Evaluation of high intensity ultrasound pre-treatment effects on the physical properties and bioactive compounds of convective dried quince samples

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**ABSTRACT**

This work was undertaken to evaluate the impact of high-intensity ultrasound (HUS) pre-treatment on some quality characteristics of convective-dried (CVD) quince fruit pieces at different temperatures (50, 60, 70, and 80 °C). CVD quince samples at 70°C with a 15 min HUS pre-treatment showed the lowest water activity (0.36 ± 0.02). On the other hand, the quince fruit samples exposed to 15 min HUS pre-treatment shrank significantly (P < .05) especially when combined with convective drying at 70°C. The dried quince samples with no HUS pre-treatment exhibited the most condense and denser porous texture. While the lowest antioxidant capacity (AOC) was described for dried quince samples at 50°C with no HUS pre-treatment (2.58 μmol TE/g dry–weight), the highest AOC was determined for the dried quince samples exposed to HUS pre-treatment for 15 min at 70 °C (7.08 μmol TE/g on dry basis). Among the HUS-treated quince samples, the highest vitamin C content was found for the CVD quince samples at 70°C with 15 min HUS pre-treatment (43.79 mg/100 g on dry weight.). In overall, HUS is a promising pre-treatment as shown in current work by its efficiency for better preservation of CVD quince quality in terms of physical and chemical characteristics.

**KEYWORDS**

Bioactive compounds; convective drying; quince fruit; texture; HUS pre-treatment

**Practical Application**

A significant improvement in the quality retention of convective-dried quince samples with an HUS pre-treatment was achieved. A practical implication is that drying of quince slices with an optimum condition by convective drying in addition to HUS pre-treatment can be used to get a high-quality product with higher bioactive compounds and improved physical properties. This study is an important to demonstrate the good potential of HUS application on dried fruit tissue comprehensively including physical properties, textures and bioactive compounds.

**Introduction**

Quince fruit is a good source of vitamins and minerals such as magnesium, copper, iron, potassium (Taghinezhad et al., 2020). Several researchers have figured out that quince fruit is well-supplied food material in terms of bioactive compounds such as polyphenols, organic acids, and amino acids with significant health benefits (Silva et al., 2004). Basically, quince fruits are described as a valuable nutritional source of compounds improving health as a consequence of their antioxidant, antimicrobial, and antilcerative activities (Fattouch et al., 2007). On the other hand, they spoil easily as like other

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fruits; therefore, drying process is favorable in a reasonable manner by reducing water activity (aw) of the food products, so decreasing the microbial activity to a level that inhibits spoilage. Even though the drying process is one of the most wide-spread application for the improvement of food product balance (Jahanbakhshi et al., 2020), it is a complex application dealing with simultaneous heat and mass transport development and the analytical employment of those developments to food products as a consequence of the physiological and chemical developments at drying process. Especially convective-drying (CVD) is an energy-intensive process and therefore a costly approach since it is a simultaneous heat and mass movement action, resulting in phase differences (Izli, 2017). Employing the pre-treatments creates a more porous network in the food products, which promotes improved mass transfer ratios at drying process (Abbaspour-Gilandeh et al., 2019; Cilla et al., 2018; Kaveh et al., 2018). Among the recent technologies, high-intensity ultrasound (HUS) is a promising technique, which is described as a non-thermal method; such methods have advantageous due to the minimization of food deterioration. No liquid phase development occurs in this technique for the removal of water (Fernandes et al., 2008). The HUS pre-treatment contains the submersion of the food product in water or in a hypertonic liquid solution where HUS is employed. Ultrasonic vibrations with the frequency of 20 to 100 kHz may lead to very quick sequences of possible compressions and expansions in a such way to a sponge effect when it is squeezed and released over and over again. Furthermore, ultrasound creates cavitation, which might be useful to eliminate firmly attached moisture (Yildiz et al., 2020). The sponge effect by HUS treatment could be the reason for the production of microscopic channels in porous food products (i.e., fruit) that reduces the diffusion boundary layers and rises the convective mass movement in the food products (De la Fuente-blanco et al., 2006). This method can be applied at ambient temperature and there is no need to heat up the food products; therefore, the possible food spoilage will be avoided. The variables that affect the drying behaviors consist of internal and external variables (e.g. physical and thermo physical attributes of the food products). However, the studies on the impacts of these variables on the dried quince fruits are still insufficient. So, the organized experiments targeted to examine the convective drying of quince fruit samples in respect to physiological and chemical properties at several temperatures (50, 60, 70, & 80°C) and air velocity of 1 m/s in addition to the effect of 2 different HUS pre-treatment times (15 and 30 min). In shortly, the central goal of current study is to investigate the impacts of drying variables and HUS pre-treatment on the quince quality and determine the best condition for CVD quince samples.

Materials and Methods

Sample Preparation

Pear-shaped fresh quince fruits (C. oblonga var. pyriformis) were bought from a local market in Iğdır, Turkey. The quince samples were washed to get rid of the dust, chemical residuals and attached dirt. The quinces cut with a dimensions of 3 cm length, 3 cm width, & 1.5 cm thickness with the help of a food slicer (Nice Dicer, China). The initial moisture content of the quince samples was defined as 84 ± 0.33% by drying at 105 ± 5°C before reaching the stable weight via forced-air convection oven (Memmert UN55, Germany).

High-Intensity Ultrasound (HUS) Application and Convective Drying Process

The quince fruit samples were employed in an ultrasonic bath (DaihanWise clean WUC-A10H, Germany) performing at a frequency of 40 kHz and a power of 200 W with the times of 15 and 30 min. The fruit-to-water ratio was managed at 1:4 (w/v). The analysis was conducted at room temperature. An increase in the temperature was figured out by a thermometer and was less than 2°C right after HUS application (30 minutes). To investigate the impact of HUS application, the same experimental design was conducted without HUS pre-treatment. After applying the HUS, the quince
fruit samples were drained and blotted on absorptive paper to get rid of the excessive water. Convective drying was implemented in a lab convective oven (Arçelik KMF 833I, Turkey) following the method proposed by İzli (2018). The quinces samples were located in a thin layer. Air velocity was well-set at 1 m/s with air temperatures of 50, 60, 70, and 80 °C for the drying process. The drying times for each sample to achieve 11 ± 0.23% moisture content were changed from 70 to 290 minutes (Table 1). The experiments were conducted with three replications. A short definition of the treatments is tabulated in Table 1.

**Water Activity (AW)**

The aw of the quince fruit samples was determined at room temperature using a Novasina AG LabMaster water activity meter (Novasina AG Labmaster-aw, Switzerland).

**Shrinkage Ratio (SR)**

The shrinkage ratio (SR) values of samples were determined by the changes of the bulk volume of the quince samples by aqueous displacement procedure using toluene (Equation 1) (Wang et al., 2012). The experiments were carried out five times for each quince sample and the average values were obtained for the calculation.

\[
SR = \frac{V_0 - V}{V_0} \times 100
\]

where \(V_0\) is the first and \(V\) is the last volume of the quince fruit piece, subsequently.

**Rehydration Ratio (RR)**

The rehydration ratio (RR) of the dried quince fruit pieces was determined by weighing ~2.5 g of CVD quince samples in distilled water with a ratio of 1:30 (w/w) under 100°C for 10 min. Subsequent to soaking, the extra water was taken off and the quince fruit samples were weighed. The calculation of RR of the quince samples were determined as below:

\[
RR(\%) = \frac{R_2}{R_1} \times 100
\]

where \(R_1\) and \(R_2\) are the constants for initial weight (g) and last weight following water absorption (g) of the quince fruit pieces, subsequently (Yildiz and İzli, 2019a).

| Sample names  | Treatments                                               | Drying Times (min) |
|---------------|----------------------------------------------------------|--------------------|
| Fresh sample  | No treatment                                             |                    |
| CVD5          | CVD quince slices at 50 °C with no pre-treatment         | 290                |
| CVD6          | CVD quince slices at 60 °C with no pre-treatment         | 245                |
| CVD7          | CVD quince slices at 70 °C with no pre-treatment         | 200                |
| CVD8          | CVD quince slices at 80 °C with no pre-treatment         | 170                |
| US1-CVD5      | CVD quince slices at 50 °C with 15 min US pre-treatment  | 135                |
| US1-CVD6      | CVD quince slices at 60 °C with 15 min US pre-treatment  | 110                |
| US1-CVD7      | CVD quince slices at 70 °C with 15 min US pre-treatment  | 95                 |
| US1-CVD8      | CVD quince slices at 80 °C with 15 min US pre-treatment  | 80                 |
| US2-CVD5      | CVD quince slices at 50 °C with 30 min US pre-treatment  | 120                |
| US2-CVD6      | CVD quince slices at 60 °C with 30 min US pre-treatment  | 100                |
| US2-CVD7      | CVD quince slices at 70 °C with 30 min US pre-treatment  | 90                 |
| US2-CVD8      | CVD quince slices at 80 °C with 30 min US pre-treatment  | 70                 |
Hardness Measurements (Textural Analysis)

Textural structure of CVD quince fruit pieces was determined by using a texture analyzer (TA.XTPlus Texture Analyzer, UK). The cylindrical penetrometer probe (5 mm diameter) was passed over the fruit pieces along with the test parameters adjusted to variables as: 2 mm/s of pre-speed, 0.5 mm/s of post-speed and test speed, and 10 g trigger. In the penetration analysis, hardness was described as the biggest force (N) required to puncture the quince fruit pieces. The analysis was carried out ten times for each quince fruit pieces in all applications.

Color Evaluation

The color changes of fresh and quince fruit pieces exposed to drying application with and without HUS application were analyzed by a Konica Minolta (CR400, Japan) that is assembled with illuminant D 65 and 8 mm measuring scope in the CIE L* a* b* color scale. Color parameters were described in a 3-dimensional L*, a*, and b* color space, where L* shows the lightness/darkness of the quince fruits, a* demonstrates the redness/greenness, and b* displays the yellowness/blueness (Yildiz et al., 2016). The chroma (C), hue angle (α) and total color differences (ΔE) values of quince samples were determined based on Equations (3–5):

\[ C = \sqrt{(a^2 + b^2)} \]  
\[ \alpha = \tan^{-1}\left(\frac{b}{a}\right) \]  
\[ \Delta E = \sqrt{(L^* - L0*)^2 + (a^* - a0*)^2 + (b^* - b0*)^2} \]

Bioactive Compounds

Vitamin C (Ascorbic Acid) Content

Ascorbic acid composition of fresh and dried quince samples was determined by titrimetric method stated by AOAC-967.21 (Association of Official Analytical Chemists (AOAC) International, 2007). According to the quantitative discoloration of 2,6-dichlorophenol indophenol (Sigma-Aldrich, St. Louis, MO, USA), homogenized quince samples were weighted (one gram) and diluted by the extraction liquid (2 g of oxalic acid in 100 g) to 100 mL and extracted for 10 min. Following the vacuum filtration stage, acquired clear supernatants were titrated by the 2,6-dichlorophenol indophenol (0.01 g /100 g). The development of a specific rose-pink color is the sign of the final point of titration process. The findings were calculated in milligrams of ascorbic acid per 100 g of dry sample weight (d.w.).

Development of Sample Extract

The extraction stage was managed according to the process proposed in the research of Yildiz and Izli (2019a). Homogenized fresh and CVD quince samples (0.5 g) with and without HUS pre-treatment were mixed with 4.5 mL of CH3OH and H2O (80/20 v/v) at room temperature and shaken at 140 rpm (Mipro ML3535, Turkey) for 2 h. The supernatant was collected right after centrifugation (3,500 g, 15 min) (Hettich Universal 320 R, Germany). By following the same procedure, 2 extractions were achieved with pellet. The supernatant was filtered with a 0.45 μm PTPE membrane filter to figure out the total phenolic content and antioxidant capacity of the quince samples.

Total Phenolic Content (TPC). The procedure stated by Igual et al. (2012) with a minor modification was followed to analyze the total phenolic content of quince samples. The technique based on the degradation of Folin–Ciacolteu reagent by phenolic substances. In brief, the quince fruit extract was
added into 1.25 mL of Folin-Ciocalteu indicator and 15 mL of distilled water on a vortex mixer (Velp Scientifica F202A0173, Italy). After 10 min in the dark place, 3.75 mL of 7.5% Na-carbonate was added into the mix and the volume was made up to 25 mL with distilled water. The absorbance was measured at 760 nm by using a spectrophotometer (Mecasys Optizen Pop, Korean) after 2-h incubation at room temperature in a dark place. The result was described as milligrams of Gallic acid (GA)/100 g on dry basis by the calibration curve \( y = 0.1162x + 0.0536, R^2 = 0.9917 \) of GA (concentration range from 5 to 50 mg/L).

**Measurement of Antioxidant Capacity (AOC).** DPPH was utilized to investigate the AOC of prepared fruit extract by the procedure proposed by Alothman et al. (2009). A 0.1 mL of quince fruit extract was mixed with a 3.9 mL 0.25 mM DPPH buffer solution and vortexed in 30 s (Velp Scientifica F202A0173, Italy) and incubated at 25°C for 30 min. Following the duration period, the absorbance of the mix was read at 515 nm (Mecasys Optizen Pop, Korean) and AOC of quince samples was demonstrated as \( \mu \text{mol Trolox equivalent (TE)} / \text{g} \) on dry basis that was calculated by the calibration curve \( y = 3464.8x + 10.3, R^2 = 0.9847 \) of trolox (0.1–1.0 mM).

**Statistical Data Analysis**

A factorial experiment \((4 \times 3): \text{temperature and HUS time}\) with a randomized complete design was used to analyze the effect of four different temperature levels \((50, 60, 70, \text{and } 80^\circ\text{C})\) and three different HUS pre-treatments \((0 \text{ or control, } 15 \text{ and } 30 \text{ min})\). Three replications for each treatment were used for all measurements, unless otherwise stated. Statistical analyses were managed using a randomized plots factorial experimental design. The results were analyzed using the JMP (Version 7.0, SAS Institute Inc., Cary, NC, USA). Differences among the mean values were obtained by Fisher’s least significant difference (LSD) test at \( \alpha = 0.05 \).

**Results**

**Aw, Shrinkage, and RR**

Aw which is in charge of chemical interactions identified as one of the major important quality parameters for dried food products especially for a long-term of storage (Quak et al., 2007). Table 2 displays the Aw in quince samples determined by convective-drying process and HUS pre-treatment. The CVD quince fruit pieces with no HUS pre-treatment exhibited significantly \( (P < .05) \) higher Aw in comparison with the CVD quince fruit slices with HUS pre-treatment (Table 2). CVD quince samples at 70°C with a 15 min HUS pre-treatment showed the lowest water activity \((0.36 \pm 0.02)\). Cavitation created by ultrasound waves is recognized as the reason for the occurrence of microscopic channels in the food products, which is the cause of the removal of moisture. Furthermore, it might be helpful to get rid of the water that is firmly adhered to the solid food materials exposed to ultrasound waves. Moreover, disruption of porous solid food materials occurred by ultrasound vibrations reduce the diffusion border layer and creates the convective mass movement in the food material because of the occurrence of microscopic channels (Piepho and Möhring, 2011). All in all, HUS pre-treatment on CVD quince samples has a favorable impact on Aw. The best condition was found as the combination of HUS pre-treatment (15 min) and convective drying at 70°C in terms of water activity.

With respect to the shrinkage ratio, CVD quince samples with no HUS pre-treatment shrank at a significantly \( (P < .05) \) higher than CVD quince fruit pieces with HUS pre-treatment (Table 2). There were no significant differences observed in the shrinkage ratios of the CVD quince samples with no pre-treatment \( (P > .05) \). Shrinkage of food products has an unfavorable development on the quality characteristics of the dried food. Customer has an adverse impression due to the differences in shape, loss of volume and increased hardness in dehydrated food materials (Mujumdar, 2014). The use of HUS pre-treatment (15 and 30 min) has a significant effect on shrinkage ratio of the quince samples. It
was determined that the quince samples exposed to 15 min HUS pre-treatment shrank significantly (P < .05) less than 30 min HUS-treated quince samples especially when combined with convective drying at 70°C. Briefly, applying HUS as a pre-treatment on CVD quince samples has a positive impact on the shrinkage and the best condition was found as the combination of HUS pre-treatment (15 min) and convective drying at 70°C in terms of shrinkage.

The RR obtained for the CVD quince samples are shown in Table 2. The higher RR values are desired for improved quality of dried food materials. As demonstrated in Table 2, RR of CVD quince samples exposed to HUS pre-treatment were significantly (P < .05) higher than that in CVD quince samples with no HUS pre-treatment, indicating that the CVD quince samples exposed to HUS pre-treatment were easy to get back closely to the fresh condition by rehydrating process. It was proven that the sponge effect created by ultrasound phenomenon might be the reason of the production of microscopic channels in porous food crops, for example; fruits, which lessen the diffusion border layers and rises the convective mass movement in the food product (De la Fuente-blancos et al., 2006).

The potential explanation was that enhanced porous form and higher cell membrane permeability were structured in the CVD quince samples exposed to HUS application. CVD quince samples with HUS pre-treatment rehydrate rapidly and more completely. The findings of current work are in a good agreement with those of Nahimana et al. (2011) who clarified that lower rehydration ratios of CVD carrot pieces are induced mostly because of the product shrinkage resulting in a less porous and unchangeable cellular fracture, displacement, and case of hardening of cell integrity. It is anticipated that dried food materials exposed to HUS pre-treatment should have enhanced rehydration ratios. For untreated sea cucumber plants, collagen fibers stiffen and shrink following drying process, which ended up with comparably poor rehydration. On the other hand, ultrasound pre-treatment right before the microwave freeze-drying process enhanced the rehydration capacity of dried sea cucumber plant (Duan et al., 2008). The improved rehydration capacity of dried mushroom plants by HUS pre-treatment was also reported in the study of Jambrak et al. (2007). Similar observations were collected by Stojanovic and Silva (2007) for rabbiteye blueberries exposed to HUS pre-treatment. According to the results, it is apparent that the water gain is more obvious in CVD quince samples exposed to HUS pre-treatment than the CVD quince samples without HUS pre-treatment (Table 2). The higher rehydration and lower shrinkage values are desired for improved condition of CVD food materials.

### Table 2. Water activity, hardness, shrinkage, and rehydration ratio in quinces induced by convective drying and ultrasound pre-treatment.

| Treatments | Water activity (aw) | Shrinkage Ratio (%) | Hardness (N) | Rehydration Ratio (%) |
|------------|---------------------|----------------------|--------------|-----------------------|
| Fresh      | 0.88 ± 0.02a        | 3.07 ± 0.06 h        | 3.43 ± 0.08de |
| CVD5       | 0.57 ± 0.03bc       | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |
| CVD6       | 0.54 ± 0.01c        | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |
| CVD7       | 0.56 ± 0.02bc       | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |
| CVD8       | 0.58 ± 0.02b        | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |
| US1-CVD5   | 0.47 ± 0.02de       | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |
| US1-CVD6   | 0.44 ± 0.01e        | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |
| US1-CVD7   | 0.36 ± 0.02 g       | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |
| US1-CVD8   | 0.38 ± 0.02fg       | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |
| US2-CVD5   | 0.49 ± 0.02d        | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |
| US2-CVD6   | 0.46 ± 0.03de       | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |
| US2-CVD7   | 0.39 ± 0.02fg       | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |
| US2-CVD8   | 0.41 ± 0.03 f       | 3.43 ± 0.06ab       | 3.55 ± 0.05d  |

*Means superscript with different letters in the same column differ significantly (P < 0.05) (CVD5: CVD quince slices at 50°C with no pre-treatment; CVD6: CVD quince slices at 60°C with no pre-treatment; CVD7: CVD quince slices at 70°C with no pre-treatment; CVD8: CVD quince slices at 80°C with no pre-treatment; US1-CVD5: CVD quince slices at 50°C with 15 min US pre-treatment; US1-CVD6: CVD quince slices at 60°C with 15 min US pre-treatment; US1-CVD7: CVD quince slices at 70°C with 15 min US pre-treatment; US1-CVD8: CVD quince slices at 80°C with 15 min US pre-treatment; US2-CVD5: CVD quince slices at 50°C with 30 min US pre-treatment; US2-CVD6: CVD quince slices at 60°C with 30 min US pre-treatment; US2-CVD7: CVD quince slices at 70°C with 30 min US pre-treatment; US2-CVD8: CVD quince slices at 80°C with 30 min US pre-treatment)*
By considering the RR and SR in the quince samples, it might be concluded that HUS pre-treatment caused a significant improvement on the quality characteristics of CVD quince fruit slices. In overall, the best conditions were found to be a combination of 15 min HUS pre-treatment and convective drying at 70°C.

**Hardness**

Hardness is seen as one of the basic structural characteristics for dried food products. Fracture of dried food materials is a complicated case that is based largely on the compounds and the microstructure of food products (Soria et al., 2008). As demonstrated in Table 2, CVD quince samples with no HUS pre-treatment displayed a significantly ($P < .05$) higher hardness values than those in CVD quince samples with HUS pre-treatment. The CVD quince samples with no HUS pre-treatment exhibited the most condense and denser porous texture, which might be because of the highest shrinkage ratio of CVD quince samples (Table 2). Therefore, the highest fracture force in CVD quince samples was predicted by looking at the microstructure shrinkage. Textural characteristics of dried food materials are linked to the behaviors of the cellular matrix, solvable solid parts in the food tissue, diverse relationship with water and mechanic attributes of food materials. Hence, it is a fact that HUS application has a great influence on dried food materials. It was figured out that the higher of both ultrasonic amplitude and intensity caused an increase the hardness of the apple fruit pieces in the study of Brncic et al. (2010) about the structural attributes of infrared-dried apple fruit pieces exposed to HUS pre-treatment. It was pointed out that dehydrated sea cucumber plants subsequent to HUS application showed the lowest hardness and highest springiness in the study related to the dried sea cucumbers (Duan et al., 2008). The ultrasound-treated apple samples were identified as the softest (around 22% loss) in a research including the liable of apple samples to various pre-treatments prior to drying process (Deng and Zhao, 2008). Food products exposed to HUS pre-treatment exhibited the lower hardness most probably as a result of the damaging of the cell walls and advancement of water movement outside of the cells because of the liquid medium ultrasonic (Gabaldo’n-leyva et al., 2007). In overall, the best condition was found to be a combination of 15 min HUS pre-treatment and convective drying at 70 oC in terms of hardness.

**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 differences observed in the food materials. The color values of quince fruit pieces are tabulated in Table 3. Lightness values exhibited a significant change in quince fruit slices, where the HUS pre-treatment was employed. The color of a 15 min HUS pretreated dried quince pieces were lighter than those of CVD quince fruit pieces with no HUS pre-treatment (Table 3). Regarding redness, the CVD fruit pieces with no HUS application displayed a significant ($P < .05$) increase in redness index followed by HUS treated and untreated quince fruit pieces, subsequently. On the other hand, the highest yellowness value was observed for the CVD quince fruit pieces with no HUS pre-treatment (Table 3). In general, ΔE values of CVD quince fruit samples decreased in relation to the rise in drying temperatures, that closely followed the decrease in lightness values. CVD5 treatment displayed the highest ΔE. On the other hand, the lowest ΔE value was observed with US1-CVD7 treatment ($P < .05$). The C value is a good indication of the color saturation or intensity. With the comparison of the fresh quince fruit pieces, the C values of HUS pretreated CVD quince pieces were increased ($P < .05$), mainly due to the higher yellowness values. The $a_r$ values of the CVD quince pieces were significantly ($P < .05$) reduced compared to fresh sample, which clearly shows the more browning occurrence, especially in no HUS pre-treated CVD samples. Color is an important quality sign 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 (Konopacka and Plocharski, 2001). Browning is getting bad at higher drying
Table 3. Color parameters in quinces induced by convective drying and ultrasound pre-treatment.

| Treatments | L* | a* | b* | C | a° | Δε |
|------------|----|----|----|---|----|----|
| Fresh      | 76.25 ± 0.79a | 9.78 ± 0.73 j | 41.28 ± 0.72 l | 42.43 ± 0.72 m | 76.71 ± 0.98a | - |
| CVDS       | 57.90 ± 1.68i | 24.28 ± 1.01 c | 58.21 ± 0.62a | 63.07 ± 0.69a | 67.39 ± 0.88 g | 28.93 ± 0.69a |
| CVD6       | 60.37 ± 1.29 h | 26.86 ± 0.74a | 55.23 ± 0.71 c | 61.42 ± 0.66 c | 64.09 ± 0.73 j | 27.20 ± 1.08b |
| CVD7       | 64.04 ± 1.74fq | 24.62 ± 0.63 c | 54.06 ± 0.35d | 59.40 ± 0.38d | 65.55 ± 0.60i | 23.12 ± 1.21 c |
| CVD8       | 61.07 ± 0.67 h | 25.85 ± 0.70b | 56.47 ± 0.65b | 62.11 ± 0.51b | 65.44 ± 0.74i | 26.83 ± 0.63b |
| US1-CVD5   | 65.70 ± 0.70d | 18.73 ± 0.59 f | 48.25 ± 0.63 h | 51.76 ± 0.39i | 68.82 ± 0.77e | 15.51 ± 0.70 g |
| US1-CVD6   | 66.41 ± 1.14d | 16.28 ± 0.47 h | 45.33 ± 0.79 j | 48.17 ± 0.73k | 70.27 ± 0.68 c | 12.52 ± 0.97 h |
| US1-CVD7   | 70.61 ± 1.19b | 15.07 ± 0.33i | 44.08 ± 0.13k | 46.58 ± 0.15 l | 71.17 ± 0.39b | 8.26 ± 0.84i |
| US1-CVD8   | 67.69 ± 1.02c | 17.21 ± 0.39g | 46.72 ± 0.62i | 49.79 ± 0.60 j | 69.81 ± 0.49 cd | 12.61 ± 0.66 h |
| US2-CVD5   | 63.21 ± 0.86g | 22.40 ± 0.80d | 51.60 ± 0.37e | 56.26 ± 0.55f | 66.57 ± 0.70 h | 20.90 ± 0.71d |
| US2-CVD6   | 65.54 ± 0.87de | 18.49 ± 0.54 f | 49.44 ± 0.38 g | 52.78 ± 0.25 g | 69.53 ± 0.62d | 16.05 ± 0.68fg |
| US2-CVD7   | 64.28 ± 1.10 f | 19.57 ± 0.37e | 48.43 ± 0.48 h | 52.23 ± 0.36 h | 68.03 ± 0.53 f | 17.06 ± 0.69e |
| US2-CVD8   | 64.69 ± 0.99ef | 17.15 ± 0.59 g | 50.78 ± 0.26 f | 53.60 ± 0.34 f | 71.37 ± 0.59b | 16.71 ± 0.70ef |

*Means superscript with different letters in the same column differ significantly (P < 0.05) (CVDS: CVD quince slices at 50 °C with no pre-treatment; CVD 6: CVD quince slices at 60 °C with no pre-treatment; CVD 7: CVD quince slices at 70 °C with no pre-treatment; CVD 8: CVD quince slices at 80 °C with no pre-treatment; US1-CVD5: CVD quince slices at 50 °C with 15 min US pre-treatment; US1-CVD6: CVD quince slices at 60 °C with 15 min US pre-treatment; US1-CVD7: CVD quince slices at 70 °C with 15 min US pre-treatment; US1-CVD8: CVD quince slices at 80 °C with 15 min US pre-treatment; US2-CVD5: CVD quince slices at 50 °C with 30 min US pre-treatment; US2-CVD6: CVD quince slices at 60 °C with 30 min US pre-treatment; US2-CVD7: CVD quince slices at 70 °C with 30 min US pre-treatment; US2-CVD8: CVD quince slices at 80 °C with 30 min US pre-treatment).

degrees. At that point, it might be discussed that HUS pre-treatment could be helpful for retaining color of dried food materials because of its potential to be employed at ambient temperature and damaging the enzymes in charge of browning activity. It was recognized that blanching and ultrasound applications employed 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 Zhao (2008) pointed out that HUS application displayed the biggest 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 vacuum and agitation. This could arise from the fact that HUS application causes physiological deformation and membrane destruction of the cell, which enables to simpler elimination of pigments from apple fruit tissue. Stojanovic and Silva (2007) announced the similar findings for rabbiteye blueberries. High-intensity ultrasound is described as more convenient application with regard to removing H₂O and preserving color of apple fruit pieces which provides the better quality and longer shelf life of dried food materials (Deng and Zhao, 2008). From that way of thinking, dried quince samples with HUS application is satisfying as they are resulted in lighter food product color and closest color parameters to the fresh quince fruit pieces.

**Bioactive Compounds**

The changes in antioxidant capacity of CVD quince fruit pieces are demonstrated in Figure 1. A significant (P < .05) loss in AOC in each and every dried quince fruit pieces was obtained. The AOC of fresh quince pieces was found out as 10.24 μmol TE/g on dry basis. On the other hand, the AOC was determined between 2.58 and 7.08 μmol TE/g for the CVD quince fruit pieces with and without HUS pre-treatment. While the lowest AOC was described for CVD quince fruit samples at 50°C with no HUS (2.58 μmol TE/g dry-weight), the highest AOC was determined for the CVD quince fruit pieces exposed to HUS pretreatment for 15 min at 70°C (7.08 μmol TE/g on dry basis). Larrauri et al. (1997) also identified the decrease in the AOC of dried red grape fruit compared to the fresh samples. The decline in AOC can correspond to a lower quantity of phenolic substances. In various research, it was announced that there is a direct connection between a total phenols and AOC in many fruits and vegetables, for instance lime and carrot (Duh et al., 1999), apricot (Sultana et al., 2012), red pepper (Zhou et al., 2016), pomelo (Yildiz and Izli, 2019a), kumquat (Izli et al., 2018) and quince (Yildiz and Izli, 2019b). Kanner et al. (1994) figured out that
the higher AOC of food stuff can be linked to the synergetic effect of natural phenolic components. In present study, it was also observed the synergetic effect between TPC and AOC. While the CVD quince fruit pieces showed the both lower TPC and AOC, the fresh quince fruit pieces displayed the highest TPC and AOC (Figure 1).

Figure 1 exhibits the ascorbic acid content of CVD quince fruit pieces with and without HUS pre-treatment. Vitamin C in CVD quince fruit pieces exposed to HUS application was evidently higher than CVD quince fruit pieces with no HUS pre-treatment (Figure 1). Among the HUS pre-treated quince fruit pieces, the highest Vitamin C content was found for the CVD quince fruit pieces at 70°C with 15 min HUS application (43.79 mg/100 g on dry weight). It might be stated that HUS application was favorable for the Vitamin C preservation in the convective drying application. It can be suggested to dry several food products with HUS pre-treatment.

Phenolic substances are bioactive metabolites in fruits and vegetables which contribute to sensorial (taste, flavor, color etc.) and functional (i.e., antioxidant, antidiabetic, and anticancer activities) attributes of food products (Fernandes et al., 2008). Drying process may diminish nutrients in fruits and vegetables because of both long drying periods and high temperatures (Fernandes et al., 2008). In accordance with the statistics, the total phenolic substances of quince fruit pieces was significantly affected by the HUS pre-treatment and drying process (Figure 1). The total phenolic contents of CVD quince fruit pieces exposed to HUS pre-treatment were significantly higher in contrast to those which were treated by means of no HUS (Figure 1). Because of the phenolics are related to the color, taste, and nutritive quality of food stuffs, its existence is a fundamental biological attribute. Similar to the AOC, a significant ($P < .05$) loss in the total phenolic substances was detected in the CVD quince fruit pieces compared to the untreated quince fruit pieces (Figure 1). The reduction in the TPC of dried quince pieces could be related to the decomposition of heat liable phenolics. 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 length at ambient degrees while pursuing the natural flavor, color, and heat-sensible nutritive components. Opalic’ et al. (2009) pointed out that extended HUS application leads to a decrease in total phenols & flavonoids in addition to the AOC of dried apple fruit pieces. In the same research, it was announced that apple fruit pieces exposed to longer HUS application were resulted in less favorable sensorial properties. The sugar content and bioactive components of dried apple fruit pieces were decreased as well. Similar to this work, CVD quince fruit pieces exposed to the longest HUS pre-treatment (30 min) had shown a lower TPC, whereas the CVD quince fruit pieces exposed to shorter HUS pre-treatment (15 min) had shown the highest TPC in recent work.
Conclusion

Pre-treatments can be applied before drying process to minimize adverse changes during drying and subsequent storage. It might even shorter the drying period which decrease the cost of the drying application. HUS treatment displays a favorable outcome in the quality retention of CVD quince samples since it can be applied at ambient degrees. This work is important to show a good potential of HUS treatment on dried fruit tissue comprehensively including physical properties, texture, and bioactive compounds. In overall, drying of quince slices with a convective drying in addition to HUS treatment can be used to acquire a high-quality food product with enhanced bioactive compounds and improved physical properties.

Abbreviations

HUS: High-intensity ultrasound
CVD: Convective-drying
AOC: Antioxidant capacity
SR: Shrinkage ratio
RR: Rehydration ratio
Total phenolic content: TPC
CVD5: CVD quince slices at 50°C with no pre-treatment
CVD6: CVD quince slices at 60°C with no pre-treatment
CVD7: CVD quince slices at 70°C with no pre-treatment
CVD8: CVD quince slices at 80°C with no pre-treatment
USD1-CVD5: CVD quince slices at 50°C with 15 min US pre-treatment
USD1-CVD6: CVD quince slices at 60°C with 15 min US pre-treatment
USD1-CVD7: CVD quince slices at 70°C with 15 min US pre-treatment
USD1-CVD8: CVD quince slices at 80°C with 15 min US pre-treatment
USD2-CVD5: CVD quince slices at 50°C with 30 min US pre-treatment
USD2-CVD6: CVD quince slices at 60°C with 30 min US pre-treatment
USD2-CVD7: CVD quince slices at 70°C with 30 min US pre-treatment
USD2-CVD8: CVD quince slices at 80°C with 30 min US pre-treatment

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