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OSMOTIC DEHYDRATION OF PAPAYA (*Carica papaya* L.): INFLUENCE OF PROCESS VARIABLES

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ABSTRACT

Brazil is the biggest world producer of papaya and because its sweet taste and vitamins content this fruit is consumed *in natura* and processed in candies and some other products. It is necessary to find alternatives to minimize product losses and osmotic dehydration (OD) is one of these effective alternatives. This process takes into consideration a chemical potential difference between product and dehydrating solution. Besides water removal from product, the process also promotes solid gain due to high concentration of solute. In this study, it was verified the influence of temperature (30, 45 and 60°C), sucrose concentration (45, 55 and 65°Brix), lactic acid concentration (0.0, 0.05 and 0.1 M) and sample geometry (slice and cube). A central composite rotatable design (2^4) was utilized to analyze responses of water loss (WL), weight loss (WR) and solid gain (SG) at significance level of 90%. Temperature and sample geometry had more influence on water loss and weight loss, followed by sucrose and lactic acid concentration. This behavior showed that an increase of the variables leads to an increase in water and weight losses. Slice provided more water loss, weight loss and solid gain than cubic geometry. Obtained models for WL and WR responses through response surface methodology were significant and predictive.

INTRODUCTION

Fruit and vegetable dehydration by immersion in osmotic solutions has been of rising interest during the last decades since it can improve food quality when combined with air, freeze or vacuum drying or other preservation techniques, such as freezing. In osmotic dehydration a food is immersed in a concentrated solution containing one or more solutes. In the process partial dehydration and solute uptake occurs simultaneously. More water than solute usually transfers due to deferential permeability of cellular membranes (Mauro & Menegalli, 2003).

The driving force for water removal is the difference of chemical potential between the solution and the intracellular fluid. If the membrane is perfectly semi-permeable (i.e., water-permeable, solute-repellant) solute is unable to diffuse through the membrane into the cells. However, due to absence of semi-permeable membrane in food, there is always some solute diffusion into the food and leaching out of the foods own solute. Thus, mass transport in osmotic dehydration is actually a combination of simultaneous water and solutes transfer processes (Sablani et al., 2002; Rahman & Perera, 1999).

Osmotic dehydration can be used as a pre-treatment for partial dehydration of fruits and vegetables. This technique also allows the incorporation of certain solutes, without modifying the integrity of the product. The removal of water from solid foods is a form of food conservation, inhibiting the growth of microorganisms, besides preventing a large part of biochemical reactions, which occur while the moisture, is present (Park et al., 2002).

Recently osmotic dehydration process received more attention due to the consumer demand of minimally processed products. The use of the osmotic dehydration process in the food industry has several advantages: quality improvement in terms of color, flavor, and texture, energy efficiency, packaging and distribution cost reduction, no chemical pretreatment, provide required product stability and retention of nutrients during storage (Sablani et al., 2002; Rahman & Perera, 1999).

The osmotic dehydration process can be characterized by equilibrium and dynamic periods. In the dynamic period, the mass transfer rates are increased or decreased until equilibrium is reached. Equilibrium is the end of osmotic process, i.e. the net rate of mass transport is zero. The study of the equilibrium state is necessary for the modeling of osmotic process as a unit operation and also important for a good understanding of the mass transfer mechanisms involved in this system (Barat et al., 1999). Moreover knowledge of the end-point criteria can allow development of theoretical models allowing calculation of the process parameters (Sablani & Rahman, 2003; Lenart & Flink, 1984a).

It is very common in literature to consider finite food geometry as an infinite flat plate configuration, neglecting the diffusion in the other directions.Only few works have considered unsteady state mass transfer during osmotic dehydration (Beristain et al., 1990; Azuara et al., 1992; Rastogi & Raghavrao, 1997). Such assumptions hold good when thickness is very small as compared to sides (thickness<<sides) indicating negligible peripheral diffusion. However, when thickness is of equal magnitude to length and breadth (parallelepiped or cube), this assumption is no longer valid, because significant amount of diffusion takes place through peripheral sides as well. In such situation, it is much more required to account for the peripheral diffusion considering food piece as rectangular parallelepiped (cube is special case when all sides are equal) rather than infinite plate (Rastogi & Raghavarao, 2004).

The purpose of this work was to study the effect of the temperature (30, 40 and 60°C), sucrose concentration (45, 55 and 65°Brix), concentration of lactic acid (0; 0.05 and 0.1M) and geometry of the sample (cubic and flat plate) in the water loss, weight loss and solid gain during the process of osmotic dehydration of papaya.

MATERIAL AND METHODS

Material

The utilized papayas (*Carica papaya L.*) were purchased in a local market (CEASA – Campinas-SP), and had similar ripeness, skin color and format. Fruits were hand peeled and cut into cubes (2.0cm) and slice (5.5x3.0x0.5cm) keeping the same weight.

Analysis of physicochemical properties

Moisture content and total solids of samples was determined by A.O.A.C method no. 22013 (1984))*it would be helpful for the reader to have a short description).*

Osmotic treatments

The dehydrating solution was prepared by adding sucrose and/or lactic acid to distilled water until the desired concentration was reached. Osmotic dehydration (OD) was carried out in equipment with temperature and agitation control (80rpm). Product/solution ratio was 1/10. After 4 hours, samples were removed from the solution, drained and the excess of solution at the surface was removed with absorbent paper for posterior weight.

In each treatment, the OD parameters of the fruits were calculated based on the following equations expressed in g/100g of initial fresh fruit weight (Mújica-Paz et al., 2003):

$$WL = \frac{(ww_0)-(w_t - ws_t)}{(ws_0 + ww_0)} \times 100 \qquad (1)$$

$$SG = \frac{(ws_t - ws_0)}{(ws_0 + ww_0)} \times 100 \qquad (2)$$

$$WR = WL - SG \qquad (3)$$

where WL, SG, and WR represent the water loss, solids gain and weight reduction, respectively; ww_0 is the weight of water (g), ws_0 is the weight of solids initially present in the fruit (g); wt and ws_t are the weight of the fruit (g) and the weight of solids at the end of treatment (g), respectively.

Experimental method and statistical analysis

A second-level design with four factors at three levels each was used in order to take into account the individual effects. The experimental design included 16 different treatments and 3 central points for the each geometry sample, totaling 22 experiments.

The independent variables studied were the temperature (30, 40 and 60°C), sucrose concentration (45, 55 and 65°Brix), lactic acid concentration (0; 0.05 and 0.1M) and sample geometry (slice and cube). In each treatment, the sample was characterized before and after each step for moisture content and total solids.

Analysis of variance (ANOVA) was performed to determine the lack of fit and the significance of the linear and cross product effects of the independent variables on the quality attributes. The lack of fit test is a measure of the failure of a model to represent data in the experimental domain at which points were not included in the regression. The same analysis of variance was performed on all the dependent variables. The *F* value is the ratio of the mean square due to regression and the mean square due to real error. Generally, the calculated *F*-values should be several times the tabulated value, if the model is a good predictor of the experimental results. The model adequacies were checked by prediction error sum of squares and predicted R^2 (Barros Neto et al., 1996). Data statistical analyses were performed using Statistica 5.0 Software (Statsoft, 1997).

The following polynomial model was fitted to the data:

$$Y = b_0 + b_1 A + b_2 B + b_3 C + b_4 D + b_{12} AB + b_{13} AC + b_{14} AD + b_{23} BC + b_{24} BD + b_{34} CD \quad (4)$$

where bn are constant regression coefficients; Y is the response (i.e. WL or WR, %); A, B, C and D are temperature (°C), sucrose concentration (°Brix), lactic acid concentration (M) and geometry, respectively. Statistical significance of the terms in the regression equations was examined. Response surface plots were generated with the same software.

RESULTS AND DISCUSSION

Moisture content of fresh papaya was 90.12% (wet basis). Results of different runs of osmotic dehydration are shown in Table 1. The water loss, solid gain and weight reduction of papaya increase with an increased immersion time in the osmotic solution. In the most intense processing condition (65°Brix, 0.1M, 65°C for 4 hours and flat plate geometry), water loss and weight loss attained 79.73 and 74.15g /100g of initial fresh fruit, respectively.

Table 1- Experimental design and observed values of response variables.

Independent variables*				Dependents variables		
Temperature (°C)	Sucrose concentration (°Brix)	Lactic acid concentration (M)	Geometry	WL (%)	SG (%)	WR (%)
30 (-1)	45 (-1)	0 (-1)	Slice (-1)	45.31	11.71	33.82
60 (+1)	45 (-1)	0 (-1)	Slice (-1)	67.93	8.55	60.00
30 (-1)	65 (+1)	0 (-1)	Slice (-1)	54.08	13.47	40.61
60 (+1)	65 (+1)	0 (-1)	Slice (-1)	77.63	9.70	68.64
30 (-1)	45 (-1)	0.1 (+1)	Slice (-1)	50.84	10.20	41.32
60 (+1)	45 (-1)	0.1 (+1)	Slice (-1)	68.98	11.46	56.79
30 (-1)	65 (+1)	0.1 (+1)	Slice (-1)	63.35	8.51	54.84
60 (+1)	65 (+1)	0.1 (+1)	Slice (-1)	79.73	11.97	74.15
30 (-1)	45 (-1)	0 (-1)	Cube (+1)	25.75	10.40	15.35
60 (+1)	45 (-1)	0 (-1)	Cube (+1)	48.18	8.05	40.12
30 (-1)	65 (+1)	0 (-1)	Cube (+1)	33.04	4.97	29.23
60 (+1)	65 (+1)	0 (-1)	Cube (+1)	68.98	8.29	64.45
30 (-1)	45 (-1)	0.1 (+1)	Cube (+1)	37.89	8.12	30.37
60 (+1)	45 (-1)	0.1 (+1)	Cube (+1)	57.15	7.84	50.96
30 (-1)	65 (+1)	0.1 (+1)	Cube (+1)	44.71	8.21	33.81
60 (+1)	65 (+1)	0.1 (+1)	Cube (+1)	67.24	8.99	55.74
45 (0)	55 (0)	0.05 (0)	Slice (-1)	69.79	12.51	57.61
45 (0)	55 (0)	0.05 (0)	Slice (-1)	73.56	9.91	65.91
45 (0)	55 (0)	0.05 (0)	Slice (-1)	72.10	10.16	63.16
45 (0)	55 (0)	0.05 (0)	Cube (+1)	47.64	9.18	40.18
45 (0)	55 (0)	0.05 (0)	Cube (+1)	59.18	11.21	52.28
45 (0)	55 (0)	0.05 (0)	Cube (+1)	52.13	10.99	44.78

* Coded levels of the experimental design indicated in brackets

The analyzed variables (temperature, sucrose concentration, lactic acid concentration) and the intensity of their effects are presented on Figure 1.This results showed that the more concentrated dehydration solution and the higher temperature gave the higher water loss and weight loss.

Water loss was mostly influenced by temperature, followed by sucrose concentration and lactic acid concentration; this strong temperature influence has been clearly shown before in previous works (Lenart & Flink, 1984b; Lazarides et al., 1995) using other products and geometry.

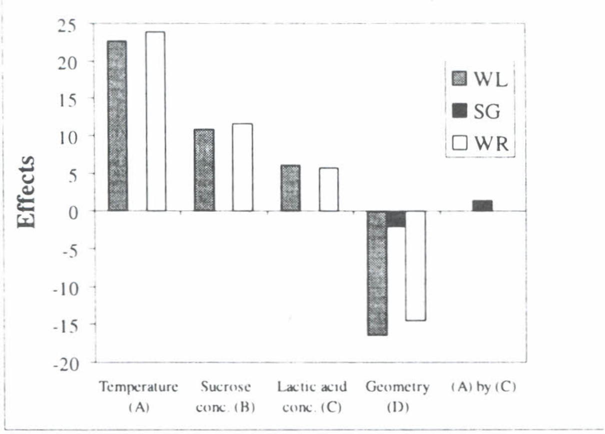

Figure 1- Effects of water loss, solid gain and weight reduction during osmotic dehydration process of papaya.

Slices provided higher water loss and weight loss than cubic geometry in all of the analyzed answers, what can be explained by the diffusion direction and the small sample thickness, which contributes for the water exit and, consequently, the weight decrease. The solids gain was influenced negatively by the geometry (the geometry of plane plate favored the increase of this response) and positively by the interaction of the temperature and concentration of lactic acid.

Models obtained for WL and WR response through response surface methodology were significant and predictive, are shown in Table 2.

Figure 2 shows that maximum water loss occurred when osmotic treatment was conducted in the higher temperature and higher solution concentration, independent of the type of solute. A similar effect was observed for weight loss (Figure 3), where it can be seen that increasing temperature and concentration of the osmotic solution also caused an increase in weight loss. Slice provided higher water loss and weight loss than cubic geometry.

Table 2 - Variance analysis of the second-order models to evaluate the OD process applied to papaya.

Source	DF*	SS**	MS***	$F_{calculated}$	$F_{0,90}$	Model
WL						
Regression	4	4160.10	1040.02	42.72	2.29	WL=57.51+11.30A+5.42B+3.06C-8.25D
Reside	18	438.17	24.34			
- Lack of fit	13	363.19				
- Pure error	5	74.98				
Total	21	4598.27			**R^2 = 0.93**	
WR						
Regression	4	4117.43	1029.35	30.38	2.29	WR=48.82+11.97A+5.79B+2.86C-7.25D
Reside	18	609.96	33.89			
- Lack of fit	13	499.64				
- Pure error	5	110.32				
Total	21	4727.39			**R^2 = 0.91**	

*DF = Degree of freedom; **SS = Square sun; ***MS = Mean square.

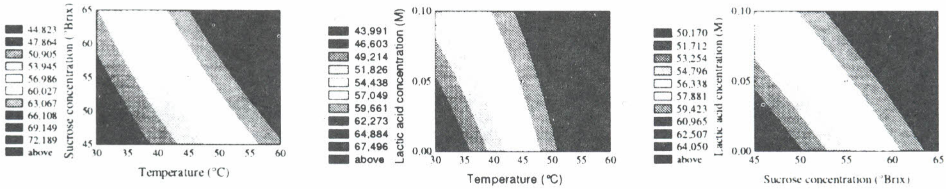

Figure 2 - Response contour plots for WL of papaya.

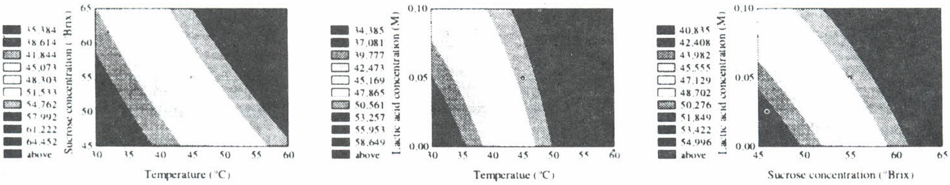

Figure 3 - Response contour plots for WR of papaya.

CONCLUSIONS

- Osmotic dehydration rate increased with the concentration of osmotic solution and process temperature;
- The water loss and the weight loss during osmotic dehydration of papaya pieces were influenced positively by the temperature, sucrose and lactic acid concentration and negatively by the sample geometry;
- The solids gain was influenced by interaction of the temperature and concentration of lactic acid solution;
- Slice provided more water loss, weight loss and solid gain than cubic geometry;
- The obtained models for the responses of water loss and weight reduction were significant, while for solid gain this did not happen.

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