Physical Pretreatments to Enhance Purple-Fleshed Potatoes Drying: Effects of Blanching, Ohmic Heating and Ultrasound Pretreatments on Quality Attributes

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Abstract

In this study, it was aimed to investigate alternative pretreatment solutions including blanching, ultrasound and ohmic heating to limit the adverse effects of drying conditions on the functional properties of purple-fleshed potato (PFP). In order to investigate how functional properties were saved with pretreatments carried before drying, treatment-specific operational conditions were studied for each method. Control drying (drying of potato slices without any pretreatment) was used for comparison. Thus, whether the pretreatment created any considerable change in the functional properties of potato samples was evaluated. Voltage gradients of 20 and 40 V/cm and application times of 2 and 4 min were the studied operational conditions of ohmic heating, whereas ultrasound amplitude levels of 50% and 100% were used with the same application time values. For the blanching process, potato slices were dipped in the boiling water and kept for 2 min. Results showed that the drying time of PFP was independent of pretreatments. Total phenolic content, antioxidant activity (DPPH and ABTS) and anthocyanin content of potato slices subjected to low amplitude short-term ultrasound pretreatment were found to be higher than the corresponding values of the control group. Also, the total phenolic and anthocyanin contents of potato samples treated before drying by ohmic heating at a high electric field (40 V/cm) for 4 min were better than the control samples. The closest colour values to fresh potato were obtained on the samples pretreated by ultrasound application (US-50/2). Depending on pretreatments, any significant change in the rehydration ratio of dried PFP was observed. Also, FTIR spectroscopy with chemometric analyses was studied and results indicated that ohmic heating and ultrasound treatments revealed high potential as innovative pretreatments applied before drying of PFP slices and they were superior with respect to control one.

Keywords Bioactive compounds · Drying · Ohmic heating · Pretreatments · Purple-fleshed potato · Ultrasound

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Introduction

Potato varieties are one of the basic sources of nutrients that are widely consumed both in our country and in the world. With the developing and changing world, consumers' interest towards healthy nutrition increases. Potatoes respond to that interest by their carbohydrate, dietary fibre, vitamin, and mineral content (Zaheer and Akhtar 2016). Furthermore, depending on variety, they have important bioactives such as phenolic compounds and anthocyanins (Brown 2005). These compounds positively affect human health thanks to their properties such as anti-cancer, anti-bacterial, anti-inflammatory and antioxidant activity (Tungmunnithum et al. 2018). Especially purple-flesh potatoes (PFP) are very rich in anthocyanins in the form of acylated glycosides such as malvidin, petunidin, peonidin and delphinine (Brown 2005), and therefore, its potential as an important nutritional source for human diet can be examined. However, anthocyanins have high sensitivity to environmental conditions and process parameters like temperature, light, pH, oxygen and others (Tonon et al. 2010) (Musilova et al. 2020). Therefore, they easily deteriorate and turn into colourless and undesirable brown compounds (Kırca et al. 2007). Thus, foods being sources of bioactives including anthocyanins need extra attention in food processing.

Drying is one of the most popular and effective food preservation techniques in the food industry. Briefly, the drying process is the evaporation of water throughout food material as a result of energy given by heat transfer, generally under controlled conditions. Drying reduces the water activity of food products. It is aimed to reduce the moisture per cent of fruits and vegetables from 80–95% to 10–20% levels and to make the dried product microbiologically, enzymatically and chemically stable. Thus, the product becomes more durable and can be stored longer. Taste, appearance, colour, nutritional value and rehydration ability should be preserved as much as possible besides gains in terms of product stability. Therefore, these quality criteria should be considered when looking for the answer which type of drying technique we should use, because there are many drying techniques in the food industry and those have different advantages and disadvantages directly affecting final product properties.

Among the drying methods, conventional drying based on hot air flow is the most common method used to remove moisture from foods. This method is common due to its low investment and operational cost requirement, as well as its easy operational control. However, it is not true to think that drying is the best choice for food preservation without considering any side effects. Because food materials are susceptible to drying processes. Especially those at high-temperature levels for a long time result in nutritional losses and adverse changes in sensorial properties like flavour, colour and taste (Calín-Sánchez et al. 2013). Therefore, to avoid heat damages on foods, alternative approaches have been investigated. In this extent, different technologies have been developed as alternatives to hot air drying. Besides, some pretreatments have been also invented to prevent or to limit the disadvantages of hot air drying.

In the food industry, some pretreatments are successfully applied to shorten the drying time of product and reduce the changes in product quality during drying.

Because of this, the topic, pretreatments before drying, is being deeply studied. In literature, there are chemical (dipping in a chemical solution) and physical (blanching, vacuum processes, high hydrostatic pressure, pulsed electric field, microwave, ultrasound, carbonic maceration and ohmic heating) pretreatments (Deng et al. 2019).

Blanching is a process that is usually applied to vegetables, but it can be used for some fruits as well. It reduces microorganism load and stops enzyme activity that negatively affects product quality. It makes the colour of many vegetables and fruits brighter (Liu et al. 2015). Heat treatment also softens the product's texture, which results in changes in drying characteristics. The time required for drying is shortened, on the other hand, tissue loss may occur. Furthermore, food components sensitive to high temperatures may be damaged or dissolved into boiling water (Martínez et al. 2013). Undesirable changes that may occur during processes are prevented with the appropriate blanching process or alternative techniques. New pretreatment methods like ultrasound and ohmic heating have been studied to figure out their potential as an alternative to blanching (Ciurzyńska et al. 2021; Poojitha and Athmaselvi 2020).

During ultrasound pretreatment, the produced sound waves make the molecules in the ambient fluid vibrate and transfer this vibration to the neighbouring molecule. With this pretreatment, contractions and loosening occur in the product, called the sponge effect, micro channels are formed in the product tissue with this sponge effect and these micro-channels help transfer water molecules throughout the structure (Nowacka et al. 2012).

Thus, the drying of the product is accelerated, the amount of energy required for drying is reduced and the drying time is shortened. In other words, the process becomes more efficient, the physical and nutritional quality of the product may be protected in a better way, and as a consequence, consumer acceptance may be increased. On the other hand, it is also worth emphasising that as a result of ultrasound application, the occurrence of oxidation reactions provoked by transient hydroxyl and hydrogen free radicals can have a detrimental effect on certain types of bioactive ingredients (Adekunte et al. 2010). Another technique, being ohmic heating, is based on the principle of heating food as a result of its electrical resistance while alternating current passes through the system. This technique provides volumetric heating. Studies have shown that ohmic heating pretreatments before hot air drying increase the drying rate by improving the mass transfer properties and lead to low drying time (Wang and Sastry 2000). Hence, it provides faster heating compared to thermal processes and provides high-quality products (Darvishi et al. 2011).

To the best of our knowledge, there is no application of ultrasound or ohmic heating application as a pretreatment before drying of PFP by hot air. Therefore, it was aimed to determine the effect of blanching, ultrasound or ohmic heating as pretreatment used before the drying process on the physicochemical properties of dried PFP. Subsequently, the changes in physicochemical properties were measured to figure out the impacts of applied pretreatments. Moreover, the dried potato samples were examined by FTIR spectroscopy, and the results obtained were analysed by chemometric methods.

Materials and Methods

Materials and Sample Preparation

Purple-fleshed potato (*Solanum tuberosum* L. İlkmor) was supplied from Niğde Ömer Halisdemir University, Faculty of Agricultural Sciences and Technologies, Research and Application Fields in Niğde, Turkiye. Potatoes were stored at 4 °C, and all drying experiments were conducted in 1 month. Before drying, tubers were classified, washed,and sliced at 4 mm thickness by a slicer (Arisco, HBS-220, TÜRKİYE) before drying.

Pretreatments

Three pretreatments were individually applied to PFP before the drying process. These were blanching, ultrasound or ohmic heating. All conducted trials and relevant process conditions are summarised in Table 1. Approximately 140 g of unpeeled potatoes were used for each pretreatment. Before application, potatoes were sliced. Slice thickness was 4 mm. Slices having a diameter in between 50 and 60 mm were selected for trials. Details of each pretreatment are given below.

Blanching

Potato slices were dipped into 1 L of the boiling water (around at 95–97 °C) for 2 min. The treatment temperature change was electronically monitored. Experimental measurements showed that medium temperature only changed by 1–2 °C after

Table 1 Drying process conditions

	Pretreatment	Pretreatment conditions		Drying process
F	Raw material			
C	Untreated (control)	-		
B	Blanching pretreated	95–97 °C 2 min		
US-50/2	Ultrasound pretreated	50% amplitude	2 min	
US-50/4			4 min	
US-100/2		100% amplitude	2 min	Hot air drying at 70 °C
US-100/4			4 min	
OH-20/2	Ohmic pretreated	20 V/cm	2 min	
OH-20/4			4 min	
OH-40/2		40 V/cm	2 min	
OH-40/4			4 min	

F fresh, C control, B blanched, *US-50/2* 50% amplitude 2 min, *US-50/4* 50% amplitude 4 min, *US-100/2* 100% amplitude 2 min, *US-100/4* 100% amplitude 4 min, *OH-20/2* 20 V 2 min, *OH-20/4* 20 V 4 min, *OH-40/2* 40 V 2 min, *OH-40/4* 40 V 4 min

potato slices addition, since the slice/boiling water ratio (0.14 g/ml) was not high. At the end of the blanching pretreatments, a soluble solid content of medium was also measured by using a refractometer. It was detected that there was no remarkable soluble solid transition to the liquid medium.

Ultrasound

For ultrasound applications, potato slices were treated by using an ultrasonic probe releasing sound waves produced at an ultrasonic frequency of 20 kHz and power intensity of 500 W cm^{-2} (Ultrasonic-Homogenizer, Cy-500, Spain). Power intensity is defined as output power divided by beam area. The measurement of power output of the ultrasound system for studied amplitudes levels (50% and 100%) was calculated by the calorimetric method proposed by Raso et al. (1999), Kobus and Kusinska (2008) and Vartolomei et al. (2022). The output power transferred into the aqueous medium was calculated as 2.56 and 8.60 W for 50 and 100% amplitude levels, respectively. Ultrasound pretreatment was applied for 2 and 4 min for all studied amplitudes (50% and 100%). Medium temperature was also monitored during the pretreatments. The initial medium (water) temperature was between 18 and 19 °C and did not exceed 23 °C at the end of the ultrasound cycle.

Ohmic Heating

For ohmic heating trials, potato slices were treated in an ohmic cell being in the form of a rectangular prism (10 × 10 × 20 cm). The distance between the electrodes was adjusted to 10 cm, and the size of the electrodes was 6 cm × 10 cm. In the ohmic heating trials, two voltage gradients (20 and 40 V/cm) were studied for two time periods (2 and 4 min) using a power supply (220 V input–400 V output, max 10 A, Eraktek Machine, Konya, Türkiye). Medium temperature was also monitored for ohmic heating pretreatments. Similar to ultrasound treatments, the initial medium (water) temperature was between 18 and 19 °C. However, the final temperature level was higher; it reached up to 65 °C for ohmic heating at 40 V/cm in case of treatment time of 4 min.

Drying Experiments

For the drying process, approximately 100 g of potato slices were arranged as a single layer on the tray (1.1 kg m^{-2} loading weight) and dried in a pre-heated convectional hot air dryer (Microtest, MKD, Turkey) at 70 °C under the air flow rate of 1.3 ± 0.02 m.s^{-1} (flowing parallel to the tray). After drying, the samples were packaged under vacuum (Vacuum Packaging Machine, DZ-350/MS, CHINA) in a polyamide/polyethylene bag and stored at − 45 °C until analyses. Each pretreatment and following drying trial were conducted as two parallel and analyses were separately performed for each of them, and results were given as mean ± std-error.

Analyses of Samples

Moisture Content

For the moisture content of the sample for each trial, 3–5 g of pieced dried potato was weighed using a moisture analyser (DBS 60–3, Kern & Sohn GmbH, Germany) at 105 °C with a precision of 0.02/100 g. Results were calculated as per cent moisture content on a wet basis.

Colour Measurement

Colour parameters (L*, a*, b*) of the dried and fresh whole PFP slices were measured by a colorimeter (NH310 High Quality Portable Colorimeter, Shenzhen 3NH Technology CO., LTD., China) based on CIELab colour space, after calibration with the white and black standards (Vega-Gálvez et al. 2008). Other parameters (C*, Hue) were calculated and the results were given by the same equipment. For each potato slice, surface colour parameters were measured on both faces and two measurements per face were carried out. For each drying trial, three potato slices were used for colour measurement. Thus, twelve results for each colour parameter (L*, a*, b*, C*, Hue) were obtained and their averages were presented for each drying trial. Similarly, the measured colour parameters were used to calculate ΔE values (Eq. 1).

$$\Delta E = \sqrt{\left(L^* - L_0^*\right)^2 + \left(a^* - a_0^*\right)^2 + \left(b^* - b_0^*\right)^2} \qquad (1)$$

where L*, a* and b* are the surface colour parameters of dried samples; L_0^*, a_0^* and b_0^* are the surface colour parameters of fresh potato slices; and C* and h° represent the saturation value and hue angle, respectively.

Rehydration Ratio (RR)

While measuring the rehydration ratio of dried whole PFP slices, distilled water (at 20 ± 1 °C) was used. Approximately 3 g of dried sample was immersed in 100 mL distilled water and weighed periodically (for 30 min, 60 min, 120 min, 180 min, 240 min and 24 h). Before weighing, the rehydrated samples were slightly dried with a paper towel to remove excess surface water. Rehydration ratio was calculated using Eq. (2).

$$RR = \frac{Wr}{Wd} \qquad (2)$$

where W_r is the total weight after rehydration and W_d is the weight of the dried sample (not dry matter), respectively. The RR was measured in two parallels.

Determination of Bioactive Contents and Functional Potential of Dried Samples

Extraction of Samples To determine the total phenolic content (TPC), total antioxidant capacity (TAC), and total monomeric anthocyanin (TMA) contents of fresh

and dried potato slices, extraction was carried out by following the method reported by Marzuki et al. (2020) with modification. Approximately 1.5 g and 5 g of pieced solid sample was weighed for dried and fresh samples respectively and mixed with 15 ml of 80% ethanol and then vortexed for 1 min. Afterward, the mixture was sonicated in the ultrasonic water bath (Bandelin RK 100, Berlin, Germany) for 5 min, centrifuged at 3500 rpm for 10 min and filtered by a Whatman filter paper No. 1. The extraction was carried out in two repetitions.

Total Phenolic Content The method proposed by Singleton and Rossi (1965) was used to determine the total amount of phenolic compounds in the extracts. 40 μL of the prepared extracts was taken and 2.4 mL of distilled water was added and vortexed. Then 0.2 mL of Folin-Ciocalteu solution was added and vortexed once more. Subsequently, 0.6 mL of saturated sodium carbonate (Na_2CO_3) and 0.76 mL of distilled water were consequently added to the resulting mixtures and incubated for 2 h in dark. Samples' absorbances were measured with a spectrophotometer (T70 + UV rsz/ VIS spectrophotometer, PG Instruments, UK) at 765 nm wavelength. Total phenolic content (TPC) results of samples were calculated in terms of "mg equivalent gallic acid/g dry matter". The total phenolic contents of the samples were determined in two parallels.

Determination of Antioxidant Activity In order to determine the total antioxidant capacity (TAC) of the samples, the method used by Dorman et al. (2003) was applied. 50 μL of the extract was mixed with 450 μL of reagent buffer (Tris–HCl, 50 mM, pH 7.4) and the mixture was vortexed. 1 mL of 0.10 mM DPPH (2,2-diphenyl-1-picrylhydrazyl) solution was added and left for 30 min incubation in dark. The absorbance of samples was measured with a spectrophotometer (T70 + UV/VIS spectrophotometer, PG Instruments, UK) at 515 nm. The percentage inhibition of samples was calculated using the following Eq. (3).

$$\%\text{Inhibition} = \left[\frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \right] \times 100 \tag{3}$$

where A_{control} is the absorbance of the control (only DPPH without extract) and A_{sample} is the absorbance of sample extract.

To determine the antioxidant activities of the samples, the ABTS method reported by Re et al. (1999) was modified and used. ABTS/water solution was adjusted to 7 mM. ABTS radical cation ($\text{ABTS}^{\bullet+}$) was produced by reacting ABTS stock solution with 2.45 mM potassium persulphate (final concentration) and allowing the mixture to stand in dark at room temperature for 12–16 h. ABTS solution was diluted with ethanol to achieve an absorbance of 0.700 (± 0.02) at 734 nm. Ten microliters of the prepared extracts and 990 μl of ABTS solution were mixed. Absorbance values (at 734 nm) were taken at the beginning and 6 min later. The result was calculated with Eq. (4).

$$\%\text{Inhibition} = \left[\frac{A_0 - A_1}{A_0} \right] \times 100 \tag{4}$$

A_0 and A_1 represent the corresponding absorbance values of measurements at the initial and 6 min later, respectively.

Results for both antioxidant capacity methods were calculated as "mg trolox equivalent antioxidant capacity/g dry matter". The total antioxidant capacities of the samples were determined in two parallels.

Total Monomeric Anthocyanin Content Total monomeric anthocyanin (TMA) contents of both dried and fresh PFP slices were determined by pH differential method (Giusti and Wrolstad 2001). Absorbance value of extract was measured at 520 and 700 nm using the UV–VIS spectrophotometer for pH 1 (KCl buffer) and pH 4.5 (CH$_3$COONa buffer). Anthocyanin content was calculated by the following Eq. (5).

$$W = \frac{\left[(A_{520} - A_{700})_{pH1.0} - (A_{520} - A_{700})_{pH4,5}\right] \times M_w \times DF}{\varepsilon \times W_t} \tag{5}$$

where W is the total monomeric anthocyanin content, Mw is molecular weight (449.2 g/mole for cyanidin-3-glucoside), DF is the dilution factor, ε is molar extinction coefficient (26,900/cm/mg for Cy-3G), A was obtained from measured absorbance values at 520 and 700 nm for pH 1 (KCl buffer) and pH 4.5 (CH$_3$COONa buffer), Wt is sampling volume, mL. Total monomeric anthocyanin content of the sample was calculated as "mg equivalent of cyanidin-3-glucoside/g dry matter". The total monomeric anthocyanin contents of the samples were assessed in two repetitions.

Determination of Vitamin C

Ascorbic acid contents of both dried and fresh PFP slices were determined using the method reported by Giovanelli et al. (2002) with some modifications. Approximately 1 g of pieced sample was weighed. Sample was diluted 1:12.5 (g/mL) with 4.5% meta-phosphoric and homogenised. Sample was centrifuged $4000 \times g$ at 4 °C for 20 min. Subsequently, the supernatant was filtered through a 0.45 μm syringe filter. For HPLC analyses, an ACE 5C18 ($250 \times 4,6$ mm, ID: 5 μm) column was used with the isocratic elution of mobile phase containing ultra-pure water (at pH 3 adjusted with H$_3$PO$_4$) at a flow rate of 0.8 mL/min at 35 °C. Injection volume was 20 μL, and the wavelength of the detector was set to 254 nm.

Ascorbic acid peak was determined by comparing its retention time with an external standard. Results were calculated as "mg ascorbic acid/100 g dry matter" according to the standard curve prepared using an external standard. Ascorbic acid contents of the samples were determined in two parallels.

Fourier-Transformed Infrared (FTIR) Spectroscopy

To avoid the band that would be caused by any water molecules remaining in the sample closing the spectral bands, untreated and dried samples were frozen in an

ultra-low temperature freezer (VWR Symphony, United States) at -80 °C, and then the frozen samples were dried in a freeze dryer (Scanvac Coolsafe 95–15 Pro, Denmark) at a chamber temperature of -100 °C and shelves temperatures of 20 °C at a pressure of 1 Pa. The freeze-dried samples were grounded into powder with a kitchen grinder (Sinbo SCM 2934, Turkey) for 1 min at the highest speed and stored in a refrigerator at -18 °C (Arçelik, Turkey) for a few hours until use. FTIR spectra of the lyophilized powder of dried PFP samples were recorded by FTIR (Vertex 70, Bruker Optics, Germany) spectroscopy as described previously (Okur et al. 2019). One hundred twenty-eight scans were taken at a resolution of 2 cm^{-1} for each spectrum over the frequency range of 4000–400 cm^{-1}.

Chemometric Analyses

Principal component analyses (PCA), hierarchical cluster analysis (HCA) and partial least squares (PLS) regression analyses were conducted by using Minitab 17 (Minitab Inc.). Prior to chemometric analysis, vector normalisation was applied to the spectra. FTIR spectra of dried PFP samples using different pretreatment methods were discriminated by using PCA and HCA. PCA results were presented as a score plot. HCA analysis was performed using Euclidean distance and complete linkage. The total phenolic content, antioxidant activity (DPPH and ABTS), total anthocyanin content and ascorbic acid of samples were estimated using FTIR spectral data with PLS regression analyses. The FTIR spectral data were used as X variables (predictors), and each of the analysis results was used as a Y variable (responses) to generate PLS models as described previously (Baltacıoğlu et al. 2021b). Cross-validation (leave-one-out) was used in all analyses to evaluate calibration models. The wave numbers between 4000 and 400 cm^{-1} were used for the analyses.

Statistical Analyses

All analyses except for colour were conducted in triplicates for each parallel of the combined pretreatment and drying trial. One-way analyses of variance (ANOVA) were carried out by SPSS statistical software (IBM, Armonk, NY, USA). Duncan's test was performed to determine the minimum significant difference between means ($p \leq 0.05$). Correlation coefficient (r) was calculated using MS Office-365 Excel add-in (Data solver tool).

Results

In this study, the effect of pretreatment on the physicochemical properties of PFP was examined by the way of blanching, ohmic heating and ultrasound application prior to hot air drying. Moisture values of fresh and dried purple-fleshed potato samples were measured. Initial moisture content of fresh potatoes was found to be $79.21 \pm 2.61\%$. Moisture values of dried potato samples changed between 7.45 and 11.62% (w.b.). The drying process for all trials was monitored and time values for corresponding trials are given in Table 2. As can be seen from Table 2,

Table 2 Total drying time of drying experiments

Pretreatment	Drying	Total drying time (min)
C		152.5 ± 7.50^a
B		157.5 ± 2.5^a
US-50/2		150.0 ± 10^a
US-50/4		147.5 ± 2.5^a
US-100/2	Convectional drying at 70 °C as a single layer in an oven	147.5 ± 7.5^a
US-100/4		150.0 ± 5.0^a
OH-20/2		155.0 ± 5.0^a
OH-20/4		150.0 ± 10.0^a
OH-40/2		145.0 ± 5.0^a
OH-40/4		150.0 ± 5.0^a

The same letter in the same column means that there are no significant differences between mean values

C control, *B* blanched, *US-50/2* 50% amplitude 2 min, *US-50/4* 50% amplitude 4 min, *US-100/2* 100% amplitude 2 min, *US-100/4* 100% amplitude 4 min, *OH-20/2* 20 V 2 min, *OH-20/4* 20 V 4 min, *OH-40/2* 40 V 2 min, *OH-40/4* 40 V 4 min

statistical analysis indicated that there was not any significant difference in drying time values ($p > 0.05$). Drying time roughly changed in the range of 140–160 min. In other words, it can be said that the studied pretreatments did not create any impact on drying time.

Colour Measurement

The effect of applied pretreatment on the colour values of dried PFP was analysed and results are given in Table 3. Colour parameters of fresh PFP were also measured and L*, a*, b*, C* and h° values were found to be 27.07 ± 0.51, $10.89 \pm 0.43, -6.80 \pm 0.30$ 12.85 ± 0.51 and 328.03 ± 0.52, respectively. Wang et al. (2020) studied hot air drying of purple sweet potato and reported values for colour parameters similar to the current ones. Generally, the colour values of samples pretreated by different methods (blanching, ultrasound or ohmic heating) and conventionally dried samples were significantly higher than the fresh sample ($p \leq 0.05$), except for hue angle.

Lightness value of the samples was examined. In general, an increase was observed in the L* values of dried samples pretreated by most of the cases ($p \leq 0.05$). However, any difference was detected between those values of the fresh sample and of samples pretreated by blanching, US-50/2, or OH-40/4. Similarly, Bondaruk et al. (2007) have reported an increase in L* values of potato cubes after drying. Xiao et al. (2014) have reported similar results for ginseng samples and explained this increase after drying in L* value by the stronger light reflection of starch as a result of more opaque slice occurrence depending on moisture removal. On the other hand, it was seen that the lightness value of blanched potatoes decreased compared to the control group (dried without any pretreatment) because starch gelatinization occurred. It is well known that starch granules in potato gelatinise, when the

Table 3 Physical properties of purple-fleshed potatoes dried using different pretreatments

Drying experiments	L*	a*	b*	C*	h°	ΔE	Rehydration Ratio
Fresh	27.07±0.505 [c]	10.89±0.429 [a]	−6.80±0.299 [d]	12.85±0.511 [a]	328.03±0.517 [a,b]	-	-
Control	34.86±0.995 [a,b]	6.05±0.331 [a]	−4.78±0.290 [c]	7.73±0.415 [b,c,d]	321.75±1.077 [b]	9.71±0.99 [b,c,d]	3.30±0.235 [a,b,c]
Blanching	29.11±1.160 [c]	4.21±0.292 [f]	−4.95±0.336 [c]	6.55±0.398 [c,d,e]	310.33±1.641 [a]	7.57±0.13 [d,e]	3.09±0.045 [b,c,d]
US-50/2	27.88±0.915 [c]	5.63±0.109 [c,d]	−3.23±0.227 [a,b]	6.52±0.148 [c,d,e]	330.41±1.814 [a]	6.44±0.29 [e]	3.36±0.170 [a,b,c]
US-50/4	34.17±0.969 [b]	5.64±0.146 [c,d]	−3.25±0.167 [a,b]	6.51±0.194 [c,d,e]	330.23±0.957 [a]	9.55±0.65 [b,c,d]	3.04±0.045 [c,d]
US-100/2	36.62±1.016 [a,b]	6.12±0.259 [c]	−3.73±0.463 [a,b,c]	7.26±0.406 [b,c,d]	329.96±2.806 [a]	11.11±1.14 [a,b,c]	3.37±0.080 [a,b,c]
US-100/4	37.01±1.009 [a,b]	5.74±0.307 [c,d]	−4.21±0.374 [a,b,c]	7.17±0.412 [b,c,d]	324.35±2.074 [a,b]	11.50±0.70 [a,b]	3.44±0.050 [a,b]
OH-20/2	34.03±0.0.945 [b]	6.40±0.392 [b,c]	−4.39±0.582 [b,c]	7.84±0.631 [b,c]	327.47±2.395 [a,b]	8.71±0.68 [c,d,e]	3.50±0.020 [a]
OH-20/4	37.44±1.191 [a]	5.10±0.334 [d,e]	−3.82±0.618 [a,b,c]	6.49±0.594 [d,e]	325.46±3.296 [a,b]	12.41±1.10 [a]	3.12±0.175 [a,b,c,d]
OH-40/2	36.39±0.605 [a,b]	7.23±0.354 [b]	−4.03±0.326 [a,b,c]	8.37±0.299 [b]	330.55±2.614 [a]	10.42±0.21 [a,b,c]	2.89±0.040 [d]
OH-40/4	28.98±0.993 [c]	4.51±0.132 [e,f]	−3.07±0.193 [a]	5.48±0.190 [e]	330.25±4.236 [a]	7.66±0.20 [d,e]	3.24±0.025 [a,b,c,d]

US-50/2 50% amplitude 2 min, *US-50/4* 50% amplitude 4 min, *US-100/2* 100% amplitude 2 min, *US-100/4* 100% amplitude 4 min, *OH-20/2* 20 V 2 min, *OH-20/4* 20 V 4 min, *OH-40/2* 40 V 2 min, *OH-40/4* 40 V 4 min. Different letters in the same column for each part are significantly different ($p \leq 0.05$)

temperature is around 60 °C. The measured temperature value of the potato slice reached to a sufficient level for the starch gelation by the blanching process, taking place at 95–97 °C. It is thought that this decrease in L* value may be due to the clarity-like characteristics of gelatinized starch after blanching (Pimpaporn et al. 2007). Additionally, pretreatment time was found to be significant for US application. An increase in the lightness values of the dried potato slices was observed with increasing time in the application of US-50 from 2 to 4 min ($p \leq 0.05$). The remaining ultrasound trials did not create any significant change in L*($p > 0.05$). It has been reported by Lagnika et al. (2018) that higher L* values observed in the ultrasound process may be due to the formation of hydrogen peroxide, which is responsible for the delay of browning during sonication. The effect of hydrogen peroxide on anthocyanins was also studied by Van de Velde et al. (2016). Commercial sanitiser used in that study included 20% hydrogen peroxide. The resulting lighter fruits with the application of sanitiser by fogging were associated with the oxidation of anthocyanins in the presence of hydrogen peroxide. Besides the effect of hydrogen peroxide formation in US application, another opinion to explain this observed phenomenon in L* is about the leaching of compounds responsible for the colour (Lagnika et al. 2018). Leaching effect may be valid in case of US application, since anthocyanins are water-soluble, and ultrasound promotes dissolution of these pigments. In the current study, another pretreatment, where higher L* values compared to fresh potato were observed, was ohmic heating with only one exception being a treatment at 40 V/cm for 4 min. The adverse effect of ohmic heating at this level was associated with the temperature level at which potato slices reached. Product's temperature rises with electric field strength and time during ohmic heating pretreatment. During the applied ohmic pretreatment at voltage gradient of 40 V/cm it was detected that temperature reached its required level at which starch gelation starts and the resultant change in L* value depending on the gelation of starch was seen, as explained above. Additionally, samples pretreated at a low electric field for a short application time during ohmic heating have a close lightness value to the control groups. The reason was due to the presence of non-gelatinase starch granules on the surface of samples as a result of insufficient heating for starch gelatinization. Similarly, the high L* value has been associated with the starch granules on the surface which did not gel at low temperatures (Iyota et al. 2001). At this point it is worth to emphasise the presence of nonenzymatic browning reactions occurred as a result of both treatment with high energy dose and the drying process, which may cause change in colour values including lightness.

a* values ranged from 4.51 ± 0.132 to 10.89 ± 0.429 ($p < 0.05$). b* values were in the range of -3.07 ± 0.193 to -6.80 ± 0.299 ($p < 0.05$). As a* values decreased, b* increased for all studied drying processes compared to fresh PFP. It has been reported that this decrease in a* was attributed to the browning effects (Gan et al. 2019). Although fresh potato samples and all dried ones have – b* values, an increasing trend for this colour parameter was observed. In a study conducted by Zielinska et al. (2018), it was stated that anthocyanins may transform into colourless and/or yellow chalcones, and then brown polymers by drying processes. Subsequently, as the b* value increases due to this transformation, the redness decreases.

Irrespective of whether pretreatment was applied or not, the chroma values of the dried samples significantly decreased compared to the fresh sample ($p\check{}0.05$), since the drying process affects the colour parameters of foods and causes changes. However, the only treatment which caused a significant change in chroma values of dried samples compared to control drying was ohmic heating at 40 V/cm for 4 min (OH40/4). The decrease in chroma values is thought to be caused by the transformation of the colour pigments with the effect of pretreatments and hot air drying.

The hue angle values of fresh and pretreated and then dried potato slices ranged from 310.33 ± 1.641 to 330.55 ± 2.614. When the results were examined, it was seen that the h° values of the samples were no different from the fresh sample, regardless of the applied processes ($p > 0.05$).

As it is known that minimum change in colour values compared to fresh is a desirable quality criterion in drying processes. The total colour difference results of dried potato samples based on fresh PFP are shown in Table 3. For the total colour difference values, if the corresponding value is between 0 and 2, that is insignificant and unrecognisable for an experienced and qualified observer. However, if the total colour difference exceeds the value of 5, that becomes significant and perceptible to the human eye (Zielinska and Markowski 2012). In the case of our study, it was detected that there were also some significant changes in ΔE values depending on pretreatments and all were higher than 5. In other words, the total colour change in the pretreated and dried samples was remarkable and recognisable. The reason for this change may be attributed to the effect of pretreatments and drying processes on colour pigments resulting in their leaching, transformation or browning reactions as discussed above.

Rehydration Ratio

Rehydration properties of dried products is an important quality parameter for the food industry. The rehydration ratios of purple-fleshed potato slices subjected to different pretreatments before hot air drying are shown in Table 3. Except for potatoes to which OH-40/2 pretreatment, all remaining dried samples have similar rehydration ratios compared to the control group. In other words, blanching, ultrasound or ohmic heating produced similar results for rehydration properties compared to the control one.

Effects of Pretreatments on Total Phenolic Content, Total Antioxidant Capacity and Total Monomeric Anthocyanin Content of Dried PFP

The results of total phenolic content (TPC), total antioxidant capacity (TAC) and total monomeric anthocyanin (TMA) content of pretreated PFP samples were shown in Table 4. TPC, TAC or TMA significantly changed for all trials ($p \leq 0.05$). The total phenolic content of samples ranged from 2.81 ± 0.023 to 5.66 ± 0.037 mg GAE/g DW. The total antioxidant capacity of the samples determined by DPPH and ABTS methods ranged from 2.56 ± 0.041 to 6.87 ± 0.034 mg TE/g dw, and from 2.50 ± 0.063 to 4.75 ± 0.085 mg TE/g dw, respectively. Additionally, the total monomeric anthocyanin content of samples was found in between 0.89 ± 0.001 to 3.34 ± 0.016. In general, TPC, TAC (DPPH and ABTS),

Table 4 Total phenolics, total antioxidant capacity, total anthocyanins and ascorbic acid content of fresh and pretreated dried purple-fleshed potato

	TPC (mg GAE/g dw)	DPPH (mg TE/g dw)	TEAC (mg TE/g dw)	TMA (mg Cyn-3-glu/g dw)
F	5.42 ± 0.104^b	5.91 ± 0.051^b	3.12 ± 0.030^c	2.40 ± 0.010^e
C	$3.08 \pm 0.009^{f,g}$	4.34 ± 0.034^d	3.06 ± 0.018^c	1.53 ± 0.018^g
B	2.81 ± 0.023^h	3.48 ± 0.151^g	2.74 ± 0.014^e	0.89 ± 0.001^k
US-50/2	5.66 ± 0.037^a	6.87 ± 0.034^a	4.75 ± 0.085^a	3.34 ± 0.016^a
US-50/4	4.21 ± 0.019^d	5.76 ± 0.051^b	4.27 ± 0.174^b	2.06 ± 0.015^c
US-100/2	2.11 ± 0.010^i	2.56 ± 0.041^h	$2.77 \pm 0.083^{d,e}$	0.93 ± 0.011^j
US-100/4	3.01 ± 0.019^g	$3.83 \pm 0.035^{e,f}$	3.11 ± 0.040^c	1.91 ± 0.005^d
OH-20/2	3.19 ± 0.004^f	$3.62 \pm 0.033^{f,g}$	2.76 ± 0.004^e	1.13 ± 0.011^i
OH-20/4	2.98 ± 0.014^g	$4.05 \pm 0.025^{d,e}$	2.50 ± 0.063^f	1.21 ± 0.000^h
OH-40/2	3.43 ± 0.015^e	4.29 ± 0.009^d	$2.99 \pm 0.031^{c,d}$	1.62 ± 0.001^f
OH-40/4	4.91 ± 0.024^c	5.29 ± 0.225^c	3.07 ± 0.016^c	2.16 ± 0.006^b

F fresh, *C* control, *B* blanched, *US-50/2* 50% amplitude 2 min, *US-50/4* 50% amplitude 4 min, *US-100/2* 100% amplitude 2 min, *US-100/4* 100% amplitude 4 min, *OH-20/2* 20 V 2 min, *OH-20/4* 20 V 4 min, *OH-40/2* 40 V 2 min, *OH-40/4* 40 V 4 min. Different letters in the same column for each part are significantly different ($p \leq 0.05$)

and TMA of dried samples changed in similar manner with respect to the applied pretreatments. Correlation was established to figure out the relations between total phenolic content and corresponding antioxidant activity and anthocyanin of extracts obtained from fresh and dried potato slices (Fig. 1). The correlation
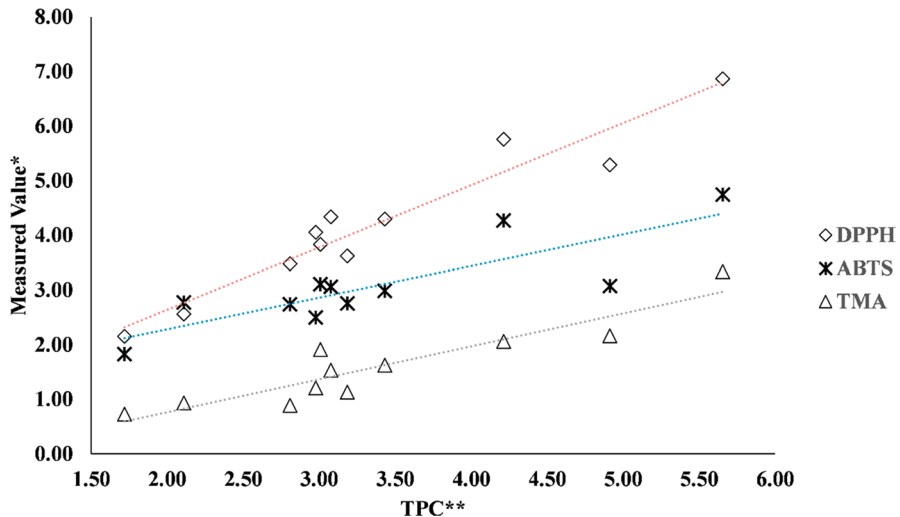

Fig. 1 The relation between TPC and other measured bioactive contents. *: Measured values of DPPH (2,2-difenil-1-pikrilhidrazil) (mg troloks equivalent/g DW), ABTS (2,2-azino-bis (3-ethylbenzothiazo-line-6-sulfonic acid)) (mg roloks equivalent/g DW), TMA (total monomeric anthocyanins) (mg Cyn-3-glu/g DW). **: *TPC* total phenolic content of extracts (mg gallic acid equivalent/g DW)

coefficients (r) of TPC-DPPH, TPC-TEAC and TPC-TMA were found to be 0.98, 0.91, and 0.96, respectively. Considering the correlation coefficients, it is possible to say that there was a strong relationship between total phenolic content and total antioxidant activity and total monomeric anthocyanin content. As it is known, anthocyanins are classified as a subgroup of phenolic compounds and compose part of antioxidant potential. Similar relations between phenolic groups and antioxidant activity have also been reported in the literature (Azuma et al. 2008; Kita et al. 2013). Thus, it is concluded that the strong relation between observed trends in bioactive compounds and antioxidant activity is meaningful in the current study.

Compared to fresh samples, corresponding TPC and TMA values of the dried PFP samples decreased irrespective of pretreatment technique except for US-50/2 only at which they increased. Similarly, TPC and TMA of the control sample were lower than of the fresh sample ($p \leq 0.05$). The antioxidant activity of the samples was evaluated by two methods, DPPH and TEAC. According to the results of antioxidant analyses, drying caused decreases in DPPH and TEAC values of potato samples, no matter whether they were pretreated or not. That decrease was not seen only for samples pretreated by US at 50% amplitude (Table 4).

To figure out the influence of pretreatments compare to control one, Table 4 can be used. Blanching process adversely affected the bioactive content and antioxidant potential of dried PFP samples. TPC and TMA content as well as TAC significantly decreased (*p ≤ 0.05*) (Table 4). During the thermal processing of fruits and vegetables, anthocyanins and phenolics were exposed to high-temperature levels and that ended in their structural damage. In other words, these processes caused losses in those bioactive groups due in part to thermal degradation, oxidation and/or dissolution of antioxidants into water. Blanching is a common pretreatment application for the food industry. However, during blanching, cell wall structure degrades, and the damaged complex molecular structure increases the release of phytochemicals. So, water-soluble vitamins and phenolic substances pass into the blanching water (Rawson et al. 2011). In literature, studies showed that during blanching, thermal degradation of phenolic compounds and anthocyanins and/or loss of water-soluble components reduce radical scavenging capacity of foods (Jaiswal et al. 2012). These reports and our results are in agreement with each others. To overcome adverse thermal effect and to make comparison and to figure out their potentials as an alternative, ultrasound and ohmic heating pretreatments were also investigated besides blanching.

TPC of dried samples were seen to be comparable to the results determined for control samples when a voltage gradient of 20 V/cm was studied for ohmic heating system irrespective of time. Besides, OH-20/4 produced a similar DPPH result to the control one ($p > 0.05$). Another OH-20 application made differences in DPPH, TEAC, and TMA ($p \leq 0.05$). When the voltage gradient of ohmic heating was adjusted as 40 V, on the other hand, TPC and TMA were found to be higher than the control one irrespective of time ($p \leq 0.05$). These pretreatments caused also significant changes in DPPH but only for 4 min applications ($p \leq 0.05$). There was not any difference between the DPPH values of OH-40/2 and the control one ($p > 0.05$). TEAC values of OH-40 for 2 and 4 min applications were not different from the control ($p > 0.05$). It is thought that the observed promoting effect of ohmic heating

may be associated with the change in the extractability of bioactives as a result of structural changes. An increase in phenolic compounds was generally observed with increasing electric field strength and duration. Salari and Jafari (2020) reviewed the literatures about the effect of ohmic heating on phenolic compounds and revealed that studies were divided into two groups. Some of the studies reported that phenolic compounds deteriorated with ohmic heating, whereas, in the other group, it was pointed out that there was a positive effect on bioactive compounds. The extractability of phenolics is greatly affected by the type of pretreatments. The researchers, who said that phenolic content increases with ohmic heating, stated that this increase is probably due to the breakdown or softening of cells which causes higher permeability for the cell wall (Brochier et al. 2016). Additionally, the high extractability of phenolics with ohmic heating is attributed to non-thermal effects at frequencies greater than 40 Hz in which medium temperature is less than the corresponding level of blanching. This leads to limited degradation of phenolics (Bhat et al. 2017).

In the case of US-50 applications for 2 and 4 min, TPC, DPPH, TEAC, and TMA values were found to be higher than the control one ($p \leq 0.05$). However, compared to the control sample, all measured parameters, given in Table 4 decreased with the amplitude level increased from 50 to 100%, when the pretreatment was applied for 2 min. In the case of 4 min application at US-100, some improvements were achieved in TPC, DPPH, TEAC, and TMA. TPC and TEAC values of the dried samples were similar to the control sample, whereas the TMA value exceeded the corresponding value for the control and DPPH still remained lower. Ultrasound treatment had positive effects on bioactive contents. This positive effect can be attributed to the fact that ultrasound application causes cell rupture and the easy release of phenolic compounds from the membrane matrix, which usually occurs during the decomposition of cell components (Abbaspour-Gilandeh et al. 2021). However, an adverse effect of ultrasound was also observed in this study besides its positive aspect. The adverse effect of ultrasound has been attributed to the heat sensitivity of those compounds and related loss in their functionality (Maghsoudlou et al. 2019), since sudden temperature and pressure increases occur as a result of cavitation being a phenomenon of sonication (Mason et al. 1996). This change is stronger during prolonged ultrasound applications. Additionally, that negative effect may also be attributed to the disrupting action of ultrasound. With an increase in treatment time at high ultrasound power and amplitude, ultrasound produces free radicals and different charged/uncharged particles, which may have adverse effects on the stability of bioactive compounds (Bursać Kovačević et al. 2019).

Ascorbic Acid Content of PFP

The ascorbic acid content of dried PFP slices ranged from 15.48 to 38.35 mg/100 g dw (Fig. 2). It was observed that compared to the fresh sample, the ascorbic acid content of PFP slices decreased with the drying process irrespective of whether pretreatment was applied or not (Fig. 2). It is well known that ascorbic acid is a water-soluble compound that is sensitive to pH, light and heat. So, thermal processes such as blanching and drying adversely affect the ascorbic acid stability (Munyaka et al. 2010). However, it has been determined that the blanching process applied before drying had higher ascorbic acid content than the control group had. In this sense,
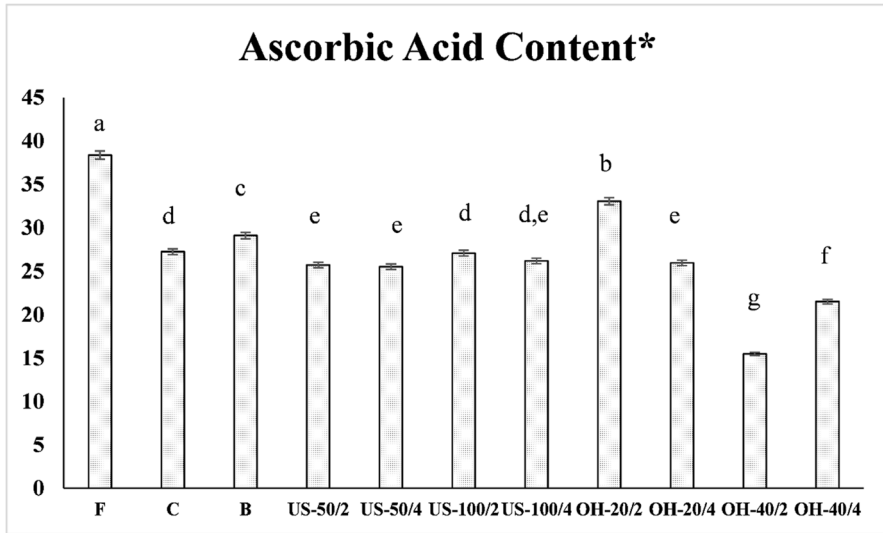
Fig. 2 Ascorbic acid content of fresh and dried potato samples. C, control; B, blanched; US-50/2, 50% amplitude 2 min; US-50/4, 50% amplitude 4 min; US-100/2, 100% amplitude 2 min; US-100/4, 100% amplitude 4 mi;, OH-20/2, 20 V 2 min; OH-20/4, 20 V 4 min; OH-40/2, 40 V 2 mi;, OH-40/4, 40 V 4 mi;, F, fresh. Different letters are significantly different ($p \leq 0.05$), *mg ascorbic acid/100 g dry matter

there are two approaches in the literature to explain its reason. One of them is the inactivation of the oxidative enzymes in potatoes at around 85–90 °C (Kincal and Giray 1987), and with blanching that temperature level has already been exceeded. In the latter approach, the stability of the ascorbic acid in potatoes is attributed to the protective effect of the starch gel formed in the blanching process (Wang et al. 2010).

Comparison between ohmic pretreated groups indicated that the ascorbic acid content of dried samples reduced with increasing electric field application ($p \leq 0.05$). Additionally, duration caused an adverse effect on ascorbic acid content in the case of OH treatment at 20 V/cm ($p \leq 0.05$), whereas this was not observed when the voltage gradient shifted from 20 V/cm to 40 V/cm ($p > 0.05$) The adverse effects of electric field and process time may be attributed to the resultant high-temperature level, since ascorbic acid is known as one of the most heat sensitive food compounds. However, according to our results adverse effect of process time was not seen in the case of OH at 40 V/cm when time shifted from 2 to 4 min. This surprising result can be related to starch gelatinization phenomena. We have already mentioned that during the applied ohmic pretreatments, in the OH-40/4 trial, which was the highest application power and time, the temperature reached to the required temperature levels at which starch can gel. The reason for this increase in ascorbic acid content for the trial of OH-40/4 can be similarly attributed to the protective effect of the starch gelatinization on ascorbic acid as reported by Wang et al. (2010).

When ultrasound was used as a pretreatment, ascorbic acid content of dried samples differed from the control one in the case of 50% amplitude level ($p \leq 0.05$). That slight decrease disappeared when ultrasound was applied at 100% amplitude level

for 4 min ($p > 0.05$). Adekunte et al. (2010) reported that ultrasound treatment has physical (cavitation, mechanical effects, micro-mechanical shocks) and/or chemical (free radical formation due to sonochemical reaction) effects. Ascorbic acid lost in dried samples may be attributed to those effects.

FTIR Analyses

FTIR spectra of samples are given in Fig. 3. When the spectra of the samples were investigated, some differences were observed between the fresh and dried samples. These differences were determined for the regions between 1700 and 1500 cm^{-1} where protein bands were observed and between 1500 and 1200 cm^{-1} where phenolic compounds were examined. Spectral difference in the protein molecules related region may be due to the changes in the enzyme structure that was affected by drying. Another difference observed for the region of 1500–1200 cm^{-1} may be as a result of the degradation of phenolics during applied treatments. The functional groups assigned in the FTIR spectra were shown in Table 5.

The band located at 3281 cm^{-1} was associated with proteins and polysaccharides (Baltacıoğlu et al. 2021b). The bands observed in the region between 2980
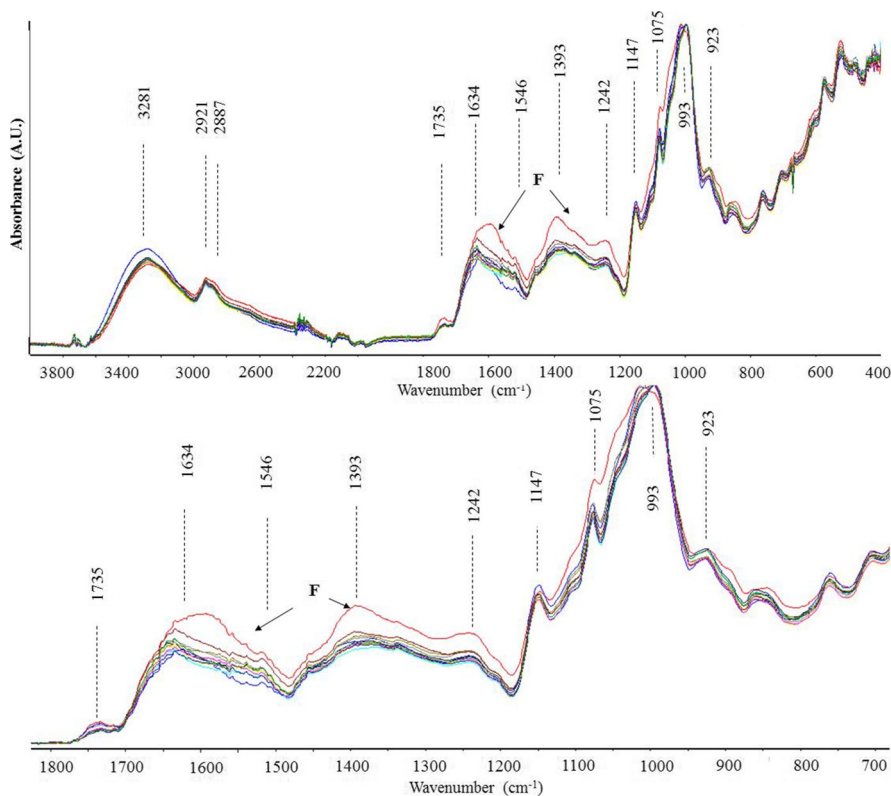
Fig. 3 FTIR spectra of fresh and dried purple-fleshed potato samples with enlarged fingerprint region

Table 5 Functional groups assigned in the FTIR spectra of fresh and dried purple-fleshed potato samples

Frequency (cm^{-1})	Functional group	References
3281	O–H stretching of polysaccharides, N–H stretching of Amide A groups of proteins	(Baltacıoğlu et al. 2021a)
2921	Asymmetric stretching vibrations of CH$_2$ groups of lipids	(Lu et al. 2011)
2887	Symmetric stretching vibrations of CH$_3$ groups of lipids	(Lu et al. 2011)
1735	C=O stretching of carboxylic acid monomers of phenolics	(Abbas et al. 2017)
1634	Amide I (C=O stretching) group of proteins and/or enzymes	(Dıblan et al. 2018; Baltacıoğlu and Coruk 2021)
1546	Amide II (C-N and N–H stretching) group of proteins and/or enzymes	(Dıblan et al. 2018)
1393	C—H stretching, O—H or C—O bending vibration of polysaccharides, (–OH deformation vibration, C–O stretch vibration of phenolic hydroxyl group	(Qin et al. 2020; Xiao et al. 2013)
1242	C-O–H bending of phenols	(Coelho et al. 2020)
1175–1065	C—OH, C—O—C and C—C stretching vibrations of phenols indicating the presence of pyran ring structure	(Baltacıoğlu et al. 2021b)
1065–870	C–O, C–C and C–H stretching of starch	(Capron et al. 2007; Nhouchi and Karoui 2018)

and 2820 cm^{-1} were mainly related to the lipids with a small contribution from proteins, carbohydrates, and nucleic acids (Lu et al. 2011). The bands observed at 1634 cm^{-1} were assigned as the Amide I of proteins. The band only observed for fresh PFP at 1546 cm^{-1} was related to Amide II bands (Baltacıoğlu and Coruk 2021; Dıblan et al. 2018). The peaks seen in the region between 1500 and 1065 cm^{-1} were assigned to C–O stretching and C–O–H bending of phenols and carbohydrates (Baltacıoğlu et al. 2021b; Coelho et al. 2020). The bands in the region between 1065 and 870 cm^{-1} were due to the stretching vibrations of C–O and C–C stretching of amylose, amylopectin, and starch (Nhouchi and Karoui 2018). When the vibrational patterns were investigated, more pronounced changes were observed in the finger-print region (1800–700 cm^{-1}) (Fig. 3). Significant changes were observed especially in the Amide 1 and Amide 2 bands, which are associated with proteins, within the fresh and dried samples. This change showed that the applied drying methods caused protein degradation. Some alterations also were observed between the fresh and dried samples in the region between 1450 and 1000 cm^{-1} which were mostly associated with phenolic compounds. In addition, some changes were determined in the bands (1393 cm^{-1} and 1065–870 cm^{-1}) related to carbohydrates.

Chemometric Analyses

FTIR spectral data were chosen as variables and correlations between spectral data were determined by using PCA. PCA was performed to discriminate fresh and dried PFP using FTIR spectra. The score plot was demonstrated with two principal components accounting for 96.5% of the total variance (Fig. 4A). PC1 and PC2 explained 83.6% and 12.9% of the total variance, respectively. The fresh purple-fleshed potato and dried ones were differentiated according to the PCA plot. The raw material was mainly located in the negative axis of PC1 and the positive axis of PC2. The control sample and some of the dried samples (OH-20/4, OH-40/4, US-50/2, US-100/2 and US-50/4) were differentiated from raw material according to PC1. Blanching pretreated conventional dried purple-fleshed potatoes (B) was located in the negative axis of PC2 contrary to the raw material. Ohmic heating dried PFP were mainly differentiated from raw material according to PC2. Ultrasound-treated dried PFP were mainly discriminated from raw material according to PC1. Similarly, PCA was used to determine the influence of ultrasonic pretreatment on the nutritional quality of potatoes dried with hot air drying (Rashid et al. 2019). PC1 was seen to be useful to discriminate dried samples pretreated by studied techniques from control (Fig. 4A), except for US-100/2. Additionally, the PC1 score indicated that the dried samples previously blanched are totally different from samples subjected to other pretreatment techniques as well as fresh samples. Furthermore, both techniques, ultrasound and
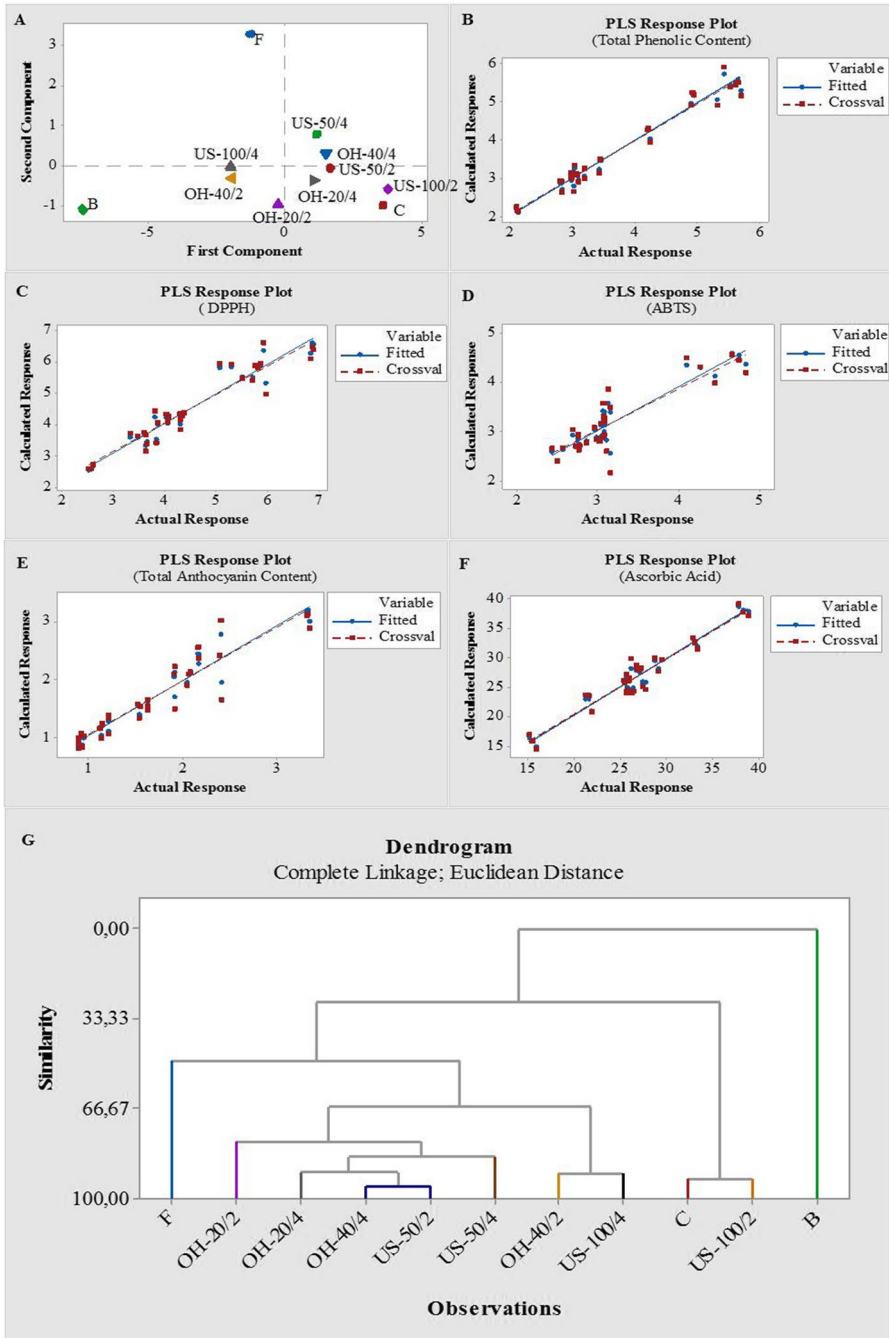
Table 6 PLS regression analyses for the prediction of bioactive compounds and antioxidant activity of purple-fleshed potatoes using FTIR spectral data

Parameters	Components	r_{CV}	r_{Pre}	RMSEC	RMSEP
Total phenolic content	8	0.9808	0.9610	0.159	0.157
Antioxidant activity (DPPH)	8	0.9445	0.8921	0.294	0.290
Antioxidant activity (ABTS)	9	0.8874	0.7321	0.227	0.224
Total anthocyanin content	9	0.9439	0.8663	0.171	0.168
Ascorbic acid	9	0.9628	0.9163	1.105	1.088

Factors: set of orthogonal factors that account for most of the variation in the response

r_{CV} correlation coefficient of cross-validation, r_{Pre} correlation coefficient of prediction, *RMSEC* root mean square error of calibration, *RMSEP* root mean square error of prediction

ohmic heating localised close to each other. In other words, PCA also revealed that these two methods did not create big differences between each other.

HCA was applied to the FTIR spectral data for further discrimination of the samples. According to the HCA dendogram graph (Fig. 4G), at a similarity level of 65.72%, clusters F, B and C were mainly separated from other samples except for US-100/2 which was in the same cluster with C at a similarity level of 92.28%. Ohmic and ultrasound pretreated samples were similar to the raw material due to the found in the same group according to HCA.

PLS regression analyses results for the prediction of total phenolic content, antioxidant activity (DPPH and ABTS), total anthocyanin content and ascorbic acid using FTIR spectral data are given in Table 6. According to Table 6, a good correlation within the calculated and reference values could be obtained because r_{CV} and r_{Pre} values for the models were higher than 0.99 and each of the models was statistically significant ($p \leq 0.05$). Moreover, the RMSE values within each model had small values, and the differences between these values were also small. It was concluded that satisfactory predictions could be provided from the created PLS models (Baltacıoğlu et al. 2021b). PLS regression plots of actual versus predicted for each analysis using FTIR spectra are shown in Fig. 4B–F for total phenolic content, DPPH, ABTS, total anthocyanin content and ascorbic acid of samples, respectively. High correlations between reference and FTIR-predicted values could also be visually perceived for these parameters. Similarly, PLS regression has been used successfully to quantify the bioactive content and antioxidant activity of tomato extracts using IR spectra (Baltacıoğlu et al. 2021b).

Conclusion

The current study serves to literature by producing new information about the application of ultrasound and ohmic heating treatments to PFP before the drying process and their effects on the bioactive contents of samples. Considering the results, it can be revealed that potato slices subjected to low ultrasound amplitude for 2 min and high electric field application for a long time (OH-40/4) were superior to the control in terms of bioactive compounds. In other words, these techniques can transfer their

advantages like fast processing, homogeneous treatments, low energy requirement and high-quality production to the processing of PFP. However, it is necessary to mention that these techniques require more effort to adopt these systems in industrial applications. Since there are some disadvantages of ultrasound and ohmic heating in their current technology levels like corrosion on electrodes of ohmic system, metal contamination into food materials from ultrasound probes, and large-scale adaption problems for both techniques. Additionally, there is a need for more studies about their applications to different food materials. As a consequence, these techniques are promising processes that can be used instead of blanching before drying.

Moreover, FTIR spectroscopy with chemometric analyses was conducted to figure out the influences of the drying process on the bioactive content of PFP and its functionality. FTIR spectral data were used in PLS regression analyses for the prediction of total phenolic content, ascorbic acid content, total anthocyanin content and antioxidant activity of PFP slices.

Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interests "Investigation of Different Pretreatments on Conventionally Dried Purple-Fleshed Potatoes". There is no financial conflict of interest with any institution, organisation, or person related to our article, and there is no conflict of interest between the authors.

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