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DRYING KINETICS OF NECTARINE (*Prunus persica*) WITH AND WITHOUT SHRINKAGE

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ABSTRACT

The objective of this work was to study the drying kinetics of nectarine (*Prunus persica*), *in natura* and osmotically pretreated in sucrose solutions, with and without shrinkage. The drying process was carried out at temperatures of 40 and 60°C and an air velocity of 2.1m/s. The experimental data were adjusted using Fick's diffusional model in terms of moisture concentration, and the results were analyzed in terms of the correlation coefficient (R^2).

INTRODUCTION

Dehydration of foods is one of the most common processes used for improving food stability, since it decreases considerably the water activity of the material, reduces microbiological activity and minimizes physical and chemical changes during its storage.

The present demand of high-quality products in the food market requires dehydrated foods that maintain at a very high level the nutritional and organoleptical properties of the initial fresh product. A thorough understanding of the factors responsible for the decrease in the quality of the product during the dehydration process is thus of major relevance.

One of the most important physical changes that the food suffers during drying is the reduction of its external volume. Loss of water and heating cause stresses in the cellular structure of the food leading to change in shape and decrease in dimension (Mayor and Sereno, 2004).

Fruits and vegetables have high initial moisture contents and suffer alterations of their original form during the drying process due to significant shrinkage. Animal or vegetable cells exhibit a property

denominated "turgor", where liquid contained in the cell wall creates pressure on the cell, compressing the liquid inside the cell. During the drying process, water leaves the cell causing a decrease in the tension that the liquid exerts against the cell wall. This decrease in tension causes shrinkage of the material. The quantification of this phenomenon is important because it allows the analysis of the drying kinetics and consequently of the whole drying phenomenon. Shrinkage considerations in drying models are hindered because there is no pertinent information about shrinkage coefficients or functional relationships between shrinkage and available mass diffusivities, in the literature (Prado, 1998).
Shrinkage of food materials has a negative consequence on the quality of the dehydrated product. Changes in shape, loss of volume and increase of hardness cause in most cases a negative impression in the consumer. There are, on the other hand, some dried products that have had traditionally a shrunken aspect, a requirement for the consumer of raisins, dried plums, peaches or dates.

The objective of this work was to study the drying kinetics of nectarine (*Prunus persica*), *in natura* and osmotically pretreated in sucrose solutions, with and without shrinkage considerations.

MATERIAL AND PROCEDURE

Sample preparation

The experiments were carried out using nectarine (*Prunus persica*) variety *sunred* purchased from a local market, with similar maturity (10°Brix) cut facility and stone removal facility. Samples were cut as flat slabs (0.03 x 0.02 x 0.005m).

Osmotic dehydration procedure

The nectarines were osmotically dehydrated in sucrose solutions. Osmotic dehydration was carried out at 47% (w/w) concentration, immersion time of 60 minutes and temperature of 42°C using a shaker (TECNAL, model 421) with agitation and temperature controls. The ratio product / solution, equal 1/10, was chosen in order to avoid significant dilution of the solution during the osmotic treatment (Vial, 1991). Osmotic dehydration conditions were determined according a complete 2^3 experimental design, with center and axial points, using as variables: solution concentration (40 – 60%, w/w), solution temperature (30 – 50°C) and immersion time (90 – 240 minutes). The responses studied were water loss and solid gain. The experimental design objective was to obtain maximum water loss with relatively small solids gain. The experimental data was analyzed using STATISTICA 5.0 software.

Drying procedure

The experimental data for the drying of nectarine in a convective tray dryer were obtained at two different temperatures (40 and 60°C) and air velocities at 2.1 m/s. The amount of water removed during the drying process was determined by periodic weighting of the samples using a semi-analytical balance.

The equilibrium moisture content was obtained dynamically until constant weight. The effective diffusivity (D_{ef}) was obtained fitting the Fick's diffusional model (equation (1 and 2)) to the experimental data, with and without shrinkage respectively, applying the nonlinear estimation resources of the STATISTICA 5.0 software (Statsoft, 1995). Fick's diffusional model was adjusted using the first term of the Fourier series (Crank, 1975). Either the half thickness of the fresh nectarine and the half thickness of the osmotic dehydrated nectarine were assumed as the initial thickness when the shrinkage was not considered. When the shrinkage was considered the average thickness of the samples was used as suggested by Park (1998).

$$\left(\frac{\overline{X} - X_{eq}}{X_0 - X_{eq}}\right) = \left[\frac{8}{\pi^2}\sum_{i=0}^{\infty}\frac{1}{(2i+1)^2}\exp\left(-(2i+1)^2\pi^2 D_x \frac{t}{4L^2}\right)\right] \tag{1}$$

$$\left(\frac{\overline{C} - C_{eq}}{C_0 - C_{eq}}\right) = \left[\frac{8}{\pi^2}\sum_{i=0}^{\infty}\frac{1}{(2i+1)^2}\exp\left(-(2i+1)^2\pi^2 D_y \frac{t}{4L^2}\right)\right] \tag{2}$$

Shrinkage determination

Digital photographic resources (digital camera Sony, model P-50) were used for determining shrinkage of the material during the drying. The photograph of the samples were taken with a reference object to obtain the sample areas using the software COREL DRAW 10.0. The thickness was obtained using equation (3).

$$L_3 = \frac{V}{L_1 L_2} \tag{3}$$

Density Determination

The experimental values of density were obtained by dividing the mass of a single sample by its volume. Measurement of volume of the sample was carried out in toluene by volume displacement using a burette with a container connected in its extremity as shown the Figure 1. The sample was put in the container and the volume displacement was read in the scale of the burette that has precision of 0.1 mL.

Figure 1 - Apparatus used for density determination.

RESULTS AND DISCUSSION

In Figure 2 the influence of air temperature is shown at fresh and osmotically dehydrated (OD) nectarine in sucrose. For the fresh samples it was observed that the temperature showed a large influence in the process while for the pretreated samples temperature did not show to exercise significant influence.

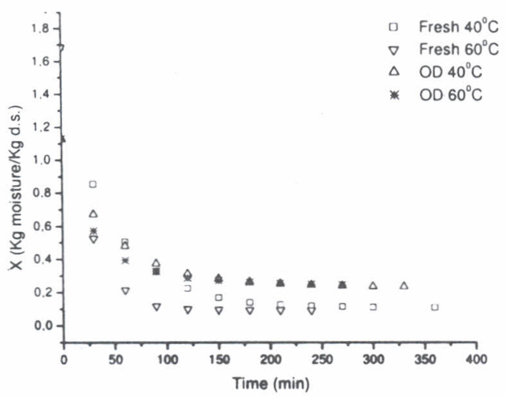


Figure 2 – Effect of air temperature on drying curves of nectarine fresh and osmotically dehydrated

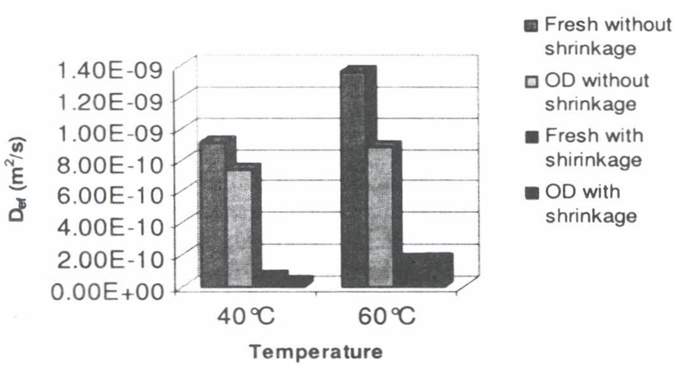
The effective diffusivity values obtained are shown in Table 1, for fresh and pretreated samples, with and without shrinkage.

The trend of increasing diffusivity along with the increase in air drying temperature is coherent with the literature. The effective diffusivity found by Park et al (2002) varied from 2.06 to 6.37 x 10^{-10} m^2/s using pear fresh samples. In the same work effective diffusivity for pear osmotically dehydrated in sucrose solution varied from 1.87 to 8.12 x 10^{-10} m^2/s. Ramaswamy and Nsonzi (1998) observed the same magnitude for blueberries with diffusivity values ranging from 1 to 2 x 10^{-10} m^2/s.

Concerning effective diffusivity of samples osmotically dehydrated it was observed that smaller values were obtained than with fresh samples. This fact can be due to larger amount of present free water in fresh samples. In the osmotic pre-treatment the samples lost about 42% of water. The effective diffusivity for samples with and without shrinkage is presented in Figure 3.

Table 1 - Effective diffusivity for samples, without and with osmotic dehydration, without shrinkage.

Without shrinkage				
T (°C)	Fresh		OD	
	D_x (m^2/s)	R^2	D_x (m^2/s)	R^2
40	9.12 x 10^{-10}	0.9970	7.43 x 10^{-10}	0.9948
60	13.60 x 10^{-10}	0.9590	8.81 x 10^{-10}	0.9937
With shrinkage				
T (°C)	Fresh		OD	
	D_y (m^2/s)	R^2	D_y (m^2/s)	R^2
40	0.70 x 10^{-10}	0.9970	0.30 x 10^{-10}	0.9948
60	1.77 x 10^{-10}	0.9590	1.70 x 10^{-10}	0.9937



The observed differences between fresh and osmosed drying diffusivity may be related to the solute uptake that occurred in the osmotic pre-treatment (12%) which resulted in a increase in the internal resistance to mass transfer, as observed by Karathanos et al. (1995), Nieto et al. (1998), El-Aouar and Murr (2003).

Figure 3 – Comparison between nectarine effective diffusivity with and without shrinkage

Mazza (1983) attributed these lower rates to the depression of water vapor pressure in the product due to dissolved sugar and the crystallization of sucrose during the drying process.

Observing effective diffusivity values with and without shrinkage it is verified that the values obtained for the samples with shrinkage presented larger values of the diffusion coefficient than the samples where the shrinkage was not considered. This fact was also observed by Park (1998) that studied the drying of salted fish muscle and for Prado (1998) studying the drying of date.

CONCLUSIONS

The diffusional model with both the moisture content parameter and the moisture concentration parameter, applied with first term of the Fourier series proved to be excellent to fit the drying curves.

The calculated values of effective diffusivity for the drying process considering no shrinkage were greater than those for the drying process considering shrinkage.

The effective diffusivities calculated from the diffusional model without shrinkage varied from 7.43 x 10^{-10} m^2/s to 13.6 x 10^{-10} m^2/s and from 0.7 x 10^{-10} m^2/s to 1.77 x 10^{-10} m^2/s for diffusional model with shrinkage.

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NOTATION

C: concentration (% w/w)
t: time (minutes)
X: moisture content (Kg moisture/ Kg dried solid (d.s.))
X_e: equilibrium moisture content (Kg moisture/ Kg dried solid (d.s.))
X_0: initial moisture content (Kg moisture/ Kg dried solid (d.s.))
D_x: effective diffusivity from equation (1) (m^2/s)
D_y: effective diffusivity from equation (2) (m^2/s)
L: diffusional path (m)
L_1:sample length (m)
L_2: sample width (m)
L_3: sample thickness (m)
V: sample volume (m^3)

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