International Journal of Food Engineering

Volume 7, *Issue* 5 | 2011 | *Article* 9

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Recommended Citation:
Igual, Marta; Castelló, María Luisa; Roda, Eva; and Ortolá, María Dolores (2011) "Development of Hot-Air Dried Cut Persimmon," *International Journal of Food Engineering*: Vol. 7: Iss. 5, Article 9.
DOI: 10.2202/1556-3758.2149
Available at: http://www.bepress.com/ijfe/vol7/iss5/art9

Development of Hot-Air Dried Cut Persimmon

Marta Igual, María Luisa Castelló, Eva Roda, and María Dolores Ortolá

Abstract

In this work the authors have studied the effect of hot-air drying with or without a previous osmotic dehydration pretreatment to produce dried cut persimmon with a different geometry (slices and sectors). A kinetic study has been carried out analysing mass variation, colour and texture changes in samples. Two sensory analyses were also performed considering drying time and geometry. Furthermore, the influence of 35 days of storage on optical and mechanical properties was also determined. The results obtained showed that geometry did not affect the parameters analyzed. According to the results of the kinetic study, the selected drying times were 8 and 12 hours. Osmotic pretreatment does not imply improvements in the final product. Judges preferred slices dried for 8 hours without osmotic pretreatment. The time of storage did not influence the optical and mechanical properties.

KEYWORDS: persimmon, drying, osmotic pretreatment, sensory analysis, colour, texture

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Introduction

Due to new techniques to remove the astringency of persimmon (*Diospyros kaki L.*) whilst keeping its firm consistency, carried out in the IVIA (Valencian Institute of Agrarian Research, Spain) (Arnal & del Río, 2005; Salvador, Arnal, Besada, Larrea, Hernando & Pérez-Munuera, 2008) the production of this fruit in Spain has increased from 4000 tonnes in 1997 to 14,000 tonnes in 2001 (Martin, 2005) and to 55600 tones in the 2006 (GVA, 2008). This increase in persimmon production means that there will be overproduction in the near future. In order to find a use for the excess of this fruit it will be necessary to provide consumers with processed products from persimmon with a longer shelf life. In this respect, there are studies related with the development of fresh cut persimmon (Albors, Castelló, Almela & Ortolá, 2008), vacuum impregnated persimmon (Igual, Castelló, Ortolá & Andrés, 2008) and persimmon jam (Igual, Castelló, Andrés & Ortolá, 2007). Moreover, the development of hot air dried cut persimmon can be an alternative for creating these kinds of products (Akyıldız, Aksay, Benli, Kıroğlu & Fenercioğlu, 2004; Nicoleti, Silveira-Jr, Telis-Romero & Telis, V.R.N., 2005; Park, Jung, Kang, Delgado-Licon, Martínez-Ayala, Tapia, Martín-Belloso, Trakhtenberg & Gorinstein, 2006; García-Pérez, Cárcel, Benedito & Mulet, 2007; Elias, Berbert, Molina, Vian, Dionello & Queiroz, 2008). The food drying can be improved by the application of a power ultrasound since it not only enhances mass transfer but also gives higher quality to the product without heating significantly the material (García-Pérez et al., 2007).

The combination of drying by hot air with a prior osmotic treatment can increase the yield of this process and it also can improve the flavour of the fruit (Pointing, 1973) and decrease structural collapse (Del Valle, Cuadros & Aguilera, 1998). In the specific case of osmo-convective cylinders of persimmon, Elias et al., (2008) showed that this combined pretreatment implied a good consumer acceptance.

One important consideration when designing new products is to choose the correct geometry for the final samples since the driving force to transport of mass will depend on it.

The aim of this work is to obtain cut persimmon dried by hot air with or without a prior treatment of osmotic dehydration in order to obtain a product with high stability that could be eaten as a snack (slices) or in combination with other dried products (sectors).

Materials and Methods

Raw material

Experiments were carried out with de-astringent persimmon var. *'Rojo Brillante'* with firm texture provided by Agrícola Alginet, S. Coop. V from the Comunidad Valenciana (Spain). Fruits were cut in cylinders of 65 mm diameter and 5 mm thickness (slices). Then some of them were cut into 4 pieces (sectors).

Drying by hot air and osmotic pretreatment

The effect of a prior osmotic treatment with sucrose solution of 63ºBrix (solution: fruit 3:1), during 3h (OD) at room temperature (≈25ºC) was studied. Then samples were dried in a convective tray drier (Back to Basics FD-600) at 80ºC with a constant air flow rat of 1.6 $m{\cdot}s^{-1}$ during 2, 4, 6, 8, 12, 24 and 48 h.

Analytical determinations

- *Moisture content, ºBrix, mass variation*

Moisture content was determined by drying to constant weight at 60ºC in a vacuum oven at 10 kPa for 72 h (adaptation of method 934.06 AOAC, 2000) in duplicate. ºBrix were measured with a refractometer (Zeiss, ATAGO model NAR-3T, Japan). Changes in mass were measured over the duration of the process.

- *Mechanical properties*

Changes in mechanical properties were studied using a texture analyser (TA/XT/PLUS Stable Micro. Systems Ltd., Godalming, UK) by means of a puncture test (2 mm diameter punch) with a penetration rate of 1.5 mm/s until the entire sample was penetrated. The temperature during this test was maintained at 25ºC. Five replicas were performed for each treatment. The parameters analysed were: maximum force (F_{max}) and distance (d_{Fmax}) at the maximum force.

- *Optical properties*

The optical properties (translucency and colour coordinates) of fresh, pre-treated and dehydrated samples of persimmon were obtained from the surface reflectance spectra between 400 and 700 nm (D65, 10º) when measured on black and white backgrounds, using a spectrocolorimeter (Minolta CM- 3600D) with a 7 mm diameter window. For each treatment, 3 measurements were carried out on five

DOI: 10.2202/1556-3758.2149

different samples. The translucency was determined by applying the Kubelka–Munk theory (Hutchings, 1999). Spectral distribution of the Kubelka–Munk coefficient (ratio between light absorption (K) and scattering (S)) was obtained with the equations 1, 2, 3 and 4:

$$\frac{K}{S} = \frac{(1 - R_{\infty})^2}{2R_{\infty}} \quad (1)$$

$$R_{\infty} = a - b \quad (2)$$

$$a = \frac{1}{2}\left(R + \frac{R_o - R + R_g}{R_o * R_g} \right) \quad (3)$$

$$b = \left(a^2 - 1 \right)^{1/2} \quad (4)$$

where R_{∞} is the reflectance of an infinitely thick layer of the material; R and R_o are the reflectance of sample over white and ideally black backgrounds, respectively; and R_g is the reflectance of the white background. For translucent samples, R and R_o take different values. In these cases, to obtain CIEL*a*b* colour coordinates, R_{∞} was calculated (Hutchings, 1999). When no translucency was observed, R_o was used to obtain the CIEL*a*b* colour values. The colour coordinates were then used to calculate hue degree (h=arctangent [b*/a]) and chrome ($C^* = [a^{*2} + b^{*2}]^{1/2}$).

Colour and texture determinations were performed initially and every 6 days during storage.

Storage

Dried slices and sectors of persimmon with or without osmotic pre-treatment were stored in transparent vacuum bags (Magic Vac PA-PE) for 35 days at room temperature (≈25ºC) exposed to the natural light inside a room.

Sensory analysis

Two sensory analyses were performed. The aim of the first one was to find out which geometry was preferred by the judges (slices or sectors, dried for 8 hours) and the effect of the osmotic pre-treatment (HAD, OD+HAD). Once the geometry was chosen, the second sensory analysis was carried out. In this case, as the geometry chosen was the slices, only samples with this shape were tasted to determine the preferred drying time (8 or 12 h), also taking into consideration the application of the osmotic pre-treatment. In each sensory analysis, judges tasted combinations of four different samples.

To carry out these analyses, a panel of 30 semi-trained judges was selected to perform a test of preference on a compared trial by pairs (UNE, 87-005-92, AENOR, 1997). The age of the panellists ranged from 20 to 40 years. The attributes evaluated were: colour intensity, aspect, texture and typical taste. Additionally, the panel indicated the preferred sample for each pair.

In order to study the attributes which were statistically significant, an analysis using Friedman's T (Pairwise Ranking Test) was performed following the equation (5) (Meilgaard, Civille & Carr, 1999).

$$T = \left(\frac{4}{pt}\right)\sum_{i=1}^{t} R^2 - \left(9p[t-1]^2\right) \tag{5}$$

p: times the basic design was repeated (p=30).
t: number of treatments (t=4).
R: sum of range of each treatment.

These results were compared with values of the X^2 function, in such a way that with 3 degrees of freedom and for a 0.05 level of significance, the function gives a value of 7.81.

To study the treatments which were statistically significant, Tukey's HSD (Honestly Significance Difference) method has been used (Meilgaard et al., 1999), considering the equation (6).

$$HSD = q_{\alpha,T,\infty}\sqrt{\frac{pt}{4}} \tag{6}$$

q: a tabled value which is 3.63 for 4 degrees of freedom and for a level of confidence of 0.95.
p: times the basic design was repeated (p=30).
t: number of treatments (t=4).

Statistical analysis

ANOVA analysis using Statgraphics Plus 5 Software was applied to evaluate differences among treatments. The significance level was considered as 95%.

DOI: 10.2202/1556-3758.2149

Results and Discussion

Drying kinetics

Figure 1 shows the changes in water mass during the drying stage (a), the drying curve (b) and the drying rate curves (c) and (d) of sectors or slices of persimmon osmotically pre-treated (OD+HAD) or not (HAD). Osmotic pre-treatment caused around 24% of mass loss, which corresponded with an increase in sugar concentration from 16ºBrix of the raw material to 27ºBrix. This fact suggested the differences in water mass found between OD+HAD and HAD samples. The equilibrium situation was reached after 8 hours of drying, when samples reached the equilibrium moisture content, as can be seen in the drying curve. Only the period of falling rate of drying was detected in these samples. The shapes studied did not affect the changes in water mass.

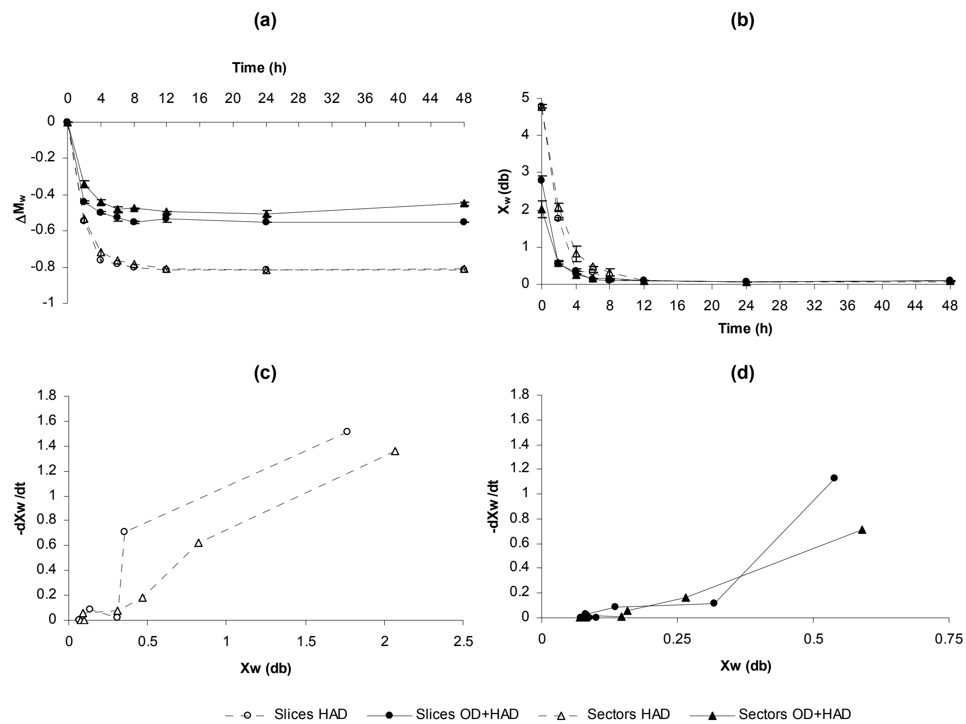

Figure 1. Changes of water mass (ΔM_w) during the drying stage (a), the drying curve (X_w: mass ratio of water) (b) and the drying rate curves (c) and (d) of sectors or slices of osmotically pre-treated persimmon (OD+HAD) or not (HAD).

To evaluate the kinetics of drying during the falling rate period, it is frequently assumed that the main mechanism is a diffusional one (Andrés, Bilbao

& Fito, 2004; Castilho-Garcia, Aparecida-Mauro & Kimura, 2007). In this case, the solution of Fick's Second Law may be used. In particular, the simplified solution of Fick's Second Law, valid for a infinite plane sheet and long drying times along with well mixed and high velocity of the air, was used to obtain the value of effective water diffusivity of the product being studied (equation 7).

$$Y = \frac{(X_{wt} - X_{we})}{(X_{w0} - X_{we})} = \frac{8}{\pi^2} \exp\left(\frac{-D_e \pi^2 t}{4l^2} \right) \quad (7)$$

where: Y is the driving force, X_w is the water content (g/g dry matter) with superscripts: o (initial condition), t (at time t) or e (at equilibrium condition); D_e is the effective water diffusivity (m^2/s); l is the slab half thickness (m); and t is the time (s).

From this equation, by using a non linear regression procedure the effective diffusivity of water was found to be $3.43x10^{-10}$ and $3.05x10^{-10}$ m^2/s for slices HAD and OD+HAD respectively and 3.12 $x10^{-10}$ and 2.64 $x10^{-10}$ m^2/s for sectors, HAD and OD+HAD in the same range as other fruits (Andrés et al., 2004; Contreras, Martín-Esparza, Chiralt, & Martínez-Navarrete, 2008). According to these results, osmotic pre-treatment reduced the values of diffusivity as a consequence of the lower driving force in the drying process since the moisture content in pre-treated samples was lower. This behaviour has also been observed by other authors (Simal, Deya, Frau & Rossello, 1997; Karathanos, Kostrapoulos & Saravacos, 1995; Rahman & Lamb, 1991).

Changes in mechanical properties

In figure 2 the values of maximum force and distance at which this force was produced are shown. As was expected, maximum force increased with drying time but only up to 24 hours. After 48 hours registered force was lower, although this change in mechanical behaviour was due to the fact that samples were crunchier and broke before the puncture penetrated the sample. This provides evidence that the sample becomes brittle between 24 and 48 hours and therefore the registered force was the failure force and not the penetration force.

DOI: 10.2202/1556-3758.2149

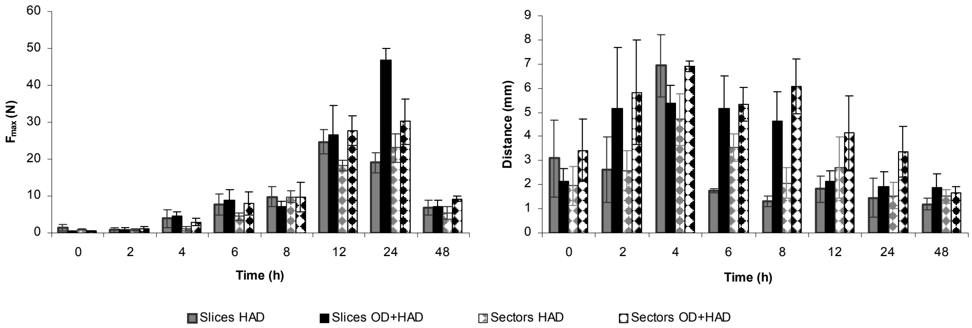

Figure 2. Maximum force (F_{max}) and distance of the maximum force according to drying time and osmotic pre-treatment.

The effect of osmotic pre-treatment and geometry on textural parameters, also taking into consideration the drying time, were analysed by means of a multi-factor ANOVA. The results showed that the osmotic pre-treatment caused a significant increase in force values at 12 hours of drying for sectors and at 24 hours of drying for slices. This could be a consequence of the hardening of the product as a result of sugar replacing air during the osmotic pre-treatment, which was more evident when the ratio of water in the product was low. In general, the distance corresponding to the maximum force was significantly lower for HAD than for OD+HAD samples, as set out above.

Changes in optical properties

In order to quantify the changes in product translucency caused by treatments, the analysis of spectral distribution of Kubelka Munk coefficients obtained from reflectance spectra can be carried out; the higher the K/S values, the greater the product translucency (Hutchings, 1999). In the analysed samples, there were only slight differences between the backgrounds employed in the colour measurements in OD+HAD and HAD samples up to 6 and 8 h of drying respectively.

In figure 3, a*b* chromatic diagrams and clarity (L*)-Chrome(C^*_{ab}) plains are shown for selected times (0, 8, 24 and 48 h) of the kinetics study. Following the same pattern showed in persimmon by other authors (Akyildiz et al., 2004), clarity did not change with drying time, except in very long drying periods (48 h, especially for slices). The osmotic treatment decreased the clarity of samples slightly in comparison with fresh samples, checked in other fruits (Chiralt & Talens, 2005). Moreover, no differences were found which depended on the shape studied, although drying time reduced hue and b* especially in OD+HAD samples treated for 48 h. Values of chrome were also lower with regards to the drying time as a consequence of the reduction in b*. It was notable that all treated samples showed the same value of a*. This meant an expected darkening of dried samples as can be seen in figure 4.

Taking all these results into consideration, the optimum drying times were 8 and 12 hours. Therefore, the study of the effect of storage was carried out taking these drying times into consideration.

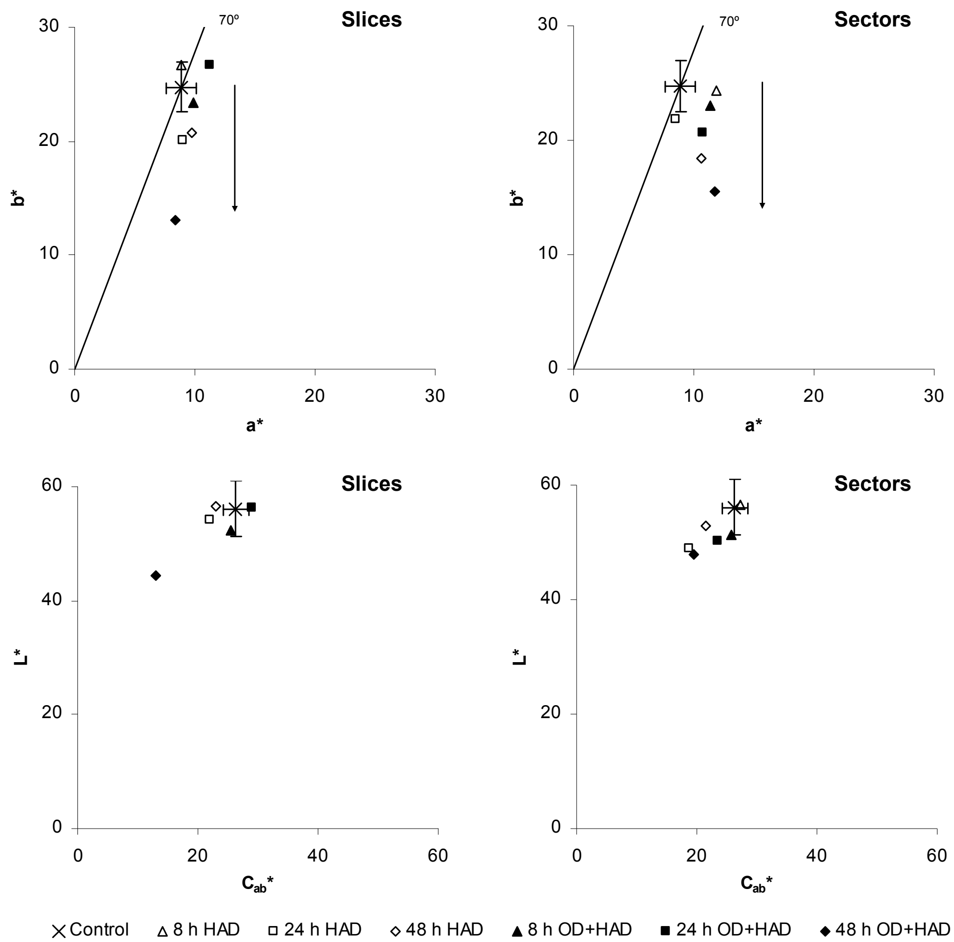

Figure 3. a*-b* chromatic diagrams and clarity (L*)-chrome(C^*_{ab}) plains of dried cut persimmon according to drying time and depending on osmotic pre-treatment and shape (0, 8, 24, 48h).

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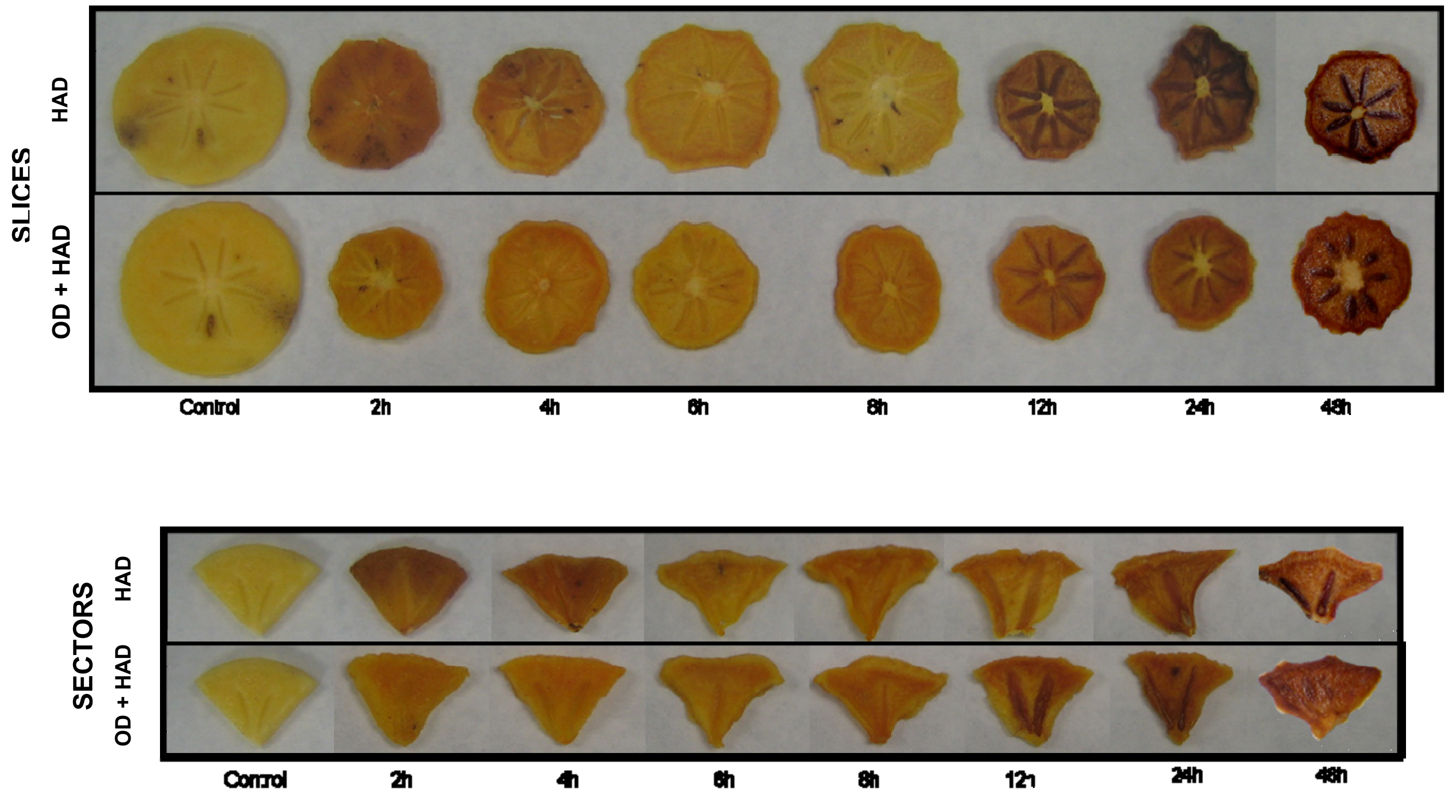

Figure 4. Changes of colour with regard to drying time and depending on osmotic pre-treatment and geometry.

Changes of mechanical and optical properties during storage

According to the mechanical results of figure 5, there was only a notable decrease in the maximum force particularly in HAD samples, dried for 12 hours for both geometries. In addition to these cases, storage caused an increase in the distance at which the maximum force happened, which might suggest a more rubbery nature.

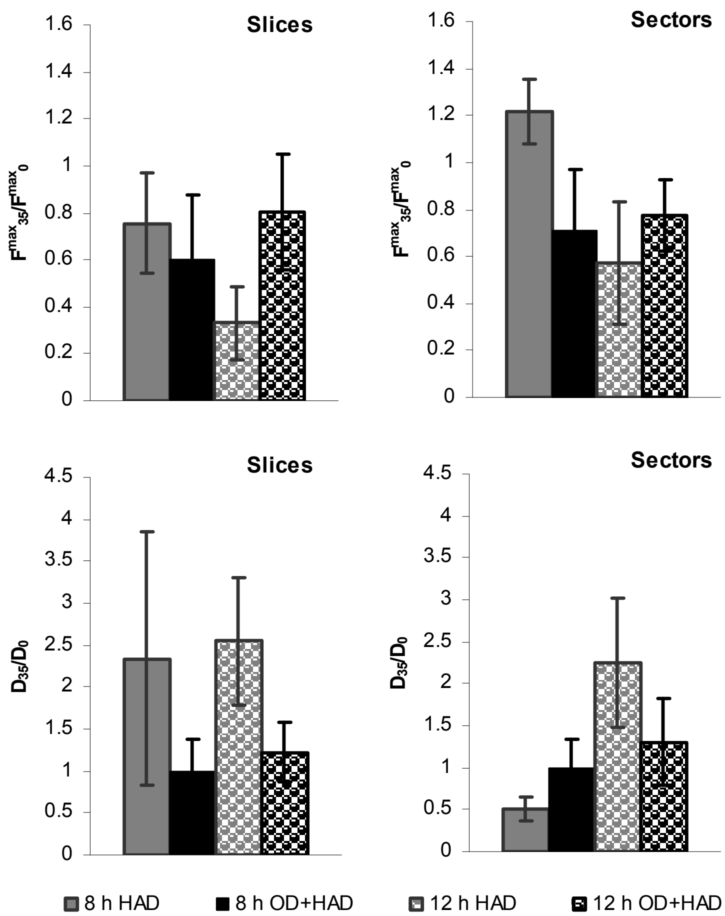

Figure 5. Relation between the maximum force after 35 d of storage and the initial maximum force (F^{max}_{35}/F^{max}_{0}) and relation between the distance at which maximum force takes place after 35 d of storage with regard to the initial value (D^{max}_{35}/D^{max}_{0}) of dried persimmon with or without osmotic pre-treatment (OD+HAD, HAD) and taking into consideration drying time (8, 12 h) and the shape of samples (slices or sectors).

DOI: 10.2202/1556-3758.2149

No variations in the optical parameters were detected in the established storage time, as can be seen in figure 6.

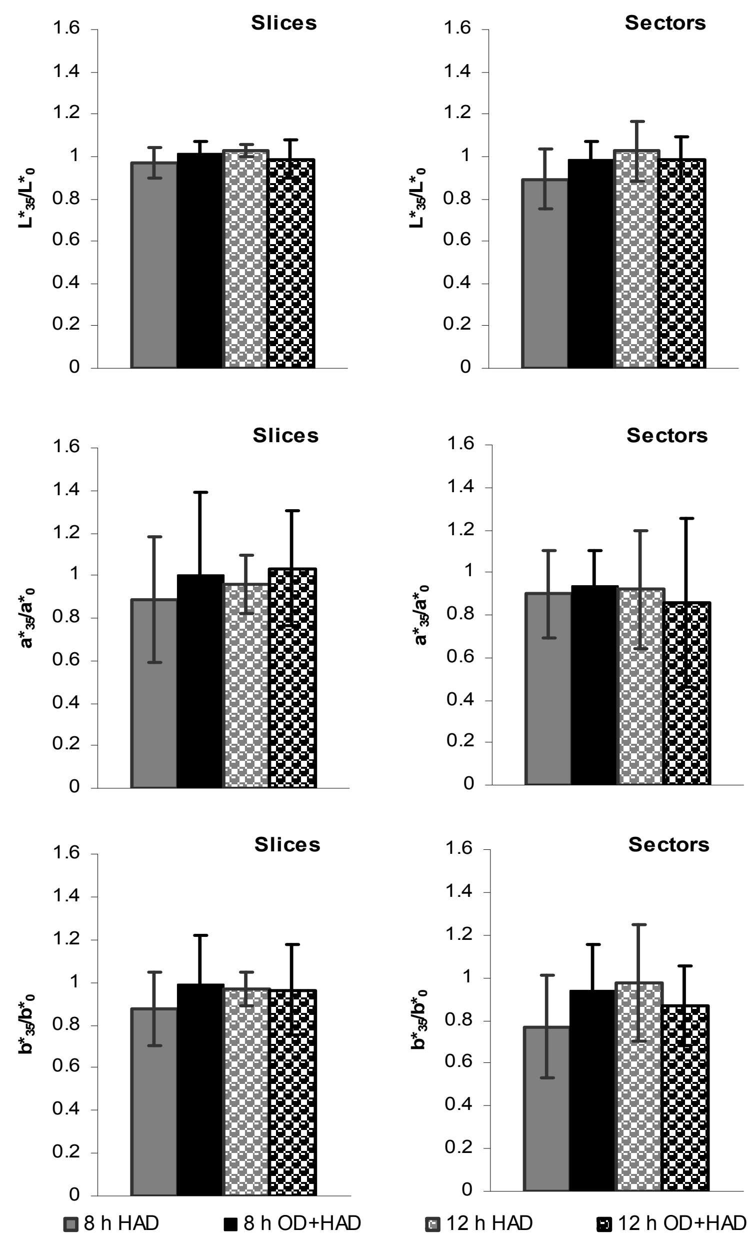

Figure 6. Quotient between the optical parameters (L*, a*, b*) after 35 days with regard to the initial values of dried persimmon with or without osmotic pre-treatment (OD+HAD, HAD) and taking into consideration drying time (8, 12 h) and the shape of samples (slices or sectors).

Sensorial analysis

The results of the sensorial analysis to study the effect of shape and osmotic pre-treatment are shown in figure 7. It was observed that the higher scores were obtained for non-osmotically pre-treated slices, except for the attribute of colour, for which OD+HAD samples were evaluated more favourably.

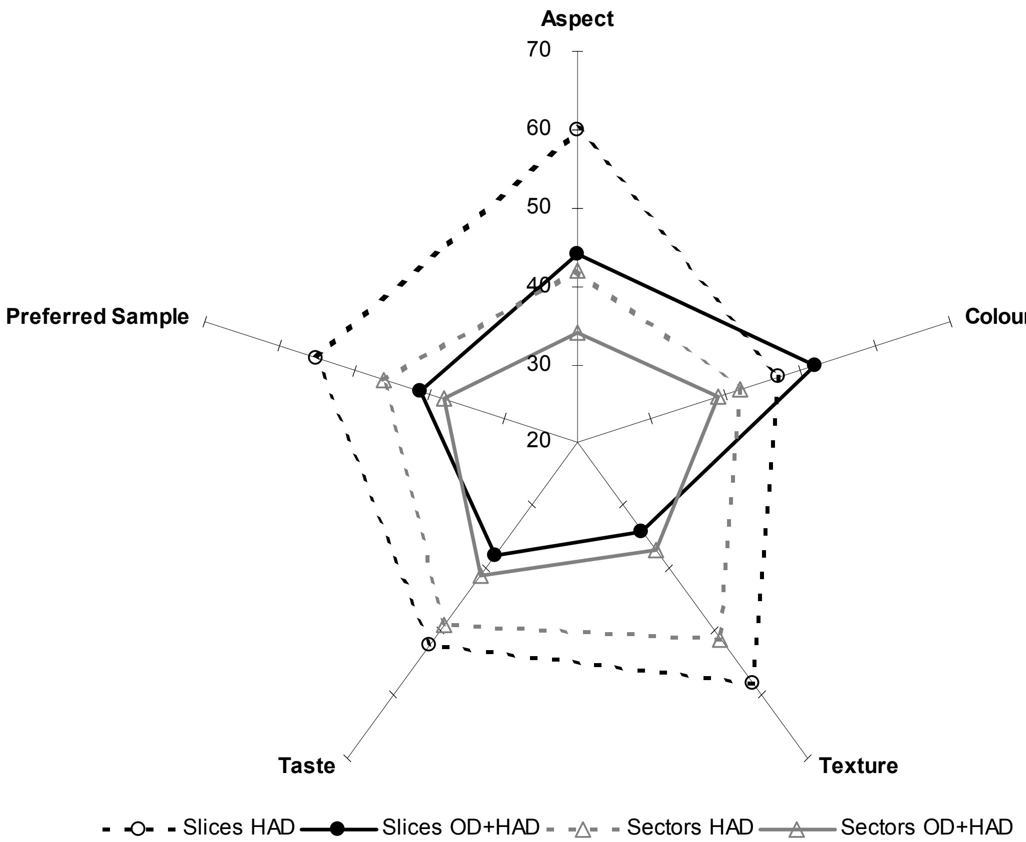

Figure 7. Scores of the attributes in the sensorial analysis taking into consideration shape and osmotic pre-treatment.

According to the results of Friedman's T test, aspect and texture were the attributes which showed statistically significant differences in the studied samples. In contrast, Elias et al., (2008) observed that in the osmo-convective dried persimmon cylinders dried at 40ºC texture was the predominant sensory parameter meanwhile appearance was the least important characteristic. Maybe these differences could be associated with the higher temperature of drying applied in this work (80ºC).

The differences between the sums of ranges of each treatment are shown in table 1. In comparison with the statistical parameter obtained from equation 6, only OD+HAD sectors and HAD slices showed statistically significant differences for aspect, whilst for texture, differences were found between HAD slices and OD+HAD slices.

In accordance with these results, slices without osmotic pre-treatment were selected as the preferred samples.

Table 1. Differences between the sums of ranges for treatments in the sensorial analysis that considered geometry and osmotic pre-treatment.

	ASPECT	TEXTURE
Sector HAD-Sector OD+HAD	2	6
Sector HAD-Slice HAD	18	13
Sector HAD-Slice OD+HAD	4	15
Sector OD+HAD-Slice HAD	20*	19
Sector OD+HAD-Slice OD+HAD	6	9
Slice HAD -Slice OD+HAD	14	28*

*significant differences at the 0.05 level

In terms of the effects of drying time and osmotic pre-treatment, the results of the sensorial analysis are included in figure 8. It can be observed that the best score was registered for HAD slices dried for 8 hours. In this case, the most favourably evaluated attribute was texture. In table 2, pairs of samples with significant differences as a function of the evaluated attribute are considered. It is important to note that all attributes were statistically significant according to Friedman's T.

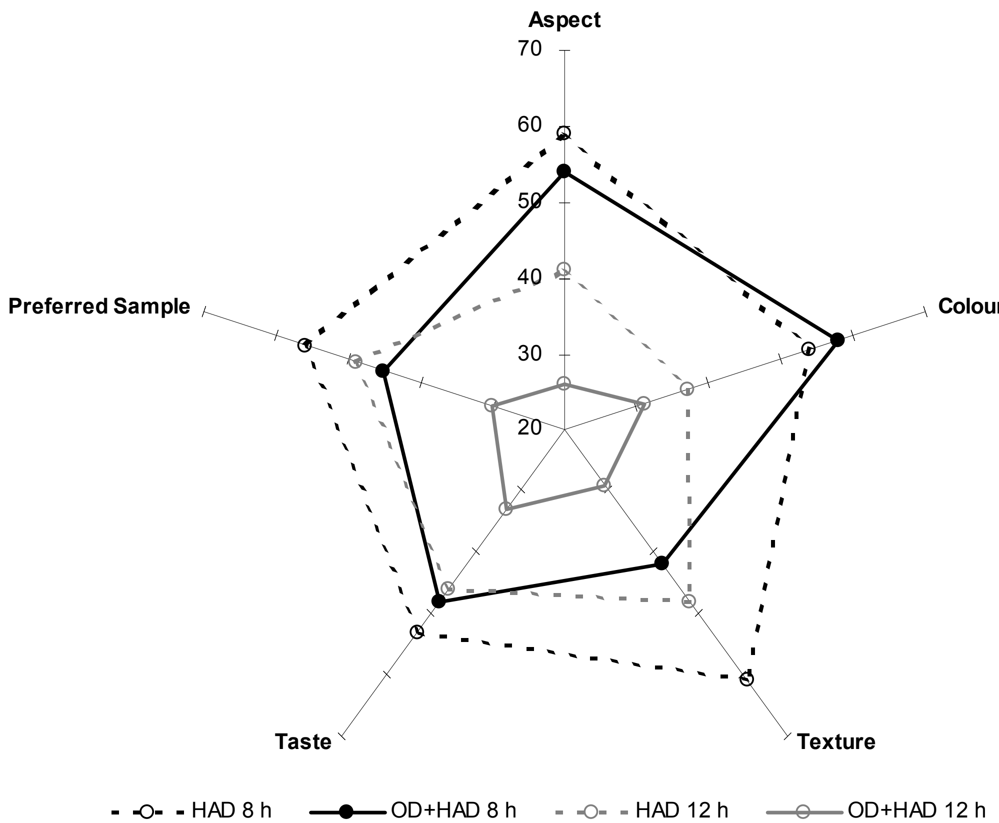

Figure 8. Scores of the attributes in the sensorial analysis taking into account drying time and pre-treatment.

Table 2. Differences between the sums of ranges for treatments in the sensorial analysis that considered drying time and osmotic pre-treatment.

	ASPECT	COLOUR	TEXTURE	TASTE	PREFERENCE
HAD 8h-OD+HAD 8h	5	7	16	5	15
HAD 8h-HAD 12h	18	17	14	10	12
HAD 8h-OD+HAD 12h	33*	26*	34*	25*	33*
OD+HAD 8h-HAD 12h	13	24*	2	5	3
OD+HAD 8h-OD+HAD 12h	28*	33*	18	20*	18
HAD 12h-OD+HAD 12h	15	9	20*	15	21*

*significant differences at the 0.05 level

Conclusions

According to this work, non-osmotically pre-treated slices dried for 8 hours were the optimum conditions for obtaining a new dried persimmon product from the sensorial, mechanical and optical points of view. Nevertheless, the selection of the shape will depend on the final destination of the product, since in a mixture with other dried fruits small pieces (sectors) will be more suitable, whilst for eating directly as snacks a larger shape (slices) will probably be more suitable. Osmotic pre-treatment does not entail improvements in the final product. Although in the considered storage conditions no changes of colour and texture were found, it would be recommended to study more different storage conditions in order to ascertain the best way to keep this product, avoiding the energy consumption inherent in vacuum packaging.

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