



INFLUENCE OF ULTRASONIC AND ELECTRICAL PRETREATMENTS ON THE DRYING AND QUALITY CHARACTERISTICS OF KIWİ FRUIT SLICES

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Received / Geliş: 02.02.2021; Accepted / Kabul: 05.05.2021; Published online / Online baskı: 21.05.2021

Bozkır, H., Rayman-Ergün, A. (2021). Influence of ultrasonic and electrical pretreatments on the drying and quality characteristics of kiwi fruit slices. *GIDA* (2021) 46 (4) 817-829 doi: 10.15237/gida.GD21025

Bozkır, H., Rayman-Ergün, A. (2021). Ultrasonik ve elektriksel ön işlemlerin kiwi dilimlerinin kuruma ve kalite özelliklerine etkisi. *GIDA* (2021) 46 (4) 817-829 doi: 10.15237/gida.GD21025

ABSTRACT

In this study, the drying characteristics and quality properties of electrical (ET) and ultrasound (US) pretreated kiwi fruit slices were investigated. Electrical and ultrasound pretreatments were carried out on the parameters of 100 V- 40 sec. and 35 kHz-30 min respectively. After the pretreatments, the kiwi fruit slices were dehydrated using a convective dryer at 50°C and 1.5 m/s air flow rate. The effects of these pretreatments on the drying rate and quality properties (the total phenolic content, vitamin C, pectin contents, rehydration rate, acidity, and color values) were evaluated. Consequently, the US and ET pretreatments provided an increase in the drying rate by 18.34% and 21.65% respectively. The combination of pretreatments (ET+US) increased the drying rate by 35.70%. The ET pretreatment produced minimum changes in the samples' pectin content and color values, and the US application increased the vitamin C, rehydration capacity, and acidity.

Keywords: Kiwi fruit, electrical, ultrasound, drying, and quality.

ULTRASONİK VE ELEKTRİKSEL ÖN İŞLEMLERİN KİVİ DİLİMLERİNİN KURUMA VE KALİTE ÖZELLİKLERİNE ETKİSİ

ÖZ

Bu çalışmada, elektriksel (ET) ve ultrases (US) ön işlemi görmüş kiwi dilimlerinin kuruma karakteristiği ve kalite özellikleri araştırılmıştır. Elektriksel ve ultrasonik ön işlemler sırasıyla, 100V-40 s ve 35 kHz frekansta 30 dak. parametreleriyle gerçekleştirilmiştir. Ön işlemlerden sonra kiwi dilimleri, 50 °C'de ve 1.5 m/s hava akış hızında bir konvektif kurutucu kullanılarak kurutulmuştur. Bu ön işlemlerin kuruma hızı ve kalite özelliklerine (toplam fenolik madde, C vitamini, pektin içerikleri, rehidrasyon hızı, asitlik ve renk değerleri) etkileri değerlendirilmiştir. Sonuç olarak, US ve ET ön işlemleri, kurutma hızında sırasıyla %18.34 ve %21.65 artış sağlamıştır. Ön işlemlerin kombinasyonu (ET + US) kuruma hızını %35.70 artırmıştır. ET ön işlemi, örneklerin pektin içeriği ve renk değerlerinde minimum değişiklik meydana getirirken, US uygulaması kiwi dilimlerinde C vitamini, rehidrasyon kapasitesi ve asitlik gibi kalite özelliklerini artırmıştır.

Anahtar kelimeler: Kivi, elektriksel, ultrases, kurutma, kalite

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INTRODUCTION

Drying is one of the oldest method of food preservation and the most common technique used in the food industry. Conventional air-drying allows longer shelf life and smaller space for storage (Nowacka et al., 2012; Demiray et al., 2017; Bozkır et al., 2021). However, there is a large loss of thermal energy and a lengthy drying time throughout the falling rate period in convective drying (Wang and Xi, 2005). Moreover, conventional hot air drying also causes changes in the physical, chemical, and nutritional properties of food such as undesired food flavor, color decomposition, tough texture, severe browning, low rehydration rate, vitamin degradation, and loss of essential amino acids (Deng and Zhao, 2008; Ricce et al., 2016).

In recent years, some pre-treatment operations have been performed to enhance the drying rate, to decrease the initial water content, or to change the fruit tissue structure (Fernandes and Rodrigues, 2007). These pre-treatments include blanching, vacuum, electric pulses, electrical applications, and power ultrasound (Jambrak et al., 2007; Fernandes et al., 2008a; Deng and Zhao, 2008; Barba et al., 2015; Çakmak et al., 2016).

Electrical pre-treatment application improves the cell membrane permeability of fruit tissues and increases the coefficients of mass transfer (Bazhal, et al., 2003). Electrical pre-treatment enables water to transition faster from the cell to the fruit surface decreasing the time of drying. The electrical application as a pre-treatment was applied previously for the drying of carrots and mushrooms (Baysal et al., 2012; İçier et al., 2013; Çakmak et al., 2016). Ultrasonic pretreatment is used for decreasing the moisture content or altering the fruit and vegetable tissue microstructure so that drying becomes faster (Azoubel et al., 2010). It was reported that ultrasound pretreatment improves the processes or products chemically, mechanically, and physically (Fernandes et al., 2011). The ultrasonic pretreatment could be applied by immersing of the fruit in water or in a hypertonic aqueous solution (Azoubel et al., 2010). Ultrasound as a pre-treatment was applied for dehydration of

pineapple (Fernandes et al., 2008a), genipap, banana, jambo, melon, pineapple, papaya (Fernandes and Rodrigues, 2008), banana (Azoubel et al., 2010), strawberry (Gamboa-Santos et al., 2014), garlic (Bozkır et al., 2019), and carrot (Santacatalina et al., 2012). However, ultrasound pre-treatment has been investigated for fruit and vegetable drying, to the best of the authors' knowledge, no studies have been available about applying electrical and ultrasound pretreatments prior to the drying of kiwi fruit.

Literature studies with kiwi fruit (*Actinidia chinensis*) stated that the stableness of kiwi fruit, which has a short-life, is lost during storage because of softening and vitamin loss (Femenia et al., 2009). In addition, drying of this fruit leads to a reduction in precious bioactive ingredients (vitamins, antioxidants, phenolic compounds, and flavor compounds) and sensory properties (color and flavor) (Simal et al., 2005; Kaya et al., 2008; Darıcı and Şen, 2011). Consequently, in this study, the aims were to evaluate the influences of electrical and ultrasound applications on the conventional air drying of kiwi fruits in terms of drying rates and quality properties.

MATERIALS AND METHODS

Material

Hayward (*Actinidia deliciosa*) type kiwi fruits were supplied from the markets in Izmir, Turkey. The kiwi fruits were kept at +4°C and 80-90% relative humidity until processing.

Method

Drying procedure

Electrical pretreatment

The electrical pretreatment (ET) was performed using a drum type electroplasmolyzator sketched out with the cooperation of Çermak Machine (Manisa-Turkey). ET possess two drums with stainless steel pins and voltage part, which delivers alternative electric current to the system. The distance between pins was 2.4 cm, distance between the drums was 5 cm, and the cycling speed of cylinders was 25 s per 1 cycle (Baysal et al., 2007). The ET was carried out at the conditions of 20 V-90 s, 40 V-60 s, and 100 V-40 s. After performing the experiments 100V-40 s

was chosen due to ensuring the shortest drying time. The ET pretreatment was performed to whole the kiwi fruits (30°C), and then the kiwi fruits were washed, peeled and sliced to a

thickness of 6 mm (Çakmak et al., 2016). The production scheme for dried fruit is shown in Fig. 1.

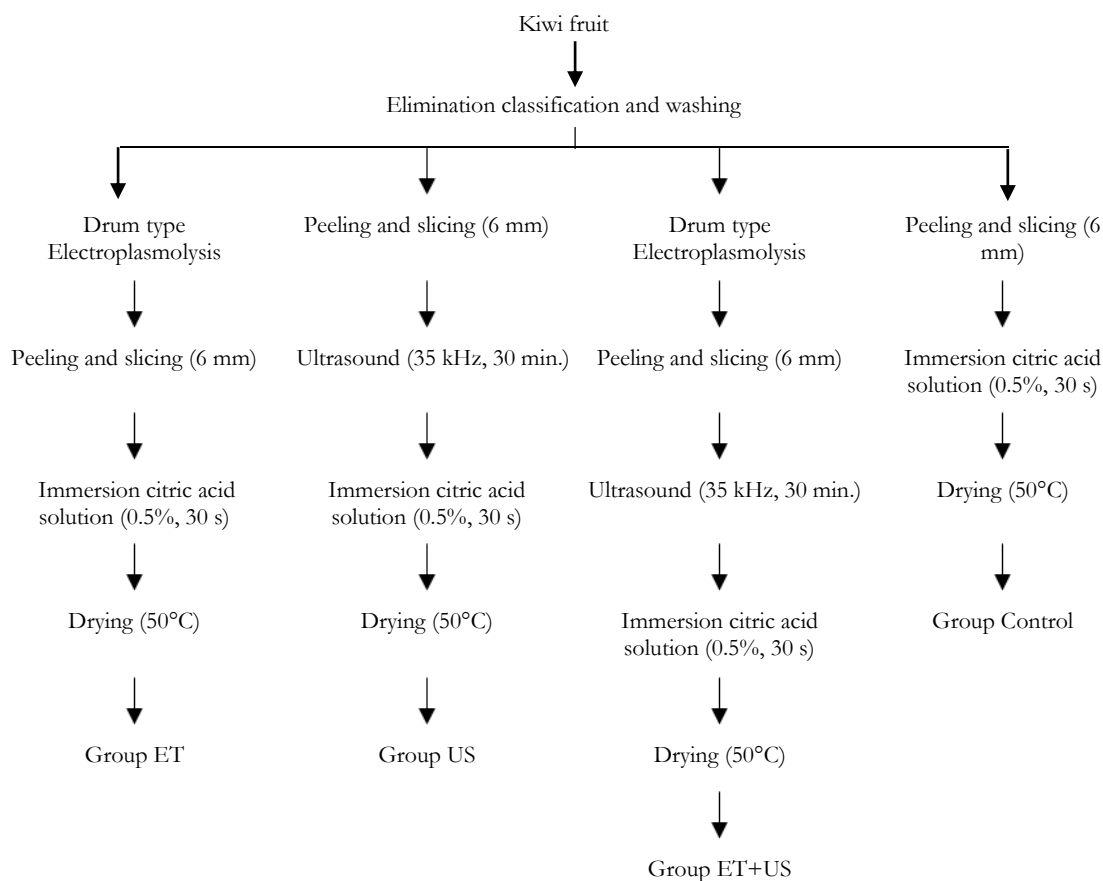


Figure 1. Dried kiwi fruit slices production scheme

*ET: Electrical pre-treatment, US:Ultrasound pre-treatment, and ET+US:Electrical and ultrasound pre-treatment

Ultrasound pretreatment

The kiwi fruits were washed and peeled. The kiwi fruit samples were sliced to a 6 mm thickness. Then, the kiwi fruit to water was set to 1:4 (w/w) (Sonorex Super Ultrasonic Bath-RK-106, 100% power: 480 W, 35 kHz and 30°C). The ultrasound pretreatment was performed for 10, 20, and 30 min at 30°C (Çakmak et al., 2016). The ultrasound 30 min application was decided, and it provided the shortest drying time.

Convective drying

Before convective drying, a sliced 6 mm sample was immersed into a citric acid solution (0.5%) for

30 s to reduce the degradation of color. The kiwi fruit slices placed uniformly on a perforated aluminum tray (18x27cm) were dried in the tray dryer (Model UOP8, Armfield Limited, England). The operating conditions of the dryer were adjusted as 50°C and 1.5 m s⁻¹ air velocity. In the drying process, the weights of kiwi fruit slices were weighed with digital scales (RADWAG WTC 2000, Radom, Poland) at each 5 min until moisture content of below 10%. The initial moisture content of samples were identified as 81±0.01 g/100 g (wet basis) using an MOC-63U Shimadzu infrared moisture detector (AOAC, 1990).

Drying rate

To collect data the drying process, the weight of the dry matter (d.m.) of kiwi fruits was detected (W_s), and the weight of the wet solid (W) was defined at different times (t):

$$X_t = \frac{W - W_s}{W_s} \text{ (kg H}_2\text{O/kg d.m.)} \quad (1)$$

X : free moisture content (kg H₂O/kg d.m.) was computed for every value of X_t for the constant drying and X_e : equilibrium moisture content (kg H₂O/kg d.m.) was determined.

$$X = X_t - X_e \quad (2)$$

The drying rate of kiwi fruit slices (R) was calculated using equation (3),

$$R = - \left(\frac{W_s}{A} \right) * \left(\frac{dx}{dt} \right) \quad (3)$$

where A is the surface field of drying process (m²) (Çakmak et al., 2016).

The moisture ratio of kiwi fruit slices (MR) was computed using equation 4.

$$MR = \frac{M_t - M_e}{M_i - M_e} \quad (4)$$

where M_t is the moisture content at any time, M_i is the initial moisture content, and M_e is the equilibrium moisture content (kg H₂O/kg d.m.). The effective moisture diffusivity (D_{eff}) of the samples was computed using Fick's laws diffusion (Eq. 5).

$$MR = \frac{8}{\pi^2} \sum_{n=1}^{\infty} \frac{1}{(2n-1)^2} \exp \left[- (2n-1)^2 \pi^2 \frac{D_{eff}}{4L^2} t \right] \quad (5)$$

where D_{eff} is the effective moisture diffusivity (m²/s), t is the time (s), and L is the thickness of kiwi fruit slices. The only first term of equation (6) was taken into to account, because of long drying time; it was presented in a logarithmic form.

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

The effective diffusion coefficients of samples (slope) was computed by plotting $\ln(MR)$ versus drying time using equation (7) (Demiray et al., 2017; Tekgöl and Çalışkan Koç, 2020).

$$slope = \pi^2 \frac{D_{eff}}{4L^2} \quad (7)$$

Methods of Analyses

The quality characteristics were investigated using physical and chemical analyses. Samples were analyzed to determine the following:

The moisture content was determined using 5 g sliced kiwi fruit samples and analyzing them with an infrared moisture detector at 105°C, 1 h (Shimadzu MOC-63U). The total acidity was measured using the potentiometric titration of the acidity by placing 10 g of a sample into 90 mL of deionized water. After filtration, the 10 g filtrate was taken to titration, with a solution of 0.1 N NaOH (Merck, Darmstadt, Germany) up to a pH 8.1. The result is given as g /100 g dry matter (d.m.) when referencing the citric acid (AOAC, 1995). The pH values were identified with a pH-meter (WTW InoLab, Weilheim, Germany) (AOAC, 1995). The water activity of samples was detected using the water activity detector Testo AG 400 (Germany). The total phenolic content of samples was determined using the method of Folin-Ciocalteu (Franke et al., 2004). The amount of total phenolic content in the samples expressed as milligrams of gallic acid (Sigma-Aldrich Corp., St. Louis) equivalents (GAE) per gram of dry basis. The ascorbic acid content of samples was determined with the spectrophotometric (Varian Cary 50 Scan spectrophotometer) method (Hişıl 2004). For standart curve the oxalic acid (Merck) solution (4%), a dye solution (2,6-dichloroindophenol) and ascorbic acid (Riedel de Haen, Hannover, Germany) solution using a series of different concentrations were prepared and the absorbance at a wavelength of 518 nm against a standard showing the concentration of vitamin C curve was obtained 10 g sample and 90 mL of stabilizer solution was mixed and then filtered with filter paper (Whatman No.1). Two separate test tubes containing 1 mL of sample and 9 mL of distilled water which is blank and 1 mL of sample and 9 mL of dye solution were prepared. The concentration was determined from the standard curve versus the absorbance value by multiplying by 10 for calculating the amount of ascorbic acid in the 100 g sample and expressed as mg/100 g d.m.

The rehydration capacity of dried kiwi fruit samples was determined in accordance with Cui et al. (2008) and Çakmak et al. (2016). The rehydration ratio was computed using equation 8.

$$\text{Rehydration ratio} = \frac{\text{Weight rehydrated sample (g)}}{\text{Weight dry sample (g)}} \quad (8)$$

Bulk density of samples was computed using equation (9) and the volume of 2 g dried sample measured using a graduated cylinder (Goula and Adamopoulos, 2005).

$$\rho_{\text{bulk}} = \frac{m}{V} \text{ (g/ml)} \quad (9)$$

Pectin content was investigated according to Anon (1968). The method is based on the extraction of pectin with ethanol after centrifugation; the precipitated part was treated with NaOH and completed to 100 mL with deionized water. After filtration, samples were prepared with carbazol and ethanol. Six milliliters of sulfuric acid were added to both samples then they were placed in a water bath for 5 min. Then absorbance values were taken at 525 nm with Varian Cary 50 Scan (Australia) spectrophotometre and pectin contents were

calculated with the calibration curve, which was made by using gallactronic acid anhydrate standards. Results were expressed as mg gallactronic acid anhydrate (GA-AH)/100 g dry matter. The Color values (L^* , a^* , and b^*) of samples were detected with a Hunter Lab Color CX1633 (Flex, Management Company).

Statistical analysis

Statistical analysis was analyzed using SPSS 20 (SPSS Inc., USA). The one-way analysis of variance (ANOVA) and Duncan's multiple range test ($P < 0.05$) was performed to determine the difference between the pretreatment groups. The drying experiments were repeated three times, and all measurements were triplicated.

RESULTS AND DISCUSSION

Effects of pretreatments on the drying characteristics

The dimensionless moisture content (MR) versus drying time was shown in Fig. 2. The MR of the samples reduced exponentially with drying time. The results agreed with the previous studies about varied materials when dried (Gogus and Maskan, 2001; Kadi and Hamlat, 2002).

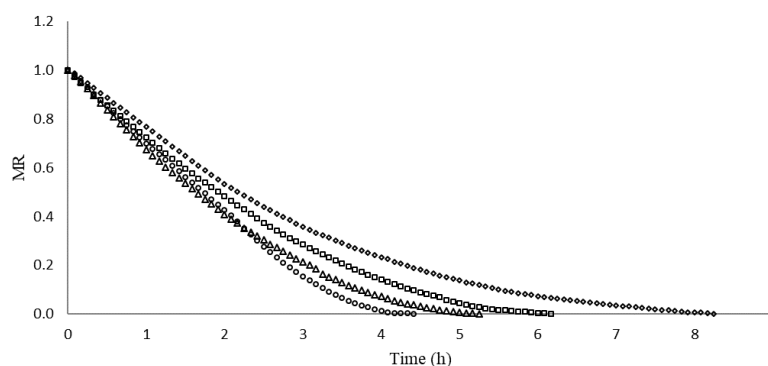


Figure 2. The dimensionless moisture content in the untreated and the pretreated kiwi slices during drying (◇Control, □ET, △US, ○ET+US).

*ET: Electrical pre-treatment, US:Ultrasound pre-treatment, and ET+US:Electrical and ultrasound pre-treatment

In figure 3 the changes in the moisture contents of samples due to time were given. The kiwi fruit slices' moisture contents were about 4.26 kg H₂O/kg d.m. for the control and ET and 4.66 kg

H₂O/kg d.m. for US and US+ET groups, respectively. The ultrasound pre-treatment increased the initial moisture content of samples in the US and US+ET groups. Similarly, the

ultrasound pretreated apple slices at a frequency of 35 kHz for 30 min increased the moisture content from 5.6 H₂O/kg d.m. to 7.5 H₂O/kg d.m. (Fijalkowska et al., 2016). Moreover, it was reported that the ultrasound-pretreated banana prior to drying created an increasing the moisture content (Fernandes and Rodrigues, 2007; Azoubel et al., 2010). The ultrasound pretreatment created a rapid compression and expansion of the food cells. This phenomenon is called the sponge effect (Mulet et al., 2003; Miano et al., 2016; Ricce et al., 2016). The US and ET pre-treatments decreased the drying time compared to the control samples. The time was 8.25 h in the control group but in the ET pretreated samples 6.17 hours was sufficient for drying. Decrease of the drying time after electrical pre-treatment was explained due to the electroporation and thermal breakdown of the membranes (Wang and Sastry, 2002). In the US group this time falls to 5.25 hours, whereas, in the

group of combined pretreatments the samples dried within 4.42 hours. The ultrasound pretreatment reduced the drying time compared to the control. Similar results were reported that ultrasound decreased the drying time of pineapples by over 1 hour of air-drying time (Fernandes et al., 2008a). It was reported that mass transfer was affected with the break down the cell organelles before causing in the cell wall disruption (Rojas et al., 2016).

Similar results were found in accordance with former researches it was detected ultrasound pretreatment reduced the drying time 5 - 40% for banana (Fernandes and Rodrigues, 2007; Azoubel et al., 2010), 36% for pineapple (Fernandes et al., 2008a), 28% for melon (Fernandes et al., 2008b), 16% for papaya (Fernandes et al. 2008c), and 17% for apple (Fijalkowska et al., 2016).

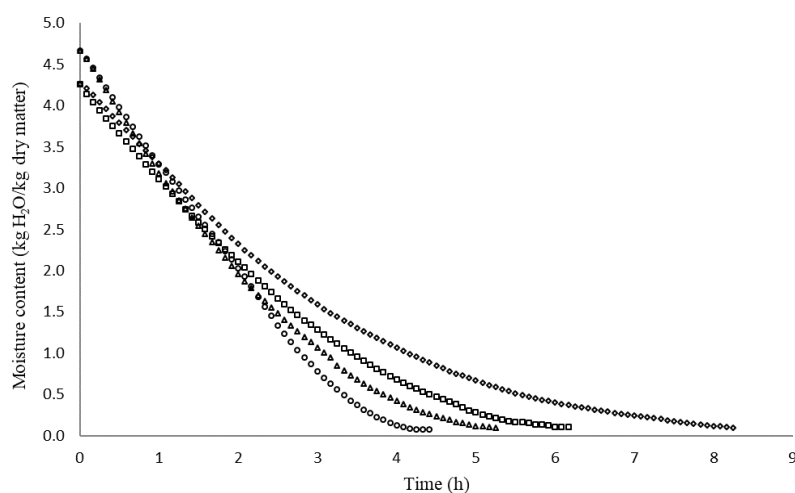


Figure 3. Drying curves for the sliced kiwi fruit (\diamond Control, \square ET, Δ US, \circ ET+US).

*ET: Electrical pre-treatment, US:Ultrasound pre-treatment, and ET+US:Electrical and ultrasound pre-treatment

In figure 4 the drying rates changing with the moisture content were given. The constant rate period did not exist so drying occurred at a falling rate period. The drying rate of samples reduced as the moisture content declined. Similar to this study, the drying kinetics exhibited only a falling rate period in the research of Simal et al. (2005). The drying rates were found as 0.713 kg H₂O/h.m² in the control group; 0.844 kg

H₂O/h.m² in the ET group, 0.867 kg H₂O/h.m² in the US and 0.968 kg H₂O/h.m² in the combined group. The drying rate increased in the ET, US, US+ET groups to 18.34, 21.65, and 35.70%, respectively, compared to the control group. Similar to these results, It was determined that the drying rate of the electrical and ultrasound pretreated mushroom slices increased about 37.10% compared to untreated group

(Çakmak et al., 2016). The drying rate of the ultrasound pretreated apple cubes (30 min) resulted in a higher value (0.052 kg/kg d.b. min) than the group with untreated group (0.042 kg/kg d.b. min) (Nowacka et al., 2012). Similarly, the increase of the drying rate for the ultrasound pretreatment samples was observed in carrot slices, apples and, scallop (Ricce et al., 2016; Magalhães et al., 2017; Bai et al., 2017). It was found that high-intensity ultrasound increased the drying rate of persimmon at the lowest air velocities (0.5, 1, 2, and 4 m/s) (Cárcel et al., 2007). The ultrasound

was effective on heat sensitive fruits, such as strawberry, for improving the drying rate (García-Noguera et al., 2010; Gamboa-Santos et al., 2014). In addition, for the other types of drying applications, sonication was also preferred because the ultrasonic treatment enhanced the dehydration rate and reduced the time required for the microwave freeze drying of sea cucumbers (Duan et al., 2008) and the ultrasonic application during atmospheric freeze drying of carrot provided a decrease of drying time by 60% (Santacatalina et al., 2012).

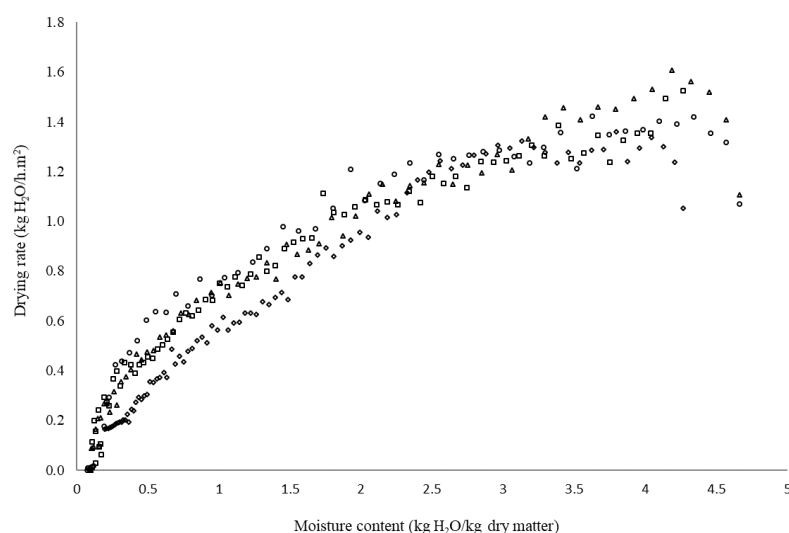


Figure 4. Drying rate versus the moisture content for sliced kiwi fruit (\diamond Control, \square ET, Δ US, \circ ET+US).

*ET: Electrical pre-treatment, US: Ultrasound pre-treatment, and ET+US:Electrical and ultrasound pre-treatment

The moisture transfer during the drying of kiwi fruit slices were computed using Fick's laws diffusion model. The effective moisture diffusivity (D_{eff}) of the samples were found to be as 6.085, 7.303, 9.128, and, $10.954 \times 10^{-10} \text{ m}^2 \text{ s}^{-1}$ for the control, ET, US, and ET+US respectively. It was reported that the effective moisture diffusivity of hot air-dried kiwi fruit slices (30 – 90°C) varied between 3.00 and $17.21 \times 10^{-10} \text{ m}^2 \text{ s}^{-1}$ (Simal et al., 2005). Nowacka et al. (2012) reported that the effective moisture diffusivity of ultrasound pretreated apple cubes (30 min) prior to hot air drying (70°C, 1.5 m/s) raised ($2.168 \times 10^{-9} \text{ m}^2 \text{ s}^{-1}$) when compared to untreated group

($1.829 \times 10^{-9} \text{ m}^2 \text{ s}^{-1}$). Similarly, Fijalkowska et al. (2016) reported that the effective diffusivity coefficient of ultrasound pretreated apple slices prior to hot air-drying (70°C, 2 m/s) resulted in a higher value than the untreated sample. In another study, the effective moisture diffusivity of the kiwi fruit slices in drying after the application of the ultrasound pretreatment increased parallel with the treatment time when the thickness was 6 mm. They also emphasized that the thickness of 6 mm was more effective than the thickness of 8 mm. It was stated that increases in the value of diffusivity had a great significance during the drying stage (Toosi et al., 2011). Kek et al. (2013)

who studied the osmotic dehydration of guava slices via indirect sonication using an ultrasonic bath system and direct sonication using an ultrasonic probe system found that applying ultrasound pre-osmotic treatment in 70°Brix before the hot air drying, decreased the drying time by 33%, and increased the effective diffusivity by 35%.

Effects of pretreatments on the quality parameters

The final moisture content was below 10 g water/100 g dry matter. There were no significant difference among the moisture contents of the pretreated groups ($p>0.05$). However, the moisture content of the control groups were significantly different from the ET and the US ($P<0.05$). The acidity was found highest in the US group and lowest in the combination group. It could be said that ultrasound pretreated was more effective for cell degradation than ET in terms of releasing the compounds, but after the drying process the acidic compounds diminished. The

difference between the pretreated and control groups were statistically significant ($P< 0.05$) as shown in the Table 1. After the drying process total acidity of sample reduced so, the pH values increased. In the control group this value was 3.48, in US+ET group the value was found as 3.63. Castaldo et al. (1992) found that the pH values of kiwi puree samples changes between 3.11 - 3.47. Femenia et al. (2009) found the pH values of kiwi fruit between 4.0 ± 0.3 - 5.3 ± 0.5 for unripe, half-ripe, and ripe fruits.

The water activities of the samples were also shown in the Table 1. In the US pretreated group, the water activity was found higher than the other groups. This was because of the high moisture content of this group. The difference between the pretreated and untreated samples was found statistically significant ($P<0.05$). Kek et al. (2013) identified the water activity of hot-air dried guava as 0.48 whereas the sonicated samples had higher values (0.53 – 0.61).

Table 1. Some quality characteristics of dried kiwi slices

| Samples | Moisture content (g water/100g d.m.) | Titration acidity (g/100g d.m.) | pH | Water activity | Total phenolic contents (mg/g d.m.) | Vitamin C (mg/100g d.m.) | Rehydration rate | Bulk density (g/ml) | Pectin content (mg G/A-AH/100g d.m.) |
|---------|---|---------------------------------|--------------------------|--------------------------|--|-----------------------------|--------------------------|--------------------------|---|
| Control | 7.210±0.11 ^b | 3.527±0.012 ^b | 3.485±0.005 ^c | 0.496±0.001 ^d | 4.888±0.037 ^a | 41.417±0.211 ^b | 3.098±0.003 ^d | 0.414±0.001 ^a | 8.104±0.134 ^d |
| ET | 7.715±0.365 ^a | 3.246±0.013 ^c | 3.597±0.006 ^b | 0.528±0.001 ^b | 4.576±0.055 ^c | 47.647±1.165 ^a | 3.190±0.001 ^c | 0.281±0.017 ^c | 9.535±.355 ^c |
| US | 7.775±0.215 ^a | 3.717±0.101 ^a | 3.445±0.005 ^d | 0.543±0.001 ^a | 4.700±0.063 ^b | 48.992±1.145 ^a | 3.452±0.001 ^b | 0.305±0.005 ^b | 10.851±0.153 ^b |
| ET+US | 7.405±0.195 ^{ab} | 3.154±0.026 ^d | 3.635±0.005 ^a | 0.502±0.003 ^c | 4.468±0.060 ^d | 30.154±0.829 ^c | 3.490±0.002 ^a | 0.243±0.013 ^d | 13.699±0.170 ^a |

Different letters (^a to ^d) within columns represent significant difference at the level of $P<0.05$.

*ET: Electrical pre-treatment, US:Ultrasound pre-treatment, and ET+US:Electrical and ultrasound pre-treatment

The effect of the applications on the total phenolic contents of the ET, US and, ET+US groups were detected statistically significant ($P<0.05$). The US pretreated samples had the higher total phenolic content than ET and ET+US groups. Park et al. (2014) found the total polyphenols of Hayward type kiwi fruit as $4.48 \pm$

0.44 (mg GAE/g). For the kiwi fruit, the phenolics were found as 5.62 ± 0.65 mg GAE/g d.m., and the flavonoids were found as 1.68 ± 0.1 mg catechin equivalent/g d.m. (Gorinstein et al., 2009). Due to these phenolic compounds in different cultivars the antioxidant contents of the kiwi fruits were found between 1.61 ± 0.15 to 42.1

4 ± 4.32 mg GAE/g d.m. (Park et al., 2014). It was noticed that the total phenolic content of the dried kiwi fruit slices using hot air (40 – 60°C) between 500 and 958.70 mg gallic acid/100g d.m. (Chin et al., 2015). Similarly, to these results Opalic et al. (2009) reported that the ultrasound pre-treatment of dried apple causes a decrease in the total phenol content. The loss in the phenolics and anthocyanins was explained with the cell rupture surface after cavitation in the ultrasound treatments (Stojanovic and Silva, 2007). In contrast to this study, the total phenolics content of hot air dried apple slices decreased with temperature, but at high air velocity, the retardation of thermal degradation occurred (Vega-Gálvez et al., 2012).

In Table 1, the vitamin C contents of kiwi fruit slices were given as mg/100g d.m. The vitamin C content of US pretreatment group was raised by 18% in comparison with untreated group. However, in the combined ET+US group the vitamin C loss was found as 17.5%. The difference was statistically significant in all groups compared to the untreated groups ($P < 0.05$). However, the difference between the US and ET groups were not statistically significant ($p > 0.05$). Indeed, ascorbic acid which is known as being sensitive to heat, light, and processes, the loss was an expected result, but, the pretreatments minimized the losses. In contrast to this study, decreases in the L-ascorbic acid after sonication were determined in a previous study (Lee et al., 2005). Kaya et al. (2010) determined that the vitamin C of dried kiwi slices using hot air (35, 45, 55, and 65°C and velocities at 0.3, 0.6 and 0.9 m s⁻¹) ranged between 27.47 and 117.65 vitamin C mg/100 g of kiwi fruit. Çalışkan et al. (2015) reported that the vitamin C of freeze dried kiwi fruit was found as 40.95 - 54.97 mg/100 g.

The rehydration capacity was effective on the continuity, and sensory quality (Erbay et al., 2009). In Table 1, the rehydration capacities were given for the samples. The ET+US group was found as the group that had the higher capacity. This showed that, electrical and ultrasound assisted drying produced only minimal damage to the product. The rehydration capacity was found

higher in the US assisted atmospheric freeze drying than atmospheric freeze drying of carrot (Santacatalina et al., 2012). The rehydration ratio changed with air velocity and temperature indicating tissue damage due to applications in the apple slices (Vega-Gálvez et al., 2012). The maximum bulk density was determined in the control group and the minimum in the combination group. It was determined that there was a significant difference among the bulk densities of all the samples ($P < 0.05$).

In all the pretreated samples when compared to the control group due to the cell degradation the total pectin contents increased and it was found statistically significant ($P < 0.05$). Femenia et al. (2009) investigated the pectin contents of air dried kiwi fruits at different ripening stages. They mentioned that the degree of methylesterification of pectin changes with ripening and methylated pectin was more resistant to degradation and solubilization because of the heat effect.

L*, a*, and b* values samples were measured and shown in the Table 2. It was found that the maximum and minimum lightness values were the ET and ET+US groups respectively. The difference was not statistically significant in the US when compared to the untreated group ($p > 0.05$). Similar results were found in previous studies such as the ultrasound pretreatment applied green peas and potatoes had no effect on the color of plant tissue compared to the control samples (Bantle and Eikevik, 2011; Schössler et al., 2012). It was found that the difference between a* value of all groups was determined statistically significant ($P < 0.05$). Similarly, Fijalkowska et al. (2016) reported that the a* value of the ultrasound pretreated apple slices before hot air-drying increased more than that of the untreated sample group. It has been determined that the b* values decreased after pre-treatments. The changes in the b* values were found significant ($P < 0.05$). Kek et al. (2013) who studied the hot air drying of guava slices found that the ultrasound pre-osmotic treatment decreased the total color change by 38%. They also indicated that ultrasound before air drying

caused a decrease in the a^* , and increase in the b^* values. Vega-Gálvez et al. (2012) indicated that the color difference showed the best results at 80°C for the drying of apples. In parallel with our results, the values of the browning index showed that hot air drying caused more brown compounds in the kiwi fruit (Mohammadi et al., 2008). After air the drying of kiwi fruit, the L^* and

b^* reduced, and the a^* value increased during drying (Maskan, 2001). It was previously explained by Pingret et al. (2013) that ultrasound causes color changes due to the degradation of pigments and browning reactions in the fruits and fruit products.

Table 2. Color properties of dried kiwifruit samples

| Samples | L^* | a^* | b^* |
|---------|--------------------------|-------------------------|--------------------------|
| CONTROL | 44.94±0.04 ^b | -9.24±0.02 ^a | 31.835±0.09 ^a |
| ET | 47.51±0.08 ^a | -6.95±0.02 ^d | 24.96±0.03 ^c |
| US | 46.24±0.12 ^{ab} | -7.87±0.03 ^c | 28.44±0.01 ^b |
| ET+US | 38.12±1.53 ^c | -8.83±0.05 ^b | 23.34±0.07 ^d |

Different letters (^a to ^d) within columns represent significant difference at the level of $P<0.05$.

*ET: Electrical pre-treatment, US:Ultrasound pre-treatment, and ET+US:Electrical and ultrasound pre-treatment

CONCLUSION

The drying rate increased by 18.34, 21.65, and 35.70% with the applications of ET, US, and a combination of them, respectively, when compared to the control samples. While the mass transfer and diffusivity increased, the drying time of the kiwi slices decreased due to cell degradation. It was found that the ultrasound pretreatments protected the quality characteristics of the samples such as total phenolic content, rehydration capacity, and acidity better than the other applications. Losses in the a^* values of the kiwi samples were due to the oxidation and browning reactions and were found to be minimized in the ET pretreated samples. The bulk density values were found lower in the pretreated groups compared to the control samples due to the shrinkage after quick drying. The results show that ET, US, and also the combination of them improves the drying quality and also the chemical and physical properties of kiwi fruit slices. In further studies, this subject could be evaluated for the sensory quality of the fruits and vegetables.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

Hamza Bozkir: Conceptualization, data curation, investigation, methodology, supervision, writing - review & editing, formal analysis. Ahsen Rayman

Ergün: Conceptualization, data curation, investigation, methodology, writing - review & editing, formal analysis.

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