OSMOTIC DEHYDRATION OF CASHEW APPLE (*Anacardium occidentale* L.)IN SUCROSE SOLUTIONS: INFLUENCE OF PROCESS VARIABLES

P. M. Azoubel[1*], Â. A. El-Aouar[2], L. E. Kurozawa[2], G. C. Antonio[2], F. E. X. Murr[2]
[1]EMBRAPA Semi-Árido
[2]Faculdade de Engenharia de Alimentos - Universidade Estadual de Campinas

Abstract. The objective of this work was the study of osmotic dehydration of cashew apple slices in sucrose solutions as a function of temperature (30-50^{0}C), solution concentration (40-60% w/w) and immersion time (90-240 min) by using response surface methodology. A 2^3 full-factorial central composite was used as experimental design. The water loss (WL) and solid gain (SG) were taken as the dependent variables or response of the design experiment. Results shown that the water removal was higher than the rate of osmosis agent penetration. Temperature was the most important significant factor affecting water loss ($p \leq 0.05$), while immersion time was the most significant factor affecting solid gain ($p \leq 0.05$). The F-test analysis of variance revealed that the models were statistically significant at 5% level, showing high determination coefficients, explaining 96% of the variability in WL and 95% in SG.

Keywords: cashew, experimental design, osmotic dehydration.

1. Introduction

Pre-drying treatments of solid materials have been usually used to improve product quality and reduce product water load in the dryer (Alvarez et al., 1995). Dehydration of food products by osmosis is an age-old process that has received constant attention over the years as a pretreatment to further processing (Raoult-Wack, 1994; Torreggiani, 1995).

In osmotic dehydration a cellular tissue is immersed is a concentrated solution of sugars or salts in order to promote water loss in the cells due to the differences in water chemical potential established between the external solution and the internal liquid phase of cells. Nevertheless, due to the open structure of the tissues in the intercellular spaces and cut external cells, diffusion of external solutes also occur. This contributes to a net opposite flux of water and solutes that allows the tissue to become concentrated, depending on process conditions (Chiralt and Fito, 2003).

The rate of diffusion of water from any material made up of such tissues depends upon factors such as: type and concentration of the osmotic solutions, processing temperature and time, fruit/solution ratio, the size and geometry of the material and the level of agitation (Torreggiani, 1995).

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

* To whom all correspondence should be addressed.
Address: BR 428, km 152- C.P. 23- Zona Rural- Petrolina, PE – Brazil
E-mail: pazoubel@cpatsa.embrapa.br

2. Material and Methods

2.1. Osmotic dehydration

The cashew apples (*Anacardium occidentale* L.) used were from the red coloured variety, obtained from a local market in Campinas, Brazil. The fruits were sorted visually for size and maturity level (soluble solids content from 10 to 12°Brix). The average initial fruit pulp moisture content was 85.7% (w/w).

Cashew apple slices (0.5 cm thick and 5 cm of diameter) were submerged in sucrose 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 sucrose solution, 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), where the water loss and the solids uptake can be determined by gravimetric measurement, by assuming that, under the conditions used, the solutes initially present in the fruit slices will not diffuse against the total solids concentration gradient into the concentrated osmotic solution. The total wet weight (*tw*) is the weight of the cashew slice at the time of sampling, determined upon removal from the solution, and the total solids weight (*ws*) determined in a vacuum oven at 70°C for 24h. The solids gain (g solids/100g initial wet cashew apple) can be defined as:

$$SG = \frac{ws - ws_o}{w_o}.100 \qquad (1)$$

and the water loss (g water/100g initial wet cashew apple) as:

$$WL = \frac{ww_o - (tw - ws)}{w_o}.100 \qquad (2)$$

where ws_o is the initial weight of solids, ww_o the initial weight of water and w_o the initial wet weight of the sample.

2.2. Experimental Design and Statistical Analysis

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. 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:

$$Y = \varphi(T, C, t) = \beta_o + \beta_1 T + \beta_2 C + \beta_3 t + \beta_{11} T^2 + \beta_{22} C^2 + \beta_{33} t^2 + \beta_{12} T.C + \beta_{13} T.t + \beta_{23} C.t \qquad (3)$$

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.

3. Results and Discussion

The experimental values for water loss and solids gain under different treatment conditions are presented in Table 1. It can be observed higher values for water loss when compared to solid gain, indicating that the process mass transfer is mainly governed by the flux of water from the sample to the osmotic medium.

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)

Experiment	T (ºC)	C (%)	t (min)	WL (%)	SG (%)
1	34	44	120	28.01	4.20
2	46	44	120	51.07	2.67
3	34	56	120	32.67	2.83
4	46	56	120	53.94	5.03
5	34	44	210	39.55	4.67
6	46	44	210	53.90	5.82
7	34	56	210	43.64	3.72
8	46	56	210	64.14	6.76
9	40	50	165	41.11	3.31
10	40	50	165	41.33	3.56
11	40	50	165	42.65	3.34
12	30	50	165	32.99	2.10
13	50	50	165	61.54	4.29
14	40	40	165	35.72	3.52
15	40	60	165	45.96	4.17
16	40	50	90	31.74	3.47
17	40	50	240	55.32	6.18

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. It is important to point out that the largest contribution in the residual value was due to the lack of fit, indicating that the experimental data presented good reliability.

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

	WL			SG		
	DF	MS	F	DF	MS	F
MODEL	4	442.34	65.53*	7	3.43	24.50*
RESIDUAL	12	6.75		9	0.14	
Lack of fit	10	7.96	11.37 (NS)	7	0.18	9.00 (NS)
Pure error	2	0.70		2	0.02	
TOTAL	16			16		
$R^2 = 0.96$				$R^2 = 0.95$		

NS: non-significant ; * Significant at 5% level

Regression analysis of the data obtained yielded the following polynomial models for water loss (WL) and solids gain (SG):

$$WL = 32.102 - 3.237\,T + 0.060\,T^2 + 0.479\,C + 0.123\,t \quad (4)$$

$$SG = 69.674 - 1.142\,T - 1.428\,C - 0.144\,t + 0.007\,C^2 + 0.0003\,t^2 + 0.020\,T\,C + 0.002\,T\,t \quad (5)$$

Figure 1 shows the effects of concentration and temperature of the solution and immersion time on water loss and solid gain in the osmotic dehydration of cashew apple in sucrose solution. All effects shown were significant at a significance level of 5%.

For water loss (Fig 1a), the temperature (T) was the most important factor and it positively affected this response, indicating that an increase in temperature would lead to an increase in water loss. This strong temperature influence on water loss was observed by Lenart and Flink (1984), Lazarides et al. (1995) and Antonio et al. (2004) using other products. There was no interaction among factors, meaning that water loss was a simple function of temperature, sugar concentration and immersion time.

For solid gain (Fig. 1b), immersion time and temperature were the most significant factors. The temperature also interacted with sugar concentration and time in determining the incorporation of solids. Higher values of solid uptake was observed at treatment temperature above 45^{o}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.

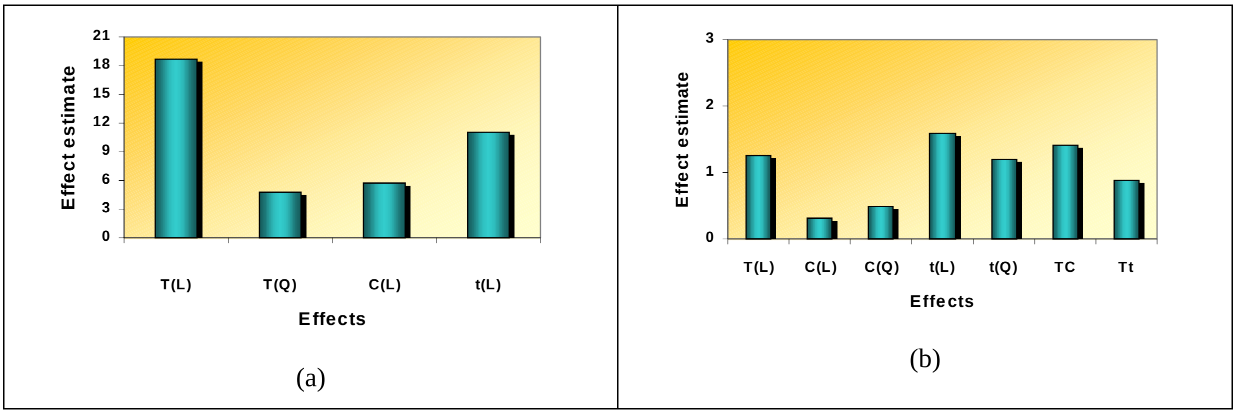

Fig. 1. Influence of concentration and temperature linear (L) and quadratic (Q) terms and the interaction among them on water loss (a) and solid gain (b) for cashew apple osmotic dehydration.

4. Conclusion

Water loss and solid gain take place in a parallel mode, with the rate of water loss always higher than the rate of solid uptake. Water loss was significantly influenced by temperature, while for solid gain, immersion time had the greatest effect. An increase of the variables leads to an increase in water loss and solid gain. Temperatures close to 50°C should be avoided because they lead to disadvantageous modifications in the material structure.

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