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Impact of Ohmic Heating and Ultrasound Pretreatments on Oil Absorption and Other Quality Parameters of Fried Potato

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Abstract

In this study, the effect of pretreatments ((hot water blanching (HWB), ultrasound (US) and ohmic heating (OH)) on reducing the oil absorption of potato during frying and the changes in the quality parameters of the product ((total polyphenol (TP), in vitro digestion, total flavonoid (TF), antioxidant capacity (AC), chlorogenic acid (CA), textural and sensorial properties)) were investigated. The pretreatments applied significantly affected oil absorption and quality parameters of fried potato. The oil content of fried potatoes ranged from 26.06 to 32.01% depending on the pretreatment. OH-pretreated potato had the highest content of TP (41.27 mg GAE/100 g dry matter-DM), TF (32.89 mg RE/100 g DM) and CA (1.72 mg/100 g DM). However, there was no significant difference between the pretreatments in terms of bioaccessibility of polyphenols at the end of digestion. Also, AC value of fried potato pretreated by OH (124.13 mmol AAE/100 g DM) was higher compared to that of fresh potato (83.91 mmol AAE/100 g DM), but other two pretreatments caused a decrease in AC. The highest hardness was observed in HWB-treated potato strips. OH-treated potato had the best color parameters. Sensory data indicated that US-pretreated potato had the highest sensory scores followed by OH- and HWB-pretreated ones, respectively. Consequently, based on the above comprehensive quality evaluation, it can be suggested that OH pretreatment is a better choice for preparing deep fried potato.

Keywords Bioactive compounds · Frying · Ohmic heating · Oil absorption · Potato

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Introduction

Frying is one of the oldest food processing methods that gains color, taste, smell and crispness to foods (Oladejo et al. 2017). Deep fried potato (*Solanum tuberosum*) is very popular among consumers due to its taste, aroma, desirable sensory properties and easy preparation (Yang et al. 2020). However, with the consumption of fried foods, a large amount of fat enters the body, which causes excess calorie intake, and also carries a risk in terms of diseases such as obesity, coronary heart disease, cancer, diabetes and hypertension (Zhang et al. 2016). Therefore, it is of great importance to consume fried products containing less fat. Oil absorption of fried potato is affected by some factors such as oil quality, frying temperature, food moisture content and pre-and post-treatments. For example, lower oil uptake was detected as increased ultrasonic frequency and frying temperature (Movahhed and Ahmadi Chenarbon 2018).

Fruits and vegetables are important source of polyphenols (Nemš et al. 2015) which are considered health-promoting phytochemicals having antioxidant activity, anticarcinogenic, antiglycemic, anti-inflammatory and vasodilatory properties (Musilova et al. 2015). Potatoes are one of the vegetables that contain large amount of polyphenols (Cebulak et al. 2023). The main polyphenol in potato is chlorogenic acid which is one of the phenolic acids (Deußer et al. 2012; Nemš et al. 2015). Cebulak et al. (2023) reported that total phenolic acid contents in different potato varieties were 64.78–129.94 mg/100 g fresh mass, with chlorogenic acid being dominant. Since potato is one of the most consumed foods in the world, investigating polyphenol content of fried potato and even bioaccessibility of its polyphenols is very important. However, polyphenols have lower stability during exposure to higher temperatures (Ruiz et al. 2018). Thus, thermal processing techniques such as frying and roasting have a significant impact on concentration of polyphenols in the product and, consequently, on its antioxidant activity (Burgos et al. 2013; Gao et al. 2022).

In recent years, some pretreatments such as edible coating (Yu et al. 2016), microwave heating and vacuum drying (Yang et al. 2020), ultrasound (US) (Oladejo et al. 2017), high pressure (Al-Khusaibi and Niranjan 2012), ohmic heating (OH) (Salengke and Sastry 2007) and osmotic dehydration (Udomkun and Innawong 2018) to reduce oil absorption during frying can be applied. OH is an innovative food processing method based on the passage of electrical current through a food having an electrical resistance (Soghani et al. 2018; Zulekha et al. 2018) and provides rapid and uniform heating, resulting in less thermal damage to the product (Kaur et al. 2016). US is also a novel pretreatment with a sound wave of 20 kHz and above. It can improve the quality of food because of its nonthermal character (Fijalkowska et al. 2016). It causes alternate expansion and compression effect on the food material thereby creating microscopic channels within the food structure (Dehghannya et al. 2016; Oladejo et al. 2017). These applications not only ensure better preservation of the quality of the food, but also enable healthier food consumption. According to our knowledge, there is a limited information regarding the effect of OH and US pretreatments on the reduction of oil uptake during potato frying and quality parameters. In this study, the effects of US and OH as an alternative to the hot water blanching (HWB) process used as a conventional pretreatment in commercial frozen fried potato production on reducing the oil absorption of the potato during frying and on changes in some quality parameters (total polyphenols, bioaccessibility of polyphenols, total flavonoids, antioxidant capacity, chlorogenic acid and textural and sensorial properties) of the product were investigated.

Material and Methods

Materials

"*Agria*" variety potatoes with uniform color and size, which were used in this study, were supplied from Ar Tarım Tohumculuk, a local potato company located in Kayseri/Turkey and stored in a refrigerator at 4 ± 1 °C until the experiments were conducted. High temperature resistant frying oil for deep frying of potatoes was purchased from a local market in Bursa. Chemicals used in this study were either HPLC or analytical grade.

Sample Preparation

Before processing, whole potatoes were peeled manually, washed with tap water and blotted with towel paper to remove excess water on the surface. Then, the potatoes were cut into rectangular strips ($1 \times 7 \times 1$ cm^3) using a manual cutter and subjected to different treatments (HWB, OH and US) prior to frying in triplicate, as detailed below.

Pretreatments

The parameters of the three pretreatments (HWB, OH and US) were determined based on literature data and preliminary study results. After pretreatments, all samples were rapidly drained, cooled in running water, and then dried with paper towels to remove the excess water.

HWB

The potato was blanched in a beaker containing hot water at 65 °C on a hot plate for 10 min (potato-water ratio 1:10, w/w).

OH

The blanching of the potatoes was performed in an OH chamber, which consisted of a rectangular plexiglass and two stainless steel electrodes. The system of the OH chamber was described previously by İncedayi (2020). The distance between the electrodes was set at 14 cm. A 0.30% table salt solution was added to the chamber to ensure better contact between the electrodes and the sample. The sample-to-liquid ratio in the treatment chamber was 1:5 (w/w). Potato samples were treated with electric field strengths of E = 35 V/cm for 40 s at 490 V.

US

Samples were subjected to ultrasonic waves with the frequency of 24 kHz for 30 min using an ultrasonic bath (RK 510 H, Bandelin, Germany).

Frying Process

Pretreated potato slices were placed in the frying basket and deep-fried in frying oil at 180 °C for 6 min using a temperature-controlled fryer (Tefal Easy Pro Fry, France) until the potatoes were adequately fried for consumption. The parameters were selected based on literature data and preliminary experiments. At the end of the frying time, the potatoes in the basket were drained for 2 min until there were no oil drops on the surface. Then they were allowed to cool to room temperature and analyzed.

Quality Parameters

Raw and fried potatoes were homogenized in a blender (Arzum, AR 189, Turkey) and ground with a coffee grinder (Moulinex Ar1105), respectively, and the samples were kept at 20 °C until the analyses.

Determination of Oil Content

Oil content (%, on DM basis) was determined using the Soxhlet extraction method. Briefly, samples were placed in a single-thickness cellulose thimble and hexane was added as the solvent. Oil extraction was carried out for 6 h, and the extracted oil was collected in a flask. Afterward, hexane was removed from the flask by evaporating it under vacuum (using pressure between 150 and 200 mmHg at 35 °C) with a rotary evaporator. Finally, the flask containing the extracted oil was dried in a hot air oven at 105 °C for 1 h and weighted.

Determinations of Total Polyphenols, Total Flavonoids, Chlorogenic Acid and Antioxidant Capacity

The potato was extracted with aqueous methanol (91%, w/w) on a mechanical shaker for extraction of polyphenols. Methanol was selected due to its frequent use in extracting phenolic compounds from plant materials (Vázquez et al. 2012; Franco et al. 2018; Riciputi et al. 2018). The extraction was conducted at solid-to-solvent ratio of 1/5 (g/mL) for 180 min based on the optimum conditions determined in our previous unpublished study. After extraction, the suspension was filtered through Whatman No. 1 filter paper and the clear extracts were used for determining total polyphenols, total flavonoids, chlorogenic acid and antioxidant capacity. Total polyphenols of the extracts was determined using the Folin-Ciocalteu method (ISO 14502–1 2005) with a calibration curve of gallic acid ($R^2 = 0.99$), expressed as mg gallic acid equivalents per 100 g of DM. The amount of total flavonoids was determined spectrophotometrically (Rodrigues et al. 2016) using rutin (0–1500 ppm; $R^2 = 0.99$) as a standard. Results were expressed as mg rutin equivalents per 100 g of DM.

The chlorogenic acid analysis of the samples was carried out using high performance liquid chromatography (HPLC) following the method described by Türkmen Erol et al. (2009) with some modifications. The mobile phase (A) consisted of 0.1% orthophosphoric acid in water (w/v) and the mobile phase (B) was acetonitrile. The gradient elution profile started with 8% B (isocratic) for 5 min. Subsequently, B was gradually increased to 10% at 30 min, to 80% at 35 min. The column (Nova Select C18 reversed phase column; 100A, 5 µ; 125 × 4.0 mm) was re-equilibrated with the initial conditions for 5 min before the next injection. The flow rate was maintained at 1.0 mL/min and the injection volume was 20 µL. The column temperature was held constant at 25 °C. Chromatograms for chlorogenic acid were recorded at 325 nm, which is the wavelength of its maximum absorption.

The chlorogenic acid peak in the samples was identified by comparing its retention time and UV spectra with that of its reference standard and by co-chromatography with added standard. Quantification was performed from the peak area of chlorogenic acid and its corresponding calibration curve.

The antioxidant capacity of the extracts was determined by the 2,2,diphenyl-2-picryl-hydrazyl (DPPH) method of Turkmen et al. (2005). A standard curve of the reference antioxidant, ascorbic acid (0–20 µg/mL), was assayed under identical conditions to evaluate its ability to scavenge DPPH. The antioxidant capacity of the samples was then converted to ascorbic acid equivalents (AAE), defined as mmol of ascorbic acid equivalents per 100 g of DM.

In Vitro Digestion (Bioaccessibility)

In vitro digestion analysis was carried out according to Minekus et al. (2014) to evaluate the bioaccessibility of phenolic compounds of the potato extracts in two stimulated stages as gastric and intestinal. After each stage, the amount of total polyphenols was determined and the bioaccessibility (%) of polyphenols was calculated using the following equation:

$$\begin{aligned} &Bioaccessibility\ (\%) = (\mathrm{C}_{digested}/\mathrm{C}_{undigested}) \times 100 \\ &\mathrm{C}_{digested}: \text{Concentration in digested sample after gastric/intestinal stage (mg)} \\ &\mathrm{C}_{undigested}: \text{Concentration in undigested sample (mg)} \end{aligned} \tag{1}$$

Texture Analysis

Texture analysis was performed on fried potato strips using the Texture Analyzer TA.XT 2Plus (Stable Micro Systems, Surrey, UK). A cylindrical probe (Three Point Bend Ring, P/2–2 mm) was inserted at constant rate of 2 mm/s over a distance of 15 mm until it cracked the potato strip. The maximum compression force (N) was used for describing the sample texture as hardness. Five measurements were taken for each sample.

Color Analysis

The color values L*(lightness), a* (redness) and b*(yellowness) of the samples were determined using the colorimeter (Konica-Minolta CR-5, USA). Five measurements were taken for each sample and the average value was recorded.

Sensory Evaluation

The sensory assessment was conducted by 10 trained panel members from the Department of Food Engineering of Bursa Uludag University. Fried potatoes were coded with a randomly selected three-digit numbers and evaluated based on color, odor, taste, oiliness, crispness, appearance and overall acceptability. Overall liking was determined using a 5-point hedonic scale ranging from "dislike extremely" (1) to "like extremely" (5) (Incedayi et al. 2022). The members were instructed to rate their preference for the above properties of the fried potatoes and paper score-sheets were used for data collection.

Statistical Analysis

The experiments were conducted in triplicate, and results were expressed as the mean value ± standard deviation. Analysis of variance was performed using the one-way ANOVA procedure with SPSS software (SPSS statistics 23, IBM.2015). Means were compared using Duncan's multiple comparison test. Values of $p < 0.05$ were considered significantly different.

Results and Discussions

The results of the analyses belong to fresh potato and the effect of different pretreatments on the oil absorption and quality characteristics of fried potato is presented in Tables 1 and 2. The results showed that pretreatments significantly

Table 1 Analysis results of fried potatoes

Analysis	Pretreatment		
	OH	HWB	US
Oil content (%, on DM basis)	26.06 ± 0.27[a**]	32.01 ± 1.92[b]	30.71 ± 0.84[b]
TF (mg RE/100 g DM)	32.89 ± 1.55[c]	19.11 ± 1.18[a]	25.78 ± 1.17[b]
CA (mg/100 g DM)	1.72 ± 0.18[c]	0.36 ± 0.02 [a]	1.02 ± 0.06[b]
Texture (N)	357.96 ± 12.14[b]	394.75 ± 7.17[c]	324.26 ± 1.14[a]
L*	62.57 ± 0.17[c]	61.20 ± 0.16[b]	58.92 ± 0.28[a]
a*	2.66 ± 0.03[a]	2.82 ± 0.11[a]	8.68 ± 0.09[b]
b*	32.75 ± 0.12[c]	27.51 ± 0.35[a]	31.58 ± 0.03[b]

**Different letters in each column indicate significant difference ($p < 0.05$) between values

Table 2 Analysis results of fresh potato

TP (mg GAE/100 g DM)	64.71 ± 1.78
AC (mmol AAE/100 g DM)	83.91 ± 3.99
TF (mg RE/100 g DM)	100.09 ± 5.46
CA (mg/100 g DM)	3.53 ± 0.26

affected values of oil, total flavonoids, chlorogenic acid, total polyphenols, bioaccessibility of polyphenols, antioxidant capacity, texture, and color ($p < 0.05$).

Oil Content

As seen in Table 1, the oil content of fried potatoes ranged from 26.06 to 32.01%. Similar findings have been reported by Al-Khusaibi and Niranjan (2012) and Rimac-Brnčić et al. (2004) as 29.03–41.23% and 22.89–39.77%, respectively. On the other hand, Cruz et al. (2018) found higher levels of oil (39.54 to 57.81%) in fried potato chips than that detected in this study. Oil absorption is a complex process which includes numerous physical, chemical and structural transformations during frying (Lumanlan et al. 2020). Therefore, this can be due to differences in potato variety and conditions of frying and pretreatments. Although there was no significant difference between oil contents of HWB- and US-treated potatoes ($p > 0.05$), the OH-treated one had lowest oil content. This might be related to some structural changes which cause reduction in oil absorption. It is known that OH provides fast and uniform heating and results in less thermal damage in a product (Kaur et al. 2016). For this reason, this might stabilize the tissue structure more against the violence of the frying process compared to other pretreatments, increasing cell wall/tissue integrity and consequently preventing the oil migration in the potato tissue during the frying process. Additionally, OH-treated potatoes might have smooth surface resulting in lower oil uptake due to the fact that Moreno et al. (2010) found that products with rougher surfaces retained more oil after deep-fat frying. As in agreement with our result, Ignat et al. (2015) found that oil content of PEF-treated potatoes was lower than that of blanched ones. They stated that more water was probably located outside the cells creating a barrier and leading to a reduced oil uptake during frying due to PEF-induced electroporation.

Total Flavonoids

Thermal processing such as roasting, baking, steaming, frying and grilling reduce the flavonoids in foods due to their low stability (Gao et al. 2022). The highest value of total flavonoids was recorded for fresh potato as 100.09 mg RE/100 g (on DM basis) (Table 2). The results revealed that deep fat frying greatly reduced total flavonoids content of potato when compared with that of fresh form (Table 1 and Table 2) regardless of pretreatments applied. The percentages decreases of total flavonoids content in fried potatoes pretreated by OH, HWB and US were 67.14%, 80.91% and 74.24%, respectively when compared with fresh potato. This reduction in flavonoids could be due to their leaching out and/or their thermal degradation. Similar to our findings, Gunathilake et al. (2018) reported lower flavonoids contents in some fried green leaves as compared to their fresh forms. Some previous studies also notified a decrease in flavonoids in eggplant (Arkoub-Djermoune et al. 2016) and cauliflower (Ahmed and Ali 2013) after a frying process. On the contrary, Salamatullah et al. (2021) and Abong' et al. (2021) stated that total flavonoids content increased in fried eggplant fruit and sweet potato, respectively, as compared to their fresh ones. The results indicated that total flavonoids content of fried potatoes was significantly ($p<0.05$) affected by pretreatments applied as illustrated in Table 1. OH treatment resulted in the least loss of total flavonoids content in fried potato, followed by US and HWB, respectively. This result is in agreement with the study of Zulekha et al. (2018) who reported that conventional heating resulted in higher loss for phenolic compounds of coconut water when compared to OH.

Table 3 AC (mmol AAE/100 g DM), TP (mg GAE/100 g DM) and TP bioaccessibility (%) of fried potatoes

Parameter	Stage	OH	HWB	US
AC	Initial	$124.13\pm1.73^{cC*}$	54.21 ± 0.53^{cA}	77.12 ± 1.06^{cB}
	Gastric	50.92 ± 1.87^{aC}	22.00 ± 0.30^{aA}	40.64 ± 0.97^{aB}
	Intestinal	94.72 ± 1.87^{bC}	51.02 ± 0.95^{bA}	56.63 ± 1.25^{bB}
TP	Initial	41.27 ± 0.90^{bB}	26.67 ± 2.19^{aA}	29.67 ± 1.86^{bA}
	Gastric	34.33 ± 2.33^{aB}	25.33 ± 1.45^{aA}	24.67 ± 2.33^{abA}
	Intestinal	32.41 ± 1.59^{aB}	22.00 ± 1.15^{aA}	22.33 ± 1.20^{aA}
TP bioaccessibility	Initial	100.00 ± 0.00^{bA}	100.00 ± 0.00^{aA}	100.00 ± 0.00^{aA}
	Gastric	83.13 ± 4.80^{aA}	96.16 ± 9.05^{aA}	84.48 ± 12.01^{aA}
	Intestinal	78.73 ± 5.19^{aA}	84.06 ± 9.85^{aA}	75.37 ± 0.81^{aA}

*For each variable, values with different lowercase letters in the same column and different uppercase letters in the same row are significantly different ($p < 0.05$)

Total Polyphenols

In parallel with total flavonoids, total polyphenols content in all fried potatoes was lower compared with fresh content (Table 2 and Table 3). Deep frying of potatoes pretreated by OH, HWB and US decreased total polyphenols content by 36.22%, 58.79% and 54.15%, respectively compared to the content in fresh potato. This indicates degradation of polyphenols in potatoes during frying. The reduction of total polyphenols with frying process was also reported for leafy vegetables (Gunathilake et al. 2018), cauliflower (Ahmed and Ali 2013) and potato (Romano et al. 2022). Such decrease has been attributed to disruption of cell walls and breakdown of phenolic compounds. The results indicated that total polyphenols content of fried potatoes was significantly ($p < 0.05$) affected by pretreatments applied as illustrated in Table 3. As in the same tendency of total flavonoids content, OH pretreatment was better in retention of polyphenols than other pretreatments, which might be due to rapid heating process preventing the oxidation or decomposition of phenolic compounds. A similar finding has been reported by Zulekha et al. (2018). There was no significant difference between total polyphenol values of fried potatoes pretreated by HWB and US ($p > 0.05$).

After in vitro digestion, total polyphenols of fried samples pretreated with OH and US significantly decreased compared to their initial values ($p < 0.05$) (Table 3). This reduction has also been reported for walnut (Figueroa et al. 2016), edible green leaves (Gunathilake et al. 2018), *Epilobium angustifolium* (Dacrema et al. 2020) and sorghum (Ziółkiewicz et al. 2023). Polyphenols are known to be unstable under gastrointestinal digestion due to pH variations and interactions with dietary constituents such as proteins, fibre, iron or digestive enzymes (Pinto et al. 2017). On the other hand, total polyphenol content of the potato pretreated by HWB was not significantly changed ($p > 0.05$), which is consistent with the study of Helal et al. (2014) for cinnamon beverages. This might be associated with differences in type of the phenolic substances releasing from the components in potato such as proteins and carbohydrates depending on the cell structure during pretreatments applied and, consequently, their stability. As seen in Table 3, bioaccessibility of total polyphenols of fried potatoes at the end of pancreatic digestion was rather high ranging from 75.37 to 84.06% depending on the pretreatments applied. Although the highest value was observed for the samples pretreated by HWB, the differences were not significant statistically (Table 3).

Chlorogenic acid was the major phenolic acid determined in raw (3.53 mg/100 g DM) and fried potato samples (0.36–1.72 mg/100 g DM). In agreement with our results, Kasnak and Palamutoglu (2022) reported that most of the phenolic acids in eight potato cultivars was chlorogenic acid ranging from 0.066 to 1.52 mg/100 g. Similarly, Romano et al. (2022), Burgos et al. (2013) and Ruiz et al. (2018) also found chlorogenic acid as the predominant phenolic acid in potato. The results showed that frying process decreased chlorogenic acid content of potato samples ranging from 51.27 to 89.80%. This reduction was also reported by Romano et al. (2022) for purple potato. Fried potato pretreated by OH had significantly the highest retention of chlorogenic acid content (Table 1).

Antioxidant Capacity

Antioxidant capacity values of the potatoes changed significantly ($p < 0.05$) ranging from 54.21 to 124.13 mmol AAE/100 g DM after frying (Table 3). This might be the result of the fact that the contents of total flavonoids, total polyphenols and chlorogenic acid of fried potatoes changed with the pretreatments applied. Interestingly, while the only antioxidant capacity value of fried potato pretreated by OH was higher than that of the fresh potato sample (83.91 mmol AAE/100 g DM), other two pretreatments caused decrease in antioxidant capacity. This implies that OH pretreatment showed a positive effect on antioxidant capacity, which can be due to differences in the conditions of pretreatments applied to potato. Increase or remaining unchanged in antioxidant capacity of food product after OH treatment has been reported by other researchers (İncedayi 2020; Hardinasinta et al. 2022; Karacabey et al. 2023).

As seen in Table 3, after in vitro digestion, antioxidant capacity of all fried potatoes pretreated decreased significantly ($p < 0.05$). However, the higher losses were observed in the gastric stage. The increase of antioxidant capacity during the intestinal stage compared to gastric one could have been due to the ability of intestinal digestive enzymes and bile salts to extract or solubilize phenolics from food (Udomwasinakun et al. 2023). Additionally, another reason for this result might be the possibility of transformation of bioactive compounds into other substances with different structures which have more antioxidant capacity under intestinal digestion conditions.

Color

Color is one of the important parameters for giving information about the quality of foods. The results showed that pretreatments prior to frying significantly ($p < 0.05$) affected L*, a* and b* color parameters of fried potato (Table 1). Color of fried potato is the result of the Maillard reaction that depends on the content of reducing sugars and amino acids or proteins at the surface (Pedreschi et al. 2005; Qiu et al. 2018; Abduh et al. 2021). OH pretreatment contributed to the decrease of brown pigment (dark-colored melanin) during the frying process, which resulted in the highest L* value (62.57). The increase in the value of L* is an indication that the darkness of the sample has decreased. Fried potato samples treated with HWB and OH pretreatments showed lower a* values. Similarly, Abduh et al. (2021) found that a* values of fried potato slices treated blanching with and without PEF (pulsed electric field) were in the range of 1.52–5.37. However, the potato pretreated with US exhibited the highest a* value (8.68), which may be due to increasing non-enzymatic browning reactions. The higher a* value means the darker (more red) potato slice (Pedreschi et al. 2005). With respect to b* (yellowness) values, the highest b* value (32.75) was observed in fried potato treated with OH pretreatment followed by those treated with US and HWB, respectively. Decrease in b* value was considered to be contributing to the loss of the sensorial quality of the fried potato (Alvarez et al. 2000). As in agreement with our results, Cruz et al. (2018) found that b* values of fried potato chips ranged from 27.9 to 32.7 depending on frying time.

Texture

Texture is one of the most important properties for fried potato. Hardness which is defined as the peak force at the maximum compression (Qiu et al. 2018; Canedo et al. 2022) was used to describe the texture of the fried potato strips. As seen in Table 1, pretreatments before frying significantly ($p < 0.05$) affected hardness of fried potato. HWB-treated potato strips presented the highest hardness (maximum peak force) followed by OH- and US-treated samples, respectively. This result can be attributed to modification of pectin substances by activation of pectin methyl esterase (PME) enzyme during blanching (Alvarez et al. 2000) because moderate HWB condition (10 min at 65 °C) was applied in this study. On the other hand, the lower hardness of OH-treated samples can be due to electroporation which may cause partial loss in turgor pressure, impairing plant tissue firmness (Ignat et al. 2015).

Sensory Evaluation

The average scores of sensory properties of fried potatoes are shown in Fig. 1. The potato most liked by the panelists was that pretreated with US followed by OH. However, with respect to oiliness, the potato pretreated by OH had the highest score. This is an important advantage of OH pretreatment because high oil content can lead to some health problems such as obesity and coronary diseases (Cruz et al. 2018). On the other hand, in terms of all sensorial parameters except appearance, the sample pretreated with HWB had the lowest score. The results of color and oiliness for potato pretreated by HWB were, also, consistent with its lowest b* value and highest oil content, respectively.

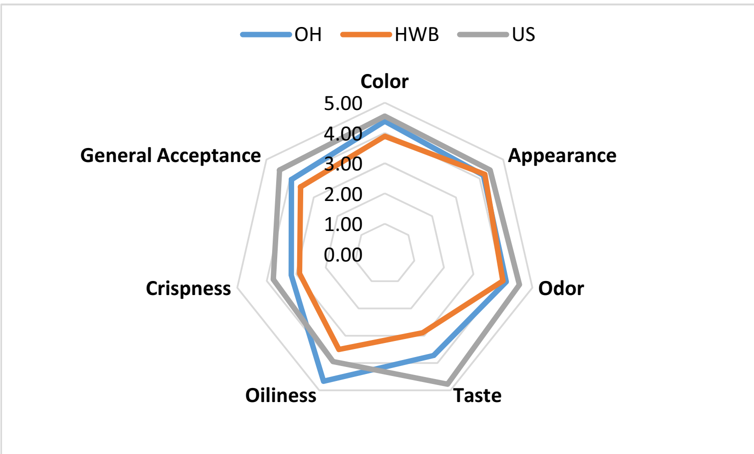

Fig. 1 Sensory properties of fried potatoes

Conclusions

The pretreatments significantly affected oil absorption and all the examined quality parameters of fried potato. OH-treated potato had lowest oil content and this pretreatment was better in retention of polyphenols, flavonoids and chlorogenic acid than other pretreatments. On the other hand, no significant difference was observed between the pretreatments in terms of bioaccessibility of polyphenols at intestinal digestion. While the only antioxidant capacity value of fried potato pretreated by OH was higher than that of the fresh potato sample, the other two pretreatments caused a decrease in antioxidant capacity. HWB-treated potato strips presented the highest hardness. OH-treated potato had the best color parameters. Sensory data indicated that US-pretreated potato had the highest sensory scores maybe in relation to its high habitual oil content. Consequently, based on the above comprehensive quality evaluation, it can be suggested that OH pretreatment is a better choice for preparing deep fried potato and other materials.

Author Contribution Ferda Sari: Formal analysis, Validation, Visualization. Bige Incedayi: Data curation, Project administration, Editing. Nihal Turkmen Erol: Conceptualization, Methodology, Writing—original draft. Pınar Akpinar: Investigation, Formal analysis. Omer Utku Copur: Funding acquisition, Resources, Supervision. All authors reviewed the manuscript.

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Data Availability The authors do not have permission to share data.

Declarations

Conflict of Interest The authors declare no competing interests.

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