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# Comparison of Bath and Probe Sonication for Osmotic Dehydration of Peach Slices: Study on the Qualitative and Nutritional Properties

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ABSTRACT: Ultrasound-osmotic dehydration as a pretreatment prior to drying can reduce the cost and processing time while increasing drying efficiency. This study evaluated the effectiveness of bath and probe ultrasound-assisted osmotic dehydration, as a pretreatment of the drying process in an oven, on the qualitative characteristics of peach slices. Different conditions of pretreatment such as type of ultrasound (bath, probe), ultrasound temperature (25, 45 °C), ultrasound time (15, 30 minutes) and probe ultrasound intensity (75, 100 %) were investigated on the efficiency of osmotic dehydration, water activity, shrinkage, texture, rehydration, color, and vitamin C. The highest efficiency of osmotic dehydration was for the pretreated sample by probe ultrasound (45 °C-15'-100%). Osmotic-ultrasound pretreatment caused tissue stiffness, reducing in shrinkage and rehydration in the sample due to absorption of solids. Probe ultrasound, especially at high temperatures, compared with the bath ultrasound increased the total color difference and decreased the amount of vitamin C in the samples. Finally, in terms of overall acceptance, the samples under the bath ultrasound (25 °C-30 ') and under the probe ultrasound (25 °C-15'-100%) had the highest score.

**Keywords**: *Drying, Invert Syrup, Osmotic Dehydration, Peach, Ultrasound.*

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## Introduction

Peach (*Prunus persica*) is a single-core fruit of the Rosaceae family (Nunes *et al.*, 2008). Annually, about 25 million tons of peaches and nectarines are produced in the world; In the meantime, Iran has an annual production of about 863000 tons of peaches and nectarines that makes it the fifth rank in the world (FAO, 2016). Peaches are very perishable and have short shelf life and reduction in its quality mainly is due to metabolic changes, mechanical damage, and shrinkage of tissue (Yadav *et al.*, 2012).

Drying is one of the oldest methods used in the food industry, which increases the stability of food through the reduction of water activity and destructive process (Tolera and Abera, 2017). On the other hand, the need for more time and a higher temperature will cause a reduction in the nutritional value of products and more energy consumption. As a result, the use of new technologies such as ultrasound and osmotic dehydration has been widely considered (Bromberger Soquetta *et al.*, 2018). Sucrose can be broken down into 1:1 mixture of glucose and fructose, which is called invert syrup. Invert syrup compared to

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sucrose is less susceptible to crystallization and is also a inexpensive solution (Veiga-Santos *et al.*, 2007).

In osmosis process, based on the concentration gradient between the food product and the solution, two opposite flows arise, which causes the flow out of the water from the tissue to the solution and the entry of solids from solution into the tissue (Park *et al.*, 2002). However, the process of osmosis is inefficient because of the need for longer time (Fei *et al*., 2018).

Ultrasound is a particular type of sound waves from 20 kHz to 100 MHz (Bromberger Soquetta *et al*., 2018; Ma *et al*., 2018). Ultrasound pretreatment is performed by immersing the fruit in an aqueous hypertonic solution and applying ultrasound waves. Ultrasound waves produce tiny air bubbles inside the fluid medium and then burst them, which are called cavitation phenomena. The abnormal bursting of these bubbles near the surface of the food products results in the transfer of high-velocity currents of sound waves to their surface and it creates microscopic canals and facilitates water withdrawal from the product during drying by creating successive contraction and expansion (sponge effect) in it (Fernandes *et al*., 2008).

Fei *et al*. (2018) compared the process of osmotic dehydration (OD) with ultrasound-assisted osmotic dehydration (UOD) on the status of water, tissue, and nutrients of the button mushroom. The results demonstrated that UOD improves the process efficiency, and reduced the processing time to 62.5%, therefore it can maintain more nutrients and flavoring compounds. In addition, the texture of the UOD products showed better stiffness and chewiness than OD, and the microstructure of UOD products was more similar to fresh products. (Bromberger Soquetta *et al*., 2018) showed that the use of probe ultrasound and bath ultrasound reduced the entire processing time to 26% and 24%, respectively. Ultimately, the use of probe ultrasound in the osmotic solution for 5 minutes as a pretreatment is an acceptable technology because without damaging the final product quality, it reduces drying time.

The aim of this study is to investigate the effect of ultrasound-assisted osmotic dehydration as a pretreatment to air-drying of peach and compare the effect of pretreatment in an ultrasound bath (indirect) and ultrasonic probe (direct) on the physicochemical and nutritional properties of dried peach slices.

## Materials and Methods

### - *Sample preparation*

Fresh peaches of (varieties of Red heaven) were bought at a local market (Iran, Amol). Peaches were washed and then, were cut into 5 mm thick slices with a sharp knife (Yadav *et al*., 2012).

### - *Invert Syrup Preparation*

First, 0.66 kg of distilled water was heated to 70 °C. 0/44 gr citric acid was dissolved in 20 gr of distilled water and eventually added to the heated distilled water. 1.32 kg Sucrose was dissolved in the desired hot solution with stirring and eventually was heated for 45 min at 90 °C. Finally, the solution was cooled to 40 °C and invert syrup weight was adjusted by adding 2 kg distilled water (Ali, Saad and El-Haj, 2015). Eventually, Invert syrup was obtained with 65 Brix, containing 47% of reducing sugar.

### - *Pretreatments*

### - *Osmotic pretreatment*

The concentration of Invert syrup, as the osmotic solution, was adjusted by adding distilled water to 40 Brix. The ratio of peach slices to osmotic solution was 1:4 (w/w) and maintained in osmotic solution with two different temperatures of 25 °C and 45 °C for 2 hours. The samples were extracted from the osmotic solution and then washed with distilled water for 10 seconds, finally dried with filter paper (Mierzwa and Kowalski, 2016).

### - *Pretreatment with probe ultrasound*

Peach slices were immersed in the osmotic solution in a 250 ml beaker in the ratio of 1:4 (fruit: solution) and were exposed to probe ultrasound (HD3200, BANDELINE, Germany) for 15 and 30 minutes. The process was carried out at two different temperatures of 25 °C and 45 °C and in two intensities of 75% and 100%. The transmission of waves from the piezoelectric converter to the sample was carried out by a titanium sonotrode (19 mm in diameter) immersed up to a depth of 5 mm below its surface (Bromberger Soquetta *et al*., 2018).

### - *Pretreatment with bath ultrasound*

Peach slices were immersed in the osmotic solution in a 250 ml beaker in the ratio of 1:4 (fruit: solution) and were exposed to bath ultrasound (HD3200, BANDELINE, Germany) with frequency of 37 kHz without stirring with internal dimensions 137 × 240 × 240 mm. The process was carried out at two different temperatures of 25 and 45 °C for 15 and 30 min (Bromberger Soquetta *et al*., 2018).

### - *Water Loss and soluble solids gain*

The rate of water loss from peach tissue and solids absorbed into peach tissue has been calculated according to the following formula (Nowacka *et al*., 2019):

$$\mathrm{WL}\ (\%) = \frac{(\mathrm{Wi}\times \mathrm{Xi}\ - \mathrm{Wf}\times \mathrm{Xf})}{\mathrm{Wi}} \times 100 \qquad (1)$$

$$\mathrm{SG}\ (\%) = \frac{(\mathrm{Wf}\times \mathrm{Xsf}\ - \mathrm{Wi}\times \mathrm{Xsi})}{\mathrm{Wi}} \times 100 \qquad (2)$$

where, Wi is the sample weight (g) before osmotic treatment; Xi is the initial moisture content on a wet basis (g water/g total mass of the fruits) prior to treatment; Wf is the sample weight (g) after osmotic treatment; Xf is the moisture content of the sample after osmotic treatment based on wet weight (g of total sample/g of water); Xsi is dry solid content of the sample before osmotic treatment (g dry matter/g total fruit weight); Xsf is dry solid content of the sample after osmotic treatment (g dry matter/g total fruit weight).

### - *Oven drying with air circulation*

The samples were transferred in an oven with hot air flow after osmotic dehydration and dried at 60 °C until to a constant final weight (Bromberger Soquetta *et al*., 2018).

### - *Physicochemical analysis*

### - *Rehydration ratio*

Firstly, the dried samples were immersed in distilled water at room temperature for 3 hours. Rehydration ratio was calculated according to the following equation: (Shukla and Singh, 2007)

$$\text{Rehydration ratio}=\frac{\text{Sample weight after rehydration}}{\text{Sample weight before rehydration}} \qquad (3)$$

### - *Shrinkage percentage*

The percentage of shrinkage was obtained by measuring the volumetric changes of the sample using the toluene displacement method according to the following equation:

$$\text{Shrinkage}\ (\%) = \frac{\mathrm{V0}-\mathrm{V}}{\mathrm{V0}} \times 100 \qquad (4)$$

Where, $V_0$ is the initial sample volume (mL) and V is the sample volume after drying (mL) (Koc, Eren, & Ertekin, 2008).

### - *Texture (compression)*

Stiffness evaluation of dried peach was evaluated by a texture analyzer (STM-5, Iran). Firstly, we used a 36 mm cylindrical probe of 5 mm diameter, test speed of 1 mm/s, and the sample is compressed to achieve a 40 percent deformation. The maximum required force (in terms of Newton) was calculated to create this deformation (Caleb *et al*., 2013).

### - *Color assessment*

Color variations in oil samples containing antioxidants were determined using the IMG-Pardazash Cam-System colorimeter by measuring the parameters of L* a* b*. The darkness-lightness was determined by L*, greenness-redness by a* and blueness-yellowness by b*. The total color change index (ΔE) was calculated by the following equation: (Farahmandfar *et al.*, 2019)

$$\Delta E = \sqrt{(L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2} \qquad (5)$$

where the subscript “0” is the color of peach sample without ultrasound-osmosis (Control).

The browning index (BI) was calculated by the following formula (Hubackova and Banout, 2017):

$$BI = \frac{[100(X - 0.31)]}{0.17} \qquad (6)$$

The variable X was calculated by the following formula:

$$X = \frac{(a* + 1.75L*)}{(5.645\ L* + a* - 3.012\ b*)} \qquad (7)$$

- *Water activity ($a_w$)*

The water activity of the samples was measured at 25 °C by Testo-650 meter. 3 grams of samples were placed in a cuvette and finally, the cuvette was placed on the water activity meter. Finally, the average of three replicates was reported (Velickova *et al.*, 2014).

- *Measurement of vitamin C*

Measurement of L-ascorbic acid (Vitamin C) was performed by high performance liquid chromatography (Shimadzu HPLC-10 AT) with Alltima C-18 column (particle size 250 x 4.6 mm, 5 µm). A moving phase of the buffer was used (Potassium phosphate 0.02 molar, pH = 2.5 by phosphoric acid): Acetonitrile (98: 2 v/v) at a flow rate of 1 mL/min. The volume of the injected sample was 10 µL. Detection of ascorbic acid in a wavelength range of 254 nm was performed by comparing the inhibition time with a standard reference (A-0278, SIGMA) (Dodson *et al.*, 1992).

- *Statistical analysis*

The experiments were carried out in a completely randomized design with factorial arrangement in three replications. In order to compare the mean of the data, Duncan's multiple range test was used at 5% probability of error. Data analysis was done using SPSS software, version 21.0 (SPSS Inc., Chicago, IL, USA).

## Results and Discussion

Table 1 and Table 2 present abbreviations used for different treatments and results of analysis of variance of established variables of dried peaches in respective order.

**Table 1.** Abbreviations used for different treatments

| Treatment | Type of Ultrasound | Temperature (°C) | Time (min) | Ultrasound severity (%) | Abbreviations |
|---|---|---|---|---|---|
| 1 | Bath | 25 | 15 | - | UB-25°C-15' |
| 2 | Bath | 25 | 30 | - | UB-25°C-30' |
| 3 | Bath | 45 | 15 | - | UB-45°C-15' |
| 4 | Bath | 45 | 30 | - | UB-45°C-30' |
| 5 | Probe | 25 | 15 | 75 | UP-25°C-15'-75% |
| 6 | Probe | 25 | 15 | 100 | UP-25°C-15'-100% |
| 7 | Probe | 25 | 30 | 75 | UP-25°C-30'-75% |
| 8 | Probe | 25 | 30 | 100 | UP-25°C-30'-100% |
| 9 | Probe | 45 | 15 | 75 | UP-45°C-15'-75% |
| 10 | Probe | 45 | 15 | 100 | UP-45°C-15'-100% |
| 11 | Probe | 45 | 30 | 75 | UP-45°C-30'-75% |
| 12 | Probe | 45 | 30 | 100 | UP-45°C-30'-100% |
| 13 | without ultrasound | 25 | - | - | Control- 25°C |
| 14 | without ultrasound | 45 | - | - | Control- 45°C |
| 15 | without ultrasound and Osmotic solution | - | - | - | Control |

**Table 2.** Results of analysis of variance (degree of freedom and mean square) of established variables of dried peaches

| Mean Square (MS) | | | | | | freedom Degree (df) | Source |
|---|---|---|---|---|---|---|---|
| **WL/SG** | **browning** | **Texture** | **Rehydration** | **Shrinkage** | **Vitamin c** | | |
| 352.9** | 3127.2 ** | 11.7 ** | 0.33 ** | 75.6 ** | 757 ** | 14 | Model |
| 493.3 ** | 1819.8 ** | 9.6 ** | 0.64 ** | 139 ** | 2653.6 ** | 2 | Ultrasound Type (A) |
| 346.3 ** | 5305.5 ** | 14 ** | 1 ** | 72.3 ** | 490.7 ** | 2 | Temperature (B) |
| 82.3 ** | 1412.8 ** | 8.3 ** | 0.03 ** | 1 $^{ns}$ | 91.5 ** | 1 | Time (C) |
| 213 ** | 366.6 $^{ns}$ | 0.45 $^{ns}$ | 0.04 ** | 133 ** | 372.4 ** | 2 | Ultrasound-Temperature (AB) |
| 299.9 ** | 49.8 $^{ns}$ | 4.3 ** | 0.07 ** | 16 ** | 66.2 ** | 2 | Ultrasound-Time (AB) |
| 43.4 ** | 1792 ** | 1.1 $^{ns}$ | 0.2 ** | 9 ** | 29.8 ** | 1 | Temperature-Time (BC) |
| 183.7 ** | 2288 ** | 0.25 $^{ns}$ | 0.02 ** | 3 $^{ns}$ | 140.8 ** | 2 | Ultrasound-Temperature-Time (ABC) |
| 0.202 | 140.3 | 0.47 | 0.001 | 1 | 1.88 | 30 | Error |
| - | - | - | - | - | - | 45 | Total |

***Note.*** ns: not meaningful at 1% and 5%. *: significant at 5% level. ** Significant at 1%

- *The amount of water loss and absorption of soluble solids*

The average percentage of water loss (WL %) and solids gain (SG %) of peach treated with ultrasound is shown in Table 3. By increasing the temperature from 25 to 45 °C, water loss in the all samples increased significantly ($P < 0.05$), and by increasing temperature from 25 to 45 °C, the absorption of solids increased in the control and pretreated samples with UB. The rate of adsorption of solids decreased with increasing temperature in pretreated samples with UP, except UP-15'-75% sample ($P < 0.05$).

If the WL to the SG was higher, the osmosis process will be more efficient and economical, obviously, any factor that increases this ratio is effective in introducing the proper conditions for osmotic dehydration. According to Table 3, the highest WL/SG ratio is for sample of UP-45°C-15'-100%, and the lowest WL/SG ratio is for Control-25 sample (without ultrasound at 25 °C). In other words, the results showed that ultrasound pretreatment resulted in a significant increase in WL/SG as compared to the non-pretreated ultrasound sample and this increase was observed in UP pretreated samples more than UB ($P < 0.05$). Ultrasound causes reactivity in the tissue and the cell becomes permeable to water. On the other hand, increasing the temperature decreases the viscosity of the osmotic solution and reduces the external resistance of the mass transfer and makes it easy to transport water and solids (Lertworasirikul and Saetan, 2010).

The results showed that the highest water activity was related to the control sample. As a result, the osmotic pretreatment caused a significant decrease in the amount of water activity of the samples compared to the control. The lowest water activity was related to sample of UP-45°C-30'-100%. The results showed that ultrasound pretreatment, especially UP, caused a further reduction in the water activity of the samples compared to the control. This condition is due to microscopic gaps created in the sample tissue due to the phenomenon of cavitation which increased the mass transfer of the sample and reduced water from the product. By increasing temperature, the water activity decreased in the samples due to swelling of the sample therefore this results in more water being released from the sample (Eren and Kaymak-Ertekin, 2007).

**Table 3.** Water Loss (WL), Solid Gain (SG) and Water Activity ($a_w$) of dried Peaches in Different Dehydration Conditions

| $a_w$ | WL/SG | SG | WL | Treatment |
|---|---|---|---|---|
| 0.30 ± 0.01 $^{c}$ | 16.82 ± 1.3 $^{hi}$ | 1.85 ± 0.48 $^{d}$ | 31.22 ± 1.51 $^{h}$ | UB-25°C-15' |
| 0.29 ± 0.01 $^{cd}$ | 18.81 ± 1.02 $^{g}$ | 1.89 ± 0.47 $^{d}$ | 35.69 ± 1.32 $^{e}$ | UB-25°C-30' |
| 0.25 ± 0.02 $^{gh}$ | 14.68 ± 1.26 $^{j}$ | 2.51 ± 0.51 $^{a}$ | 36.90 ± 1.86 $^{d}$ | UB-45°C-15' |
| 0.28 ± 0.01 $^{de}$ | 16.39 ± 1.13 $^{i}$ | 2.26 ± 0.43 $^{b}$ | 37.04 ± 1.50 $^{d}$ | UB-45°C-30' |
| 0.29 ± 0.03 $^{cd}$ | 23.78 ± 1.20 $^{f}$ | 1.34 ± 0.33 $^{g}$ | 31.92 ± 1.09 $^{g}$ | UP-25°C-15'-75% |
| 0.32 ± 0.02 $^{b}$ | 27.80 ± 0.91 $^{c}$ | 1.08 ± 0.28 $^{h}$ | 30.21 ± 0.92 $^{i}$ | UP-25°C-15'-100% |
| 0.28 ± 0.01 $^{de}$ | 16.46 ± 1.08 $^{i}$ | 1.78 ± 0.34 $^{e}$ | 29.30 ± 1.64 $^{j}$ | UP-25°C-30'-75% |
| 0.26 ± 0.03 $^{fg}$ | 17.46 ± 0.94 $^{h}$ | 2.11 ± 0.43 $^{c}$ | 36.86 ± 2.10 $^{d}$ | UP-25°C-30'-100% |
| 0.25 ± 0.02 $^{gh}$ | 24.97 ± 1.36 $^{e}$ | 1.50 ± 0.37 $^{f}$ | 37.45 ± 1.81 $^{c}$ | UP-45°C-15'-75% |
| 0.27 ± 0.04 $^{ef}$ | 44.50 ± 2.07 $^{a}$ | 0.97 ± 0.20 $^{i}$ | 43.15 ± 2.94 $^{b}$ | UP-45°C-15'-100% |
| 0.26 ± 0.03 $^{fg}$ | 39.49 ± 1.81 $^{b}$ | 0.84 ± 0.19 $^{j}$ | 33.17 ± 2.12 $^{f}$ | UP-45°C-30'-75% |
| 0.24 ± 0.02 $^{h}$ | 25.78 ± 1.23 $^{d}$ | 1.73 ± 0.27 $^{e}$ | 45.21 ± 2.50 $^{a}$ | UP-45°C-30'-100% |
| 0.30 ± 0.04 $^{c}$ | 13.66 ± 0.51 $^{k}$ | 0.98 ± 0.15 $^{i}$ | 13.48 ± 0.87 $^{l}$ | Control - 25°C |
| 0.29 ± 0.04 $^{cd}$ | 14.02 ± 0.42 $^{jk}$ | 1.5 ± 0.36 $^{f}$ | 21.03 ± 1.73 $^{k}$ | Control - 45°C |
| 0.52 ± 0.08 $^{a}$ | - | - | - | Control |

Values (Mean ± SD, n = 3) in the same column with different letters are significantly different ($P < 0.05$). Abbreviations are explained in Table 1

### *- The effect of ultrasound-Osmotic pretreatment on color indexes*

Table 4 present analysis of variance results results of measured dried peach characteristics. Changing the values of L*, a* and b* that occurs during the drying of food samples can increase the amount of ΔE, BI, and finally the change in the dry matter content quality. According to the results (Table 5), by increasing the temperature from 25 to 45 °C in all samples the color changes and eventually the browning index can be increased ($P < 0.05$) due to caramelization of sugar compounds and, non-enzymatic browning reaction (Millard). In this reaction, the aldehyde agent of sugars and the amino acid agent of the proteins interact with each other and cause brown pigmentation. The results obtained by Krokida *et al*. (2000) confirm the effects of the increase in temperature on color variations.

On the other hand, pretreatment with UP reduced brightness (L) and, consequently, increased color difference and BI of the samples. In fact, the peach is white and invert syrup is dark in color, as a result, peach dipping in invert syrup increased the amount of yellowness (b) and redness (a) and decreased brightness (L) in peach samples pretreated with osmotic solution as compared to the control sample. The browning index of UP sample was higher than other samples due to better osmotic dehydration and higher percentage of water loss and sugar gain ($P < 0.05$).

### *- Texture analysis*

According to Figure 1, the lowest and highest hardness, the amount force during compression, were observed for the control sample (without an osmotic solution) and UB-45°C-15' sample, respectively. In fact, with the pretreatment of osmotic-ultrasound, increasing the rate of inter-tissue water loss, the absorption of solids in the tissue also increased. By reducing the inter-tissue water, the sugar content of the resulting osmosis has increased and the empty spaces caused by drying are filled, which makes the texture of the samples under the process harder (Jalaee *et al*., 2011). The UB-45°C-15' sample showed the highest state of hardness due to the highest absorption of solids ($P < 0.05$).

*- Effect of Ultrasound-Osmotic pretreatment on shrinkage*

According to Figure 2, the highest shrinkage was for the Control sample (without ultrasound and osmosis), while the UB-45°C-15' sample showed the lowest shrinkage due to the highest absorption of solids. The osmotic pretreatment can reduce the shrinkage due to the volume occupied by the sugar in tissue and increasing in hardening of the tissue, as well as the reduction of the drying time. In fact, the shrinkage can greatly reduce by penetration of solids in spaces (Garcia *et al.*, 2007). Also, the shrinkage of samples decreased due to the application of ultrasound in order to create micro-channels and the increase in the adsorption of solids (Fernandes *et al.*, 2008).

**Table 4.** Analysis of variance results (degree of freedom and mean square) of measured dried peach characteristics

| Sensory evaluation (general acceptance) | | Total Color Difference (ΔE) | | Source |
|---|---|---|---|---|
| **Mean squares (MS)** | **Degree of freedom (df)** | **Mean squares (MS)** | **Degree of freedom (df)** | |
| 3.7 ** | 14 | 112.4 ** | 13 | Model |
| 2.7 * | 2 | 102.5 ** | 2 | Ultrasound (A) |
| 1.7 $^{ns}$ | 2 | 365.2 ** | 1 | Temperature (B) |
| 0.01 $^{ns}$ | 1 | 61 * | 1 | Time(C) |
| 0.52 $^{ns}$ | 2 | 27.6 $^{ns}$ | 2 | Ultrasound-Temperature Interaction(AB) |
| 7 ** | 2 | 1.87 $^{ns}$ | 2 | Ultrasound-Time interaction(AC) |
| 1 $^{ns}$ | 1 | 92.6 ** | 1 | Temperature-Time interaction(BC) |
| 1.3 $^{ns}$ | 2 | 88.9 ** | 2 | Ultrasound -Temperature-Time Interaction (ABC) |
| 0.61 | 135 | 10.2 | 28 | Error |
| - | 150 | - | 42 | Total |

***Note.*** ns: not meaningful at 1% and 5%. *: significant at 5% level. **: Significant at 1%

**Table 5.** Effect of process variables on total color difference (ΔE) and browning index (BI) in color space L * a * b$^*$

| L* | a* | b* | ΔE | BI | Treatment |
|---|---|---|---|---|---|
| 79.25 ± 1.57 $^{ab}$ | 0.76 ± 0.52 $^{d}$ | 56.93 ± 2.1 $^{bc}$ | 13.25 ± 4.36 $^{fg}$ | 114.1 ±3.04 $^{e}$ | UB-25°C-15' |
| 77.56 ±1.60 $^{ab}$ | 1.867 ± 1.09 $^{d}$ | 58.63 ±2.96 $^{abc}$ | 15.49 ±4.43$^{defg}$ | 125.3 ±4.51 $^{de}$ | UB-25°C-30' |
| 70.08 ±1.72 $^{de}$ | 10.1 ± 5.52 $^{b}$ | 58.47 ±1.84 $^{abc}$ | 22.65 ±3.33 $^{bc}$ | 158.1 ±9.57 $^{b}$ | UB-45°C-15' |
| 75.79 ±3.83 $^{bc}$ | 5.25 ± 3.62 $^{c}$ | 57.25 ±1.63 $^{bc}$ | 16.83 ±2.50$^{cdef}$ | 130.2 ±9.82$^{cde}$ | UB-45°C-30' |
| 73.50 ±1.73 $^{cd}$ | 6.35 ± 0.98 $^{c}$ | 59.86 ±2.75 $^{ab}$ | 19.88 ±2.36 $^{cde}$ | 147.4 ±8.90 $^{bc}$ | UP-25°C-15'-75% |
| 80.48 ±1.27 $^{a}$ | 0.59 ± 0.21 $^{d}$ | 59.47 ±3.53 $^{ab}$ | 15.47 ±3.21$^{defg}$ | 119.3 ±2.46 $^{e}$ | UP-25°C-15'-100% |
| 78.38 ±0.45 $^{ab}$ | 1.53 ± 1.41 $^{d}$ | 57.09 ±1.64 $^{bc}$ | 14.03 ±3.09 $^{efg}$ | 118.1 ±13.3 $^{e}$ | UP-25°C-30'-75% |
| 73.82 ±2.41 $^{c}$ | 10.14 ± 5.3 $^{b}$ | 57.60 ±2.3 $^{abc}$ | 20.74 ±2.36 $^{cd}$ | 141.7 ±13.8 $^{bcd}$ | UP-25°C-30'-100% |
| 66.71 ±3.39 $^{ef}$ | 16.29 ± 5.91 $^{a}$ | 58.26 ±1.76 $^{abc}$ | 28.45 ±3.30 $^{a}$ | 178.1 ±12.07 $^{a}$ | UP-45°C-15'-75% |
| 65.87 ±1.79 $^{f}$ | 15.82 ± 4.82 $^{a}$ | 60.90 ±2.5 $^{a}$ | 30.25 ±3.36 $^{a}$ | 196.1 ±11.9 $^{a}$ | UP-45°C-15'-100% |
| 68.06 ±1.65 $^{ef}$ | 14.65 ± 4.33 $^{a}$ | 60.34 ±2.23 $^{ab}$ | 27.86 ±4.14 $^{ab}$ | 180.2 ±12.25 $^{a}$ | UP-45°C-30'-75% |
| 72.81 ±3.20 $^{cd}$ | 7.66 ± 2.74 $^{bc}$ | 57.44 ±1.09 $^{bc}$ | 19.22 ±1.06 $^{cdef}$ | 141.5 ±12.1 $^{bcd}$ | UP-45°C-30'-100% |
| 79.36 ±1.99 $^{ab}$ | 0.27 ± 0.13 $^{d}$ | 55.44 ±1.87 $^{bc}$ | 11.73 ±1.46 $^{g}$ | 108.7 ±3.51 $^{e}$ | Control- 25°C |
| 79.74 ±1.28 $^{a}$ | -1.03 ± 0.98 $^{d}$ | 57.09 ±2.44 $^{bc}$ | 13.12 ±3.58 $^{fg}$ | 126.3 ±2.5 $^{e}$ | Control - 45°C |
| 80.65 ±2.98 $^{a}$ | -4.25 ± 2.79 $^{e}$ | 44.78 ±1.89 $^{d}$ | 0 | 72.69 ±10.81 $^{f}$ | Control |

Values (Mean ± SD, n = 3) in the same column with different letters are significantly different ($P < 0.05$). Abbreviations are explained in Table 1.

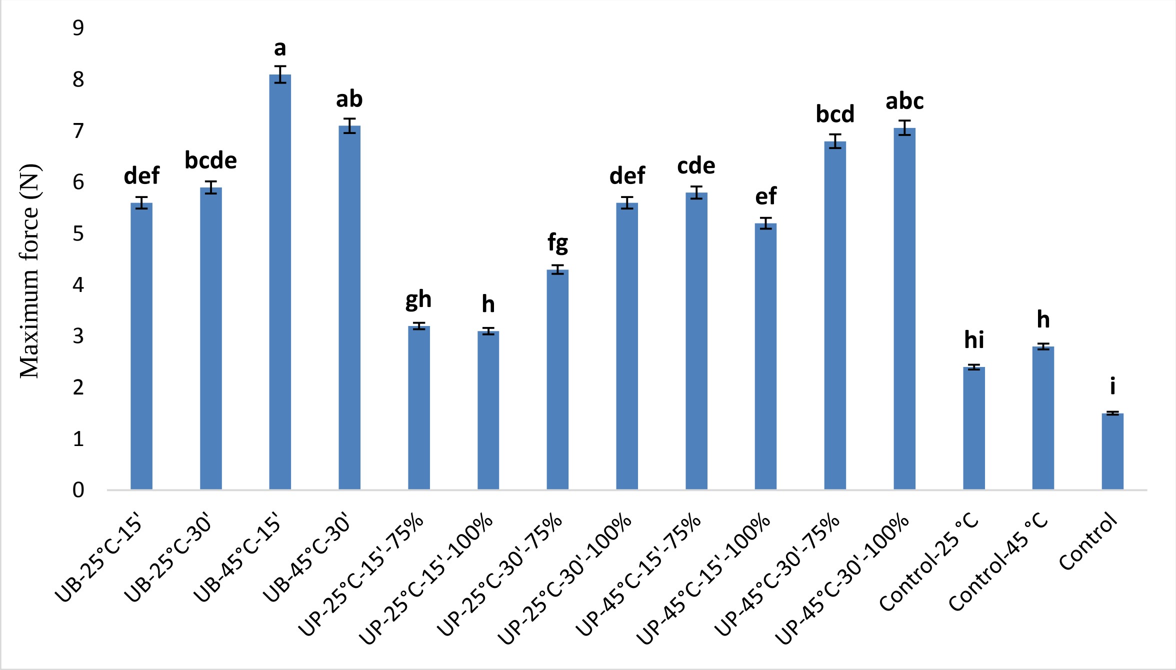

**Fig. 1**. Average of maximum force during compression test on dried peach samples. The vertical bars represent standard deviation (±SD) of the means. Abbreviations are explained in Table 1.

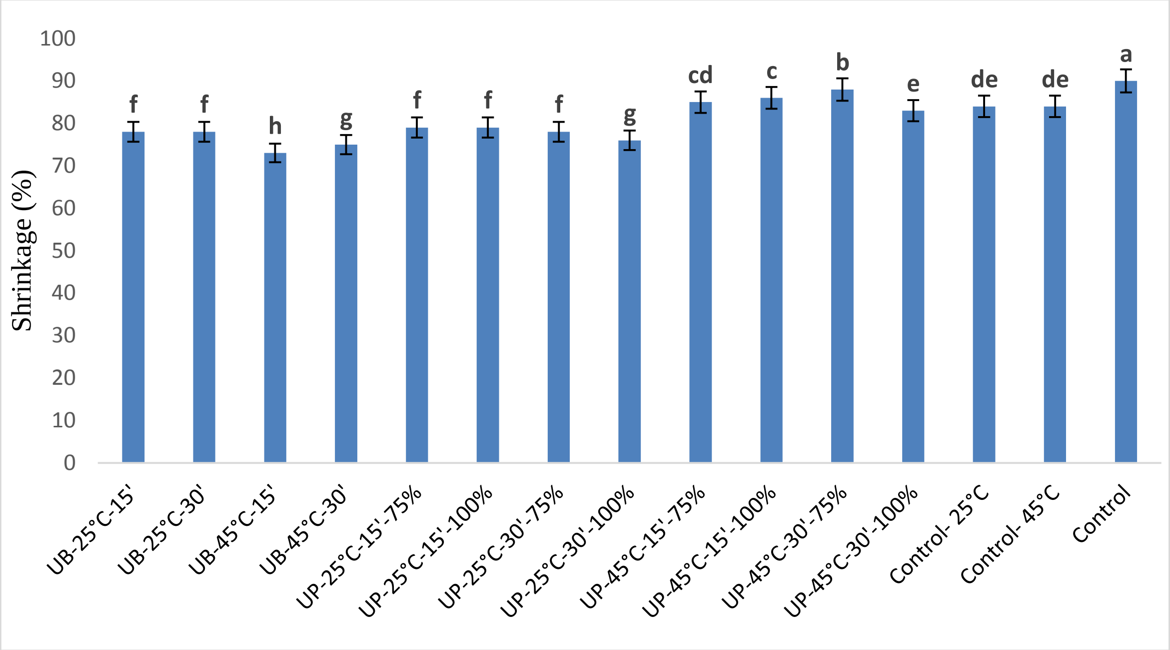

**Fig. 2**. Average of shrinkage percentage of dried Peach samples. The vertical bars represent standard deviation (±SD) of the means. Abbreviations are explained in Table 1.

- *Effect of Ultrasound-Osmotic pretreatment on rehydration*

According to Figure 3, there was a significant difference in the rehydration rate of pretreated Ultrasound-Osmosis samples compared to control samples ($P < 0.05$). So that the highest rehydration was for a sample without ultrasound and osmosis (control) and the lowest rehydration was for UB-45°C-15' sample. This is probably due to adsorption of solids in the process of osmosis, which also affects cell permeability and as a result, the rate of rehydration is reduced. Bakalis and Karathanos (2005) showed that the osmotic dehydration process has a negative effect on the rate of rehydration due to the rapid saturation of the substrate with the sugar content of the tissue and the lowering of the sugar content compared to the natural texture of the food.

### - *Effect of Ultrasound-Osmotic pretreatment on Vitamin C content*

Another feature that can indicate the quality of the dried product is the amount of vitamin C (Figure 4). Vitamin C is naturally susceptible to factors such as temperature and oxygen, so, the high remaining of vitamin C in the product can reflect that the drying process was more appropriate (Wang *et al*., 1992). As you can see in Figure 4, the highest and lowest amount of vitamin C were for the control sample and the pretreated probe ultrasound sample (UP-45 °C -30'-75%), respectively. Probe ultrasound compared to bath ultrasound significantly reduced the vitamin C content of the samples ($P < 0.05$). The destruction of vitamin C in the ultrasound method can be caused by oxidation reactions and interactions with free radicals formed during the ultrasound process. The chemical reactions and physical conditions occur during the ultrasound, the formation of hydrogen ions ($H^+$), free radicals ($O^-$, $OH^-$, $HO_2^-$) and hydrogen peroxide from the water molecules present in the sample during ultrasound has been identified (Pétrier *et al*., 2007). Also, hydroxyl radicals produced by cavitation can be effective in destroying vitamin C (Adekunte *et al*., 2010).

## Conclusion

The use of the ultrasound probe and the ultrasound bath increased the water loss value due to the formation of micro channels and the facilitates of mass transfer. Ultrasound-assisted osmotic reduced the amount of shrinkage due to the adsorption of

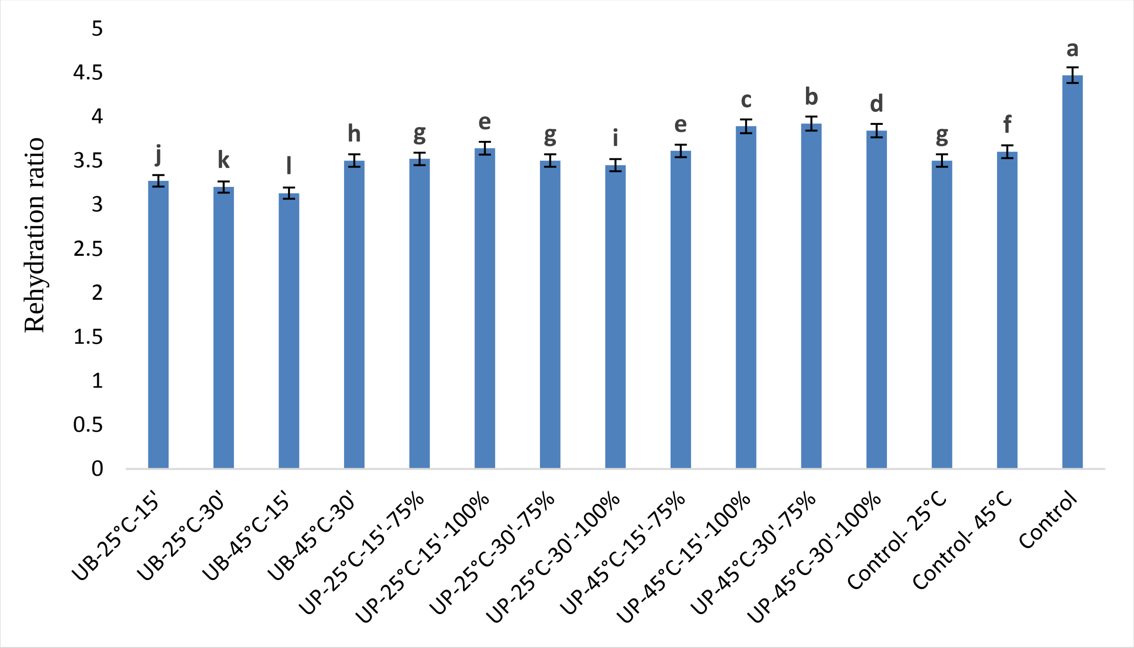

**Fig. 3**. Rehydration ratio of dried Peach samples. The vertical bars represent standard deviation (±SD) of the means. Abbreviations are explained in Table 1.

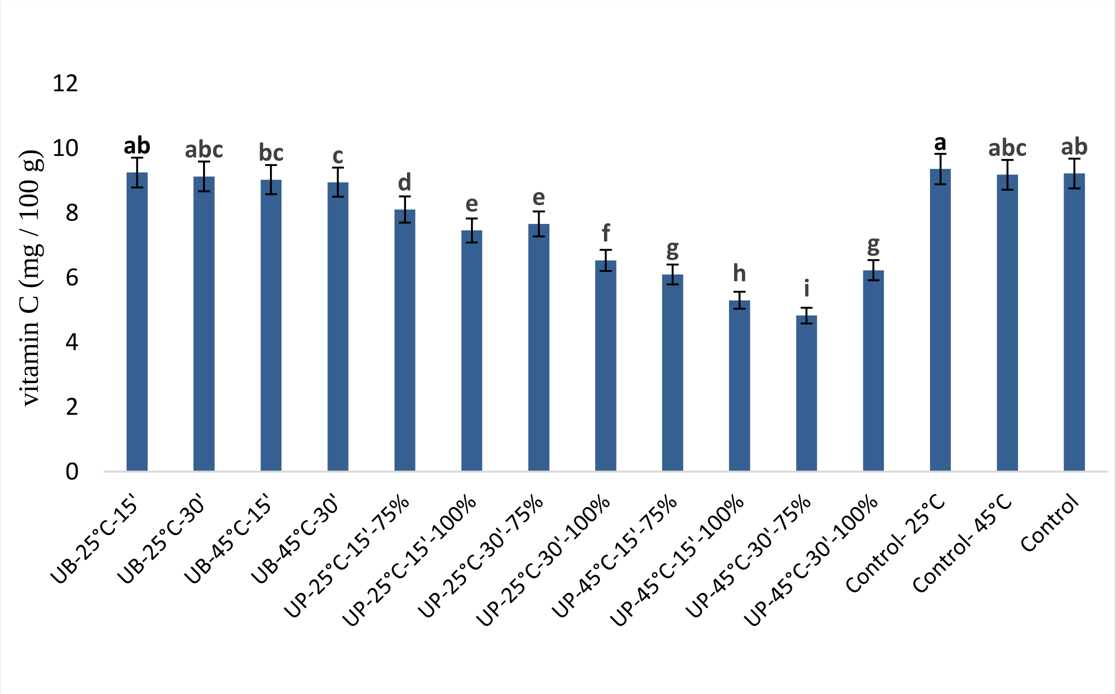

**Fig. 4**. Mean amount of vitamin C of dried Peach samples (mg/100 g). The vertical bars represent standard deviation (±SD) of the means. Abbreviations are explained in Table 1

solids and the hardening of the tissue. The rehydration of samples reduced by ultrasound-assisted osmotic process due to the absorption of more solid. Ultrasound (especially probe ultrasound) increased the total color difference and browning index as compared to the control sample due to the more water loss. In terms of nutritional value, the ultrasound probe reduced vitamin C as compared to the bath ultrasound. The use of ultrasound pretreatment in osmotic solution is feasible to obtain dried peach, due to more water loss and energy and time reduction.

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