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OSMOTIC DEHYDRATION OF CASHEW APPLE IN CORN SYRUP: INFLUENCE OF PROCESS VARIABLES

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ABSTRACT

Cashew apple slices were osmotically treated in corn syrup solids solutions at different concentrations (40-60% w/w), temperatures (30-50°C) and immersion times (90-240 min). Temperature was the most important factor affecting water loss, while immersion time was the most significant factor affecting solid gain. The model fitted the experimental data observations accurately, with regression coefficients that varied from 0.92 to 0.99.

INTRODUCTION

Cashew (*Anacardium occidentale* L.) is a native of tropical America, including Brazil and the West Indies. The key problem limiting its acceptability is its astringency. Other constraints hidering the full utilization of the fruits are the brief harvest period, poor storeability and lack of information on an appropriate processing technology (Ohler, 1979; Ortiz et al., 1982; Bidaisee and Badrie, 2001).

Osmotic dehydration is a process that has been proposed for the production of intermediate moisture foods as a preliminary stage to air drying, pasteurization or freezing (Palou et al., 1994). It consists in putting pieces of the fruit (or other foods) into a solution with high osmotic pressure (Ponting, 1973). This causes a water transfer from the product to the solution and solute transfer from the solution into the fruit and conversely (Lerici et al., 1985).

Rate and dewatering degree depend of the material and changes in its chemical composition depend on the kind of osmotic substance used, as well as the ratio of the material to osmotic solution, temperature, dehydration time and type of apparatus (Salvatori et al., 1997).

The aim of this work was to study the osmotic dehydration of cashew apple as a function of sugar concentration, temperature and immersion time through response surface methodology (RSM).

MATERIAL AND METHODS

The cashew apples used were from the red coloured variety, obtained from a local market in Campinas, Brazil. The average initial fruit pulp moisture content was 85.7% (w/w) and soluble solids content from 10 to 12°Brix.

Cashew apple slices (0.5 cm thick and 5 cm of diameter) were submerged in corn syrup solids (MOR-REX® 1940, Corn Products Brazil) solutions in 600 mL beakers at a solution/product ratio of 10:1 and placed inside shaker with agitation of 80 rpm. After removed from the sugar syrup, samples were drained and the excess of solution at the surface was removed with absorbent paper for posterior weight. The water loss and the solids gain were determined as outlined in Hawkes and Flink (1978).

A central composite rotatable design (Khuri and Cornell, 1996) was used for designing the experiments for osmotic dehydration of cashew apple using three factors: temperature (30-50°C), concentration (40-60% w/w) and time (90-240 min), which required 17 experiments, including the center point and two axial points (Table 1). Each experimental run was performed in triplicate.

It was assumed that a mathematical function, φ, exists for the response variable Y (water loss and solids gain), in terms of three independent process variables (Khuri and Cornell, 1996), temperature, concentration and time:

$$Y = \varphi(T, C, t) = \beta_o + \beta_1 T + \beta_2 C + \beta_3 t + \beta_{11} T^2 + \beta_{22} C^2 + \beta_{33} t^2 + \beta_{12} T.C + \beta_{13} T.t + \beta_{23} C.t \qquad (1)$$

In order to obtain the regression coefficients, analysis of variance, test of lack of fit and the generation of three dimensional graphs, the Statistica 5.0 (Statsoft, 1997) package was used.

Table 1. Experimental data for water loss (WL) and solids gain (SG) under different treatment conditions of temperature (T), corn syrup concentration (C) and time (t)

Treatment	T (°C)	C (%) w/w	t (min)	WL (%)	SG (%)
1	34	44	120	24.20	1.00
2	46	44	120	35.72	1.65
3	34	56	120	26.97	1.34
4	46	56	120	42.39	2.26
5	34	44	210	32.06	1.61
6	46	44	210	50.71	1.98
7	34	56	210	38.03	2.02
8	46	56	210	56.55	2.65
9	40	50	165	36.12	1.14
10	40	50	165	38.59	1.18
11	40	50	165	37.80	1.15
12	30	50	165	26.74	0.45
13	50	50	165	49.51	1.81
14	40	40	165	26.91	1.38
15	40	60	165	36.02	2.01
16	40	50	90	29.39	1.93
17	40	50	240	45.95	2.99

RESULTS AND DISCUSSION

The experimental values for water loss and solids gain under different treatment conditions are presented in Table 1. Regression analysis of the data obtained yielded the following polynomial models for water loss (WL) and solids gain (SG):

$$WL = -55.790 + 1.255T + 0.448C + 0.124t \quad (2)$$

$$SG = 17.756 + 0.013T - 0.581C - 0.060t + 0.005C^2 + 0.0002t^2 + 0.002TC + 0.0003Tt \quad (3)$$

The analysis of variance (ANOVA) results are presented in Table 2. The fitted models were significant ($p \leq 0.05$), possessing no lack of fit and satisfactory values of multiple correlation coefficients.
For water loss, the temperature (T) was the most important factor. There was no interaction among factors, meaning that water loss was a simple function of temperature, sugar concentration and immersion time.
For solid gain, immersion time and temperature were the most significant factors. The temperature also interacted with sugar concentration and time in determining the incorporation of solids.

Table 2. Analysis of variance for water loss (WL) and solids gain (SG) in the osmotic dehydration of cashew apple in corn syrup solids solutions

Corn Syrup	WL			SG		
	DF	MS	F	DF	MS	F
MODEL	3	429.616	52.037*	7	0.904	145.823*
RESIDUAL	13	8.256		9	0.006	
Lack of fit	11	9.467	5.924 (NS)	7	0.008	16.00 (NS)
Pure error	2	1.598		2	0.001	
Total	16			16		
R^2	0.923			0.991		

NS: non-significant
* Significant at 5% level

Computer generated surfaces were obtained using regression equations, as shown in Figures 1 to 4. Figures 1 and 2 show the variation of WL as a function of syrup concentration and temperature, and as a function of immersion time and temperature, respectively, which followed a linear pattern. The effect of syrup concentration and time was small when processing at temperatures lower than 34°C, leading to WL values lower than 40%. On the other hand, higher temperatures (close to 50°C) allow the use of osmotic solution concentration in its lower level (40%) and immersion time around 100 min in order to obtain WL values greater than 45%.
Figures 3 and 4 present the variation of SG as a function of the studied variables. A curvature of the surfaces was observed due to the high significance of pure quadratic terms. The solid pick up was minimum when lower temperatures (30 to 34°C) and intermediate immersion time (140 to 160 min) were used, independent of the concentration of the syrup used. On the other side, higher values of solid uptake was observed at treatment temperature above 45°C, which are probably due to the membrane swelling and plasticising effect, which improves the cell membrane permeability to sugar molecules. However, modified color and texture of the cashew apple slice were observed. As described by Lazarides et al. (1995), higher process temperatures seem to promote faster water loss through swelling and plasticising of cell membranes, faster water diffusion within the product and better mass transfer characteristics on the surface due to lower viscosity of the osmotic medium.

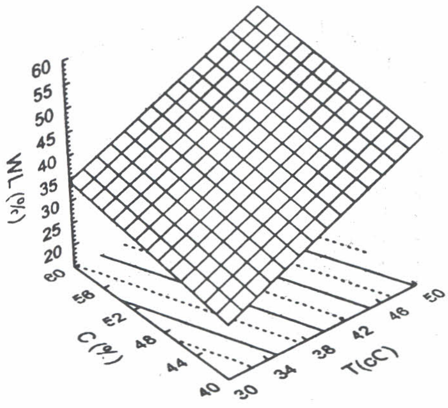

Figure 1- Response surface and counter plots of *WL* as a function of syrup concentration and process temperature at 165 min time

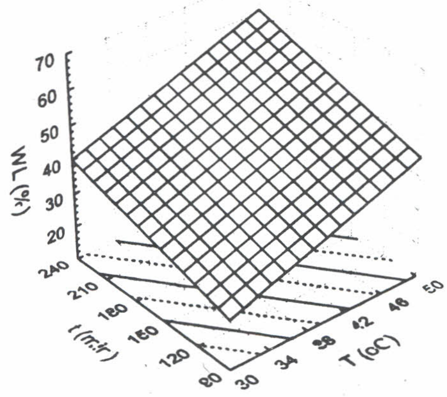

Figure 2- Response surface and counter plots of *WL* as a function of immersion time and temperature at 40% (w/w) corn syrup concentration

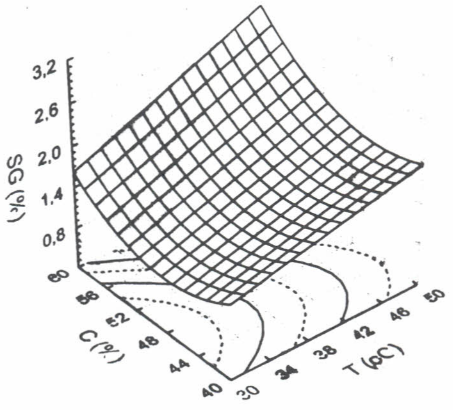

Figure 3. Response surface and counter plots of *SG* as a function of syrup concentration and process temperature at 165 min time

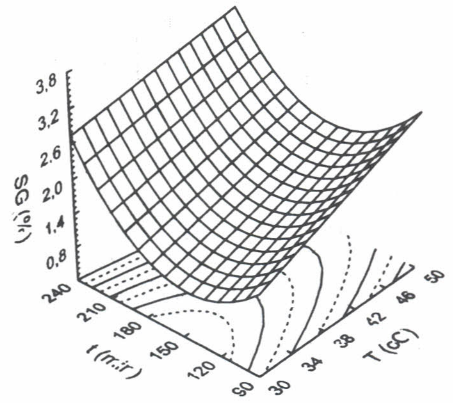

Figure 4. Response surface and counter plots of *SG* as a function of immersion time and temperature at 40% (w/w) corn syrup concentration

CONCLUSION

Water loss and solid gain take place in a parallel mode, with the rate of water loss was always higher than the rate of solid gain. Both process temperature and immersion time and solution concentration have a significant effect on water loss and solid gain during the osmotic dehydration of cashew apple slices in corn syrup. Temperatures close to 50°C should be avoided because they lead to disadvantageous modifications in the material structure. Depending on specific process goals one could choose from a range of process conditions to direct product treatment towards dewatering, impregnation or a mixed effect.

ACKNOWLEDGEMENT

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NOTATION

C	concentration	%, w/w
DF	degree of freedom	-
MS	mean square	-
SG	solids gain	g solids/100g initial wet cashew apple
t	time	min
T	temperature	°C
WL	water loss	g water/100g initial wet cashew apple

Greek Symbols

φ	function
β	equation coefficient

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