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Effect of Osmo-dehydration Conditions on the Quality Attributes of Pears

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Abstract

The aim of this work is to study the effect of osmotic dehydration on mass transfer (solid gain (SG) and water loss (WL)) and on some quality attributes kinetics degradation of pears (ascorbic acid and total phenolic contents, color). Pears samples (1×0.8×0.8 cm^3) were osmotically dehydrated for different time, following a 5^3 central composite experimental design (osmosis time: 30, 120, 210, 300, and 390 min, sucrose concentration: 25, 35, 45, 55 and 65 °Brix and temperature 20, 30, 40, 50, and 60°C). The interactive term of osmosis time, sucrose concentration and temperature have a significant effect on WL and SG. As expected, water loss and solids gain increased with the increase of temperature and solution concentration. Sucrose concentration, osmosis time and temperature induce significant increase of a* and b* colormetric parameters but did not affect the lightness (L*) of pear slices. This seems to be a result of matrix concentration and solids uptake. Osmosis time is the most important factor affecting total phenolic content. Volume change is linearly correlated with temperature and osmosis time. These results suggest that shrinkage is essentially due to water loss and solid gain.

Keywords: Osmotic dehydration; Quality; Antioxidants; *Pyrus communis Conference*

Introduction

There's a constant increasing demand for healthy, natural and delicious fruits. Studies on fruits and vegetables, especially, have shown how these products lower the risk of several chronic diseases such as a heart disease, cancer, and diabetes. These effects are mostly associated with biologically active components that naturally exist in the product. The most important are the phenolic compounds, the carotenoids, vitamins C and E, and fibers. Composite foods such as ice creams, cereals, dairy and bakery products highly require finished processed fruits.

Osmotic treatment is a procedure that involves immersing a solid food in a hypertonic aqueous solution. It leads to the loss of water and a solute shift from the solution into the food. Osmotic solute transfer from the solution into the product goes hand in hand with water change from the product into the osmotic solution [1,2]. The factors affecting the rates of water removal and solute impregnation are the composition and the concentration of the osmotic solutes, the temperature of the osmotic solution, immersion time, the level of agitation, the specific characteristics of the food and the solution-to-food ratio. The osmotic dehydration of common fruits and vegetables, such as apples, bananas, carrots, potatoes, tomatoes etc. has been described by several authors [3-5].

Osmotic dehydration system has drawn increased attention thanks to the following advantages: (1) mild process temperatures do not affect the semi-permeable characteristics of cell membranes, (2) moderate temperatures can enhance the retention of color and flavor, (3) osmotic dehydration can reduce the overall energy requirement for further drying processes of the product such as hot-air drying and freeze drying [6,7]. In spite of those advantages, its commercial applications are still quite limited. Problems associated with difficulties to control large solute uptake by the food material, recycling and microbial stability of osmotic solutions are the main reasons for the limited industrial development [8]. Large solute uptake tends to cause a decreasing of the dehydration rate during the osmotic dehydration and further drying processes due to the reduced osmotic pressure gradient across the product-medium interface. In addition, large solute uptake gives negative impact on the nutritional profile of the product [8].

Most of the papers dealing with osmotic treatment of foodstuffs have been mainly focused on the modeling of the dehydration step in order to optimize the process conditions and ultimately expedite dehydration, but fewer studies have quantified the impact of process conditions on the quality attributes of the final product. The authors examined the effect of variables process on the final product quality attributes, whereas the investigation of the kinetic degradation of these quality attributes during processing is essential for the choice of the optimal processing condition.

The aim of the present work is to evaluate the influence of osmotic dehydration parameters on the kinetic degradation of some quality attributes of pear slices (total phenol content, ascorbic acid content, color, volume change) and on mass transfers (water loss and solid gain).

Material and Methods

Raw material

Fresh pears (*Pyrus communis* vc. Conference) were purchased

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from a local market in Massy (France) and stored at (4°C) until use. Individual weight of pear was 300 ± 25 g. Pears were equilibrated to room temperature before being cut into parallelepipedic pieces (1×0.8×0.8 cm^3, initial dimensions) with a cutter and a knife.

Osmotic dehydration procedure

Osmotic dehydration of the pears was conducted at a reduced factorial design of five levels of temperatures (20, 30, 40, 50 and 60°C) and five levels of osmotic sucrose solution concentrations (25, 35, 45, 55 and 65 w/w). Sampling period was fixed at 30, 120, 210, 300 and 390 min (Table 1). Samples were removed for solid gain, water loss, color parameters (L*, a* and b*), volume change, total phenolic and ascorbic acid contents measurements.

Osmotic solutions were prepared with commercial sucrose and distilled water. The slices were placed in 650 ml beakers containing the osmotic solution and maintained in a temperature-controlled bath for different drying times (according to the conditions presented in Table 1). Homogenization of the osmotic solution was obtained by mild and constant mechanical agitation at 100 rpm. The mass ratio of the osmotic medium to the sample was 20:1 in order to avoid significant dilution of the medium and subsequent decrease in driving force during the process. Mild temperatures (20-60°C) were used to avoid fruit degradation and cooking. The oxidation associated with long exposure to light was also prevented by keeping the samples in darkness during the processing. The samples were removed from the solution, drained, and the excess solution on the surface was removed using absorbent paper.]

Determination of solid gain and moisture loss

Weight and moisture content of pear slices were measured individually. For each set of experiments, before and after the process, samples of the fruits were weighed and then oven dried and weighed to determine their solid content.

The initial mass differences between samples were accounted for by expressing the water loss and solid gain in gram per gram initial dry matter (g g IDM^{-1}) [9-11]. Calculations of the amount of water loss and solid gain and their rates using the gravimetric method were based on the following relations:

$$\text{Water loss in relation to initial fresh mass of sample (g/g)} = \frac{\left[(m_0 - m) + (S - S_0)\right]}{m_0} \quad (1)$$

$$\text{Solid gain in relation to initial fresh mass of sample (g/g)} = \frac{(S - S_0)}{S_0} \quad (2)$$

where m_0, m are the initial mass and mass after sample period, S_0, S the initial mass of solids and mass of solids after sampling period, respectively.

Analysis

Moisture content: Moisture content was determined using the gravimetric method. The sample was dried in a ventilated oven at 70°C for 24 h. Moisture content was calculated from the weight difference between the fresh and the dried sample and expressed as g per g of the dry mater (DM).

	Variable levels				
Variables	-2	-1	0	1	2
Sucrose concentration (C) (°Brix)	25	35	45	55	65
Temperature of sucrose solution (T) (°C)	20	30	40	50	60
Osmosis time (t) (min)	30	120	210	300	390

Table 1: Operating conditions used for osmo-dehydration pear pieces.

Surface colour measurement: The colour of pear slices was determined using a Minolta Chroma Meter (HunterLab, CR-200, France) calibrated with a white standard tile. The results were expressed as Hunter colour values of L*, a*, and b*, where L* was used to denote lightness, a* redness and greenness, and b* yellowness and blueness. Hunter values of the fresh and osmotic dehydrated samples were measured in triplicate.

The chroma value is calculated by the following equation:

$$\text{Chroma} = (a^{*2} + b^{*2})^{1/2}, \quad (3)$$

Determination of total phenolic and ascorbic acid contents: A sample (5 g, weighed with precision) was homogenized with 10 mL of acetone (70:30, v/v) for 10 min. The raw extract was obtained after filtration on a filter paper (Whatman n°2). The complete analytical procedure was performed according to Georgé S et al. [12]. Polyphenols are commonly determined using Folin-Ciocalteu reagent, which interacts with other different reducing non-phenolic substances and can lead to an overestimation of polyphenol content. A solid phase extraction using a 1 cc-Oasis-HLB™ cartridge (Waters) was carried out on the raw extract of pear to eliminate the water-soluble reducing interferences, including ascorbic acid (AA). Colorimetric correction was performed by subtracting interfering substances contained in the water washing extract to the raw extract.

The water washing extract was then heated (2 h at 85°C) in order to eliminate AA. AA content was determined by subtracting substances contained in the water washing extract to the heated washing extract.

Total phenolic content (PC) was expressed as equivalent gallic acid (GA) (mg GA /100 g IDM) using a standard curve prepared at different concentrations of GA. AA content was expressed in mg/100 g IDM of pears.

Volume change: Sample dimensions before and after osmotic dehydration process were measured by using a numeric calliper.

Statistical analysis: The STATGRAPHICS plus 5.1 was used for the statistical analysis of results. Data obtained were subjected to a multiple analysis of variance (ANOVA) and the average values were compared using the Duncan multiple range test, at the 95% confidence level. Additionally, contour plots were performed.

Results and Discussion

Effect of osmotic dehydration conditions on mass transfers

The ANOVA of studied quality attributes and contour plots of water loss and solid gain of pear pieces osmotically dehydrated are shown in Table 2 and Figure 1, respectively.

The magnitude of *p-value* and coefficient *(Coef)* value in Table 2 indicate the positive contribution of sucrose concentration on water loss. It implies increased water loss with increase of solution concentration. Further, the interaction term of immersion time, sucrose concentration and temperature have positive and significant effect on water loss. The main factor affecting solid gain was the interaction between immersion time, sucrose concentration and temperature of pears. The increase in solution concentration resulted in an increase in the osmotic pressure gradients and, hence, higher water loss (Figure 1a and Figure 1b) and

Effect	Water loss (g/g IDM)		Solid gain (g/g IDM)		Volume change (cm^3)		AA (mg/100 IDM)		Total phenol content (mg/100 IDM)		Color parameter (a*)		Color parameter (b*)		Chroma	
	Coef	*p*	Coef	*p*	Coef	*p*	Coef	*p*	Coef	*p*	Coef	*p*	Coef	*p*	Coef	*p*
Constant	2.182	0.002	0.217	$< 10^{-3}$	0.623	0.052	0.631	0.048	9.206	0.556	-2.363	0.829	13.3	1.402	13.295	$< 10^{-3}$
C	0.032	0.034	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
t	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C^2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T^2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
t^2	-	-	-		-	-	-	-	$-3.732 \cdot 10^{-5}$	$< 10^{-3}$	-	-	-	-	-	-
C × T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C × t	-	-	-	-	-	-	-	-	-	-	-	-	0.001	$< 10^{-3}$	0.001	0.001
T × t	-	-	-	-	$-2.187 \cdot 10^{-5}$	$< 10^{-3}$	-	-	-	-	0.0012	$< 10^{-3}$	-	-	-	-
Fitted R^2	0.975		0.986		0.835		0.956		0.930		0.903		0.903		0.919	
Adjusted R^2	0.865		0.921		0.760		0.934		0.900		0.865		0.872		0.887	

p-value < 0.05 is significant at $\alpha = 0.05$

Table 2: Analysis of variance showing the effect of the variables.

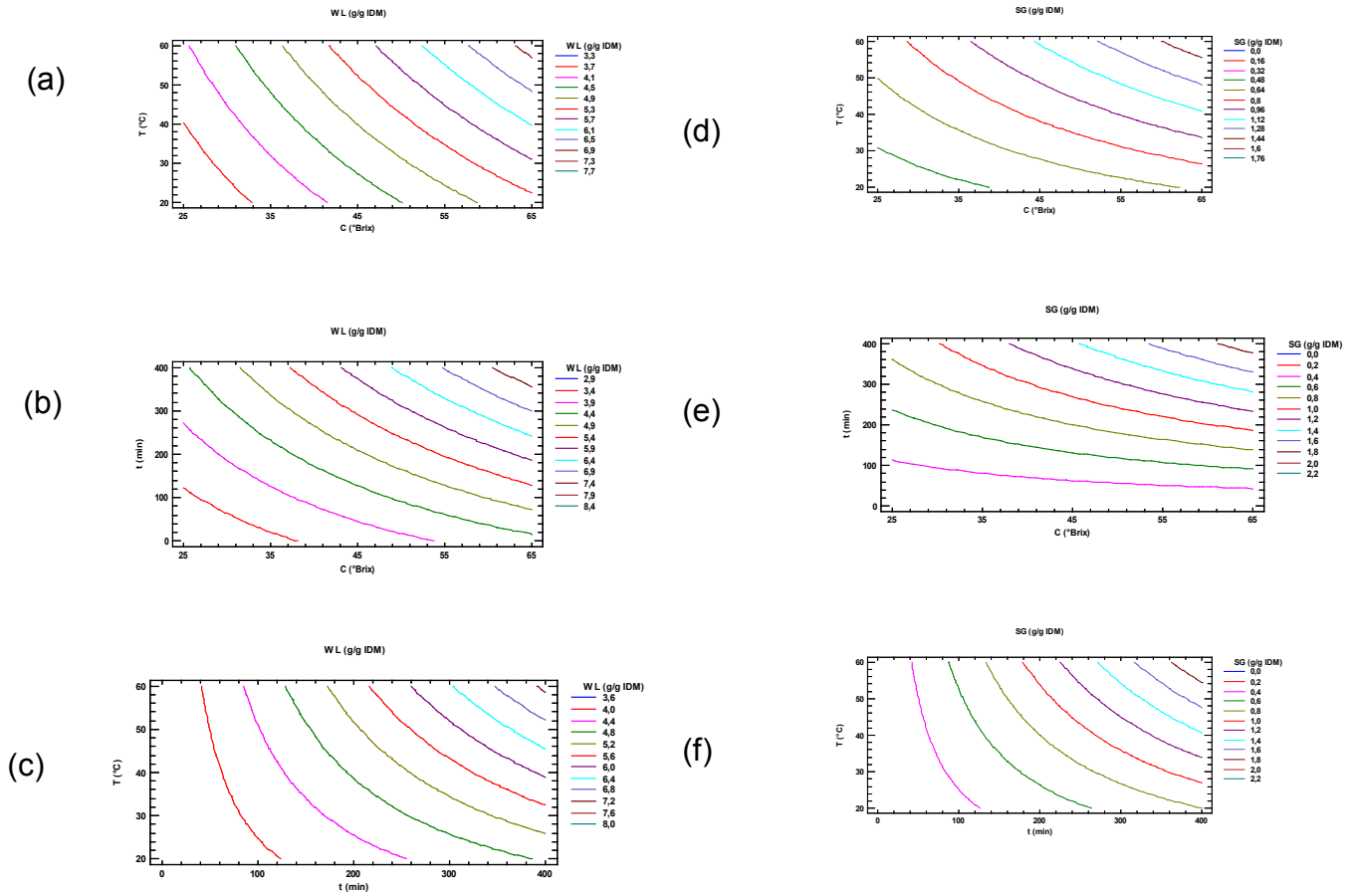

Figure 1: Contour plots for water loss (WL) and solid gain (SG) of pear pieces. Constant osmo-dehydration conditions: (a and d) osmosis time = 210 min, (b and e) temperature = 40°C, (c and f) sucrose concentration=45°brix.

solid uptake (Figure 1d and Figure 1e) values throughout the osmosis period were obtained. Similar results were reported by [13]. These results indicate that by choosing a higher concentration medium (60%), some benefits in terms of faster water loss could be achieved. However, a much greater gain of solid is observed. The increasing on solids gain and water loss with the solution concentration is due the high concentration difference between the pear samples and osmotic solution which increased the rate of diffusion of solute and water exchange with osmotic solution. Earlier report of [5] stated that water loss and solids gain by fruit pieces increased with increase in osmotic solution concentration [14] attributed the increased mass transfer of sugar molecules with increasing concentration to possible membrane swelling effect, which might increase the cell membrane permeability.

Typical temperature effect on osmotic dehydration of pears is

presented in Figure 1c and Figure 1f for the 45% (w/w) solutions. It was observed that temperature has increasing effect on the osmotic dehydration of pears. The increasing of osmotic medium temperature caused increased water loss and solid gain. Higher water loss and solids gain were observed at 40°C compared to those at 30°C and 20°C. Increase in solids gain and water loss when samples were immersed into a high temperature solution is due to increase in rate of diffusion in this condition. Higher temperatures seem to promote faster water loss through swelling and plasticizing of cell membranes as well as the better water transfer characteristics on the product surface due to lower viscosity of the osmotic medium [15]. This increasing of temperature influence has been clearly shown in previous works dealing with osmotic dehydration [16,8].

Effect of osmotic dehydration variables on the quality attributes of pears

Ascorbic acid: Figure 2 represents the contour plots of ascorbic acid content versus solution temperature and sucrose concentration (Figure 2a), versus immersion time and sucrose concentration (Figure 2b) and versus osmosis time and solution temperature (Figure 2c). The ascorbic acid content decreases with increasing processing time, osmotic concentration and temperature. Similar results were observed by Devic E et al. [17] for osmodehydrated apples. The authors reported that two independent mechanisms could be considered to explain the AA losses during osmo-dehydration of fruit: losses by diffusion from the fruit tissue into the osmotic solution during dehydration and losses due to chemical degradation during processing.

During osmotic dehydration, sucrose concentration in the soaking solution had a noticeable impact on ascorbic acid loss [18] showed that increasing the concentration of the soaking solution accelerates the outgoing moisture flux. This could explain the loss of ascorbic acid, which is highly soluble in water, by leaching with water.

A change of temperature of the sucrose solution from 20 to 60°C appears to have also an important impact on ascorbic acid content (Figures 2a and 2c). Ascorbic acid was mainly lost due to heat-sensitive reactions, mainly oxidation.

Total phenolic content: The total phenolic content of osmotic dehydration pears obtained as a result of different osmosis time and temperature is presented in Figure 3. The highest significant decrease

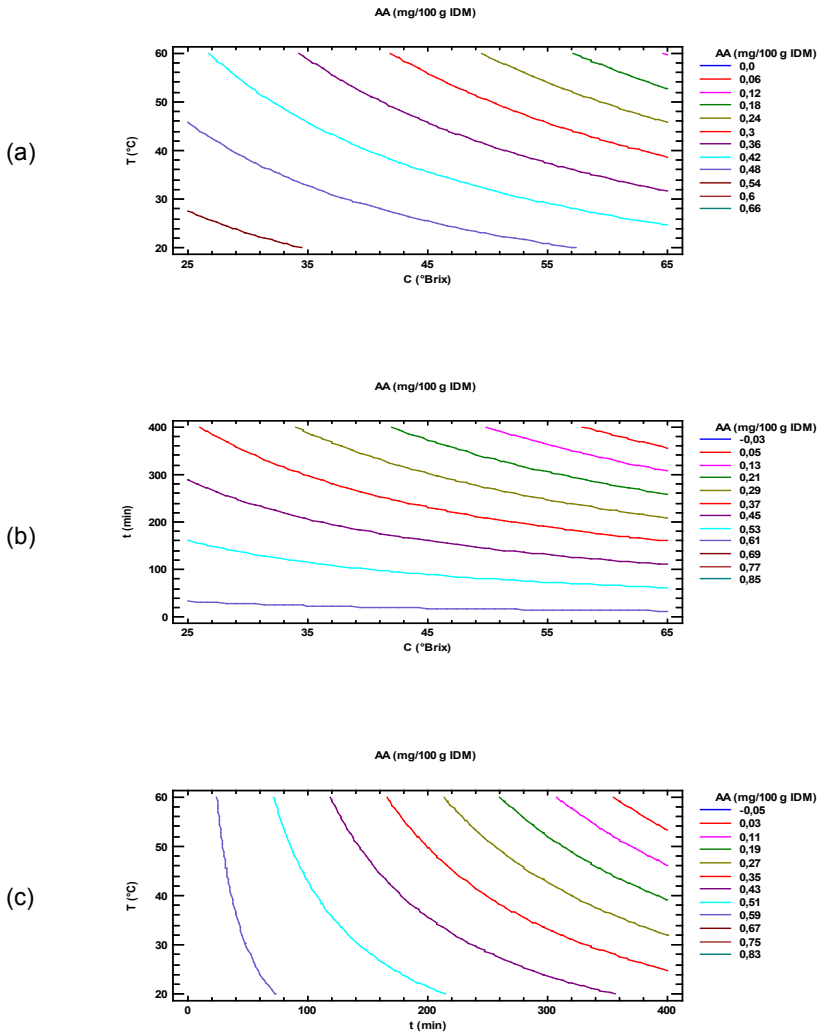

Figure 2: Contour plots for ascorbic acid content (AA) of pear pieces. Constant osmo-dehydration conditions: (a) osmosis time = 210 min, (b) temperature = 40°C, (c) sucrose concentration = 45°brix.

in the total phenolic was observed in the sample that was osmotically treated for 390 min. The osmosis time is the most significant factor ($p<10^{-3}$ (Table 2)) affecting the total phenolic content. More than one half of the total phenolics present in samples were lost (68.8%). Decreasing osmotic concentration time to 1 h decreased the loss of total phenolics to only 20% (Figure 3).

Total phenolic content of osmo-convective dried pears was significantly affected by the temperature of the sucrose solution and also by the sucrose concentration (($p < 0.05$), Table 2).

The loss of phenolic compounds during osmo-dehydration of fruit may be explained by both phenomena:

- The diffusion of the pear's hydrophilic smallest phenolic compounds with water into the osmotic solution during osmotic drying [17,19]. But this explanation is not sufficient because the essential phenolic compounds of pear are procyanidins, which are polymerized compounds and they cannot leach easily with water.

- The oxidation; increasing temperature resulted in an enhanced thermal degradation of cell membranes integrity, putting into contact phenolics and enzyme responsible of the oxidation reactions.

Volume change: In the conditions tested, final volume of pear slices, on average, ranged between 0.71 and 0.12 cm^3. The extent to which the pear pieces volume was significantly affected by the interaction between temperature and osmosis time (Table 2). For both variables (temperature and osmosis time), the harsher the conditions used, the greater the volume loss and the lower the final volume. These results suggest a better preservation of the cellular structure in pear pieces dehydrated under the mildest conditions of temperature and osmosis time (40°C and 210 min). High temperature promotes mobility in the system and favors the mass transfers, resulting in more extensive shrinkage when high temperature was applied as shown in Figure 4.

Color: During the osmotic dehydration of fruits and vegetables, the loss of color is one of the most significant changes. An increase was found in the a*, and b* values of osmotic dehydrated parallelipedic pieces of pears, whereas L* still invariant. Thus, for fresh fruit the values were L*=65.82 ± 1.67, a*=-0.42 ± 0.41, b*=16.77 ± 0.01, and for osmotic dehydrated fruits these values ranged as follows: L* from 56.47 to 71.21, a* from -1.93 to 3.75, and b* from 10.95 to 25.95.

Changes in redness and yellowness of pear can be evaluated by chroma colorimetric parameter, calculated according to Eq. (5) previously shown. Only the interaction term between osmosis time and sucrose concentration has a significant effect ($p < 0.05$) on the chroma variable (Table 2).

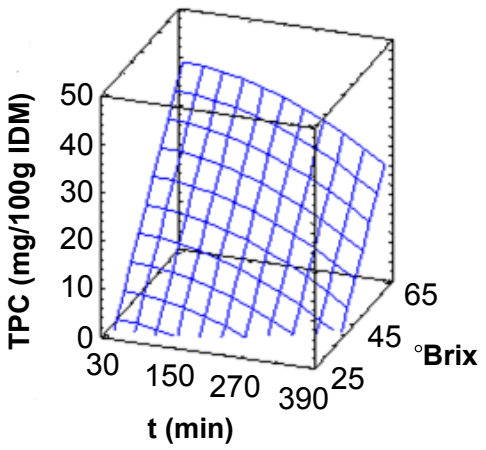

Figure 3: Contour plot for total phenolic content (TPC) of osmo-dehydrated pear pieces.

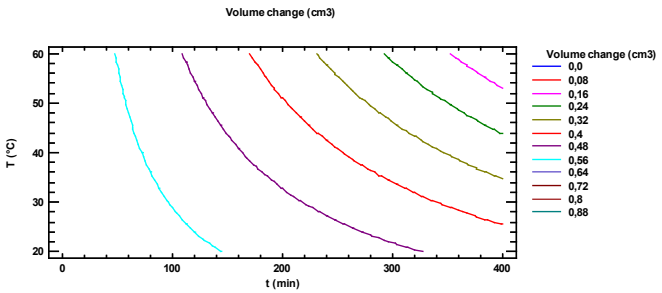

Figure 4: Contour plot for volume change of osmo-dehydrated pear pieces.

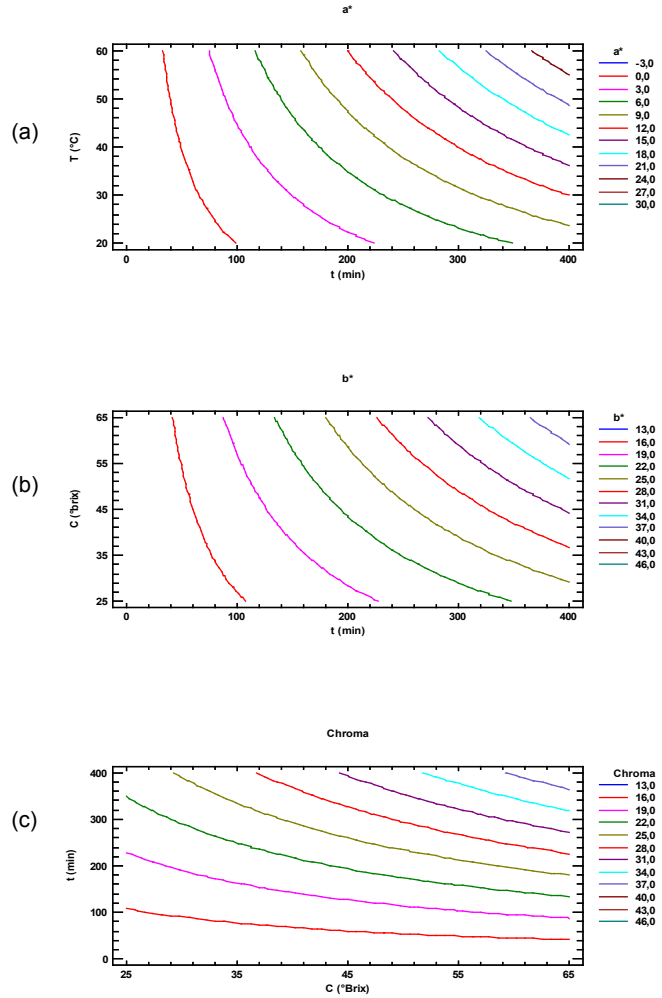

Figure 5: Contour plots for color parameters (a*,b* and chroma) of pear pieces. Constant osmo-dehydration conditions: (a) sucrose concentration = 45° brix, (b) temperature = 40°C.

Redness (a*), yellowness (b*) and chroma parameters for pear samples increased when they were treated in sucrose solutions. It could be observed that redness (a*) and yellowness (b*) parameters increased with the osmotic solution concentration Figure 5. This indicated lightening in color, and concentration of red pigment due the removal of water from pear samples. The increase in redness and yellowness is clear and seems to be a result of matrix concentration and solids uptake. Moreover, chroma increased with increase the osmotic solution concentration. Chroma values (Figure 5) increase during the osmotic dehydration. It was the only color parameter that had a significant increase along the process, denoting color intensification.

Conclusion

The stability of various nutritional and functional quality parameters of parallelipedic pieces of pears during osmotic dehydration depended mostly on the applied operating conditions.

The sucrose concentration in the osmotic solution (25-65% w/ w), osmosis time (30-390 min) and temperature (20-60°C) had a linear significant impact on water loss and solid gain. The water loss and solid gain were increased with increasing concentration and temperature.

Chroma revealed color intensification along osmotic dehydration. Sugar impregnation seemed to maintain luminosity, resulting in a final product very close to the fresh fruit. Longer osmotic concentration time resulted in higher loss of phytonutrients, mainly due to the leaching into sucrose solution and negative influence of oxygen.

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