RESEARCH PAPER | International Journal of Agricultural Engineering | Volume 6 | Issue 2 | October, 2013 | 323–328

Mass exchange during osmotic dehydration of sapota

KEDARNATH, R.C. VERMA, ASHOK KUMAR AND LEENA TYAGI

Received : 09.05.2013; **Revised :** 10.09.2013; **Accepted :** 10.10.2013

See end of the Paper for authors' affiliation

Correspondence to :

KEDARNATH
College of Food Processing Technology and Bio Energy, Anand Agricultural University, ANAND (GUJARAT) INDIA
Email : patil0386@gmail.com

ABSTRACT : In osmotic dehydration, the sapota samples were dried by immersing in a sugar syrup solution in three sugar concentrations 30, 40 and 50 °Brix at three syrup temperatures 30, 40 and 50°C. In the process, exchange of various components as loss of water and sugar gain from and by the samples takes place. The water loss, sugar gain and mass reduction were found to be 13.54 to 30.25; 23.84 to 36.66 and 3.80 to 6.40 per cent in 30, 40, and 50 °Brix sugar solution at 30, 40, and 50°C.

KEY WORDS : Osmotic dehydration, Water loss, Mass reduction, Solid gain

HOW TO CITE THIS PAPER : Kedarnath, Verma, R.C., Kumar, Ashok and Tyagi, Leena (2013). Mass exchange during osmotic dehydration of sapota. *Internat. J. Agric. Engg.*, **6**(2) : 323-328.

In India, sapota (*Achras sapota* L.) is generally consumed fresh. Ripened sapota cannot be stored for more than a day or two as it is highly perishable in nature, ripens faster and becomes unfit for consumption very soon (Jain and Jain, 1998). In sapota, post-harvest losses ranged from 25-30 per cent. Wastage of large quantities of sapota fruits before it reaches the consumer is due to poor quality transportation, high ethylene evaluation and metabolic activity during storage. One effective method of reducing this huge loss would be by converting it into various commercial sapota products like slices, powder, juice, concentrate, *etc.* from the fruits before it perishes (Ganjyal *et al.*, 2005). Among the various preservation methods, drying is the most convenient and simplest method throughout the world. Besides preserving seasonal commodities, dehydrated fruit products have inherent advantages, such as prolong shelf life, higher degree of resistance to bacterial attack and lower transportation, handling and storage costs.

Osmotic dehydration is a process used for to water removal at low temperature with low energy consumption. Since this process cannot remove moisture to a level that will avoid microbial growth, it can be suitable only for pre-treatment (Barbosa-Canovas and Vega-Mercado, 1996).

Many researchers have studied osmotic dehydration of various fruits and vegetables, such as apple, banana, carrot, cherry, citrus fruits, grape, guava, mango, *etc.* (Sethi *et al.*, 1999; Torreggiani and Bertolo, 2001; Jain *et al.*, 2003). The osmotic dehydration process has been studied and used as a pre-treatment prior to further processing such as freezing (Ponting, 1973), vacuum drying (Dixon *et al.*, 1976) and convective-drying (Pisalkar *et al.*, 2011). Very few attempts have been made to study osmotic dehydration characteristics of sapota. Therefore, a study was proposed to investigate osmotic dehydration characteristic of sapota.

METHODOLOGY

Raw materials preparation :

A widely grown fruit sapota (cv. KALIPATTI) was selected for the osmotic dehydration experiment. Food grade sugar was used as an osmotic agent being cheap and easily available. Ripened sapota of uniform size, colour and firm texture were taken for experiment. Selected fruits were thoroughly washed under tap water to remove adhering impurities before slicing the fruit. The outer skin of the ripened fruit was carefully peeled off manually using a sharp stainless steel knife without damaging the pulp. The peeled sapota fruits were cut into about 4-5 mm thick slices for the experiment. Sugar syrups of various concentrations were prepared by dissolving required amount of sugar in distilled water.

Sugar syrup of 30, 40 and 50 °Brix concentration was prepared by adding the required amount of sugar in distilled water and the total soluble solids of prepared syrup were determined by hand refractometers of various ranges (0-32, 28-62 and 58-92 °Brix). The moisture content of the fresh as well as osmotically dehydrated sapota samples was determined by oven drying at 70°C for 18 h (Ranganna, 2000).

Experimental set up and procedure for osmotic dehydration :

Experiments were conducted at three concentrations (30, 40 and 50 °Brix) and three temperatures (30, 40 and 50°C). The sapota slices of 4-5 mm thickness, sample to solution ratio of 1:5 were kept constant for all combinations. The prepared samples (sapota slices) were weighed approximately 40 g for every experiment and immersed in the sugar syrup contained in a 250 ml glass beaker and the beakers were placed inside a constant temperature water bath. The syrup in the beakers was manually stirred at regular intervals to maintain uniform temperature. One beaker at a time was removed from the water bath at designated time (after every 10 min intervals) and placed on tissue paper to remove the surface moisture. The samples were weighed and their moisture contents were determined. The moisture loss and solid gain were calculated on wet basis as described below.

Water loss :

The water loss (WL) is defined as the net weight loss of the fruit on initial weight basis and will be estimated (Lenart and Flink, 1984) as

$$WL = \frac{W_i \cdot X_i - W_\theta \cdot X_\theta}{W_i} \quad (1)$$

Sugar gain :

The solids from the osmotic solution get diffused into the sample of sapota slices during osmotic dehydration while the loss of water from the sample takes place in osmotic dehydration consequently it increases the solid content. The solid gain is the net uptake of solids by the sapota slices on initial weight basis. It is computed using following expression (Lenart and Flink, 1984):

$$SG = \frac{W_\theta (1 - X_\theta) - W_i (1 - X_i)}{W_i} \times 100 \quad (2)$$

Mass reduction :

The overall exchange in the solid and liquid of the sample do affect the final weight of the sample. The mass reduction (MR) can be defined as the net weight loss of the fruit on initial weight basis.

$$MR = \frac{W_i - W_\theta}{W_i} \quad (3)$$

where,

WL = water loss (g per 100 g mass of sample)

SG = sugar gain (g per 100 g mass of sample)

MR= Mass reduction (g per 100 g mass of sample)

W_θ=mass of slices after time θ, g

W_i=initial mass of slices, g

X_θ=water content as a fraction of mass of slices at time θ

X_i=water content as a fraction of initial mass of slices, fraction.

RESULTS AND DISCUSSION

The results of the investigation carried out on osmotic dehydration have been presented in the following sections.

Mass transport in osmosis :

The mass transport during osmotic dehydration was evaluated in terms of water loss, sugar gain and mass reduction in per cent. The effect of these process parameters are presented and discussed in the following sections.

Water loss in osmosis :

The loss of water from sample is affected by duration of osmosis at different syrup concentration and temperature has been predicted in Fig. 1. Water loss was found to increase with duration of osmosis at all the osmotic solution concentrations and the three solution temperatures *i.e.* at 30, 40 and 50°C. It was also found to increase at a faster rate initial 10 min later it reduced and almost levelled off and approach equilibrium.

The water loss increased from 0 to 23.84, 28.04 and 32.83 per cent when duration of osmotic dehydration increased from 0 to 1 h for 30 °Brix at 30, 40 and 50°C temperatures, respectively. For 40 °Brix, the water loss was found to vary from 0 to 25.18, 32.26, and 35.17 per cent and similarly at 50 °Brix was found to vary from 0 to 27.18, 32.68 and 36.66 per cent at 30, 40 and 50°C, respectively.

A low temperature-low concentration condition (30°C-30 °Brix) resulted in a low water loss (23.84 per cent after 1 h of osmosis) and a high temp-high concentration condition (50°C-50 °Brix) resulted in a higher water loss (36.66 per cent after 1 h of osmosis). This indicates that water loss can be increased by either increasing the syrup temperature or concentration of solution. Similar results have been reported for osmotic dehydration of bananas (Sagar, 2001). Such effects have also been reported in various fruits and vegetables (Ertekin and Cakaloz, 1996; Hawkes and Flink, 1978; Karathanos and Mavroudis, 1995; Lazarides *et al.*, 1995; Pokharkar and Prasad, 1998a).

Increased water loss with increase in syrup concentration at a particular temperature of syrup may be due to increased osmotic pressure at higher concentrations, which increased the driving force available for water transport. This is in agreement with Pokharkar and Prasad (1998a and b); Nieuwenhuijzen *et al.* (2001).

The water loss data were statistically analysed and second order polynomial equations were found to best fit with coefficient of determination in the range of 0.81 to 0.90 (Table 1) :

$$WL = aX^2 + bX + C$$

where,

WL is the water loss in per cent and

a, b, c are regression coefficients predicted in Table 1.

Sugar gain in osmosis :

Sugar gains by the sample with duration of osmosis at all the three temperatures and syrup concentration has been presented in Fig. 2. The sugar gain was increased from 0 to 3.80, 4.20 and 4.74 per cent when duration of osmotic dehydration increased from 0 to 1 h for 30 °Brix concentration at 30, 40 and 50°C syrup temperatures, respectively. For 40 °Brix concentration, the sugar gain was found to vary from 0 to 4.71, 5.10 and 5.71 and for 50 °Brix it varied from 0 to 5.60, 6.03 and 6.40 per cent for 30, 40 and 50°C syrup temperature, respectively.

It can be seen that sugar gain increased with duration of osmosis and approach the equilibrium after 1 hour of osmotic dehydration. The sugar gain also increased when the concentration of the syrup was increased. This is because of the increased concentration difference between samples. The sugar gain also increased with increase in syrup temperature. It may be due to collapse of the cell membrane at higher temperatures. Similar results have been reported by Ertekin and Cakaloz (1996).

A low temperature-low concentration condition (30°C-

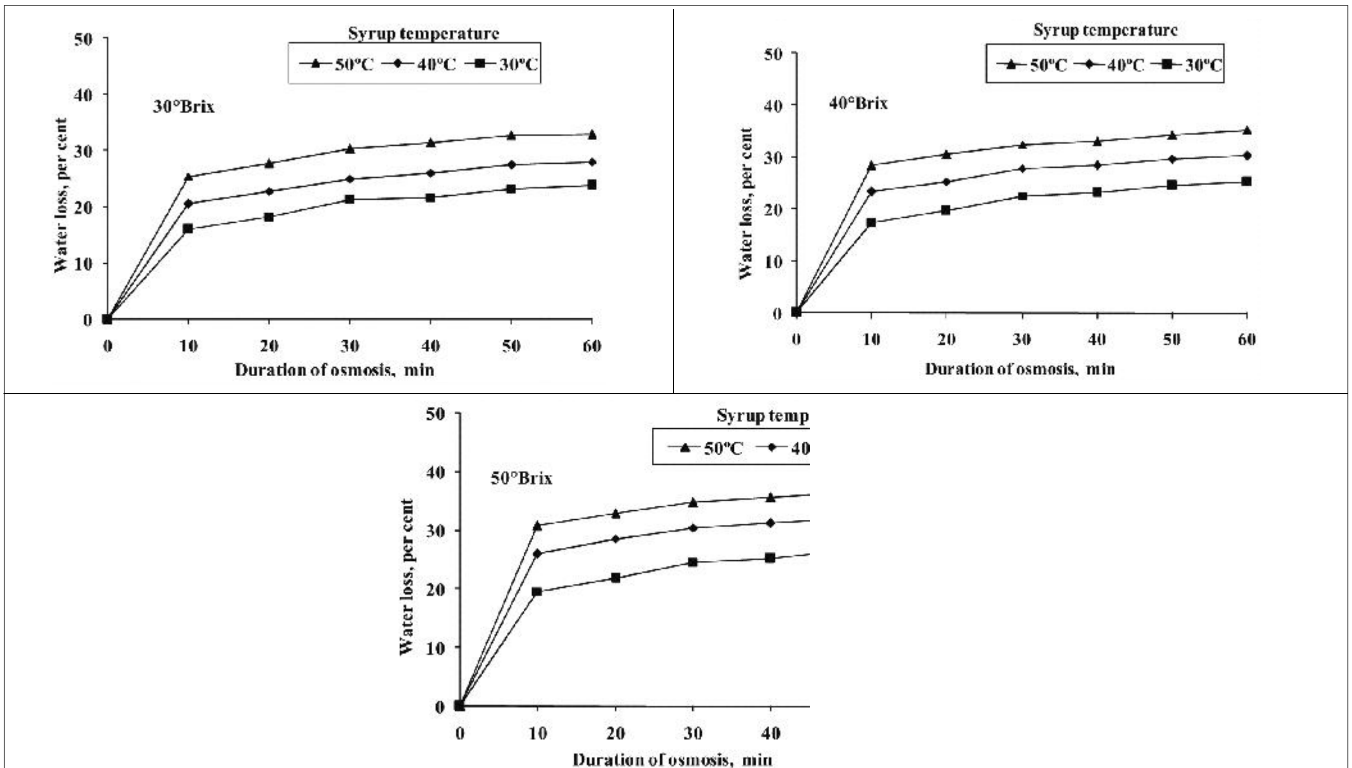

Fig. 1 : Variation in water loss with duration of osmosis at 30, 40 and 50 °Brix syrup concentration

Table 1 : Predicted equations and coefficient of determination values for water loss

Syrup concentration (°Brix)	Temperature of osmotic solution (°C)	a	b	c	R^2
30	30	-0.010	0.93	3.07	0.90
	40	-0.012	1.12	4.25	0.86
	50	-0.016	1.37	5.25	0.85
40	30	-0.011	0.99	3.42	0.89
	40	-0.014	1.24	4.90	0.85
	50	-0.017	1.45	6.28	0.81
50	30	-0.012	1.09	3.95	0.87
	40	-0.016	1.38	5.57	0.83
	50	-0.019	1.58	6.70	0.81

30 °Brix) gave a low sugar gain (3.80 per cent after 1 h of osmosis) and a high temp-high concentration condition (50°C-50 °Brix) resulted in higher sugar gain (6.40 % after 1 h of osmosis) (Fig. 2). The low temperature-high concentration condition (30°C-40 °Brix and 30°C-50 °Brix) gave a slightly lower sugar gain of 4.71 and 5.60 after 1 h of osmosis than high temperature-high concentration condition 50°C-40 °Brix and 50°C-50 °Brix as 5.71 and 6.40% sugar gain indicates a pronounced effect of temperature on sugar gain.

This indicates that sugar gain can be increased by either increasing the syrup temperature or concentration of solution. However, an increase in temperature of sugar solution by 10°C had more influence on sugar gain than an increase in concentration by 10 °Brix, may be because of higher temperature causes destruction of cell membrane structure (Maguer, 1988; Lenart and Flink, 1984). Similar results have been reported by Lazarides *et al.* (1995) with osmotic dehydration of apple slices in a temperature range of 20-50°C.

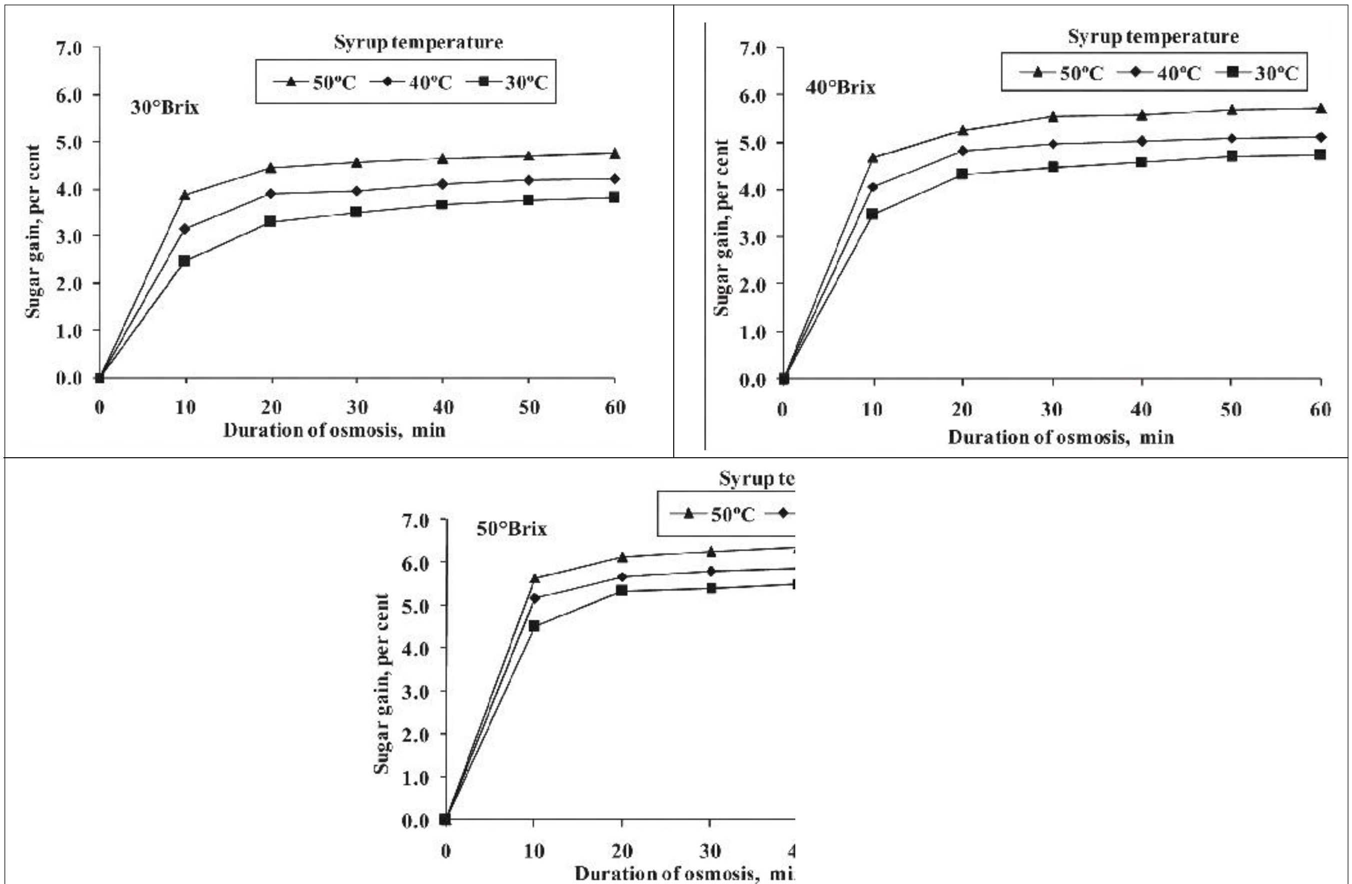

Fig. 2 : Variation in sugar gain with duration of osmosis at 30, 40 and 50 °Brix syrup concentration

Table 2 : Predicted equations and coefficient of determination values for sugar gain

Syrup concentration (°Brix)	Temperature of osmotic solution (°C)	a	b	c	R^2
30	30	-0.001	0.16	0.44	0.92
	40	-0.002	0.18	0.64	0.87
	50	-0.002	0.21	0.82	0.83
40	30	-0.002	0.20	0.69	0.87
	40	-0.002	0.23	0.85	0.85
	50	-0.003	0.25	0.99	0.83
50	30	-0.003	0.25	0.96	0.84
	40	-0.003	0.26	1.15	0.80
	50	-0.003	0.29	1.25	0.80

The sugar gain data were statistically regressed and second order polynomial equation was found to give best fit as

$SG = aX^2 + bX + C$ where, SG-Sugar gain

Mass reduction in osmosis :

The mass reduction after osmotic dehydration was found to be in the range of 13.54 to 30.25 per cent, corresponding to experiments at low level (30 °Brix, 30°C) and at high level (50 °Brix, 50°C) (Fig. 3). The mass reduction increased from 0 to 20.04, 23.84 and 28.08 per cent when duration of osmotic dehydration increased from 0 to 1 h at 30, 40 and 50°C temperatures, respectively for 30 °Brix while for 40 °Brix and 50 °Brix it was found to vary from 0 to 20.46, 25.16 and 29.49 per cent and from 0 to 21.57, 26.65 and 30.25 per cent at 30, 40 and 50°C, respectively.

A low temperature-low concentration condition (30°C-30 °Brix) resulted in a low mass reduction (13.54 %) and a high temp-high concentration condition (50°C-50 °Brix) resulted in a higher mass reduction (30.25 %). This indicates that mass reduction can be increased by either increasing the syrup temperature or concentration of solution. Similar results have been reported for osmotic dehydration of onions (Sagar, 2001).

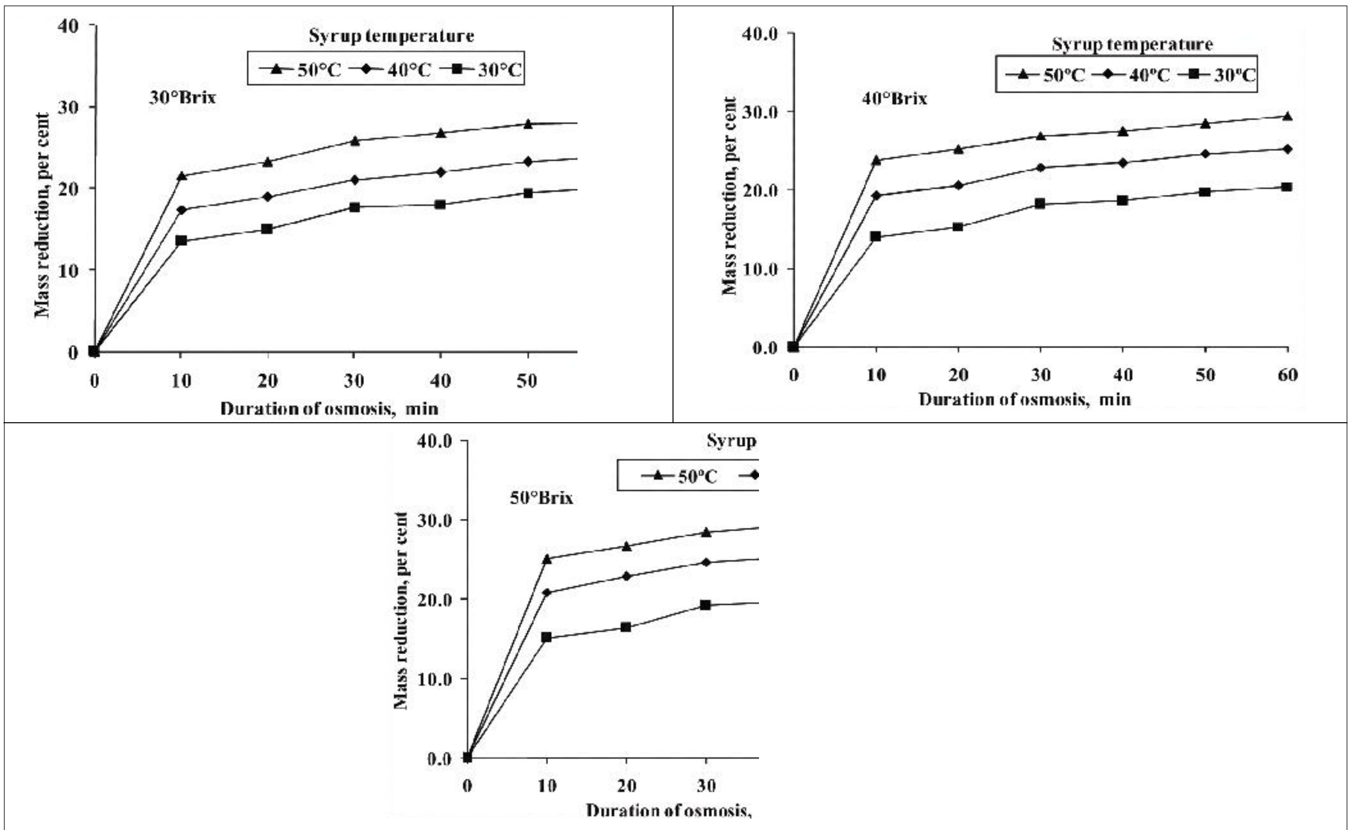

Fig. 3 : Variation in mass reduction with duration of osmosis at 30, 40 and 50 °Brix syrup concentration

Table 3 : Predicted equations and coefficient of determination values for mass reduction

Syrup concentration (°Brix)	Temperature of osmotic solution (°C)	a	b	c	R^2
30	30	-0.008	0.76	2.63	0.89
	40	-0.010	0.93	3.61	0.86
	50	-0.013	1.16	4.42	0.86
40	30	-0.008	0.78	4.72	0.89
	40	-0.011	1.01	4.05	0.85
	50	-0.014	1.20	5.29	0.81
50	30	-0.009	0.83	2.99	0.88
	40	-0.013	1.11	4.42	0.84
	50	-0.015	1.29	5.44	0.82

The statistical analysis revealed that second order polynomial equation provided best fit to the observed values of mass reduction. The predicted equations with their coefficient of determination values are presented in the Table 3.

$$MR = aX^2 + bX + c$$

where, MR-Mass reduction in per cent

It was observed that the values of coefficient of determination were more than 0.81 for all the experiment condition which revealed the good determination between the predicted and observed data.

Conclusion:

Syrup concentration, temperature of solution and duration of osmosis had definite effect on the kinetics of osmotic dehydration of sapota samples. In osmotic dehydration, an increase of sugar concentration and temperature of osmosis increased water loss and mass reduction. In all the experiments, the rate of water loss was more in the beginning of process and decreased gradually with the increase of duration of osmosis, and approaches equilibrium. After 1 h of osmotic dehydration, the minimum and maximum mass reduction, water loss and sugar gain were in the range of 13.54 to 30.25; 23.84 to 36.66 and 3.80 to 6.40 per cent corresponding to low levels (30 ^{o}Brix, 30^{o}C) and high levels (50 ^{o}Brix, 50^{o}C) of syrup concentration and temperature, respectively. Osmosis as a pre-treatment prior to any drying can be used to decrease drying time.

Authors' affiliations:

R.C. VERMA AND LEENA TYAGI, Department of Processing and Food Engineering, College of Technology and Agricultural Engineering, M.P. University of Agriculture and Technology, UDAIPUR (RAJASTHAN) INDIA (Email : rcvermashp@yahoo.com; leenatyagi@gmail.com)

ASHOK KUMAR, Department of Agricultural Engineering, Bihar College of Agriculture, Sabour, BHAGALPUR (BIHAR) INDIA (Email : ashokcae@gmail.com)

REFERENCES

Barbosa-Canovas, G.V. and Vega-Mercado, H. (1996). *Dehydration of food*. Chapman and Hall, New York, 330 pp.

Dixon, G.M., Jen, J.J. and Paynter, V.A. (1976). Tasty apple slices results from combined osmotic dehydration and vacuum drying process. *Food Product Develop.*, **10** (7) : 60-66.

Ertekin, F.K. and Cakaloz, T. (1996). Osmotic dehydration of peas: 2 Influence of osmosis on drying behaviour and product quality. *J. Food Processing & Preservation*, **20** (2) : 105-119.

Ganjyal, G.M., Hanna, M.A. and Devadattam, D.S.K. (2005). Processing of sapota (sapodilla) Powdering. *J. Food Technol.*, **3** (3): 326–330.

Hawkes, J. and Flink, J.M. (1978). Osmotic concentration of fruits slices prior to freeze dehydration. *J. Food Proc. & Preservation*, **2** (4) :268.

Jain, R.K. and Jain, S.K. (1998). Sensory evaluation of an intermediate moisture product from sapota (*Achras sapota*). *J. Food Engg.*, **37** (3) : 323-330.

Jain, S.K., Verma, R.C. and Mathur, A.N. (2003). Osmo-convective drying of papaya. *Beverage & Food World*, **30**(1):64-67.

Karathanos, V.T., Kostaropoulos, A.E. and Saravacos, G.D. (1995). Air drying kinetics of osmotically dehydrated fruits. *Drying Technol.*, **13**(5-7):1503-1521.

Lazarides, H.N. and Mavroudis, N.E. (1995). Freeze/thaw effect on mass transfer rates during osmotic dehydration. *J. Food Sci.*, **60**(4):826-829.

Lenart, A. and Flink, S.M. (1984). Osmotic concentration of potato I. Criteria for the end point of the osmosis process. *J. Food Technol.*, **19** (1) : 65-89.

Maguer, M. (1988). Osmotic dehydration: review and future directions. In: Proceedings of the international symposium on progress in food preservation processes (pp. 283–309), Ceria, Brussels, Belgium.

Nieuwenhuijzen, N., Zareifard, M.R. and Ramaswamy, H.S. (2001). Osmotic drying kinetics of cylindrical apple slices of different sizes. *Drying Technol. J.*, **19**(3-4):525-545.

Pisalkar, P.S., Jain, N.K. and Jain, S.K. (2011). Osmo-air drying of aloe vera gel cubes. *J. Food Sci. & Technol.*, **48**(2):183–189.

Pokharkar, S.M. and Prasad, S. (1998a). Water de-sorption isotherm of osmotically concentrated pineapple. *J. Food Sci. & Technol.*, **35**(6): 518-520.

Pokharkar, S.M. and Prasad, S. (1998b). Mass transfer during osmotic dehydration of banana slices. *J. Food Sci. & Technol.*, **35** (4) : 336-38.

Ponting, J.D. (1973). Osmotic dehydration of fruits-recent modification and application. *Process Biochem.*, **8** : 18-20.

Ranganna, S. (2000). *Handbook of analysis and quality control for fruits and vegetable products.* Tata McGraw Hill Publishing Co. Ltd., New Delhi (INDIA).

Sagar, V.R. (2001). Preparation of onion powder by means of osmotic dehydration and its packaging and storage. *J. Food Sci. & Technol.*, **38** (5) : 525–528.

Sethi, V., Sahni, C.K., Sharma, K.D. and Sen, N. (1999). Osmotic dehydration of tropical temperate fruits- A review. *Indian Food Packer*, **53** (1) : 34-43.

Torreggiani, D. and Bertolo, G. (2001). Osmotic pre-treatments in fruit processing: chemical, physical and structural effects. *J. Food Engg.*, **49**(2-3):247-253.