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Effect of Pretreatment Osmotic-ultrasonic on Quality Characteristics of Dried Quince

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Abstract

The effect of pretreatment osmotic-ultrasonic dehydration on the drying kinetic, rehydration kinetic, texture, shrinkage and color change of quince slices was investigated. Quince slices were osmotic-ultrasonic processed at 27.25 min for ultrasonic time, 120 min for osmotic dehydration and 50.52 % for sucrose concentration. The un-treated and pre-treated samples were then dehydrated at80°C. The effective diffusivity calculated by applying the Fick's diffusion model. The pretreatment caused a decrease in D_{eff}. Application of osmotic-ultrasonic dehydration reduced the sample hardness, color changes and shrinkage while it had increased the sample springiness, and chewiness.

Keywords: Color changes, Drying and Rehydration kinetic, Osmotic-ultrasonic dehydration, Quince, Shrinkage, Texture

Introduction

Fruits and vegetables play an important role in human diet and nutrition but are highly perishable due to their high moisture content. Decreasing the moisture content of fresh foods to make them less perishable is a simple way to preserve these foods. Drying is one of the oldest and most cost-effective means of preservation of the vegetables and fruits. Using dehydrated products in many processed or ready-to-eat foods as replacement of fresh foods has several vantages such as convenience in transportation, storage and preparation(Lewicki, *et al.*, 1998, Mazza and LeMaguer 1980, Lewicki 1998).From energy and the environmental points of view as well as the global requirement regarding the improvement in the food supply for the growing human population, it is important that drying technology be enhanced in order to reduce spoilage and thus contribute to a higher quality of dried products. Thus, there is a need to modify the drying method so as to limit its adverse influence, especially on flavor, color, nutrients and fruit tissue. One possible solution is to apply osmotic dehydration, which involves the immersion of fruit in osmotic solution resulting in the removal of water from tissue, and replacing it with soluble solids (Fernandes and Rodrigues 2007, Azoubel, *et al.*, 2009). Among emergent new technologies, ultrasonic is an encouraging process which is commonly regarded as a non-thermal process such processes is favorable because of reduction in food degradation. No liquid phase change will occur in this process for water removal. Complementary treatments such as hot air or vacuum drying may be applied to previously osmotic-ultrasonic fruit or vegetable to produce an intermediate moisture food product. Intermediate moisture fruit products are developed to preserve quality characteristics such as color, flavor, appearance, and texture as close as possible to their fresh counterparts.

Quince is a very ancient and delicious fruit. Iran is one of the leading countries of quince production in the world. Dried quinces are used to make jam, marmalade and jelly, as well as quince pudding. Additionally, dried quince can be used as ingredients of traditional Iranian food such as quince Khoresh and Chowder and other food. It is notable that no published data is present in literature on rehydration of quince. Therefore, the aim of the work reported in this paper was to investigate the effect of combination of osmotic dehydration and ultrasonic as a pretreatment and its effect on the drying kinetics of quince drying kinetics and product quality.

Material and methods

Preparation of samples

Fresh quinces were bought from a local market in Mashhad, Iran. Quince samples were cut to obtain slabs of the same dimensions (9 mm average in height and 26 mm average diameter) and then immersed in 1% sodium Meta bisulphate (Merck-Germany) solution for 5 min in order to prevent enzymatic browning reactions. The moisture content was determined by heating in a drying oven at 105 ºC for 48h according to AOAC method 931.04 (AOAC, 1990).

Ultrasonic pre-treatment

An experimental set of four quince samples was immersed in distilled water (The water to fruit ratio was

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maintained at 20:1 (weight basis)) and submitted to ultrasonic waves for 0- 30 min. The experiments with ultrasonic treatment were carried out in separate 250 ml Erlenmeyer flasks to avoid interference between the samples and runs. The experiments were carried out under ambient temperature (30 ºC) in an ultrasonic bath (Schaper model Unique USC 25 kHz) without mechanical agitation. The ultrasonic frequency was 25 kHz and the intensity was 500 KW .The temperature increase during the experiments was measured using a thermometer and was lower than 2ºC after 30 min of ultrasonic treatment. To determine the effect of ultrasonic, the same experimental procedure was carried out without applying ultrasonic. After removal from the distilled water, the samples from each group were drained, blotted with absorbent paper to remove the excess water. Weight and moisture content were measured individually. At the end, samples were transferred to osmotic solution.

Light microscopic analysis

After the end of ultrasonic pre-treatment, the samples were carefully cut into cubes of 5 mm average side. The sample cubes were fixed with 4% solution of paraformaldehyde in 0.1 M phosphate buffer, pH 7.2 and 1% glutaraldehyde for 24 h at ambient temperature. The material was then dehydrated in a graded ethanol series and embedded in Historesin embedding kit (Jung). The tissue blocks were sectioned at 8 µm. The Periodic Acid-Schiff reagent (PAS) cytochemical reaction was employed for polysaccharide detection(Fernandes, et al. 2008). Photomicrographs of the cell structure were taken using an Olympus BX41 (Olympus, Japan) light microscope with digital image capture system.

Osmotic dehydration

Each experimental group consisting of three quince slabs was immersed in the osmotic solution for 1, 1.5 or 2 h. The osmotic solution used in each experiment was prepared by mixing food grade sucrose with distilled water to give a concentration of 40- 60 ˚Brix. The osmotic solution to fruit ratio was maintained at 20:1 (weight basis). Experiments were performed with the same constant magnetic agitation. The temperature was monitored by thermocouple was set at 50 ºC. After removal from the solution, the dehydrated samples from each group were drained, blotted with absorbent paper to remove the excess solution. Weight and moisture content were measured individually.

Response surface methodology (RSM) was applied to optimize the osmotic-ultrasonic conditions considered in this research. As a consideration of the osmotic-ultrasonic pre-drying treatment, it was considered appropriate to maximize water loss (WL) and weight reduction and minimize solid gain (SG). The results of the optimum conditions for quinces were found to be 27.25 min for ultrasonic time, 120 min for osmotic dehydration and 50.52 % for sucrose concentration (Noshad, *et al*., 2011).

Air Drying

Hot air drying was performed in a laboratory drier (Soroush Medical Company) operating with air velocity of 1.5 m/s. Before each drying experiment the drier was run without sample for about 0.5h to set desired conditions. The quince samples, fresh and pre-treated with optimized combined osmotic-ultrasonic dehydration condition, were subjected to air drying at 80°C (The temperature and time for hot air drying was optimized using Response Surface Methodology. (Noshad, *et al*., 2011). The drying process was stopped when the moisture content decreased to 19 ± 0.3% (w.b.) from an initial value of 83.13 ± 0.5% (w.b.). Finally, the moisture content of dried quince was determined at 105 ºC for 48h according to AOAC method 931.04(AOAC 1990). The experiments were conducted with 3 replications.

Calculation of effective diffusivities

It has been accepted that the drying characteristics of biological products in falling rate period can be described by using Fick's diffusion equation. The solution to this equation developed by (Crank 1979) can be used for various regularly shaped bodies such as rectangular, spherical and cylindrical products. Eq. (1) can be applicable for particles with slab geometry by assuming uniform initial moisture distribution:

$$MR = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp\left(-\frac{(2n+1)^2 \pi^2 D_{eff} t}{4L_0^2}\right) \quad (1)$$

Where D_{eff} is the effective diffusivity (m^2/s); L_0 is the half thickness of slab (m). For long drying period, Eq. (1) can be further simplified to only the first term of series (Tütüncü and Labuza 1996). Thus, Eq. (1) is written in a logarithmic form as follows:

$$\ln MR = \ln \frac{8}{\pi^2} - \frac{\pi^2 D_{eff} t}{4L_0^2} \quad (2)$$

Diffusivities are typically determined by plotting experimental drying data in terms of ln MR versus drying time t in Eq. (2), because the plot gives a straight line with a slope as follows:

$$Slope = \frac{\pi^2 D_{eff}}{4L_0^2} \quad (3)$$

Rehydration experiments

Rehydration experiments were carried out in a distilled water bath at constant temperature of 45 ˚C (±0.2 °C).Sample of dehydrated quince was placed inside a flask. For all experiments, the solid–liquid relation was kept at 1:50. The sample weight was measured every 15 min for the first hour of rehydration, then every 20 min for the next until 180 min (final stage of the process) (Garcia-Pascual, et al. 2005). Finally, the moisture content of dried quince was determined at 105 ºC for 8-10h according to AOAC method (AOAC 1980). It was assumed that water transport from the surface to the centre of the solid mainly takes place by diffusion. Therefore, an effective diffusion coefficient could be computed from the combination of the second Fick's law (Eq.4):

$$X_w = X_e + (X_0 - X_e)\sum_{n=0}^{\infty}\frac{8}{(2n+1)^2\pi^2}\exp\left(\frac{-D_{we}(2n+1)^2\pi^2 t}{4L^2}\right) \quad (4)$$

Here D_{ew} is the effective diffusivity ($m^2 s^{-1}$) X_W is the moisture content of the sample at time t (kg water kg^{-1} d.m.), X_0 is the initial moisture content (kg water kg^{-1} d.m.), X_e is the equilibrium moisture content (kg water kg^{-1} d.m.), t is the time (s), and L is the half-thickness of the slab (m).

Determination of shrinkage

Percentage of shrinkage was determined from the changes of the bulk volume of the quince slices using the liquid displacement method (Eq. 5) (Ko , et al. 2008). In this study, toluene was used instead of water because it caused reduction of liquid absorption into the fruits.

$$Sh = \frac{V_0 - V}{V_0}\times 100 \quad (5)$$

Where V_0 and V are initial and final volume of the sample.

Color analysis

Since the computer vision system perceived color as RGB signals, which is device-dependent (Fernandez, et al. 2005), the images taken were converted into L*a*b* units to ensure color reproducibility. Conversion from RGB to L*a*b* Transformation RGB into L*a*b space was performed using Color Space Converter plug-in of ImageJ software Ver.1.4g. Magic wand tool which is based on the Laplac

ian-of-Gaussian filter, used for selection of true image of quince from background in converted images. Statistical parameters of L*, a* and b* values were extracted from converted image. Color changes (ΔE) during drying process evaluated using equation (6):

$$\Delta E = \left[(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2\right]^{\frac{1}{2}}$$

Where L* is lightness component, which ranges from 0 to 100 and parameter a* (from green to red) and b* (from blue to yellow) are two chromatic components, which range from −120 to 120. Subscripts 1 and 2 are referred to as color components before and after drying, respectively.

Texture analyses

Texture analyzer (QTS Texture analyzer, CNS Farnell, Essex, U.K) was used to conduct the texture profile analysis, using a 6 mm cylindrical probe. The probe descended at a speed of 3.0 mm/s and compressed the sample at a speed of 2 mm/s up to a distance making 50% deformation. When the compression stroke was completed, the probe abruptly reversed its direction and started the upward stroke at 2 mm/s. Then a second down and up cycle was run on the same sample. A force–time curve was recorded by the instrument and three textural attributes including hardness, springiness, and chewiness were measured.

Results and discussion

Effects of pretreatment on effective diffusivities and shrinkage

The drying curve of untreated and combined Osmotic-ultrasonic dehydration quince is shown in Fig (1). the observed differences between untreated and pre-treated quince moisture ratio may be related to the solute uptake that happen in the osmotic process which results in an increase in the internal resistance to mass transfer, as observed by (El-Aouar, et al. 2003)for papaya and (Nieto, et al. 1998) for apple. The calculated values of D_{eff} are presented in Table 1. It is obvious from table 1 that pretreatment caused an decrease in $D_{eff,}$

The microscopic image analysis of the fresh fruit showed typical thin-walled cells with normal morphology and no visible intercellular spaces (Fig.2A). After ultrasonic treatment, the cells became more distorted and microscopic channels began to form (Fig. 2B). Osmosis process sugar may have entered into the micro-channel, saturating the channel, reduced the pore size and creating an extra resistance for water diffusion during drying, thus reduced the values of D_{eff}. These values are within the general range 10^{-9}-10^{-11} m^2/s for drying of food materials(Madamba, *et al.*, 1996).

The rehydration curves of quince vs. rehydration time at 45 °C are shown in Fig. 3, respectively. The calculated values of D_{eff} are presented in Table 1. It is obvious from table 1 that pretreatment caused a decrease in $D_{eff.}$ Rehydration of osmotic-ultrasonic dehydrated fruits was less than that of untreated samples. This is because of the sugar on the dehydrated fruits, which does not rehydrate as readily as the fruit tissue. (Bakalis and Karathanos 2005), also osmotic dewatering affects the rehydration properties of dried material, because of cell permeability due to osmotic stress and hence, upon rehydration these cells cannot absorb as much as water as the un-treatment (Lewicki 1998). This would be an advantage for dried quinces if they are used in such products as snack foods or breakfast cereal mixtures. With low hygroscopicity of the osmotic-ultrasonic dried products, they can be exposed in the open air for several hours without becoming sticky.

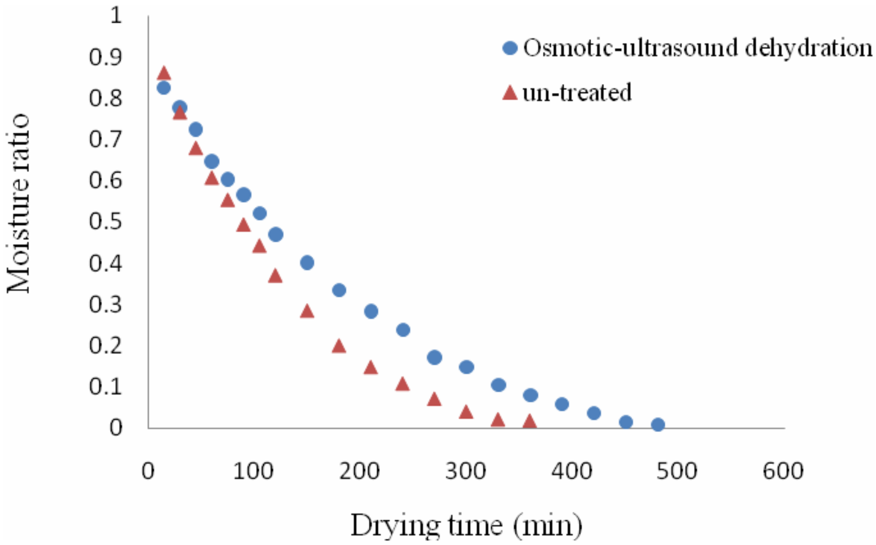

Fig. 1- Drying curves of quince at 80°C

Table. 1- Values of effective diffusivities and shrinkage for quince at different condition drying:

Sample	Effective diffusivity (m^2/s)		Shrinkage
	Drying	Rehydration	
Untreated	2.03×10^{-10}	1.14×10^{-10}	0.66±0.04
Pretreated	1.014×10^{-10}	8.316×10^{-11}	0.53±0.026

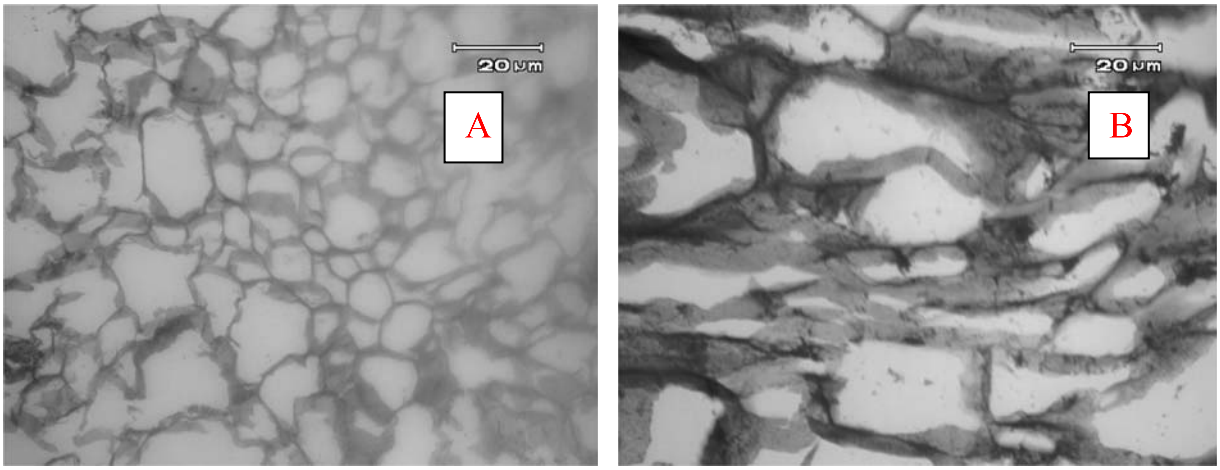

Fig. 2- Photomicrographs of quince cubes before processing: Raw fruit (A), After of ultrasonic pretreatment (B)

The reduced the water absorption during rehydration of samples pre-treated with osmotic solution was reported by (Lewicki, *et al*., 1998) and (Rastogi, *et al*., 2004).

Osmotic-ultrasonic dehydration reduced the extent of shrinkage in quince during air drying (Table.1), apparently because of the solids gained during this pretreatment. (Kim and Toledo 1987) stated that osmotic dehydration prevented shrinkage of Blueberries. They also found that the osmotic pre-dried blueberries had a larger diameter than that of none osmotic dehydrated samples.

Effects of pretreatment on color change

The infusion of sugars in fruits causes a relative stability of color parameters (L*, a*, b*), especially in comparison to air dried samples, which experienced an extensive browning. This is possibly due to the existence of sugars, which cause the relative inactivation of enzymes responsible for the enzymatic browning.

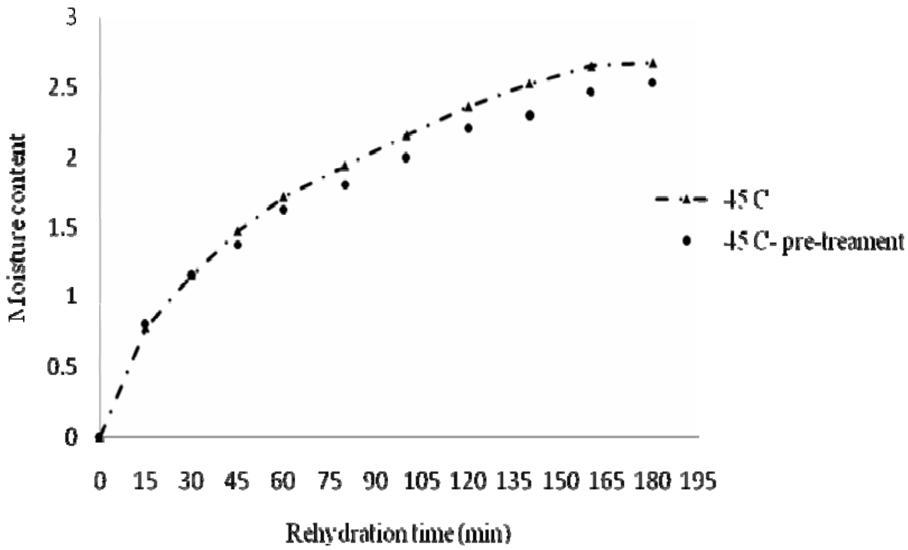

Fig.3- Rehydration curves of quince at 45 °C

The sugars may act superficially by increasing the osmotic pressure of the surface layers of fruits. The addition of sugars may result in a drop in the water activity of the sample, which in turn may reduce the non-enzymatic browning reaction. The different behavior of the untreated samples compared to that of osmotic-ultrasonic pretreated samples, regarding the color parameters during air drying, shows what it is evident by subjective methods of analysis. The osmotic-ultrasonic treatment reduce the overall color change , while the untreated samples brown significantly, which is usually undesirable (Tan, *et al.*, 2001). Thus, a method for color preservation is the immersion of fruits in sugar solution. This, apart from the drying effect caused by the difference in osmotic pressure, may result in color preservation. Thus, the osmotic dehydration seems to prevent color deterioration during drying, resulting in products with superior color compared to that of the air dried ones.

Table. 2- Color parameters at different drying methods:

Sample	b*	a*	L*	ΔE
Fresh	54.97±4.66	-6.71±0.84	90.91±1.3	-
untreated	42.55±7.31	2.38±0.92	68±3.28	27.61
pretreated	71.95±6.43	-3.56±0.49	84.31±3.69	23.18

Effects of pretreatment on Texture

In general that pretreated dried quinces were firmer because the longer the immersion time, the higher the texture loss. From 1 h onwards of osmosis there was a gradual disconnection and breakdown of the tissue, with a loss of shape of cellular walls together with loss of turgor pressure (Prinzivalli, *et al.*, 2006) and more chewier and springy in texture due to their higher solid contents, similar to what happened in air-drying of sugar-infused blueberries (Nsonzi and Ramaswamy 1998) in texture than the blueberries dried with hot air and other fruits(Fernandes, et al. 2006, Kim and Toledo 1987). (Sankat, *et al.*, 1996) reported that osmotically dehydrated banana slabs followed by air drying were softer and more chewable than slabs air dried without osmotic dehydration as pretreatment.

Conclusion

The results of this study indicate that osmotic-ultrasonic dehydration pretreatment caused reducing diffusion coefficient of water. This difference can be related to the solute uptake and cell permeabilization, due to osmotic-ultrasonic dehydration stress. The sample hardness, color changes and shrinkage reduced after osmotic-ultrasonic dehydration pretreatment while there was increased springiness and chewiness. This study allowed us to understand the structural differences between osmotic-ultrasonic-dried and air-dried quince, permitting to infer about the related textural changes. This knowledge can be used to improve process control and end product quality.

Table. 3- Texture parameters at different drying methods

Sample	Hardness	Chewiness	Springiness
Un-treated	21.474 ± 1.97 (N)	9.68 ±0.26 (mJ)	1.26± 0.01 (mm)
Pre-treated	17.745 ± 2.9 (N)	14.014 ± 0.83 (mJ)	1.47± 0.04 (mm)

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