THE EFFECT OF HIGH INTENSITY ULTRASOUND PRE-TREATMENT ON THE FUNCTIONAL PROPERTIES OF MICROWAVE-DRIED PEARS (*PYRUS COMMUNIS*)

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***Abstract*— The objective of this study was to investigate the impacts of high intensity ultrasound (HIU) pre-treatment on the quality of microwave-dried pears. Functional properties including color and bioactive compounds (total phenolic content (TPC) and antioxidant capacity (ATC)) of microwave-dried pears at 2 power levels (100 and 200 W) with and without HIU-pretreatment were compared with the fresh pear samples. It was concluded that the TPC and ATC of microwave-dried pears treated with and without HIU pre-treatment under both power levels were decreased in comparison with fresh pears. The highest phenolic content was determined in a HIU pre-treated (20 min) and microwave-dried pear slices at 200 W. The ATC of microwave-dried pear samples at 200 W with HIU pre-treatment were found higher than those of the samples dried at 100 W. All color parameters (*L**, *a**, *b**) were shown a significant change depending on the drying powers and application of HIU pre-treatment. The closest color values to the fresh pear samples were found for the microwave-dried samples at 200 W with HIU pre-treatment for 20 min. In overall, microwave drying process was proven to be more efficient when combined with HIU pre-treatment to acquire a high-quality food product with enhanced bioactive compounds and improved color.**

***Keywords*— Antioxidant capacity, high intensity ultrasound pre-treatment, microwave drying, pear fruit, total phenolic content.**

I. INTRODUCTION

Fruits and vegetables are suitable for chemical and microbiological deterioration because of having a high moisture content. Various preservation techniques such as cold storage, freezing and drying are used for the enhancement of shelf-life of these products (Topdaş *et al.*, 2011). Drying is one of the oldest methods that has been used for many years to preserve the agricultural products such as fruits and vegetables. Purpose in drying process is to remove the free water in the wet food materials, so prevent the biochemical reactions and microbial growth. Drying of agricultural crops enhances the shelf-life, minimizes losses at storage, and save shipping and transportation costs. While the drying process was achieved traditionally by natural convection drying of the products laid on the field previously, this method gave its place to faster, more hygienic and homogeneous drying applications with technological developments over time (Maskan, 2001).

Microwave-drying is one of the most common and preferred method used for the food preservation. In microwave drying, the heat is converted from microwave energy to thermal energy in wet material at suitable pressure and temperature. The heat is given directly into food materials by microwave drying. In the microwave drying, only water in the material is heated, so the final temperature is taken under control and the remaining water is completely removed. Since the temperature decreases from inside to out, the water in the food is removed easily. The drying area does not affect the heat transfer since the heat transfer occurs apart from the conduction. Since no hardening occurs on the surface, no slowdown is observed in the mass transfer and drying time extends at slow flow rate. When these situations are referenced, it is possible to say that microwave drying process have superior features in terms of product quality and the cost.

A pre-treatment could be used to acquire higher product quality with shorter drying time. One of the pre-treatments used for the reduction of drying time is called as high-intensity ultrasound application (Yıldız and İzli, 2020). Both the mechanical and physiological impacts of acoustic waves which is created by ultrasound could be used to improve several properties in where mass transfer occurs (for instance; drying). The forces involved by the sponge impact created by ultrasonic waves can produce microscopic channels. These microscopic channels can be used by water molecules as a preferred technique to diffuse toward the surface of the fruit samples. More than that, the ultrasonic waves reduce the diffusion boundary layer and increase the convective mass transfer in the food materials. Last but not least, the cavitation produced by ultrasound is important to remove firmly attached moisture (Yildiz and Izli, 2019b). The aim of current study was to explore the effect of HIU pre-treatment and microwave-drying on the functional properties of dried pears.

II. METHODS

A. Sample Preparation

The pear fruits were obtained from a local market in Iğdır, Turkey were cleaned to get rid of the dust, chemical residuals and attached dirt. The pears samples cut with a dimensions of 10 mm thicknes along with the assist of a food slicer (Nicer Dicer, China). The initial moisture content of the pear fruit pieces was defined as 77±0.12% by the help of drying application at 105 ± 5 °C before

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Table 1. Treatments used in the study

Sample names	Treatments
Fresh Sample	No treatment
MD	Microwave-dried pear slices at 100 W with no HIU pre-treatment
MD2	Microwave-dried pear slices at 200 W with no HIU pre-treatment
MD-US	Microwave-dried pear slices at 100 W with 10 min HIU pre-treatment
MD-US2	Microwave-dried pear slices at 100 W with 20 min HIU pre-treatment
MD-US3	Microwave-dried pear slices at 100 W with 30 min HIU pre-treatment
MD2-US	Microwave-dried pear slices at 200 W with 10 min HIU pre-treatment
MD2-US2	Microwave-dried pear slices at 200 W with 20 min HIU pre-treatment
MD2-US3	Microwave-dried pear slices at 200 W with 30 min HIU pre-treatment

rezching the stable weight via forced-air convection oven (ED 15 Blinder, Germany).

B. High intensity ultrasound (HIU) pre-treatment and microwave drying process

The pear fruit slices were employed in an ultrasonic bath tank (Wiseclean, WUCA-02H) performing at a frequency of 28 kHz and a power of 50 W along with different period intervals as 10, 20 and 30 min. The intensity of the application was determined as 100 kW/ m^3. The fruit to water ratio was managed at 1:4. The analysis were conducted at room temperature. The increase in the temperature was figured out with the support of a thermometer and was determined as less than 2 °C following the HIU pre-treatment (30 minutes). To investigate the impact of HIU pre-treatment, the same experimental design was applied without using the HIU pre-treatment. After applying the HIU application, the pear slices were drained and blotted on absorptive paper for the purpose of getting rid of the excessive water. Microwave drying was implemented in a microwave oven (Altus ALMD 20, Istanbul, Turkey) at 100 and 200 W output power levels. The drying was carried out to final moisture content of 12 % from initial moisture content of about 77 ± 0.12 % w.b. The experiments were conducted with 3 replications. A short definition of the treatments is tabulated in Table 1.

C. Color evaluation

The color changes of fresh and pear fruit slices exposed to microwave drying with and without HIU pre-treatment were analyzed with the help of a Konica Minolta (CR-400, Osaka, Japan) that is assembled with illuminent D65 and 8 mm measuring scope in the CIE L^* a^* b^* color scales. Color parameters were described in a 3 - dimensional L^*, a^*, *and* b^* colour spaces, where L^* shows the lightness/darkness of the pear fruits, a^* demonstrates the redness/greenness, and b^* displays the yellowness/ blueness (Yildiz *et al.*, 2016).

D. Preparation of pear fruit sample extracts

The extraction stage was managed according to the process proposed in the research of Yildiz and Izli (2019a). Homogenized untreated and microwave-dried fruit slices with and without HIU pre-treatment (0.5 g) were mixed with 5 mL of CH_3OH and H_2O mix (80/20 v/v) at room temperature and shaken at 140 rpm (BiosaAn OS.20, Latvia) for two hours. The supernatant was collected right after the centrifugation step (10000*g*, 15 min) (Sigma 3K3, United Kingdom). By following the same procedure, 2 extractions were performed with pellet. The supernatant was filtered with a 0.45 µm PTPE membrane filter to figure out the total phenolic substances and antioxidant capacity (ATC) of the pear fruit slices.

E. Antioxidant Capacity (ATC)

DPPH was utilized to investigate the ATC of prepared fruit extracts by the procedure proposed by Alotman *et al.* (2009). A 0.1 mL of pear fruit extract was mixed with a 3.9 mL 0.25 mM DPPH buffer solution and vortexed thirty - seconds and incubated at 25 ºC for 30 minutes. Following the duration period, the absorbance of the blend was read at 515 nm and ATC of the fruit pear pieces was demonstrated as µmol Trolox equivalent (TE) /g on dry basis that was calculated by the calibration curve ($y = 2464.8x + 9.3$, $R^2 = 0.9747$) of trolox (0.1-1.0 mM).

F. Total Phenolic Content (TPC)

The procedure stated by Igual *et al.* (2012) with a minor modification was followed to analyze the totol phenolic substances of pear fruit slices. The technique stands on the degradation of Folin–Ciacalteu reagent by phenolic substances. In brief, the pear fruit extract was added into 1.25 mL of Folin-Ciocolteu indicator and 15 mL of distilled water on a vortex mixer (WisMix VM-10, Dahian, Korea). After ten minute waiting in the dark place, 3.75 mL of 7.5% Na-carbonat was added into the mix and the volume was made up to 25 mL with distilled water. After that, the absorbance was measured at 760 nm using a spectrophotmeter (Cary 60 UV–vis spectro-photometer, Agilent Technologies, Santa Clara, USA) after two hours incubation at room temperature in a dark place. The outcome was described as milligrams of Gallic acid (GA)/100 g on dry basis by the calibration curve ($y = 0.2162x + 0.0436$, $R^2 = 0.9817$) of GA (concentration range from 5 to 50 mg/L).

G. Statistical Data Analysis

A randomized plots factorial experimental design was employed. The results were determined by the JMP (Version 7.0, SAS Institute Inc., NC, USA). Differences among the mean value were obtained by Fisher's least signifcant differences (LSD) test at $\alpha = 0.05$.

III. RESULTS

A. Color measurement

The color is one of the major quality specifications in dried and/or dehydrated food products, but it might change because of the biochemical changes observed in the food materials. The color values of pear fruit pieces are tabulated in Table 2. While the lightness value of fresh pear slices was found as 65.14, it was changed from 40.38 to 62.16 in microwave-dried pear slices. Lightness values exhibited a significant differences in pear fruit slices, where the HIU pre-treatment was employed. The color of a 20 min HIU pre-treated dried pear slices were lighter than those of microwave-dried pear fruit slices with no HIU pre-treatment (Table 2). The a^* values of the microwave-dried pear sllices were significantly (P < 0.05) increased compared to fresh pear samples, which shows the more browning occurrence. On the other hand, highest yellowness value was observed for untreated pear slices (Table 2). In shortly, the closest for all colour parameters (L^*, a^*, *and* b^*) were obtained for microwave dried pear slices at 200 W with HIU pre-treatment (20 min). Color is an important quality indicator for the evaluation of the excellence of dried food materials. In the majority of fruits, color degradation is distinguished by serious browning, which could be arise from either enzymatic or nonenzymatic origin (Konopack and Plocharsi, 2007). Browning is getting bad at higher drying temperatures. The favored colors are those closest to the original color of fresh pear slices. These samples can be classified as more preferred and acceptable foods by consumers related to colour quality At that point it might be discussed that high intensity ultrasound pre-treatment could be helpful for preserving color of dried food materials because of its potential to be applied at ambient temperatures and damaging the enzymes in charge of browning activity as well. It was recognized that blanching and ultrasound pretreatments applied before the hot air and freeze drying caused the lighter color of carrot pieces in a work related to carrot drying (Rawson *et al.*, 2011). Deng and Zhoa (2008) pointed out that HIU application displayed the highest increase in lightness parameter from 77 to 80 in apple fruit slices exposed to osmotic solution application in comparison with the other applications involving pulsed vacum and agitation. This could be arise from the fact that HIU application causes physiological deformation and membrane destruction of the cell, which enables to simpler elimination of pigments from apple fruit tissue. Stajonovic and Silva (2007) announced the similar findings for rabiteye blueberries. High intensity ultrasound is described as more convenient application with regard to removing water and preserving color of apple fruit pieces which provides the better quality and longer shelf life of dried food materials (Dengn and Zhao, 2008). Similarly, Yildiz and Izli (2019a) found that dried quince fruit samples with HIU pre-treatment showed the lighter color compared to the untreated quince slices. From that way of thinking, microwave-dried pear samples with HIU application is satisfying as they are resulted in lighter food product color and closest color parameters to the fresh pear fruit slices compared to the other applications.

I. Bioactive Compounds

The changes in antioxidant capacity of microwave-dried pear fruit pieces are demonstrated in Table 3. A signficant (P <0.05) decrease in antioxidant capacity in each and every dried pear fruit slices no matter if HIU is applied or not was observed. The antioxidant capacity of fresh pear pieces was found out as 9.612 µmol TE/g on dry basis. On the other way, the ATC was determined between 4.945 and 8.029 µmol TE/g on dry weight for the dried pear fruit slices with and without HIU pre-treatment. While the lowest antioxidant capacity was described for dried fruit samples at 100 W with no HIU pre-treatment (4.945 µmol TE/g dry–weight), the highest antioxidant capacity was determined for the dried pear fruit slices exposed to HIU pre-treatment for 20 minutes at 200 W (8.029 µmol TE/g on dry basis). Larauri *et al.*, (1997) also identified the decline in the ATC of dried red grape fruit. The decline in ATC can be corresponded to the lower quantity of phenolic substances. In various research, it was announced that there is a positive relationship between a total phenolic substances and antioxidant capacity in many fruits and vegetables, for instance lime and carrot (Duh *et al.*, 1999), apricot (Sultana *et al.*, 2012), red peper (Zhuo *et al.*, 2016), pomelo (Yildiz and Izli, 2019a), kumquat (Izli *et al.*, 2018) and quince (Yildiz and Izli, 2019b). This is thought to be the result of antagonistic or synergistic impacts that may occur among antioxidant components or other compounds during the drying process (Di Scala *et al.*, 2011). Kaner *et al.* (1994) figured out that the higher antioxidant capacity of food materials can be linked to the synergetic effect of natural phenolic compounds. In present study, it was also observed the synergetic effect between total phenolic content and antioxidant capacity. While the microwave-dried pear fruit slices showed the both lower TPC and ATC, the fresh pear fruit slices displayed the highest TPC and ATC (Table 3). In overall, the highest antioxidant capacity was observed for microwave dried pear slices exposed to 20 min HIU pre-treatment at 200 W.

Drying application may diminish nutrients in fruits and vegetables because of long drying times and high temperatures as well (Yıldız *et al.*, 2021a,b). Phenolic substances are bioactive metabolites in fruits and vegetables which contribute to sensorial (taste, flavour, color etc.) and functional (i.e. antioxidant, antidiabetic,

Table 2. Color parameters in pears induced by microwave drying and HIU pre-treatment

Treatments	L^*	a^*	b^*
Fresh Sample	65.14 ± 0.13^a	6.82 ± 0.04^g	35.58 ± 0.25^a
MD	40.38 ± 0.45^g	10.76 ± 0.67^e	20.64 ± 0.13^f
MD2	44.45 ± 1.42^f	14.61 ± 0.72^d	24.29 ± 0.11^e
MD-US	48.37 ± 0.24^e	15.34 ± 0.86^d	28.22 ± 0.97^d
MD-US2	51.18 ± 0.38^d	17.18 ± 0.19^c	28.13 ± 0.84^d
MD-US3	54.93 ± 1.09^c	24.07 ± 0.35^a	31.32 ± 0.83^c
MD2-US	51.25 ± 0.23^d	18.15 ± 0.22^c	31.37 ± 0.25^c
MD2-US2	62.16 ± 0.89^b	8.69 ± 0.14^f	33.48 ± 0.71^b
MD2-US3	55.83 ± 0.91^c	22.12 ± 0.35^b	31.41 ± 0.17^c

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

and anticancer activities) attributes of food materials (Fernandes *et al.*, 2008). In accordance with the statistics, the total phenolic subtances of pear fruit slices was significantly effected by the HIU and drying applications (Table 3). The total pheolic compounds of microwave-dried pear fruit pieces exposed to high-intensity ultrasound application were significantly higher in contrast to those which were treated by means of no HIU pre-treatment (Table 3). Because of the phenolic substances are related to the color, taste, and nutritional quality of food materials, their existence is a fundamental biological attribute. Similar to the antioxidant capacity, a significant (P <0.05) decrease in the total phenolic subtances was determined in the microwave-dried pear fruit slices compared to the untreated pear fruit pieces (Table 3). The reduction in the total phenolic content of microwave-dried pear slices could be related to the decomposition of heat liable phenolic substances. High intensity ultrasound application is predicted to be the most preferable technique to retain nutrients at drying period due to its capability to decrease the drying time at ambient degrees while pursuing the natural flavor, color, and heat-sensible nutritive compounds. On the other hand, since it uses aqueous media, the movement of solutes or liquids increase the loss of nutrients, specifically solvable nutrients. Opalic *et al*. (2009) pointed out that extended ultrasound application leads to a decrease in total phenols and flavonoids in addition to the antioxidant capacity of dried apple fruit pieces. In the same research, it was announced that apple fruit pieces exposed to longer ultrasound application were resulted in less favorable sensorial properties. The sugar content and bioactive compounds of dried apple fruit pieces were decreased as well. Similar to this work, the pear fruit slices exposed to the longest HIU pre-tretment which was 30 min showed a lower total phenolic content, whereas the pear fruit slices exposed to shorter HIU pre-treatment (20 min) exhibited highest TPC in recent work.

Table 3. The differences in bioactive compounds (antioxidant capacity and total phenolic content) of pears induced by microwave drying and HIU pre-treatment.

Treatments	Antioxidant capacity (μmol TE/g)	Total Phenolic Content (mg GA/100 g)
Fresh Sample	9.612 ± 0.16^{a}	191.173 ± 0.18^{a}
MD	4.945 ± 0.56^{f}	54.088 ± 0.09^{h}
MD2	5.678 ± 0.06^{e}	72.694 ± 0.32^{g}
MD-US	6.123 ± 0.09^{d}	101.892 ± 0.11^{f}
MD-US2	6.144 ± 0.07^{d}	102.378 ± 0.13^{f}
MD-US3	7.897 ± 0.11^{c}	148.598 ± 0.22^{c}
MD2-US	7.548 ± 0.54^{c}	112.302 ± 0.07^{e}
MD2-US2	8.029 ± 0.12^{b}	172.288 ± 0.56^{b}
MD2-US3	7.490 ± 0.23^{c}	129.761 ± 0.02^{d}

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

IV. CONCLUSIONS

Pretreatment of food products before the drying process might minimize the side effects of drying application on destruction of several quality properties of dried food materials. It might even shorter the drying period which decrease the cost of the drying application. This work is important to show a good potential of HIU pre-treatment on dried pear tissue including color and bioactive compounds. The closest for all colour parameters (L^*, a^*, and b^*) were obtained for microwave-dried pear slices at 200 W with HIU pre-treatment (20 min). The lowest total phenolic content was determined in microwave-dried pear samples which was not subjected to the HIU pre-treatment. The highest total phenolic content was determined in microwave-dried pear sample at 200 W with 20 min HIU pre-treatment. This combination also exhibited the highest antioxidant capacity. The present study clearly demonstrated that applying high-intensity ultrasound as a pre-treatment on the pear drying in a microwave oven is an effective process in terms of color, total phenolic content and antioxidant capacity.

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