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Influence of Different Pretreatments on Hot air and Microwave-Hot Air Combined Drying of White Sweet Cherry

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A R T I C L E I N F O	A B S T R A C T
	Microwave (MW)-hot air (HA) combined drying was applied to white sweet cherries besides solely HA drying at 50, 60 and 70°C in the presence of citric acid, sucrose and freezing pretreatment in this study. Single power level of MW (90 W) was chosen, and drying behavior of all samples was modelled by using eleven thin layer equations. Two-term, rational and sigmoid models were the most suitable models for describing drying phenomena. Effective moisture diffusivities (D_{eff}) ranged from 1.724×10^{-10} to 5.173×10^{-10} m²/s in HA drying and from 4.260×10^{-10} to 1.805×10^{-9} m²/s in MW-HA drying. Activation energies (E_a) were between 2.785 and 30.541 kJ/mol and 6.929 and 42.101 kJ/mol for HA and MW-HA drying techniques, respectively. Total color change (ΔE) levels of the outer surface of dried cherries were generally higher than the ones of inner surface. Freezing pretreatment had a comparably lower enhancing effect on the total phenolic content (TPC) of HA dried white sweet cherries compared to fresh sample. The TPC of freezing pretreated and HA dried at 50°C and HA dried at 70°C control samples were 1.481 ± 0.398 mg gallic acid equivalent (GAE)/g dry matter (DM) and 6.181 ± 0.012 mg GAE/g DM as the minimum and maximum, respectively. These values were determined as 4.183 ± 1.728 and 8.240 ± 0.502 mg GAE/g DM that were belonged to MW-HA dried at 50°C control and freezing pretreated MW-HA dried at 70°C samples in combined procedure, respectively.

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Introduction

White sweet cherry (*Prunus avium* L. stark gold) is prone to deterioration and browning during the storage due to its high moisture, sugar, and polyphenol content. Its phenolic rich content may present to several health benefits involving reduction in inflammatory biomarkers and cancer growth and antioxidant effect (Gonçalves et al., 2020). Antioxidant biomaterials are used as supplements to decrease oxidative stress which is defined as imbalance between endogenous oxidants and antioxidants, in human body (Finaud et al., 2006; Mujic et al., 2010; Sevindik et al., 2017; Mohammed et al., 2020).

Like most fruits white sweet cherry is available for short period of time, drying can be applied to increase its availability through out of season. As known, drying is a commonly used post-harvest technique to hamper microbial growths and chemical reactions in the material during the storage. Different drying techniques such as air, freeze and vacuum were applied to cherries in previous studies (Doymaz and İsmail, 2011; Pirone et al., 2014; Franceschinis et al., 2015; Vakula et al., 2020).

Among these methods, hot air (HA) drying is one of the most preferred techniques due to its low cost; however, its long drying time can affect adversely the retention of bioactive compounds. This drawback can be eliminated using microwave (MW) drying, but MW drying has several problems such as non-uniform heating and high operating cost. Also, long MW drying can damage the texture and change chemical compositions (Miraei Ashtiani et al., 2018); therefore, in order to overcome these problems, MW and HA can be combined to obtain fast and uniform drying with high quality product (Zhao et al., 2014; Wang et al., 2018). The combination of MW and HA drying has been applied for various products such as carrot (Zhao et al., 2014), cranberry (Staniszewska et al., 2020) and mushroom (Wang et al., 2019). In addition, the pretreatments can be used prior to drying to improve the physicochemical and bioactive properties of dried food. Pretreatments selected for this study were the immersion in citric acid and sucrose solution and freezing, which help to remove the water and enhance the color as well the texture.

Drying kinetics analysis is crucial which enables mathematically modelling the drying process. The thin layer models are useful for the identifying the drying parameters. They are used for optimizing or designing novel drying processes (Miraei Ashtiani et al., 2018). There have been no studies investigating the drying of white sweet cherry using the combination of MW and HA drying.

The objectives of this study were to show the effect of different pretreatments (citric acid, sucrose and freezing) on the drying kinetics and bioactive properties of white sweet cherry dried by MW and HA drying combination and compare with conventional HA drying.

Material and Method

Material

Sweet cherries (*P. avium*) L. stark gold were obtained from a local grocery in Bahçe, Osmaniye, Turkey in 2019. The initial moisture content of cherries was determined as $82.81 \pm 0.83\%$ on wet basis according to AOAC (1990).

Pretreatments

Apart from control, three pretreatments were applied prior to drying: citric acid, sucrose and freezing. In the application of citric acid and sucrose, sweet cherries were immersed in 10% (weight/volume, w/v) citric acid (Pirone et al., 2014) and 60% (w/v) sucrose solutions (Zhao et al., 2013), respectively at a ratio of 2:7 (w/v) for 30 min at $25 \pm 1°C$. In freezing, sweet cherries were frozen and stored in a freezer section of a refrigerator (Arçelik, 570504 MB, Turkey) at -18°C until drying experiments (Dandamrongrak et al., 2003). Before drying, sweet cherries were cut into two pieces and their pits were removed.

Hot Air Drying

Sweet cherries were dried by natural convection using an oven (Memmert UN55, Germany) at 50, 60 and 70°C. The dimensions and volume of the oven were $400 \times 400 \times 330$ mm and 53 L, respectively. Oven was run as idle during 30 min, until the steady-state conditions were reached. The weight of sweet cherries (initial weight of 38 g) in glass petri dishes was measured using a digital balance (OHAUS, Pioneer™, PA 114, USA) at the 15 min intervals during the first hour and then at 30 min intervals until the completion of drying. When the weight of sweet cherries became constant, drying process was terminated. All experiments were performed in duplicate.

Microwave-Hot-Air Drying Combination

The sweet cherries were dried using two stage drying process. Firstly, the cherries placed on a rotating plate (D=245 mm) was dried using kitchen-type MW oven (Bosch, HMT84G, Germany) at 90 W for nearly 22 min in a discontinuous mode. The low power of 90 W was selected to eliminate the possible occurrence of burnings and the color loss in the material. Average moisture ratio (MR) of samples was recorded as 0.324 ± 0.084 before HA drying application. The weight of samples was measured at 5 min of intervals by a digital balance (OHAUS, Pioneer™, PA 114, USA). The MW oven had the

dimensions of 513 mm × 408 mm × 305 mm with 25 L internal capacity. After MW drying, the sweet cherries were exposed to HA drying at 50, 60 and 70°C and the weight data was recorded at 30 min intervals. All experiments were performed in duplicate.

Mathematical Modeling of Drying

The experimental drying data from MW and MW-HA drying was fitted to the most used thin layer drying models in the literature (Table 1). The dimensionless MR was calculated from the moisture content (M_t) and initial moisture content (M_0, kg water kg⁻¹ DM) as stated in Eq. (1).

$$MR = \frac{M_t}{M_0} \tag{1}$$

The determination coefficient (R^2), reduced chi-square (χ^2) and root mean square error (RMSE) were used to determine the goodness of the fit of the mathematical models. The higher R^2, lower χ^2 and RSME were used to define the most appropriate model for drying process. The following equations were used to calculate the aforesaid parameters:

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{exp,i} - MR_{pre,i})^2}{N-z} \tag{2}$$

$$RMSE = [\frac{1}{N} \sum_{i=1}^{N}(MR_{exp,i} - MR_{pre,i})^2]^{1/2} \tag{3}$$

where $MR_{exp,i}$ and $MR_{pre,i}$ are experimental and predicted MR at I, N is the number of experimental data and z is the number of constant.

Effective Moisture Diffusivity

Fick's second law was used to calculate the effective moisture diffusivity (D_{eff}, m² s⁻¹) given in Eq. (4) (Doymaz and Kipcak, 2018). Uniform moisture distribution, negligible shrinkage and infinite slab geometry were assumed (Crank, 1975).

$$\frac{\partial MR}{\partial t} = D_{eff} \nabla^2 MR \tag{4}$$

$$MR = \frac{8}{\pi^2} \sum_{n=1}^{\infty} \frac{1}{n^2} \exp \left[-(2n-1)^2 \pi^2 \frac{D_{eff}t}{R^2}\right] \tag{5}$$

Eq. (5) was converted to logarithmic form in Eq. (6).

$$\ln(MR) = \ln\left(\frac{8}{\pi^2}\right) - \left(\frac{\pi^2 D_{eff}t}{4L^2}\right) \tag{6}$$

where L was the half thickness of sample (m).

Activation Energy

Activation energy (E_a, kJ mol⁻¹) of moisture diffusion was determined using Arrhenius relationship as stated in Eq. (7) (Doymaz and Kipcak, 2018).

$$D_{eff} = D_0 \exp\left(\frac{-E_a}{RT}\right) \tag{7}$$

where D_0 was the pre-exponential factor (m² s), R was the universal gas constant (J mol⁻¹ K⁻¹) and T (K) was the temperature.

Color

$L*$ (lightness), $a*$ (redness-greenness) and $b*$ (yellowness-blueness) of sweet cherries were measured using a portable chroma meter (Konica Minolta, CR-400, Japan). Measurements were performed in triplicate. Total color change (ΔE) and yellowness index (YI) (Pathare et al., 2013) were calculated using Eq. (8) and (9):

$$\Delta E = \sqrt{(L^*\text{-}L_{ref})^2 + (a^*\text{-}a_{ref})^2 + (b^*\text{-}b_{ref})^2} \qquad (8)$$

where L^*, a^* and b^* were the color parameters of the dried sweet cherry and L_{ref}, a_{ref} and b_{ref} were the color parameters of the fresh sweet cherry.

$$YI = \frac{142.86 \times b^*}{L^*} \qquad (9)$$

Total Phenolic Content

The procedure followed by Bennett et al. (2011) was modified and phenolic compounds were extracted from the sweet cherry sample (1 g) using 80% methanol solution (v/v) in the ultrasonic bath (J.P. Selecta Ultrasons HD, Spain) for 20 min at 25°C. Afterwards, this mixture was centrifuged, and supernatants were collected as the extracts. The extracts were used freshly in total phenolic content (TPC) analysis. TPC of sweet cherries was determined using Folin-Ciocalteu method at 760 nm using a spectrophotometer (Shimadzu, UV-1800, Japan) (Li et al., 2015) and the results were given as mg gallic acid equivalent (GAE) per g dry matter (DM). All tests were conducted in triplicate.

Statistical Analysis

The analyses of linear and non-linear regression were performed by Origin Pro 2016 (Origin-Lab, USA) software (trial version) for drying kinetics. Data was analyzed using one-way analysis of variance (ANOVA) by trial version of SPSS package program (IBM, USA). Duncan test applied to define differences among the TPC of samples ($P < 0.05$).

Table 1. Thin layer drying models used in this study

Model number	Model name	Equation	Reference
1	Page	$MR = \exp(-kt^n)$	Page, 1949
2	Modified Page	$MR = \exp(-kt)^n$	Overhults et al., 1973
3	Sigmoid	$MR = a + \dfrac{b}{1+e^{k(t-c)}}$	Antal et al., 2011
4	Midilli et al.	$MR = a \exp(-kt^n) + bt$	Midilli et al., 2002
5	Henderson and Pabis	$MR = a \exp(-kt)$	Henderson and Pabis, 1961
6	Two-term	$MR = a \exp(-kt) + b \exp(-k_o t)$	Henderson, 1974
7	Wang-Singh	$MR = 1 + at + bt^2$	Wang and Singh, 1978
8	Parabolic	$MR = a + bt + ct^2$	Sharma and Prasad, 2004
9	Cubic	$MR = a + bt + ct^2 + dt^3$	Dalvand et al., 2012
10	Rational	$MR = \dfrac{a + bt}{1+ct+dt^2}$	Haghi and Angiz, 2007
11	Vega Galvez	$MR = n + k\sqrt{t}$	Vega-Gálvez et al., 2008

MR: Moisture ratio; a, b, c, d, k, k_o, k_1, n: model parameters, t: time

Results and Discussion

Drying

Figure 1 shows drying times of white sweet cherries dehydrated by both two methods. Drying time of HA dried samples were longer than MW-HA dried ones, as expected because microwaves enable fast water evaporation due to ionic heat conduction and dipolar relaxation (Kumar and Karim, 2019). Operation times were ranged from 1160 to 3557 min for HA drying, and from 232 to 752 min for MW-HA drying. When the temperature level increased, durations were also decreased. All pretreatment applications influenced process times in a desirable way, compared to intact. From this observation, it is concluded that the resistance of internal moisture transfer can be diminished by either citric acid or sucrose solution (Adiletta et al., 2018; Önal et al., 2019) except freezing. Among pretreated samples, frozen samples had the lowest drying time; however, samples with citric acid had the highest one. This can be resulted from the formation of ice crystals during freezing procedure by damaging the fruit tissue causing excess water to be thrown out of the tissues, while the thawing continues (Li et al., 2018). The final moisture contents (%) of control, citric acid, sucrose and freezing pretreated white sweet cherries were recorded as 5.92 ± 1.54, 6.78 ± 2.61, 6.86 ± 1.68 and 6.33 ± 0.74 for HA dried samples and 5.20 ± 1.47, 7.74 ± 3.03, 6.06 ± 1.20 and 5.04 ± 2.21 for MW-HA dried ones on wet basis respectively, which were below 10%, the critical moisture level for microbial risks.

Table 2 summarizes the findings of the best three thin layer drying models with their statistical outcomes. Two term (Henderson, 1974), rational (Haghi and Angiz, 2007) and sigmoid (Antal et al., 2011) models were qualified satisfactorily for the experimental drying data among the others listed in Table 1. These mathematical expressions had high R^2 and low χ^2 and RMSE values ranging between 0.91160 to 099880, 0.00001 to 0.00949 and 0.00185 to 0.08104, respectively. Horuz et al. (2017) displayed that Verma and modified Logistic models were the most suitable models for describing both conventional and hybrid (microwave-convectional) drying of sour cherries. Szadzińska et al. (2019) showed that modified Page model (1949) was the best in predicting microwave- and ultrasound-assisted convective drying phenomena of raspberries.
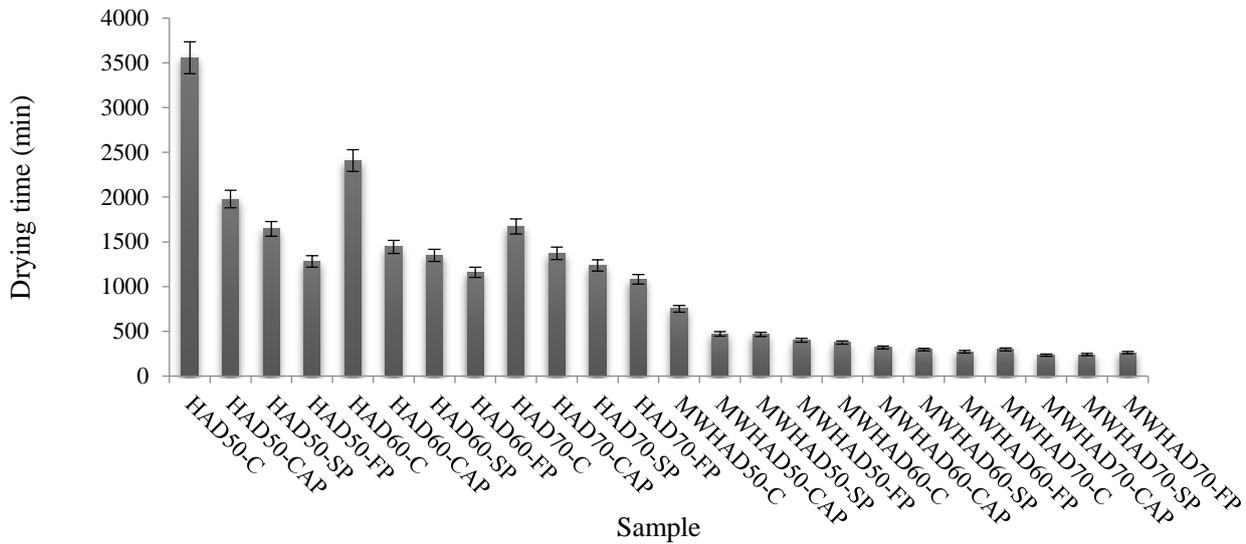
Figure 1. Drying times of white sweet cherries
HAD: Hot air dried, MWHAD: Microwave+hot air dried, 50, 60 and 70: Temperature levels (°C), C: Control, CAP: Citric acid pretreatment, SP: Sucrose pretreatment, FP: Freezing pretreatment

Table 2. The results of selected mathematical expressions applied to the data of both conventional and combination drying

S	Model	50°C			60°C			70°C		
		R^2	X^2	RMSE	R^2	X^2	RMSE	R^2	X^2	RMSE
C	Two-term	0.99331	0.00006	0.00619	0.99306	0.00010	0.00779	0.99102	0.00021	0.01160
	Rational	0.99067	0.00008	0.00731	0.99831	0.00002	0.00384	0.98913	0.00026	0.01276
	Sigmoid	0.99485	0.00005	0.00543	0.99838	0.00002	0.00377	0.98668	0.00031	0.01411
CAP	Two-term	0.99596	0.00003	0.00453	0.99265	0.00012	0.00868	0.98943	0.00026	0.04806
	Rational	0.99237	0.00006	0.00622	0.99706	0.00005	0.00549	0.97986	0.00063	0.06633
	Sigmoid	0.99152	0.00007	0.00656	0.99684	0.00005	0.00569	0.99257	0.00023	0.04037
SP	Two-term	0.99774	0.00002	0.00333	0.98155	0.00033	0.01440	0.99572	0.00012	0.02944
	Rational	0.99806	0.00001	0.00308	0.99697	0.00005	0.00185	0.99337	0.00019	0.03661
	Sigmoid	0.99751	0.00002	0.00349	0.99678	0.00006	0.00190	0.99582	0.00012	0.02910
FP	Two-term	0.99847	0.00002	0.00347	0.99583	0.00014	0.00927	0.99701	0.00010	0.00802
	Rational	0.99880	0.00001	0.00308	0.98859	0.00004	0.01534	0.99746	0.00009	0.00739
	Sigmoid	0.99829	0.00002	0.00367	0.99715	0.00009	0.00767	0.99746	0.00009	0.00739

S	Model	90W+50°C			90W+60°C			90W+70°C		
		R^2	X^2	RMSE	R^2	X^2	RMSE	R^2	X^2	RMSE
C	Two-term	0.97743	0.00255	0.04123	0.98241	0.00222	0.03851	0.97781	0.00328	0.04679
	Rational	0.95488	0.00510	0.05830	0.97753	0.00284	0.04353	0.96641	0.00515	0.05479
	Sigmoid	0.98952	0.00118	0.02809	0.98591	0.00178	0.03447	0.99592	0.00062	0.01908
CAP	Two-term	0.97272	0.00284	0.04254	0.97676	0.00352	0.04730	0.96869	0.00536	0.05840
	Rational	0.94718	0.00551	0.05920	0.96960	0.00460	0.05410	0.94876	0.00877	0.07470
	Sigmoid	0.99413	0.00061	0.01973	0.99301	0.00106	0.02595	0.99706	0.00050	0.01789
SP	Two-term	0.97245	0.00296	0.04524	0.98592	0.00177	0.03502	0.97852	0.00297	0.04351
	Rational	0.91160	0.00949	0.08104	0.96983	0.00379	0.05125	0.97525	0.00343	0.04671
	Sigmoid	0.99360	0.00069	0.02180	0.97414	0.00325	0.04745	0.98793	0.00167	0.03261
FP	Two-term	0.97500	0.00281	0.04331	0.97714	0.00259	0.04063	0.97624	0.00333	0.04603
	Rational	0.95303	0.00529	0.05936	0.96144	0.00438	0.05277	0.96698	0.00463	0.05427
	Sigmoid	0.98711	0.00145	0.03109	0.97943	0.00233	0.03853	0.96024	0.00557	0.05956

S: Sample, C: Control, CAP: citric acid pretreatment, SP: sucrose pretreatment, FP: Freezing pretreatment, R^2: Determination coefficient, $\chi2$: Reduced chi-square, RMSE: Root mean square error

Table 3. Effective moisture diffusivities and activation energies of samples

S	D_{eff} (m²/s)			E_a (kJ/mol)	D_{eff} (m²/s)			E_a (kJ/mol)
	50°C	60°C	70°C	-	90W+50°C	90W+60°C	90W+70°C	-
C	1.724×10^{-10}	2.333×10^{-10}	3.347×10^{-10}	30.541	4.260×10^{-10}	9.432×10^{-10}	1.055×10^{-9}	42.101
CAP	3.043×10^{-10}	4.057×10^{-10}	4.158×10^{-10}	13.386	9.128×10^{-10}	1.116×10^{-9}	1.247×10^{-9}	14.437
SP	3.854×10^{-10}	4.057×10^{-10}	4.564×10^{-10}	7.761	1.359×10^{-9}	1.592×10^{-9}	1.724×10^{-9}	11.002
FP	4.868×10^{-10}	4.970×10^{-10}	5.173×10^{-10}	2.785	1.552×10^{-9}	1.592×10^{-9}	1.805×10^{-9}	6.929

S: Sample, C: Control, CAP: citric acid pretreatment, SP: Sucrose pretreatment, FP: Freezing pretreatment, D_e: Effective moisture diffusivity (m²/s), R^2: Determination coefficient, E_a: Activation energy (kJ/mol)

The values of D_{eff} which are the indicators of moisture, vapor and surface diffusion, and capillary and viscous flow (Dehghannya et al., 2018a) for white sweet cherries were shown in Table 3. Drying temperature had an enhancing effect on D_{eff} because of faster water evaporation and pre-drying treatments also influenced effective moisture removal from the product positively. In general D_{eff} levels were in the following order: frozen > sucrose pretreated > citric acid pretreated > control and values belonged to MW-HA drying were always greater than HA drying. Likewise, Dehghannya et al. (2018b) stated that the osmotic solution augmented D_{eff} in three-stage hybrid osmotic–intermittent microwave–convective drying of apple when compared to the control. Up to a specific solution concentration, sucrose gain into the product can be responsible for higher D_{eff} values by the virtue of developed texture resistance (Dehghannya et al., 2018a) and similar approach may be valid for citric acid. The minimum value was 1.724×10^{-10} m^2/s at 50°C in HA drying and 4.260×10^{-10} m^2/s at 50°C combined with 90 W in MW-HA drying of white sweet cherries.

When a driving force exists, the required energy for water molecules which pass through the barrier is defined as E_a and a lower value of E_a means higher moisture diffusion in dehydration (Çelen, 2019). The E_a amounts of HA and MW-HA dried samples with citric acid, sucrose and freezing pretreated, and control sample were found to be 30.541, 13.386, 7.761, 2.785 and 42.101, 14.437, 11.002, 6.929 kJ/mol, respectively (Table 3). The E_a was reported between 12.7-110 kJ/mol in the literature (Zogzas et al., 1996). The pretreated white sweet cherries indicated lower E_a in both drying techniques and this finding was currently in line with Doymaz and Kipcak's study (2018). Furthermore, microwave application caused an increase in E_a, despite of having comparably higher D_{eff} values. Similar trend was declared by Deng et al. (2018) in red pepper drying and Motevali et al. (2016) in drying of mint leaves. Deng et al. (2018) claimed that the greater susceptibility of D_{eff} to temperature variations led to that discrepancy.

Color

Consumer choices and marketing value are primarily based on color characteristics. Thermal operations induce color degradation; hence, the extent and conditions (temperature, oxygen and moisture stages etc.) of the process play important roles within this context (Qing-Guo et al., 2006). Non-enzymatic browning (Maillard reaction, chemical oxidation of phenols and caramelization) may occur during drying (Deng et al., 2019; Önal et al., 2019) and technique of thermal operation is also effective. As shown in Figure 2, the type of drying and pretreatments had a considerable impact on the color properties of white sweet cherries. It is necessary to point out that the changes in total color and YI values were different inside and outside of the product owing to the exocarp and mesocarp structures.

ΔE was classified by Cserhalmi et al. (2006) under five groups as; (1) not noticeable, (2) slightly noticeable, (3) noticeable, (4) well visible and (5) great. When considering the data of dried fruits, results remarked that some of ΔE levels were belonged to well visible and great categories, although the most of them were apart from the aforementioned viewpoint. Furthermore, a meaningful change in color was realized in case of MW-HA drying and this can be associated with both increasing product temperature, and continuous and combined application of HA and MW which intensified the negative effect of heating. In contrast to that process, longer drying time increased ΔE in HA drying (Szadzińska et al., 2016). Zhoa et al. (2019) investigated the impact of sodium carbonate on color of air dried wolfberries, and ΔE values were calculated 13, 16 and 26 at 40, 50 and 60°C respectively, which were higher than our findings of HA drying. On the other hand, YI is strictly related to whiteness index, carotenoids, and food degradation by processing and exposure of physical factors such as oxygen, light and so on (Choo et al., 2020; Mocanu et al., 2020).
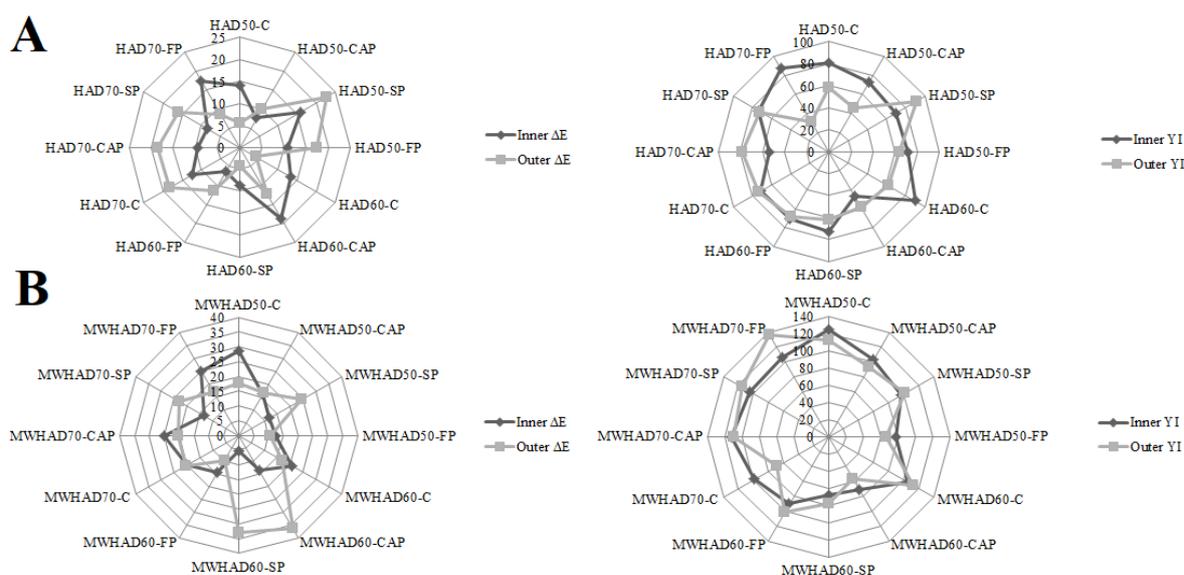
Figure 2. Total color change (ΔE) and yellowness index (YI) values of A) HAD, B) MWHAD samples
HAD: Hot air dried, MWHAD: Microwave+hot air dried, 50, 60 and 70: Temperature levels (°C), C: Control, CAP: Citric acid pretreatment, SP: Sucrose pretreatment, FP: Freezing pretreatment
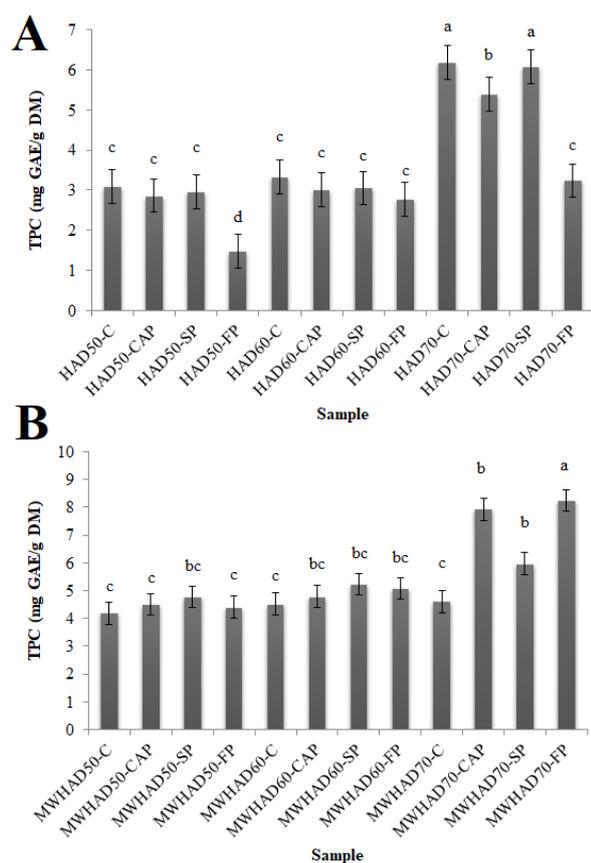
Figure 3. TPC levels of A) HAD, B) MWHAD white sweet cherries

HAD: Hot air dried, MWHAD: Microwave+hot air dried, 50, 60 and 70: Temperature levels (°C), C: Control, CAP: Citric acid pretreatment, SP: Sucrose pretreatment, FP: Freezing pretreatment

Different small letters indicate significant differences between samples (P<0.05).

Unlike ΔE, the great variations were not observed in inner and outer YI values of both HA and MW-HA dried samples. The enhanced YI can be assigned to carotenoid disintegration, the accumulation of other pigments due to higher temperature which signs the sensitivity of fruit (Kotwaliwale et al., 2007) and accordingly final products of browning reactions (Mocanu et al., 2020). Mittal et al. (2012) found the variations of YI in MW dried whole and sliced mushrooms higher than HA dried ones, which were currently in line with our study. High surface temperature in MW drying was attributed to this situation.

TPC

The antioxidant activity of a biological material is strongly related to its phenolic compounds. Thus, the TPC content clearly depicts the bioactivity of both HA and MW-HA dried white sweet cherries (Figure 3). A significantly higher level of TPC was determined in all dried samples (P<0.05), when compared with 0.71 ± 0.20 mg GAE/g DM (or 10.31 ± 2.42 mg GAE/100 g fresh weight (FW)) in fresh one. Although, thermal processing inclined the degradation of some bioactives because of the activity of polyphenol oxidase enzyme, drying operation developed the density of polyphenols (Donovan et al., 1998). The TPCs of MW-HA dried samples generally differed from each other importantly (P<0.05), with a more than one and a half times higher concentration of polyphenols in other technique.

These observations demonstrated that MW application prior to HA drying enhanced TPC in stark gold variety, similarly to sour cherry (Horuz et al., 2017) and ginger (An et al., 2016). Probably, longer drying times may destroy phenolic compounds in HA alone drying and MW energy is able to cause several damages in cell structure, so polyphenols can be easily transferred into the extraction medium (Kubra and Rao, 2012).

Freezing pretreatment induced dramatically lower TPC in especially HA drying. The quality characteristics of a frozen material may be negatively influenced from many factors such as the size and distribution of ice crystals and, volumetric and accordingly phase variations in water. All of them can cause potential stress mechanisms in tissues, while phase change (from water to ice) occurs. Hence, damaged cellular walls may reduce the bioactivity (Paciulli et al., 2015; Vallespir et al., 2019). Citric acid and sucrose pretreatments always demonstrated promising results in MW-HA drying, as higher phenolic level was specified when compared to control. As was reported by Yao et al. (2020), cyclic structure of pretreatment agents might restrict oxidation reactions which can be promoted by polyphenol oxidase enzyme. In case of MW drying, non-enzymatic reactions may also trigger the conversion of phenolic precursors to the new phenolic molecules (Soong and Barlow, 2004). Moreover, an increment in the degree of temperature intensified the effect of both citric acid and sucrose. On the contrary, the related pretreatments did not have a significant impact on HA drying (P>0.05), except 70°C. The longer drying times and exposure to air may be associated with this conflicting finding.

Conclusion

Wet infusions of citric acid and sucrose as pretreatments and as well freezing application reduced drying times of white sweet cherries in both dehydration methods. MW-HA combination technique enabled comparably shorter drying time than the conventional one. Page, modified Page, sigmoid, Midilli et al., Henderson and Pabis, two-term, Wang-Singh, parabolic, cubic, rational and Vega-Galvez equations were fitted into drying data and the best results were obtained by two-term, rational and sigmoid models. Unfortunately, the statistical outcomes of MW-HA drying were not as good as HA drying. Temperature, microwave heating and pretreatment procedures influenced dramatically D_{eff} and E_a values of samples. ΔE and YI levels were important for the quality of dried white sweet cherries and striking findings were procured. Frozen products had faster color deterioration than the others. TPC was enhanced by drying processes when compared to fresh fruit, and MW-HA drying technique was more effective in this way.

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Conflict of Interest

The authors declared no conflicts of interest for this work.

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