hot-air drying with no pre-treatment at 80 °C (100.41) were significantly (P<0.05) higher than other dried white cherry fruits, which expresses that hot air-dried white cherry fruit sample was easier to get back to original by rehydration process rather than the other dried white cherry fruit samples. The potential explanation for this action could be a better porous structure of white cherry fruits and high cell membrane permeability observed in hot air-dried white cherry fruit samples (Yildiz & Izli, 2019). On the other way, rehydration ratios of pre-treated white cherry fruits dried with hot-air drying at 70 °C (117.64) were significantly (P<0.05) higher compared to other dried white cherry fruit samples. In overall, no matter which drying methods were applied, all pre-treated white cherry fruits exhibited significantly higher rehydration capacity in comparison with the non-pretreated white cherry fruits. By taking into account of the rehydration ratio results of dried white cherry fruit samples, non-pretreated white cherry fruit samples at 80 °C and pre-treated white cherry fruit samples at 70 °C would be good candidates to be accepted as a compound for the functional food production. All things considered, hot air drying caused a significant enhancement on the physicochemical characteristics of dried white cherry fruits by considering the water activity and rehydration ratios of white cherry fruits.

Table 3. Water activity and rehydration capacity of dried white cherry fruits

	Drying methods	Water activity	Rehydration capacity
Non-pretreated	70°C	$0.70±0.00^{d}$	$92.59±1.98^{d}$
	80°C	$0.73±0.01^{bc}$	$100.41±3.44^{c}$
	200W	$0.76±0.02^{a}$	$43.41±0.78^{h}$
	200W+70°C	$0.74±0.01^{ab}$	$55.47±1.94^{g}$
	200W+80°C	$0.67±0.01^{e}$	$72.99±3.69^{e}$
Pretreated	70°C	$0.70±0.00^{d}$	$117.64±1.12^{a}$
	80°C	$0.73±0.02^{bc}$	$109.55±1.44^{b}$
	200W	$0.71±0.02^{cd}$	$92.92±2.98^{d}$
	200W+70°C	$0.65±0.01^{e}$	$63.58±2.05^{f}$
	200W+80°C	$0.62±0.01^{f}$	$92.29±3.98^{d}$

$^{a\text{-}g}$ Means superscript with different alphabets in the same column differ significantly (P < 0.05)

3.2.Colour Measurement

The most dominant factor criticized by people is the external colour of food materials. Furthermore, it is so valuable for the acceptance of food products, even prior to taste the food product. The impact of pre-treatment and drying techniques connected with color parameters of dried white cherry fruit samples was tabulated in Table 4. While the highest L^* (lightness) values were determined for microwave-hot air hybrid dried white cherry fruit samples with pre-treatment at 200W+80°C (38.05) and microwave-hot air hybrid dried white cherry fruit samples with no pre-treatment at 200W+80°C (31.56), the lowest L^* values were obtained for the hot air-dried white cherry fruit samples (Table 4). In addition, a significant increase in a^* parameter of all pretreated and non-pretreated dried white cherry fruit samples compared to the fresh white cherry fruits was observed. The highest a^* value was obtained for hot air dried white cherry fruit samples (Table 4). This indicates that more browning occurrences were observed in hot-air dried white cherry fruits compared to microwave-hot air hybrid dried white cherry fruit samples. On the contrary, the lowest a^* values were determined for both pre-treated and non-pretreated white cherry fruit samples dried by microwave-hot air hybrid drying method at 200W+70°C (Table 4). The b^* values of dried white cherry fruit samples was found out to be lower in comparison with the fresh white cherry fruits (Table 4). Among the tested three drying techniques, the highest b^* parameters were obtained with the process of microwave-hot air hybrid drying technique in pre-treated (24.74) and non-pretreated (21.51) white cherry fruit samples at 200W+80°C, while the lowest b^* parameters were gained for hot-air drying methods in pre-treated (17.01) and non-pretreated (15.07) white cherry fruits at 70°C. The pretreated white cherry fruits exposed to drying with microwave-hot air hybrid method at 200W+70°C (24.39) showed the nearest color values with fresh white cherry fruits by having lowest total color differences (ΔE) value.

Table 4. Colour parameters of dried white cherry fruits

	Drying methods	$L*$	$a*$	$b*$	C	$\alpha°$	ΔE
Non-pretreated	70°C	24.00±3.70^{c}	16.36±1.32^{b}	15.07±4.75^{d}	22.57±2.69^{d}	41.64±11.03^{f}	39.60±4.88^{a}
	80°C	23.29±3.68^{c}	18.07±1.24^{a}	17.89±3.62^{cd}	25.56±2.68^{abcd}	48.23±6.34^{ef}	40.15±3.95^{a}
	200W	30.79±4.51^{b}	13.82±1.48^{de}	19.36±3.24^{bc}	23.92±2.37^{bcd}	54.10±6.56^{c}	31.56±5.07^{c}
	200W+70°C	31.20±3.69^{b}	12.71±1.68^{ef}	19.28±3.12^{bc}	23.16±3.00^{cd}	56.40±4.57^{bc}	30.95±3.93^{c}
	200W+80°C	31.56±3.72^{b}	14.53±1.34^{cd}	21.51±3.27^{ab}	25.98±3.35^{abc}	55.81±2.46^{bc}	30.82±3.48^{c}
Pretreated	70°C	26.40±2.40^{c}	15.22±1.91^{bcd}	17.01±1.79^{cd}	22.90±1.79^{d}	48.23±4.72^{de}	36.50±2.81^{ab}
	80°C	30.19±3.99^{b}	15.72±1.46^{bc}	19.73±4.99^{bc}	25.34±4.54^{bcd}	50.64±6.26^{cd}	32.86±4.18^{bc}
	200W	32.07±3.09^{b}	12.77±1.21^{ef}	19.60±3.69^{bc}	23.50±2.99^{cd}	56.34±6.47^{bc}	30.09±3.72^{c}
	200W+70°C	36.21±4.63^{a}	12.19±1.00^{f}	23.53±2.82^{a}	26.52±2.76^{ab}	62.50±2.51^{a}	25.52±4.47^{d}
	200W+80°C	38.05±4.51^{a}	14.22±1.40^{d}	24.74±2.92^{a}	28.54±3.16^{a}	60.07±1.45^{ab}	24.39±1.43^{d}

$^{a-f}$ Means superscript with different alphabets in the same column differ significantly ($P < 0.05$)

The preparation methodology in addition to improvement in colors, tasteful and flavor of dried white cherry fruits were pointed out in various works (Wange et al., 2018; Coa et al., 2019). Colour changes observed in white cherry fruits by drying process may be connected with decomposition of pigments, particularly carotenoid decomposition caused by occurrence of brown pigmentation as a result of non-enzymatic (Maillard reaction) and enzymatic reactions (Albanese et al., 2013). If all the mentioned factors are contemplated, it can be said that the white cherry fruit samples dried with microwave-hot air hybrid drying method are satisfactory since they are resulted with a lighter product colour as well as nearest colour values with the fresh white cherry fruits (Table 4) compared to others dry method.

3.3.Total Phenolic Content

Figure 1 displays total phenolic (TP) content of dried white cherry fruits with pre-treatment and no pretreatment. Application of pre-treatment significantly influenced the total phenolic of white cherry fruit samples ($P<0.05$). While the pre-treated white cherry fruit samples showed the highest TPC values, non-pretreated samples showed the lowest TPC in all dried white cherry fruit samples (Fig. 1). Rising drying temperature from 70 °C to 80 °C increased the total phenolic in pre-treated and non-pretreated white cherry fruit samples significantly. Among the drying techniques, microwave-hot air hybrid dried white cherry fruits showed the highest TPC values (Figure 1) both in pre-treated and non-pretreated samples. The highest TPC values were obtained for the microwave-hot air hybrid dried white cherry fruit samples at 200W+80°C (645.74 mg GA/100g dw) with pre-treatment. In shortly, the pre-treatment with microwave-hot air hybrid drying methods were resulted with a higher phenolic content of white cherry fruits amongst others drying method. Simsek & Sufer (2021) also observed the significantly higher TPC of microwave-hot air-dried white cherry samples compared to other drying method. In some works, it was declared that thermally process is very suitable to incensement the phenolic content in several fruits and vegetables such as dry raisins (Caranza-Conchha et al., 2012), apricots (Sultan et al., 2012), and oranges peelings (Cheen et al., 2011). On the contrary, while some works (Mirad et al., 2012; Sultans et al., 2012) figured out that total phenolic content of fruits and vegetables exhibited a decrease with heat applications, the other works (Dewanoto et al., 2002) stated that no noticeable changes. Therefore, the influences of drying techniques on the phenolic content of different fruits and vegetables cannot be resulted with the same or similar outcomes. By taking into consideration of results from various sources, it can be said that drying processes have different effects on the phenolic contents of foods product. The highest TP content observed in the microwave-hot air hybrid dried white cherry fruit samples might be caused by more cell decomposition and rupture, hence those may cause more phenolic substances to be released.

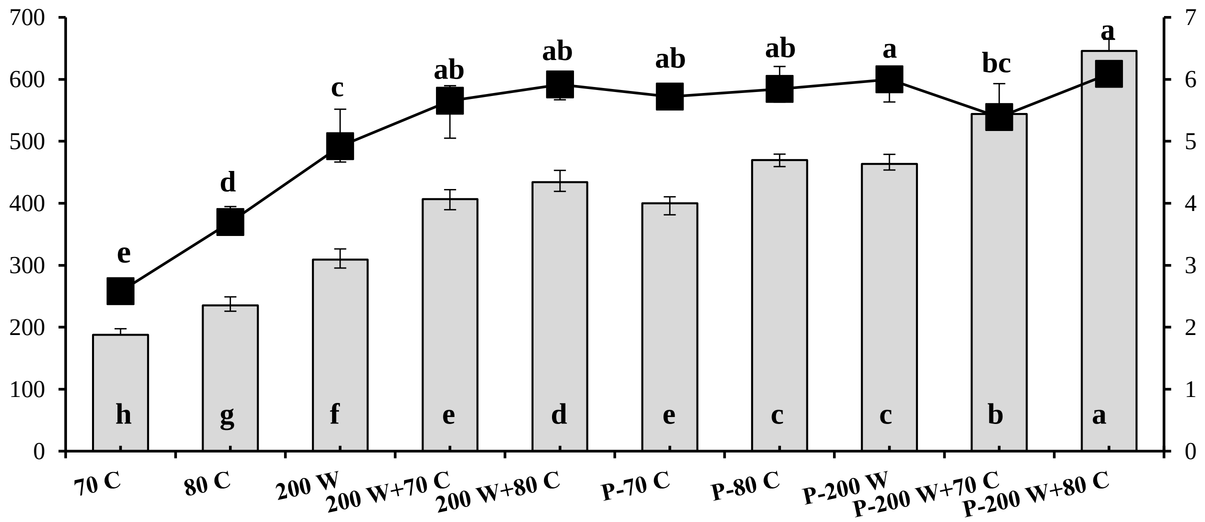

Figure 1. Total phenolic contents and antioxidant capacity of dried white cherry fruit samples

3.4.Antioxidant Capacity

Their differences in the antioxidant capacities of white cherry fruit samples treated with various drying approaches are displayed in Fig. 1. The pre-treatment process significantly influenced the antioxidant capacity of white cherry fruit samples. While the pre-treated samples showed the highest ATC values, non-pretreated samples showed the lowest ATC in all dried samples (Fig. 1). Rising drying temperature from 70 °C to 80 °C increased the ATC in pre-treated and non-pretreated samples significantly. Compared to the hot air drying, microwave-dried white cherry fruits exhibited a higher antioxidant capacity (Fig. 1). Among the drying techniques, microwave-hot air hybrid dried white cherry fruit samples showed the highest ATC values (Figure 1) both in pre-treated and non-pretreated white cherry fruits. The highest ATC values were obtained for the microwave-hot air hybrid dried white cherry fruits at 200W+80°C (6.09 µmol Trolox/g dw) with pre-treatment. In shortly, the pre-treatment with microwave-hot air hybrid dryings methods were resulted with a higher antioxidant capacity of white cherry fruit samples among other drying methods. There could be a synergistic or antagonistic effect among the antioxidant compounds and others substance (Di Scaala et al., 2011). The increase observed in ATC could be associated with the increased number of phenolic complexes. In various studies, it was record that there is a positive relationship between total phenolics and antioxidant capacity of different fruits and vegetables such as quince (Yildiz & Izli, 2019) and red pepper samples (Zho et al., 2016). The higher ATCs of food products might be linked with the synergistic effects of natural phenolic substances. In present work, it was also found the synergistic effect between TP content and ATC of white cherry fruit samples. Correlation coefficient between TPC and DPPH was determined to be positive (R^2=0.7632).

4. CONCLUSION

In the current work, the effects of microwave, hot air and microwave-hot air hybrid drying methods on the water activity, rehydration ratio, color parameters, total phenolic content and antioxidant capacity of white cherry fruit samples were analyzed. The effect of pre-treatment was also evaluated. The white cherry fruit samples dried with microwave-hot air hybrid drying exhibited a highest retention of bioactive component including total phenolic content sand antioxidant capacity, and preserved color among all drying methods. In overall, pre-treated white cherry fruit samples compared to the white cherry fruits with no pre-treatment showed better results. The findings observed in current study are significant to process dried white cherry fruit samples by the assist of optimization of drying and pretreatment condition to get a high-quality product. On the whole, microwave-hot air hybrid drying is an alternative way as demonstrated in current research by its capability to better preservation of white cherry quality related to the water activity, rehydration ratio, color parameters, total phenolic content and antioxidant capacity.

ACKNOWLEDGEMENT

This research was supported by Research Fund of Bursa Technical University. Project Number: 181N02.

REFERENCES

Abhilash, P. A., Harikrishnan, R., & Indira, M. (2013). Ascorbic acid is superior to silymarin in the recovery of ethanol-induced inflammatory reactions in hepatocytes of guinea pigs. Journal of Physiological Biochemistry, 69(4), 785-798.

Albanese, D., Cinquanta, L., Cuccurullo, G., & Di Matteo, M. (2013). Effects of microwave and hot-air drying methods on colour, β-carotene and radical scavenging activity of apricots. International Journal Food Science and Technology, 48, 1327-1333.

Brand-Williams, W., Cuvelier, M. E., & Berset, C. L. W. T. (1995). Use of a free radical method to evaluate antioxidant activity. LWT-Food Science and Technology, 28(1), 25-30.

Budak, N. H. (2017). Bioactive components of Prunus avium L. black gold (red cherry) and Prunus avium L. stark gold (white cherry) juices, wines and vinegars. Journal of Food Science and Technology, 54, 62-70.

Cao, X., Zhang, M., Mujumdar, A. S., & Zhong, Q. (2019). Evaluation of quality properties and water mobility in vacuum microwave-dried carrot slices using pulse-spouted bed with hot air. Drying Technology, 37(9), 1087-1096.

Carranza-Concha, J., Benlloch, M., Camacho, M. M., & Martínez-Navarrete, N. (2012). Effects of drying and pretreatment on the nutritional and functional quality of raisins. Food Bioproducts Processing, 90(2), 243-248.

Cemeroğlu, B. (2009) Meyve ve Sebze İşleme Teknolojisi, *Gıda Teknolojisi Yayınları* No:39 2. cilt, 3. Baskı Ankara.

Chen, M. L., Yang, D. J., & Liu, S.C. (2011). Effects of drying temperature on the flavonoid, phenolic acid and antioxidative capacities of the methanol extract of citrus fruit (Citrus sinensis (L.) Osbeck) peels. International Journal of Food Science and Technology, 46, 1179-1185.

Dewanto, V., Wu, X., Adom, K. K., & Liu, R. H. (2002). Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity. Journal of Agricultural and Food Chemistry, 50(10), 3010-3014.

Di Scala, K., Vega-Gálvez, A., Uribe, E., Oyanadel, R., Miranda, M., Vergara, J., & Quispe, I. (2011). Changes of quality characteristics of pepino fruit (Solanum muricatum Ait) during convective drying. International Journal of Food Science and Technology, 46(4), 746-753.

İzli, G., & Yildiz, G. (2021). Evaluation of the high intensity ultrasound pre-treatment effects on the physical properties and bioactive compounds of convective dried quince samples. International Journal of Fruit Science, 21(1), 645-656.

Mohsenin, N.N. (1986) Physical properties of plant and animals materials (2nd ed.). Gordon and Breach Science Publishers, New York: 891 p.

Mrad, N. D., Boudhrioua, N., Kechaou, N., Courtois, F., & Bonazzi, C. (2012). Influence of air-drying temperature on kinetics, physicochemical properties, total phenolic content and ascorbic acid of pears. Food Bioproducts Processing, 90(3), 433-441.

Rajkumar, G., Shanmugam, S., de Sousa Galvâo, M., Neta, M. T. S. L., Sandes, R. D. D., Mujumdar, A. S., & Narain, N. (2017). Comparative evaluation of physical properties and aroma profile of carrot slices subjected to hot air and freeze drying. Drying Technology, 35(6), 699-708.

Rodrigues, E., Rockenbach, I.I., Cataneo, C., Gonzaga, L.V., Chaves, E.S., & Fett R. (2009) Minerals and essential fatty acids of the exotic fruit Physalis peruviana L. Food Sci. Technol. (Campinas) 29(3), 642-645.

Simsek, M., & Sufer, O. (2021). Influence of different pretreatments on hot air and microwave-hot air combined drying of white sweet cherry. Turkish Journal of Agriculture- Food Science and Technology, 9(6), 1172-1179.

Singleton, V. L., Orthofer, R., & Lamuela-Raventos, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteau reagent. Methods in Enzymology, 299, 152-178.

Sultana, B., Anwar, F., Ashraf, M., & Saari, N. (2012). Effect of drying techniques on the total phenolic contents and antioxidant activity of selected fruits. Journal of Medicinal Plant Research, 6, 161-167.

Wang, L., Xu, B., Wei, B., & Zeng, R. (2018). Low frequency ultrasound pretreatment of carrot slices: Effect on the moisture migration and quality attributes by intermediate-wave infrared radiation drying. Ultrasonics Sonochemistry, 40, 619-628.

Yildiz, G., & Izli, G. (2019). The effect of ultrasound pretreatment on quality attributes of freeze-dried quince slices: Physical properties and bioactive compounds. Journal of Food Process Engineering, 42(5), e13223.

Yildiz, G. (2022). Color, microstructure, physicochemical, textural and sensory properties with the retention of secondary metabolites in convective-, microwave- and freeze-dried carrot (Daucus carota) slices. British Food Journal, 124 (11), 3922-3935.

Zhou, L., Cao, Z., Bi, J., Yi, J., Chen, Q., Wu, X., & Zhou, M. (2016). Degradation kinetics of total phenolic compounds, capsaicinoids and antioxidant activity in red pepper during hot air and infrared drying process. International Journal of Food Science and Technology, 51, 842-853.