

UDC: [66.093.48.084.8:547.56]:634.14:641.522.9

## EFFECT OF ULTRASOUND AND ACID PRETREATMENTS DURING DEHYDRATION ON QUALITY PROPERTIES OF QUINCE

DOI: <https://doi.org/10.15673/fst.v14i4.1893>Master graduated **Article history**

Received 20.06.2020

Reviewed 22.07.2020

Revised 25.10.2020

Approved 08.12.2020

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Sohrabpour S, Yadegari M, Kenari RE. Effect of ultrasound and acid pretreatments during dehydration on quality properties of quince. Food science and technology. 2020;14(4):88-97. DOI:

<https://doi.org/10.15673/fst.v14i4.1893>

**Цитування згідно ДСТУ 8302:2015**

Sohrabpour S., Yadegari M., Kenari R.E. Effect of ultrasound and acid pretreatments during dehydration on quality properties of quince // Food science and technology. 2020. Vol. 14, Issue 4. P. 88-97 DOI: <https://doi.org/10.15673/fst.v14i4.1893>

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### Introduction. Formulation of the problem

Quince, a fruit from the Rosacea family, is cultivated as a plant with medicinal and nutritional values in Central Europe, the Middle East, and South Africa [1]. This plant has been used as an herbal medicine for treating a variety of diseases, has a high nutrient content, has a positive impact on human health and is effective for treatment of dysentery [2]. According to the report of the council of FAO (2011), the production rate of this fruit in Iran was 35,430 tons while its global production rate was 559,765 tons in 2011 [3]. Turkey is a prominent country in cultivating quince in the world (Kaya et al., 2007). To meet a variety of industrial purposes, several methods have been used to remove the moisture from products. Among the various methods, convective drying is one of the most common ones used extensively to

dehydrate foods to meet preservation, transportation, and storage purposes [4]. Hot air-dryers are far quicker than other devices provide greater uniformity and higher sanitary level, and are inevitable in industrial food drying processes [5]. Although traditional methods that employ a forced stream of hot air for desiccation or dehydration of food products are rationally cost-effective, they take a reasonably longer time to do so. Furthermore, the product may be damaged at high temperatures. Alternative methods can possibly eliminate the mentioned drawbacks.

### Analysis of recent research and publications

Ultrasound as a pre-treatment can be used to modify the fruit tissue structure or reduce the initial water content in a way that the air-drying time becomes shorter. The ultrasound involves the immersion of the fruit in water or a hypertonic aqueous

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**Abstract.** Several methods are employed to remove the moisture from organic or non-organic materials, in a variety of industrial applications. Among all, dehydration of fruits is an alternative to decline post-harvest loss of fruits and also a process to produce dried fruits, which can be directly consumed or become part of foodstuffs like cakes, and many others. In particular, drying provokes a series of changes in materials, such as oxidation, browning, or loss of nutritional-functional properties. Ultrasound is famous to have a significant effect on the rate of various processes. Quince is a fruit which is rich in polyphenols, organic acids, and amino acids with important health benefits. The present study examined the effect of ultrasound and blanching pretreatments prior to convective drying on quality properties of dehydrated quince slices. A completely randomized design was used to address the effect of time of sonication (10–30 min), temperature (40–60°C), and anti-browning agents including acetic, citric, and ascorbic acids as well as distilled water on quality properties of dehydrated quince slices. The obtained results revealed that the shortest drying time (270.33±35.59 min) and the highest total phenolic content (57.29±12.72 mg GAE/ml) were recorded for samples exposed to the ascorbic acid solution. Comparison of the pre-treated and control samples indicated that the highest rehydration ratio (2.75±0.29 %) was achieved by blanched samples in acetic acid solution. The use of citric acid solution led to the highest score in the taste (3.45±1.1), color (3.84±0.9), and texture (3.47±1.02) of quince slices on the basis of a 5-point hedonic scale. The obtained results depended on both ultrasound and the type of blanching solution. Citric and acetic acid samples indicated the highest values of the sensory evaluation and water loss, respectively.

**Keywords:** acid, blanching, dehydration, sensorial properties, total phenolic, quince, ultrasound.

solution to which ultrasound is applied. In case of selecting distilled water as the liquid medium, the ultrasonic treatment will not incorporate soluble solids into the fruit sample as it may result in the change of the natural fruit taste. The forces involved in this mechanical mechanism can be higher than the surface tension, which can lead to the maintenance of the moisture inside the capillaries of the fruit creating microscopic channels that may increase water loss. Deformation of spongy solid materials such as fruits that is caused by ultrasonic waves takes the responsibility for the creation of microscopic channels, which result in the reduction of the diffusion boundary layer and the increase of the mass transfer in the fruits. Ultrasound provides some benefits in terms of productivity, yield, selectivity, increased quality, better processing time, lower physical and chemical risks, and more environment-friendly processes [6].

The effect of ultrasonic intensity during the drying process has been proved to be largely dependent on the product characteristics and process variables including the temperature, air velocity, and applied acoustic power. According to the available reports, a minimum ultrasonic power must be applied to obtain a noteworthy effect of ultrasound [7]. As a pre-treatment drying, ultrasound has different effects on various fruits. Further studies are required to investigate the effect of this green technology on drying process to discover which type of fruits and vegetables further benefit from this technology [8]. Application of this technology as a pre-treatment prevents the loss of fruit color by inactivating enzymes, reduces the length of drying time by relaxing tissue structure, and leads to production of a high quality dried product.

One of the pre-treatment methods before drying vegetables and fruits is blanching with steam or hot water [5]. Blanching may result in some unwanted softening of the tissues. Therefore, instead of blanching and heating, chemical additives including antioxidants and enzymatic inhibitors such as citric, acetic, ascorbic acids can be used to prevent enzymatic browning [9]. These compounds can also inhibit enzyme activity by reducing pH and/or copper chelators in polyphenol oxidase, both of which involve oxidation as their key process [10].

This study examined the use of ultrasound and blanching as two effective pre-treatments before air-drying of Quince. The effect of time spent on water loss, rehydration, and other properties in ultrasound was examined.

**The purpose** of this project was investigating the impact of ultrasound and acid pre-treatments on the quality properties of dehydrated quince slices prior to convective drying.

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#### Research materials and methods

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*Materials.* Acetic, citric and ascorbic acids were purchased from Merck (Germany).

*Sample preparation*

The quinces were purchased from a local market in Sari, Mazandaran, Iran. Fresh fruits were refrigerated until used. Tap water was used for washing, peeling, and slicing quinces manually before performing the main process. The thickness of the slices was 5 mm. The samples were immersed in a blanching solution and submitted to ultrasound. Then, they were placed on a monolayer tray and put into the dryer. The samples were pretreated with various solutions to inactivate enzymes.

#### *Ultrasound pretreatment*

An experimental set of 12 quince samples was immersed in distilled water and then submitted to ultrasonic waves for 10, 20, and 30 min at 40, 50, and 60°C temperatures, respectively. The experiments were also carried out by immersing 12 quince slices in acetic, citric, and ascorbic acid solutions (all with 1.5% concentration) and subjected to acoustic waves for the same exposure time and at the same temperature in an ultrasonic bath (P 120 H, Elmasonic, Germany). No mechanical agitation was used in this study. The frequency of ultrasound in this study was 35 kHz. In this procedure, the ultrasonic bath was filled with a liquid medium with a volume of 1.5 L. The treatment of the liquid medium was measured regularly after turning on the supplies until it reaches [11]. To increase the effect of acoustic waves on the quince slices, the samples were immersed in the liquid medium directly without using an Erlenmeyer flask.

#### *Blanching pre-treatment*

In this study, instead of blanching with hot water or steam, chemical additives were used to prevent enzymatic browning. Distilled water as well as acetic, citric, and ascorbic acid (all with 1.5% concentration) was used as anti-browning agents [5].

#### *Air-drying*

A forced circulation air-drying oven (UFE 500, Memmert and Schwabach, Germany) was used in the drying process of quince slices. After immersing the samples into the blanching agents and subjecting them to the acoustic waves of ultrasound, pre-treated quince slices were blotted with a towel and put into the dryer on a tray. The untreated samples were also sliced and transferred into the dryer. The convection dryer was set at 65°C. A digital balance (0.01) was used to measure the weighing changes during the drying process until a constant weight was reached, and then the samples were kept in a desiccator until used [12].

#### *Rehydration ratio*

In order to evaluate rehydrate ratio of samples, the dried quince slices, the samples were immersed in distilled water for 2 hours according to the reported method by Esmarilli et al. [13]. The ratio of the sample to water was 1 to 10. After passing the mentioned time, the samples were dried with the towel and then weighted utilizing a digital balance. The rehydrating rate was calculated as the ratio of the mass of dehydrated quince to the mass of dried quince:

*Total phenolic content*

Folin-Ciocalteu method described by Delfanian et al. was followed with slight modifications to determine the total phenolic (TP) content in the present study [14]. To do so, 0.5 gr of milled dried quinces was mixed with 2.5 ml of 10-fold diluted Folin-Ciocalteu reagent and 2 ml of 7.5% sodium carbonate. Then, the mixture was shaken for 1 min and allowed to stand at room temperature for 30 min. Finally, the absorbance was read at 765 nm using a spectrophotometer (Analytik Jena, spekol2000, Germany). The measurements were carried out in triplicate. The reference phenol in this study was a gallic acid (GA) calibration curve, which was traced by methanol at the concentration range of 0.04–0.4 mgGAE/ml.

**Moisture content.** To determine the moisture content of the products, the samples were first placed in an oven at 105 °C for 12 h, and then the moisture content was calculated using the following equation:

$$\text{Moister} = \frac{M_1 - M_2}{M_0}, \% \quad (1)$$

Where  $M_0$  is the weight of quince slices (sample) (g),  $M_1$  is the weight of the container and the sample before drying (g), and  $M_2$  is the weight of the container and the sample after drying (g).

#### Color evaluations

The color values of quince slices samples were determined by using a Konica Minolta (CR-400, Osaka, Japan) that is equipped with illuminant D65 and 8 mm measuring area in the CIE  $L^*$   $a^*$   $b^*$  color scale. Color values were defined in a three-dimensional  $L^*$ ,  $a^*$ , and  $b^*$  color space, where  $L^*$  represents the lightness / darkness of the sample,  $a^*$  indicates the redness / greenness, and  $b^*$  shows the yellowness / blueness [15].

#### Sensory evaluations

The sensory evaluation was performed by 20 trained panelists using the 5-point hedonic scale to compare the color, taste, and texture of the products [12].

#### Statistical analysis

Analysis of Variance (ANOVA) and Duncan's multiple range tests were performed using SPSS software (version 21.0). The level of significance was set at  $p < 0.05$ .

### Results of the research and their discussion

**Drying time.** Employing ultrasound due to its effect of contraction and dilatation series is beneficial in evaporating the water of raw materials to the surrounding environment [16]. Applying ultrasound as a pre-treatment resulted in reduced time of the drying process of quince slices. The shortest and the longest drying times were recorded for the samples exposed to ascorbic acid and the untreated samples, respectively ( $270.33 \pm 35.95$  min,  $479 \pm 0.57$  min). The length of the drying process for samples subjected to ultrasound treatment using ascorbic acid, citric acid, and distilled water as anti-browning agents was  $282.93 \pm 39.09$  min,  $293.59 \pm 22.69$  min,  $323.25 \pm 25.25$  min, respectively.

Doymaz (2010) reported that the citric acid pre-treatments affects the drying time. Pre-treated samples with citric acid solution had a shorter drying time compared to blanch and control samples [5]. Ultrasound can be helpful by generating cavitation, which is one of the most important phenomena that can be used for removal of water from materials with strongly-attached moisture. In addition, ultrasound has some other noticeable impacts including different viscosity, surface tension, and destruction of cells in raw materials. The latest impact is responsible for making microscopic channels that increase mass transfer in food products [12]. Fernandes et al. reported an 11% reduction in the overall drying time due to the application of ultrasound as a pre-treatment [17]. The same finding was reported by Romero et al for apple cubes [18]. Fabiano et al reported the fruit submitted to ultrasound pre-treatment will dry faster during the air drying stage if compared to the fresh fruit with no pretreatment [19]. Ultrasound enhance the drying rate by altering micro-structure of plant tissue [20,21,22], and improve quality of products by shortening drying time [23]. Moreover, Fuente-Blanco et al confirms that the ultrasonic pre-treatment affects the fruit tissue making easier for water to diffuse during air-drying, most probably due to the formation of microscopic channels in the structure of fruit [12]. For instant, ultrasound treatment lead to breakdown of cells in carrots, and longer ultrasound treatment time resulted in greater structure destruction of carrot [16]. The ultrasound pretreatment reduced the drying time in comparison to untreated apple cubes. Tao & Sun showed that, the drying kinetic increases with the increase of acoustic intensity within certain limits, the ultrasonic efficiency is related to acoustic intensity [21].

As it is indicated in the results, there is a significant difference between the drying time of all treated and untreated samples. Fig.1 compares the effect of ultrasound and blanching solutions on all samples.

**Rehydration.** Rehydration ratio is a quality parameter for dried sample. It indicates the physical and chemical changes during drying as affected by processing conditions, sample pre-treatment and sample composition [24].

The rehydration ratio of blanched samples resulted in the highest rehydration, compared to pre-treated with control samples. The rehydration ratio of blanched samples with acetic acid resulted in the highest rehydration ratio ( $2.75 \pm 0.29$ ) as compared to all other pre-treated and control samples which were  $2.8 \pm 0.7$ ,  $3.02 \pm 0.4$ ;  $3.05 \pm 0.25$ ;  $3.04 \pm 0.22$  for control, citric acid, ascorbic acid, and distilled water samples, respectively. Doymaz reported that samples immersed in citric acid as blanching solution had indicated the highest rehydration ratio in *Amasya* red apples [5]. Similar results have been reported for water chestnut [25]. Fig.2 represents the significant difference between the samples and the rehydration ratio of all treated and untreated samples, respectively.

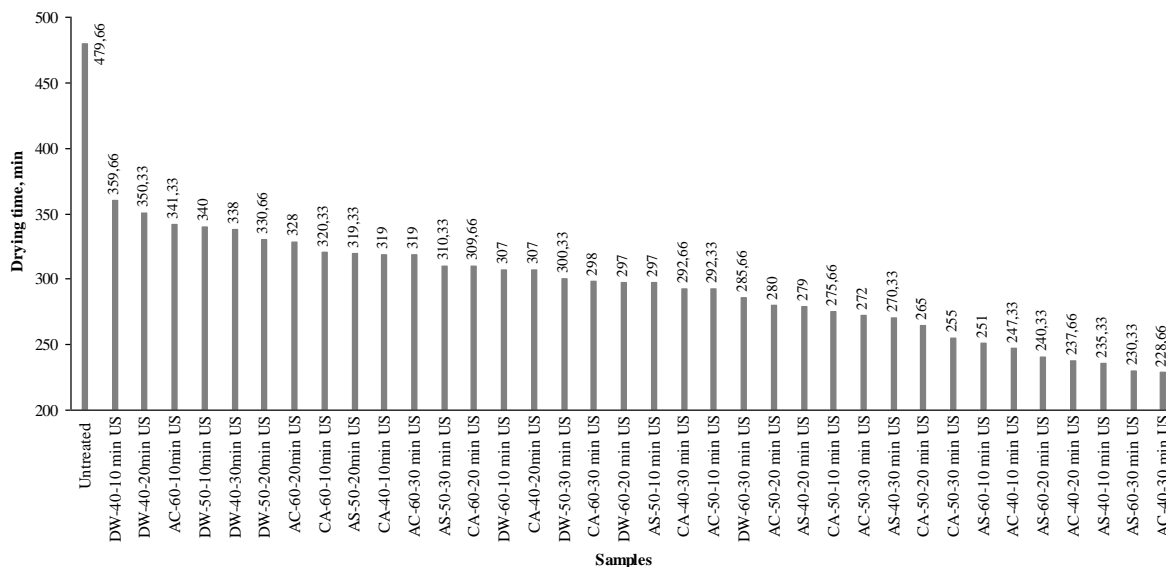


Fig. 1. Drying time of different samples

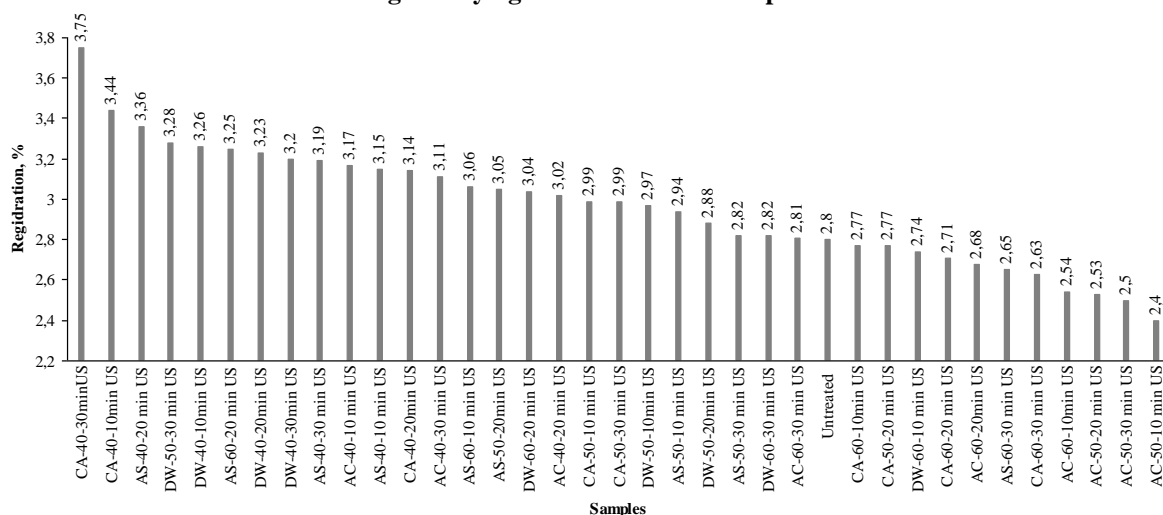


Fig. 2. Rehydration rate of different samples

US dried products should have improved rehydration capacity. Yildi and Izli reported that rehydration rate of quinces samples treated with ultrasound higher than untreated samples, showing that ultrasonically pretreated samples were easier to recover by rehydration. It is due to better porous structure and higher cell membranes permeability were formed in the samples with US treatment [15]. Similar results were collected by Stojanovic and Silva [26] for rabbiteye blueberries treated with US and by Jambrak et al. [27] for drying of mushrooms.

#### Total phenolic content

The components responsible for creating flavors and fruity taste are phenolic compounds, which also increase the antioxidant power of the materials [28].

Drying with long times and high temperature can cause nutrient loss in fruits. Phenolics are secondary metabolites which attribute to sensory (i.e., taste,

flavor, and color) and functional (antioxidant, antidiabetic and anticancer activity.) properties [29].

Adding anti-browning agents affected the concentration of phenolic compounds in quince slices as compared to untreated samples (Fig.3). The obtained results revealed the highest amount of TP content in ascorbic acid pre-treatment samples ( $57.29 \pm 12.72$  mg GAE/ml) while samples immersed in citric acid had the lowest amount of TP content ( $45.43 \pm 7.35$  mg GAE/ml). Mieszczakowska- Frać et al demonstrated that the ultrasound pretreatment modified the tissue structure of apple, which caused high loss of polyphenol, monomeric, hydroxycinnamic acids and dihydrochalcones [30]. Siucinska et al also observed that ultrasound pretreatment decreased the anthocyanin content of sour cherries and antioxidant capacity deterioration rate was higher, while the antioxidant capacity deterioration rate of non-sonicated sample was lower [31].

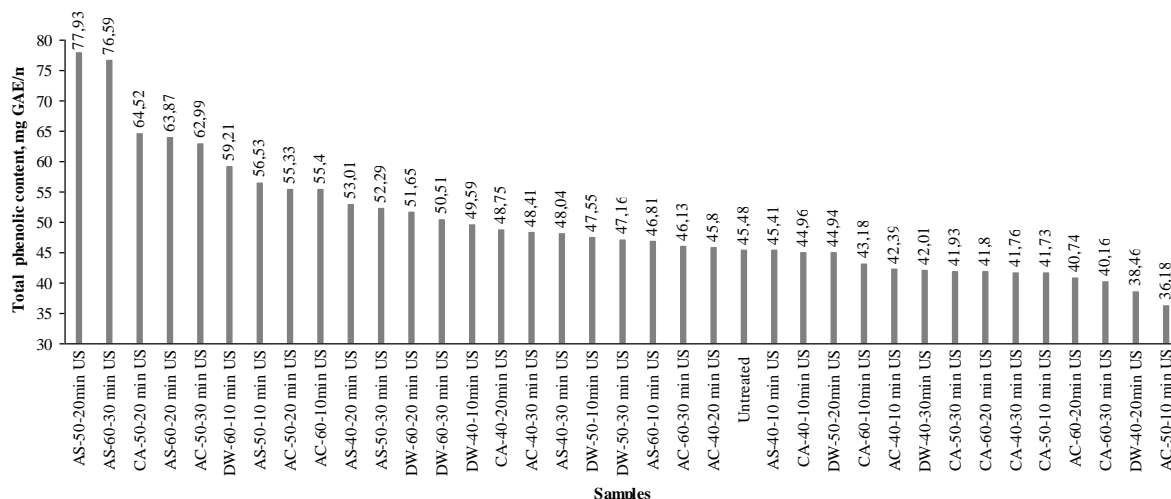


Fig. 3. Total phenolic content of different samples

Similar results was observed by Stojanovic and Silva when they pretreated blueberries [26]. Opalic et al. (2009) proposed that prolonged ultrasound treatment causes a reduction in total phenol and flavonoid of dried apples [32].

The structural damages of plant tissue simultaneously lead to decrease the phytochemicals content in products, as lacking of a barrier in the form of a compact layer of cells on the surface contributed, and then facilitating leakage of bioactive compounds from internal matrix to the external solution [30,33,34].

**Color evaluation.** Color is one of the most important quality properties of foods. Fig.4 indicate the significant difference among the samples, “L”, “a”, and “b” factors of color evaluation of samples ( $p < .05$ ). Where the ultrasound treated samples were lighter than those of quinces with no pretreatment.

Regarding  $a^*$  (redness), the quince samples with

The highest  $b^*$  value was obtained for the

The sample was lighter product color and closest color values to the fresh sample as well compared to other treatments.

Deng and Zhao observed that ultrasound pretreatment showed the highest  $L^*$  value in treated apples compared to other treatments. They are concluded that ultrasound leads to physical destruction and membrane deformation of the cells, which provides to easier elimination of pigments from apple tissues. Ultrasound is suitable for removing water and preserving color of apples [35]. Stojanovic and Silva reported similar results for rabbiteye blueberries [26].

Thermal blanching, such as hot water and steam inactivate the enzymes responsible of off-flavors and color [36]. During drying, color is deteriorated by enzymatic and non-enzymatic browning. Polyphenol oxidase (PPO) and peroxidase (POD) are responsible for enzymatic browning. Non-enzymatic browning includes a wide number of reactions such as maillard reaction, caramelisation, chemical oxidation of phenols, and maderisation [37].

During the drying process, phenolic compounds change to quinones as a result of being exposed to oxygen and oxidizing phenolic compounds. In enzymatic reaction, polyphenol oxidase affects phenolic compounds and changes them to slightly colored o-quinones. Utilizing heat to inactivate enzymes can be harmful to the tissue of materials and can lead to undesired softening. In order to reduce thermal harms in food materials during inactivating PPO (as an effective material in enzyme browning), using some chemical additives such as citric, acetic, ascorbic acids are preferable [38].

There are two inhibiting mechanisms, namely reducing pH and chelating copper as a cofactor in products [10]. The mentioned study also revealed the same result was obtained for lettuce. The low rate of degradation was obtained as a result of using ascorbic acid in this study. According to researches a reducing agent like ascorbic acid solution is not able to inactivate polyphenol oxidase and can only reduce o-quinones formed by the enzyme to diphenol to prevent browning during the drying process [39].

**Moisture content.** Fresh fruits and vegetables are perishable foods due to their high moisture content and tender texture. Drying is one of the most common preservation methods for extending the shelf life of fruits and vegetables by reducing the moisture content to prevent the growth of microorganisms and inactivate many reactions [39,40].

At the end of the ultrasonic pre-treatment little change was observed in the moisture content of the quince. As it is expressed in Fig.5, quince slices exposed to an acetic acid solution indicated the highest amount of water loss ( $88.06\% \pm 2.38$ ). Furthermore, the lowest amount of water loss was observed for control samples ( $71.8\% \pm 1.51$ ). The mentioned finding can be attributed to the cavitation effect of acoustic waves. Several studies have confirmed that ultrasonic wave pretreatment could increase the effective diffusivity of water in the plant tissues, and reduce drying

time [41,23,17]. Fabiano et al showed that the banana slices submitted to ultrasonic pre-treatment lost soluble solids to the liquid medium [8]. Ultrasonic waves

enhance mass transfer by creating microscopic channels in solid material through fluctuation and cavitation effect that make the moisture transport easier [14].

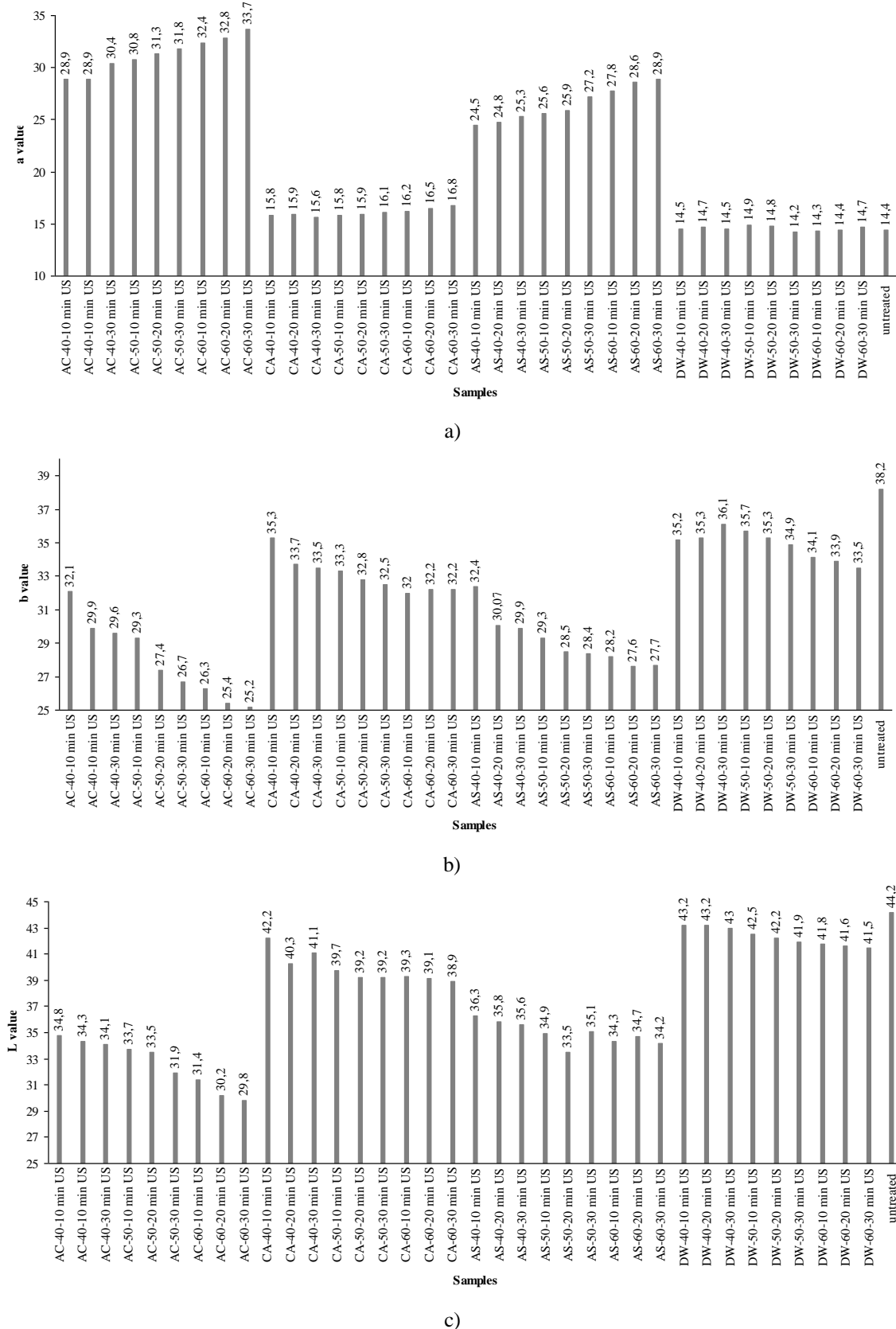


Fig. 4. Color values of different samples: a) a\*, b) b\*, c) L\*

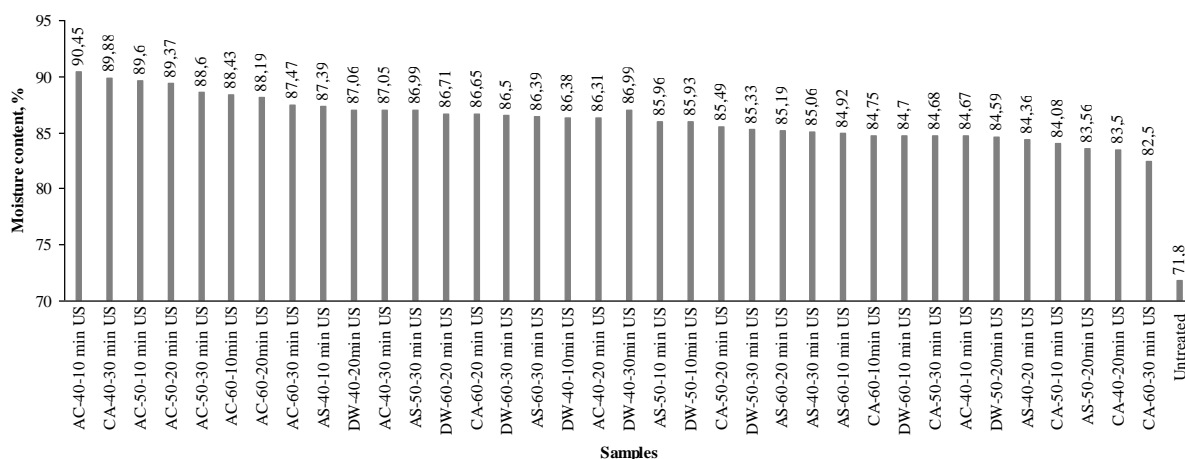


Fig. 5. Moisture content of different samples

**Sensory evaluation.** According to the results among all the treated samples, the use of citric acid solution got the highest value in taste ( $3.45 \pm 1.11$ ), color ( $3.84 \pm 0.9$ ), and texture ( $3.47 \pm 1.02$ ) by panelists on the basis of a 5-point hedonic scale. The taste of the dried quinces by the application of ultrasonic pre-treatment was more alike to the natural taste of the fruit (Fig. 6).

A better color maintaining and higher carotenoid contents was observed in dried carrots with ultrasound pretreatment [16]. Opalic et al reported that sensory characteristics; sugar content and bioactive compounds in apple samples were decreased with long ultrasound-pretreatment [32].

### Conclusion

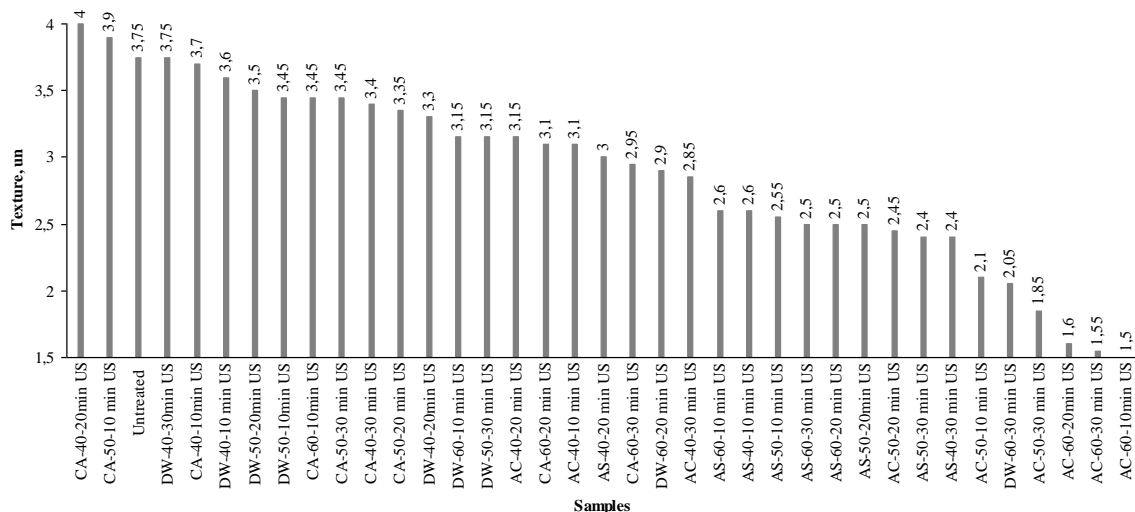
In the current study, the impact of the ultrasound and blanching was examined as a non-thermal pre-treatment procedures prior to convective drying on the quality properties of quince slices. The results proved that although air drying is known as one of the most commonly accepted methods for dehydrating vegetables and fruits, but applying other procedures and devices such as chemical additives (Which are effective additive in blanching and inactivation of enzymatic browning precursors) and ultrasound (as an efficient factor in both

heat and mass transfer in dehydration process), not only can minimize the total processing time, but also shorten the loss of fruit tissue integrity. Referring to the findings, the application of both pre-treatments had significant impact on water loss, rehydration, the quality of the product, as well as the duration of the process. Due to the quality loss of products in conventional thermal processing, application of chemical additives to inactive polyphenol oxidase is highly desirable. Besides, considering the merits like increasing the shelf-life of the product, better quality, lower process time, and being environmentally friendly, using ultrasound is an effective suggestion as well. Therefore, these two pre-treatment techniques can be promising substitutes to regular conventional thermal methods in food industries.

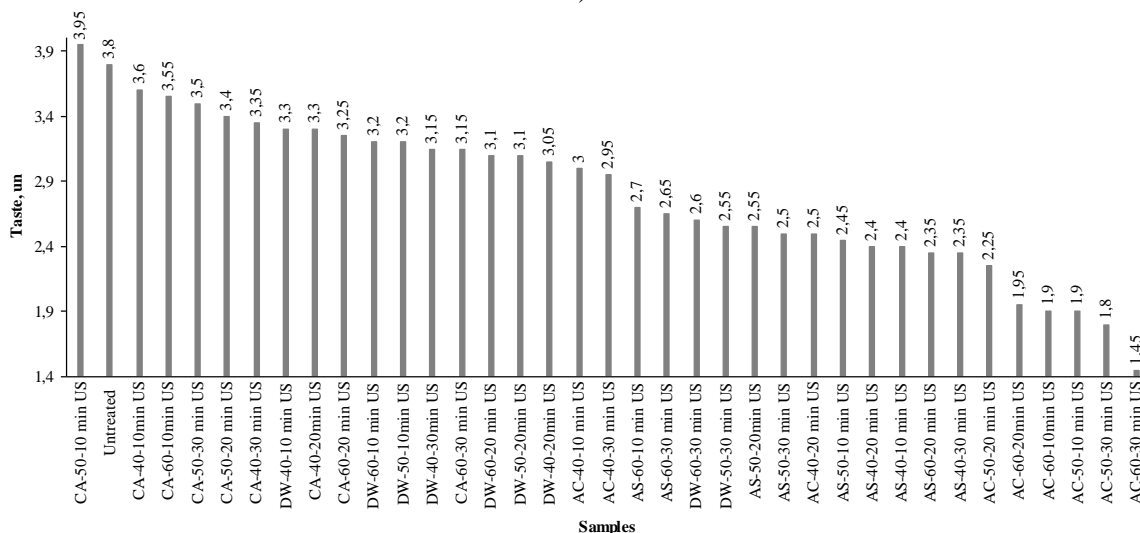
The application of pre-treatment ultrasound of quince and other fruits can be interesting to the food industry because requires simple equipment (a vessel and a vibrating plate) that can be worked in continuous mode at ambient conditions.

**Conflict Of Interest.** The authors have declared no conflicts of interest for this article.

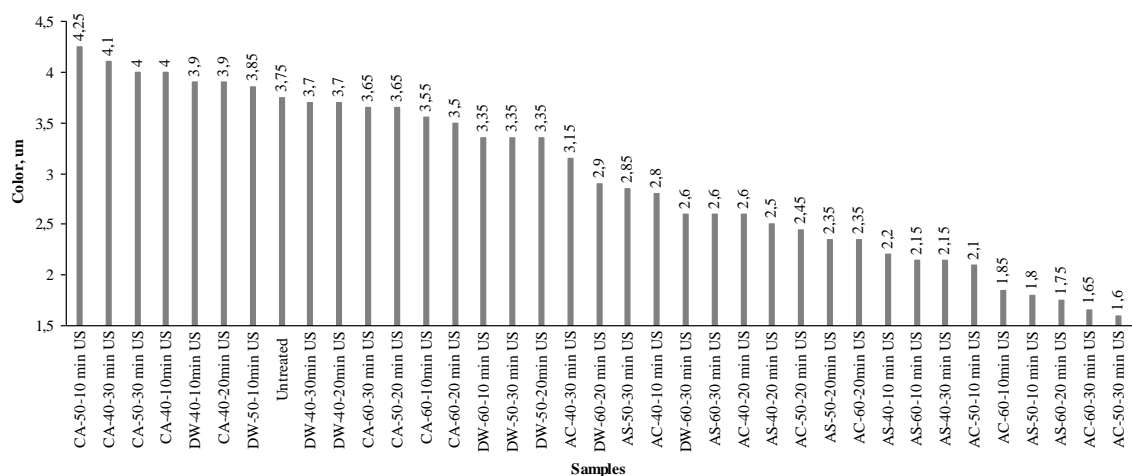
**Ethical Review.** This study was approved by the Institutional Review Board of Sari University of Agriculture and Natural Sources.



a)



b)



c)

Fig. 6. Sensory properties of different samples (a: texture, b: taste, c: color)

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