Osmotic dehydration of litchi pulp as a pretreatment for drying processes

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Abstract: Effects of osmotic dehydration on mass transfer properties such as water loss (W), solute gain (S) and weight reduction (G) during osmotic dehydration were investigated in order to determine the usefulness of this technique as pre-treatment for further drying of litchi pulp. The effects of variations in sucrose (50% and 60 % w/w) and salt concentrations (10% w/w), solution temperature, and length of immersion time on the moisture removal of the product and its organoleptic characteristics' on osmosis were analyzed. About 80% of the water loss occurred between 4-6 h under most of the conditions. Longer treatment time in high concentrations of sucrose resulted in a very soft product, which is difficult to handle and unsuitable for further drying. Increasing concentration at the same temperature did not cause significant increments in weight change. After osmotic treatment, the pulp was dried in a tray dryer at 70℃ for 10 h. Osmotic treatment was responsible for increasing drying rate in a subsequent convective tray drying.

Keywords: osmotic dehydration, cabinet drying, rehydration ratio, pretreatment, solute gain, weight loss

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1 Introduction

Litchi (*Litchi chinensis* Sonn.) is a subtropical tree of the *Sapindaceae* family, indigenous to China, India and Thailand. It is known for its attractive colour, delicious and juicy fruits with high nutritive value as well as its export potential. Due to its tremendous popularity, antiquity, excellent fruit quality and splendid aroma it should rightly be called as "the queen of fruits". The fruit is small, conical, heart-shaped or spherical in shape and bright red in colour. The edible portion of litchi fruit is a white to cream colored translucent pulp that surrounds a glossy and brown seed. The pulp is grape-like in texture, very succulent and aromatic, and is characteristic of a sweet, acid, juicy, soft but crisp (turgid) taste. With the increasing popularity of exotic fruits on the world market, litchi production has steadily increased in the past decades. Due to a very short production season of around two months in a year, markets are glutted and over-supplied, distress sales are frequent happenings in Litchi trade. Therefore, diverting a part of the produce towards processing for value addition and increasing its shelf life is a safe solution to the problem.

Osmotic dehydration is an important pre-treatment used prior to air-drying for removal of water in cellular solids (Rahman and Perera, 1996). Osmotic dehydration is a method for partial dehydration of water-rich foods, such as fruits and vegetables, by immersing them in a concentrate solution of sugar and/or salt. It results in two simultaneous crossed flows: a water outflow, from the food to the solution and a solute inflow from the solution into the food (Hough et al., 1993; Raoult-Wack et al., 1994; Spiazzi and Mascheroni,1997). The water flow may carry away other solutes (vitamins, minerals, sugars) present in the fruit. Osmotic dehydration is a preservation method that offers a high quality product by means of water removal without phase change

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(Torreggiani et al., 1990). Osmotically dehydrated fruits have a good retention of flavour, aroma, and high nutritional contents because osmotic dehydration has low influence on mineral contents and vitamin loss; it preserves organoleptic properties (Fabiano et al., 2005; Gabriela et al., 2004; Hussain et al., 2004; Lenart and Cerkowniak, 1991; Lazarides et al., 1997; Ruiz et al., 2005; Siva and Buncha, 2003; Sunjka and Raghavan, 2004; Torreggiani, 1993; Torreggiani and Bertolo, 2001).

Osmo-air drying is the combined approach of drying method in which osmotic dehydration and hot air drying is carried out simultaneously one after another (Rastogi and Raghavarao, 1997). This process of drying is an economical method of drying for fruit or vegetable materials containing higher moisture content, more than 70%. And its effect is also more acceptable than any other drying methods (Diana and Walter, 2006). Osmotic dehydration is therefore one of the effective ways to reduce overall energy requirements in dehydration. Osmotic drying has been combined with conventional drying methods such as hot air drying to produce shelf-stable fruit products. This paper reports results of effects of osmotic treatment on mass transfer and some quality characteristics of litchi slices.

2 Materials and methods

2.1 Sample preparation

Litchis obtained from local market were washed using tap water to remove the adhered extraneous materials, peeled manually and then sliced into 4 pieces. The diseased, discolored, damaged or sun burnt slices were removed. The cut slices were stored at 4℃ in refrigerator and then allowed to sit on room temperature (30±2℃) for 1 hr before the experiment was started. The slices were gently blotted with absorbent paper prior to osmotic dehydration for determination of initial weight of each sample (Lenart and Flink, 1984a and 1984b).

2.2 Osmotic pretreatment

Two sugar concentrations (50% and 60% w/w) and one salt concentration (10% w/w) were mixed to obtain two different osmotic solutions for litchi sample. These concentrations were selected as being representative of osmotic ranges recommended in various published research (Lerici et al, 1985; Lenart and Flink, 1984a and 1984b). Salt was used because it retards oxidative non-enzymatic browning (Lenart and Gródecka 1989). The effects of salt and sugar were chosen from the viewpoint of organoleptic characteristics. Potassium Metabisulphite, 0.1% by mass was added to increase storage/shelf life of product under adverse temperature conditions (Ruiz et al., 2005). The osmotic solution was used at 25, 35 and 40^{o}C, and immersed in the osmotic solution for 4 and 6 h (Gabriela et al., 2004; Singh et al., 1999; Torreggiani and Bertolo, 2001). The osmotic dehydration was carried out in separate 250 mL erlenmeyer flasks to avoid interference between the samples and runs. The osmotic solution to fruit ratio was maintained at 5:1 (weight basis). The experiment was performed with constant mechanical agitation (150 r/min) in a rotary shaker (Tecnal model TE-420), which homogenize the osmotic solution avoiding formation of local concentration gradients. After removal from the solution, the dehydrated samples from each group were drained and blotted with absorbent paper to remove excess solution. The final volume of osmotic solution was also measured using measuring cylinder. Moisture content was determined according to the method described in AOAC, Method 934.06 (AOAC 1990). This was done for calculating the total dry materials present in the litchi fruit.

The characteristics for osmotic treatment were determined using the parameters, namely water loss (W), solute gain (S) and weight loss (G).

$$W = \frac{Mwo - Mwt}{Mwo} \quad (1)$$

$$S = \frac{St - So}{Mo} \quad (2)$$

$$G = \frac{Mt - Mo}{Mo} \quad (3)$$

where, M: sample weight, kg; Mw: water content in M kg sample, kg; S: sucrose, and/or NaCl content in M kg sample; O: initial conditions; t: sampling time.

2.3 Air drying

The osmotic treated litchi was tray dried. Known amount (20 g) osmotically dehydrated litchi samples were kept in 30 Petri dishes. Three replications of each sample were done. The samples were put in a tray dryer and set at 70℃ (Ranganna, 1999). The samples were removed, two at a time for quality control during the osmotic treatment by destructive sampling at 15, 30, 45, 60, 75, 90, 120, 150, 180, 240, 300, 360, 420, 480, 600 min and their final weight measured using an electronic balance. All experiments were carried out at a constant temperature.

Dried slices were stored up to four months in refrigerated chambers in polyethylene sheet bags at 15℃. Consumer acceptance test prior to storage studies was conducted using 9-point hedonic scale (Krokida et al., 1999). The samples scoring an overall quality of seven or above were considered acceptable and those receiving below six were considered unacceptable.

2.4 Statistical analysis

Data obtained were subjected to statistical analysis to find out the effect of different treatment (OD_{124}, OD_{126}, OD_{134} and OD_{136}) and osmotic temperatures (25, 35 and 40℃) on water loss (W) and solute gain in litchi after osmotic treatment in sucrose solutions at different osmotic temperatures. The data were analyzed statistically (p<0.01) using STPR program (developed at GBPUAT, Pantnagar, Uttarakhand, India) in a Completely Randomized Design (CRD) with four levels of treatment, three levels of osmotic temperatures with three replications.

3 Results and discussion

3.1 Osmotic dehydration as pre-treatment

The dewatering process of litchi pulp (with moisture content of 83.5%, w.b.) in osmotic sucrose-salt solutions was found to slow down considerably as the immersion time exceeded six hours. Although the system was far away from the equilibrium, the rate of water removal decreased dramatically. The reduction of the water permeability of the membrane could be a possible explanation for this observation. It was seen that there was a softening of the litchi slices when treated at longer time of osmotic treatment and high temperature and high concentrated solution. This also led to unaccounted mass losses during wiping. This implies that it should not be recommended to employ high temperatures and longer time during the osmotic dehydration of the litchi pulp since a firm texture is important for further handling during subsequent drying operations.

The effect of treatments was significant on the water loss (W) and solute gain (S) (p<0.01). However, the interaction effect of treatments and osmotic temperature on water loss (W) and solute gain (S) was non-significant (Tables 1 and 2). The osmotic solution (60% sucrose-10% salt, w/w) had an increased moisture removal as compared to the other osmotic solution (50% sucrose-10% salt, w/w). The reason for such behaviour is due to greater shrinkage damage taking place due to the higher concentration of solutes in osmotic solution. Since the moisture is removed by pressure difference between the inside of the sample and solution, the pressure of solution affects the cells of the sample and high concentrated solution results greater entry of solute solid to the sample resulting in the cell breakage and ultimately the shrinkage of the sample.

Table 1 Water loss (W) in litchi after 4 and 6 h osmotic treatment in sucrose solutions at different osmotic temperatures

Treatment	Osmotic solution		Treatment time/h	Temperature/℃		
	Sucrose	Salt		25	35	40
OD_{124}	0.50	0.10	4	39.63	40.38	41.26
OD_{126}	0.50	0.10	6	38.42	38.29	40.86
OD_{134}	0.60	0.10	4	42.54	44.65	44.96
OD_{136}	0.60	0.10	6	42.05	43.48	44.10
Effect	CD (5%)		SEM			
Treatment (A)	1.762		0.445			**
Temperature (B)	1.525		0.386			*
Interaction (A XB)	3.052		0.772			NS
cv			3.218			

Table 2 Solute gain (S) in litchi after 4 and 6 h osmotic treatment in sucrose solutions at different osmotic temperatures

Treatment	Osmotic solution		Treatment time/h	Temperature/℃		
	Sucrose	Salt		25	35	40
OD_{124}	0.50	0.10	4	7.23	7.10	7.00
OD_{126}	0.50	0.10	6	7.34	7.23	7.15
OD_{134}	0.60	0.10	4	7.65	7.31	7.20
OD_{136}	0.60	0.10	6	7.72	7.52	7.33
Effect	CD (5%)		SEM			
Treatment (A)	0.313		0.079			*
Temperature (B)	0.271		0.068			*
Interaction (A XB)	0.542		0.137			NS
cv			3.256			

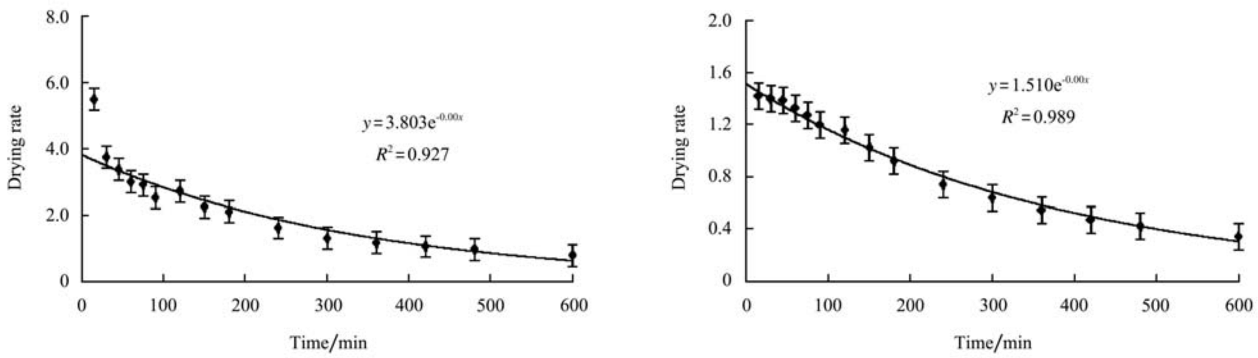
The effect of osmotic temperatures was also significant (p<0.01) on water loss (W) and solute gain (S). The temperature showed mainly an indirect effect on the overall water loss and solute gain within the studied moderate temperature range (30–40℃). An increase of the temperature results in a decrease of the viscosity of the sugar solution. This improves the surface contact between material and solution and results in an enhanced dewatering effect. Thus, an increase of the treatment temperature enhanced the weight loss of the material as a result of the enhanced water loss. Also, effect of temperature was observed on the solute gain for osmotic solutions (Tables 1 and 2). At lower concentrations of the solution an increase of the temperature was related with the decrease of the solute gain (Diana and Walter, 2006).

3.2 Convective drying

A main part of the water present in the fresh litchi was removed during the osmotic treatment after 360 min osmotic pre-treatment in a sucrose sodium-chloride solution. Pre-treated litchi in osmotic solutions need less drying time to reach the desired product. Furthermore pre-treating in a solution leads to an excellent quality retention, even after four months' storage. For this cabinet drying has been used in the drying experiment so as to reduce the moisture content (m.c.) level of the product to the optimum level of storage of the product. Moisture content during the air-drying process decreases with time which is in compliance with the nature of drying characteristics of various researches made for drying of fruit vegetable and cereals (Lyderson, 1983; Gabriela et al., 2004). From Figure 1, it can be seen that the drying rate decreases with treatment time. The reason for the above-mentioned nature of the drying curve is that initially the moist litchi surface acts as a free water surface and the rate of moisture migration from the interior of the product to the surface. With time there is a decrease in the wet surface and hence the drying rate decreases, as drying proceeds, the fraction of wet surface decreases to zero where drying process ceases. The statistical analysis of drying data for best osmo-air dried samples was carried out which gave the relationship with good coefficient of determination (R^2 values).

As far as final moisture content is concerned, osmo-air dried (OD_{124}) had the lowest final m.c. of 15.00% (w.b., %) and highest for sample with no pre-treatment (18.50%, w.b.) (Figure 2). It can be seen that moisture reduction was maximum for OD_{136} while the moisture reduction during cabinet drying was maximum in OD_{124} among the treated samples. The reason for the attainment of high m.c. in remaining osmotically treated sample was due to solute impregnated to the litchi sample which may have provided the diffusion barrier for the movement of moisture from inside to the surface and from the surface to the environment which was in compliance with results of research work done by Diana and Walter (2006) and Fabiano et al. (2005).

Consumer acceptance test prior and after 40 days storage was conducted for the rehydrated litchi pulp using 9-point hedonic scale. The result of the sensory analysis showed that 45% of the responses marked the sample as "like very much" and the remaining 55% as "like moderately" (significant at p<0.05 level). Sensory evaluation of all the samples were found to be acceptable but the osmo dried sample OD_{124} stored at room temperature showed high sensory scores as compared to raw and other osmotically treated litchi samples with respect to their color, flavor, texture (crispness) and overall quality.



a. No pretreatment

b. OD_{124}

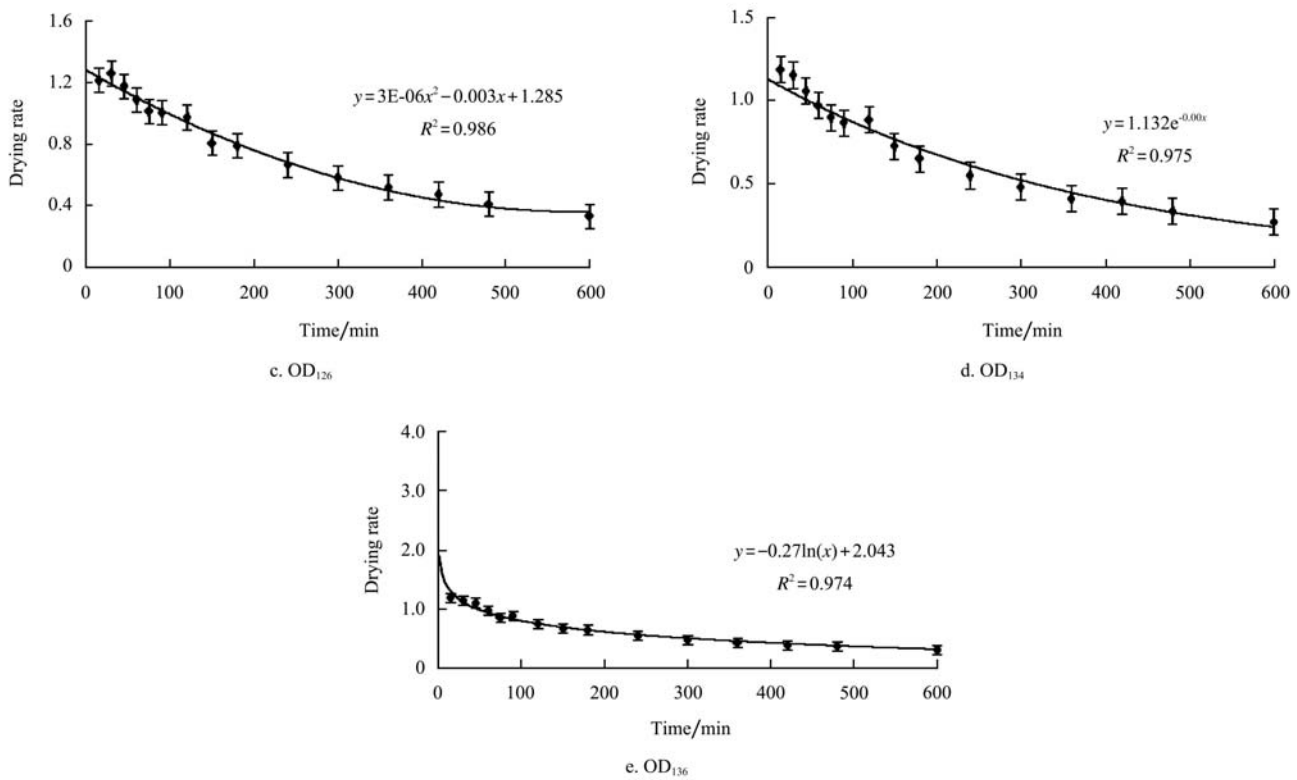


Figure 1 Drying rate (g of water removed per min per 100 g of bone dry material) versus time curve with standard error bars during convective drying of Litchi samples (error bars represent one standard error above and below the mean)

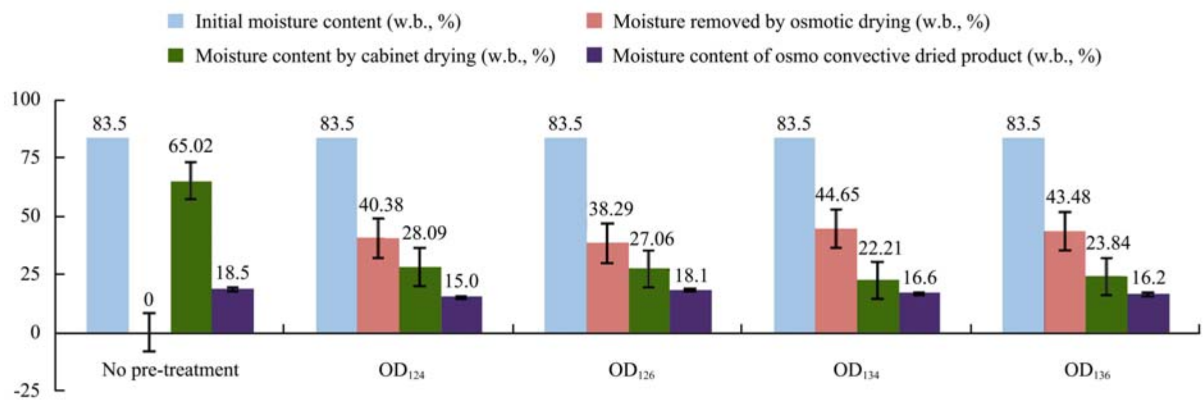


Figure 2 Overall drying behaviour of osmo-convective dried litchi pulp (error bars represent one standard error above and below the mean)

4 Conclusion

The use of ternary sucrose-salt aqueous solutions showed to be very effective concerning the water removal from litchi fruit. An increase of the concentration of sucrose solutions is associated with an enhancement of the dewatering effect. The drying time of litchi slices was reduced and the retention of physiological active compounds enhanced. Overall osmotic dehydration permits to reduce the moisture content at a low energy intake. It does not represent a saving in total drying time but can permit a significant energy saving per kg of water removed. Most efficient water removal occurred between zero to six hours indicating that it may not be necessary to carry out the osmotic treatment step for longer hours. However, water loss, solids gain and weight loss increased with longer time of treatment. The results also suggested that for litchi, temperature is an important variable. Due to the soft texture of litchi, osmotic treatment of litchi needs not to be done at extreme conditions of temperature and concentration.

ABBREVIATIONS

wb	Wet basis
db	Dry basis
^{0}C	Degrees Celsius
OD	Osmotic dehydration
OD_{124}	Osmotically dried sample, 50% sugar & 10% salt (W/V), 4 h
OD_{126}	Osmotically dried sample, 50% sugar & 10% salt (W/V), 6 h
OD_{134}	Osmotically dried sample, 60% sugar & 10% salt (W/V), 4 h
OD_{136}	Osmotically dried sample, 50% sugar & 10% salt (W/V), 6 h

References

AOAC. 1990. Official methods of analysis. Association of Official Analytical Chemists. Washinton D. C.

Diana, B., and E. L. Walter. 2006. Osmotic dehydration of fruits and vegetable. www.diana.behsnilian/online.e-paper, accessed on 01-09-2010 (11.30 am).

Fabiano, A. N., S. Fernandes, C. P. Odisséia, and L. Edson. 2005. Optimization of osmotic dehydration of papaya followed by air-drying. *Food Research International*, 39 (4): 492-498.

Gabriela, A., T. Pompeu, C. Paulo, F. Carneiro, and C. Hilary. 2004. Osmotic dehydration of mango: effects of temperature and process time. *International Sugar Journal*, 12 (8): 70-71.

Hough, G., J. Chirife, and C. Marini. 1993. A simple model for osmotic dehydration of apples. *Lebensmittel-Wissenschaft und-Technolgie*, 26 (2): 151-156.

Hussain, I., M. Iqbal, and N. Ayub. 2004. Effect of sucrose and glucose mixture on the quality characteristics of osmotically dehydrated banana slices. *Pakistan Journal of Nutrition*, 3 (5): 282-284.

Krokida, M. K., C. T. Kiranoudis, and Z. B. Maroulis. 1999. Viscoelastic behavior of dehydrated products during rehydration. *Journal of Food Engineering*, 40 (1999): 269-277.

Lazarides, H., V. Gekas, and N. Mavroudis. 1997. Apparent mass diffusivities in fruit and vegetable tissues undergoing osmotic processing. *Journal of Food Engineering*, 31 (1): 315-324.

Lenart, A., and M. Cerkowniak. 1991. The effect of osmotic dehydration on convective drying of apples. In *Proc. second European Commission Copernicus Programme Concerted action CIPA-CT94-0195*. 9-14. Warsaw, Poland

Lenart, A., and J. M. Flink. 1984a. Osmotic concentration of potato - criteria for end point of osmosis process. *Journal of Food Technology*, 19(6): 45-63.

Lenart, A. and J. M. Flink. 1984b. Osmotic concentration of potato - spatial distribution of the osmotic effect. *Journal of Food Technology*, 19(6), 65-89.

Lenart, A. and E. Gródecka. 1989. Influence of kind of osmotic substance on the kinetics of convection drying of apples and carrots. *Food Technology and Nutrition*, 18(1): 27-35.

Lerici, C. R., G. Pinnavaia, M. Rosa, and L. Bartolucci. 1985. Osmotic dehydration of fruits: influence of osmotic agents on drying behaviour and product quality. *Journal of Food Science*, 50 (5): 1217-1226.

Lyderson, A. L. 1983. Mass transfer in engineering practice. John Wiley and Sons publishing company, New York.

Rahman, M. S., and C. Perera. 1996. Osmotic dehydration: a pretreatment for fruit and vegetables to improve quality and process efficiency. *The Food Technologyst*, 25 (4): 144-147.

Ranganna, S. 1999. Handbook of analysis and quality control for fruit and vegetable products (II Edition). Tata Mc-Graw Hill publishing company Ltd, New Delhi.

Raoult-Wack, A., G. Rios, R. Saurel, F. Giroux, and S. Guilbert. 1994. Modeling of dewatering and impregnation soaking process (osmotic dehydration). *Food Research International*, 27 (2): 207-209.

Rastogi, N. K., and K. S. M. S. Raghavarao. 1997. Water and solute diffusion n coefficients of carrot as a function of temperature and concentration. *Journal of Food Engineering*, 34 (4): 429–440.

Ruiz, R. Y., L. A. Caicedo, G. Camacho, and L. M. Clavijo. 2005. Determining the effect of sucrose osmotic solution re-use on the pineapple´s osmotic dehydration kinetic. *Journal of Chemical Engineering*, 30 (45): 03-06.

Singh, S., U. S. Shivhare, J. Ahmed, and G. S. V. Raghavan. 1999. Osmotic concentration kinetics and quality of carrot preserve. *Food Research International*, 32(7): 509–514.

Siva, A. and P. Buncha. 2003. A mathematical model of effective moisture diffusivity for lychee drying. In Proceedings of the International Conference on Crop Harvesting and Processing, 9, Louisville, Kentucky USA.

Spiazzi, E., and R. H. Mascheroni. 1997. Mass transfer model for osmotic dehydration of fruits and vegetables- I. development of the simulation model. *Journal of Food Engineering*, 34(4): 387-410.

Sunjka, P. S., and G. S. V. Raghavan. 2004. Assessment of pretreatment methods and osmotic dehydration for cranberries. *Canadian Biosystems Engineering*, 46 (1): 45-48.

Torreggiani, D. 1993. Osmotic dehydration in fruit and vegetables. *Process and Food International*, 26 (1): 59–68.

Torreggiani, D., E. Senesi, E. Forni, and G. Bertolo. 1990. Influence of pasteurisation on the quality of osmo-dehydrated fruit: cherry, apricot, clingstone peach. In proceeding of Engineering and Food. Spiess, Elsevier Applied Science, London.

Torreggianni, D., and G. Bertolo. 2001. Osmotic pre-treatments in fruit processing: chemical, physical and structural effects. *Journal of Food Engineering*, 49 (2-3): 247.