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RESEARCH PAPER

Osmo convective drying of sapota slices

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ABSTRACT

The present study is carried out to standardize the pretreatment of sapota slices and study drying characteristics during convective drying. The effect of process parameters during osmotic dehydration such as osmosis, concentration and temperature of syrup on mass reduction, water loss and solid gain increased with increase of syrup concentration and temperature. The water loss and solid gain during osmosis at 30, 40 and 50 °Brix was varied in the range of 13.54 to 30.25 and 23.84 to 36.66 per cent at 30, 40 and 50° C temperatures, respectively. The drying temperature and pretreatment as osmotic dehydration had a significant effect on the rehydration ratio and colour. The drying times of osmosed sapota slices by convective drying at 50, 60, 70 and 80 per cent drying temperature were 12, 10 and 8 and 6 hrs, respectively. Quality of dried product in respect to colour and rehydration was superior. The osmo-convective dehydrated samples were found more acceptable than convective dried ones. The sapota dried at 40°C brix solution concentration, 30°C osmosis temperature and 70°C drying temperature was more acceptable on the basis of colour and rehydration.

KEY WORDS : Osmo-convective drying, Colour value, Sapota dehydration

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INTRODUCTION

Sapota (*Achras sapota*) is native to Central and South America, specifically from the Yucatan Peninsula of Mexico to Costa Rica, where the largest population of native trees still exists (Gilly, 1943). It has become widespread throughout the tropical regions of the world, including Central and South America. Dried fruit, in particular as a semi manufactured product, could assume greater importance in industrial production. In addition, it can be substituted for other fruit derivatives traditionally used. In order to obtain this result it is necessary to improve the quality of industrial dried fruit (Mastrocola and Dallaglio, 1993).

India is the largest producer of sapota with 30 to 40 thousand hectares area and is one of the best loved fruit of country. In India, Maharashtra will lead the table with highest area, production and productivity of sapota followed by Karnataka and others states (National Horticulture Board, 2008).

Raw sapota fruits are astringent, while ripe fruits are sweet. Mature fruits are used for making mixed fruit jams and provide a valuable source of raw material for the manufacture of industrial glucose, pectin and natural fruit jellies. Ripe sapota is eaten as dessert fruit and also is canned. Only the pulp is usually consumed, although skin is richer in nutritive value than pulp (Gopalan *et al.,* 1985). An average sapota tree yields between 250-2500 fruits, depending on its age. Mature fruits contain about 72 to 78 per cent moisture content (w.b) and total soluble solids (TSS) values range from 12 to 18 ^{0}Brix. Because fruits are easily bruised, most harvesting is done by hand (Ganjyal *et al.,* 2005).

The simplest and most economic method for dehydration of foods is air-drying; although certain problems such as the considerable shrinkage caused by cell collapse following the loss of water, the poor re-hydration characteristics of dried products and unfavourable changes in colour, texture, flavour and nutritive value may occur. A faster dehydration that yields a higher quality production is always required. A number of drying technique has been developed over year and year such as conduction, convection and radiation. The simplest and economic method for dehydration of foods is hot air-drying in conventional tray, cabinet or vacuum dryers but these dehydrated products have fewer acceptances since the products quality is considerably reduced. The problems associated with products obtained by air-drying are woody texture, slow or substantial amount of water loss. It also brings about undesirable changes in colour, texture, flavour and loss in nutritive value.

EXPERIMENTAL PROCEDURE

The experiments were divided into two parts, *viz.*, osmotic dehydration of sapota slices in sugar solution and convective drying of osmotically dehydrated product. The preliminary experiments were planned for fixing the levels of input variables such as concentration and temperature of sugar solution, ratio of sugar solution to sapota and optimization of process parameters for osmotic dehydration followed by convective drying.

Experimental procedure for osmotic dehydration :

Selection of raw materials :

The fresh sapota (*var Kalipatti*) was used for this investigation. The fresh harvested sapota fruits were brought from Navsari farm (Navsari Agricultural University). Fruits of similar size were selected and were allowed at room temperature to get uniform ripeness.

Preparation of sample and solution :

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 peeled off manually using a knife without damaging the pulp. The peeled sapota fruits were cut into halves, quarters and about 4 mm thick slices for the experiment. Sugar syrups of various concentrations were prepared by dissolving required amount of sugar in distilled water.

Measurement of moisture content :

The moisture content of fresh as well as osmotically dehydrated sapota samples was determined by using air oven method and calculated by using following equation :

$$\text{Per cent moisture content (db)} = \frac{W_1 - W_2}{W_2} \times 100$$

Total soluble solids :

The total soluble solids of prepared syrup was found out by using hand operated refractometers of various ranges (0-32, 28-62 and 58-92 °Brix), which gave the reading directly in °Brix (Ranganna, 2000).

Osmotic dehydration of sapota slices :

The prepared samples (sapota slices) were weighed approximately 40 g for every experiment and immersed in the sugar syrup (30, 40 and 50 °Brix) contained in a 250 ml glass beaker. The beakers were placed inside the constant temperature water bath. The syrup in the beakers was manually stirred at regular intervals to maintain uniform temperature. One beaker was removed from the water bath at designated time and placed on tissue paper to remove the surface moisture. The samples were weighed and their moisture contents were determined.

Osmotic dehydration characteristics :

Water loss :

Water loss is the quantity of water lost by food during osmotic processing. The water loss (WL) is defined as the net weight loss of the fruit on initial weight basis and will be estimated as:

$$\mathbf{WL} = \frac{W_i.X_i - W_\theta.X_\theta}{W_i}$$

Solid gain :

The solids from the osmotic solution get added to the samples during osmotic dehydration. 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 slices on initial weight basis and computed using following expression:

$$\mathbf{SG} = \frac{W_\theta(1 - X_\theta) - W_i(1 - X_i)}{W_i} \mathbf{x100}$$

Mass reduction :

The overall exchange in the solid and liquid of the sample do affect the final weight of the sample.

$$\mathbf{WR} = \frac{W_i - W_\theta}{W_i}$$

Level of input parameters in convective drying of sapota :

Osmotically dehydrated sapota :

In convective drying of osmotic dehydrated sapota slices, the details on experimental parameters varied according to the predetermined levels of input variables under study in osmotic dehydration and further followed by convective drying is shown in Table A.

Drying characteristics :

Moisture content during drying :

Moisture content of sapota slices during drying experiment was determined on the basis of dry matter using equation :

$$\textbf{Per cent moisture content (d.b.)} = \frac{W_\theta - DM}{DM} \mathbf{x100}$$ ....(Brooker *et al*., 1974)

Dry matter :

It is the matter left after complete removal of moisture from the product. The dry matter percentage and weight of dry matter in sample were calculated as follows:

DM (%) = 100.0 - IMC (% w.b) .... (Brooker *et al.*,1974)

Table A : Levels of input parameters in convective drying of osmotically dehydrated sapota

Pretreatment condition of osmotic dehydration					Convective drying	
Duration of osmosis (h)	Thickness of sample (mm)	Sample to solution ratio	Concentration of solution (°Brix)	Temperature of solution (°C)	Convective drying temperature (°C)	Air velocity (m/s)
				30		
			30	40	50, 60, 70 and 80	1, 1.5 and 2
				50		
				30		
			40	40	50, 60, 70 and 80	1, 1.5 and 2
				50		
				30		
1	4-5	1:5	50	40	50, 60, 70 and 80	1, 1.5 and 2
				50		

$$\text{Weight of DM} = \frac{\text{Initial mass of sample}}{100} \times \text{DM (\%)}$$

Quality evaluation:

The quality of osmo-convective dried sapota samples had been evaluated on the basis of several parameters such as sugar gain, colour determination and rehydration characteristics.

Colour measurement :

Colour of the dried sapota powder was measured using a Hunter Lab Colorimeter (Model CFLX/DIFF, CFLX-45). A cylindrical glass sample cup (63.5 mm in diameter x 40 mm height) was placed at the light port (31.75 mm diameter). The instrument was initially calibrated with a black as well as with standard white plate supplied with the equipment. The 3-dimensional scale L*, a* and b* is used in a Hunter Lab Colorimeter. The L* is the lightness co-efficient, ranging from 0 (black) to 100 (white) on a vertical axis. The a* is purple-red (positive a* value) and blue-green (negative a* value) on a horizontal axis. A second horizontal axis is b*, that represent yellow (positive b* value) or blue (negative b* value) colour. This 3D colour system can be seen in Plate 3.5. The values of L*, a* and b* can be converted to Chroma (C*) values, analogous to colour saturation or intensity (McGuire, 1992).

$$C^* = \sqrt{(\alpha^*)^2 + (b^*)^2}$$

Rehydration characteristics :

The rehydration capacity can be influenced by the drying process. Drying processes that change product composition to a lesser extent are supposed to offer better rehydration characteristics of finished product. Due to drying process collapsing of cellular structure and shrinkage, rehydration is affected which may eventually affect the rehydration characteristics. For rehydration capacity, pre-weighed samples were soaked in ample amount of water for 5 hours at room temperature. This steeping is known as re-hydration. The ratio of mass of re-hydrated and dehydrated samples can be used to find following re-hydration characteristics (Pokharkar, 1994):

$$\text{Re-hydration ratio RR} = \frac{C}{D}$$

Sensory evaluation :

Sensory evaluation is important to assess the consumer's requirements. It is difficult to classify 100 per cent by machine because it is a subjective factor. Dehydrated products should have a typical taste, flavour and texture. To test these organoleptic characteristics, sensory evaluation was done on the basis of numerical sensory card. The sensory evaluation was carried out for taste, flavour, colour, texture and over all acceptability. A sample of dehydrated product was served for the evaluation to a 12 panelists at a time. The score sheet was provided with product and panelists were requested to mark the product according to their liking, then the average scores of all the panelists were computed.

Water activity (a_w) :

Water activity was determined as a measure of storage stability using a Hygrolab-3 water activity meter. A2 g sample was used to cover the filling indicator of the sample cup. The filled sample cup was kept in contact with sensor probe of water activity meter and values of water activity were recorded. A digital water activity analyser used in measuring water activity of the dehydrated sapota samples.

$$\alpha_w = \frac{\text{Vapour pressure of water exerted by food}}{\text{Saturated vapour pressure of water at the same temperature}}$$

EXPERIMENTAL FINDINGS AND ANALYSIS

The findings of the present study as well as relevant discussion have been presented in Fig. 1 to 4 and Tables 1

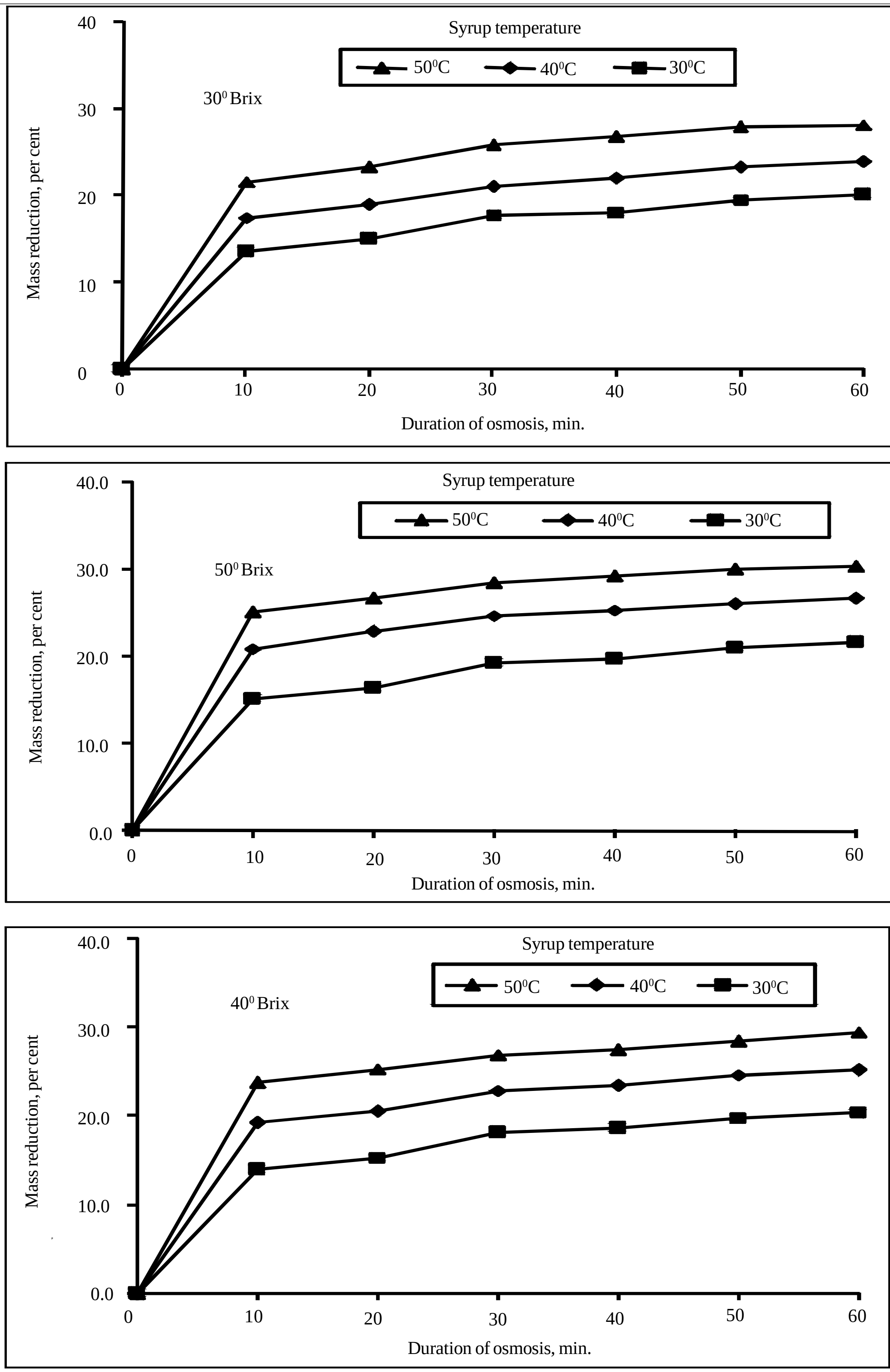

Fig. 1 : **Variation in mass reduction with salt solution concentration and temperature**

and 2.

Initial moisture content :

The initial moisture content of sapota slices was determined by oven drying. The average initial moisture content of sapota slices found as 69 to 72 per cent (w.b).

Effect of osmotic treatment on mass reduction :

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). 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.

Effect of osmotic treatment water loss :

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 % after 1 h of osmosis) and a high temp-high concentration condition (50°C-50 °Brix) resulted in a higher water loss (36.66 % after 1 h of osmosis). This indicates that water loss can be increased by either increasing the syrup temperature or concentration of solution.

Effect of osmotic treatment sugar gain :

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. A low temperature-low concentration condition (30°C-30 °Brix) gave a low sugar gain (3.80 % 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). 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 per cent sugar gain indicates a pronounced effect of temperature on sugar gain.

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 Ertekin and Cakaloz (1996) and Nsonzi and Ramaswamy (1998) for peas and blueberries, respectively.

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 has 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).

In this part, results of osmotically dehydrated sapota slices under convective drying have been presented. The osmotically dehydrated sapota samples were taken out of the sugar solution and blotted on tissue paper to remove the

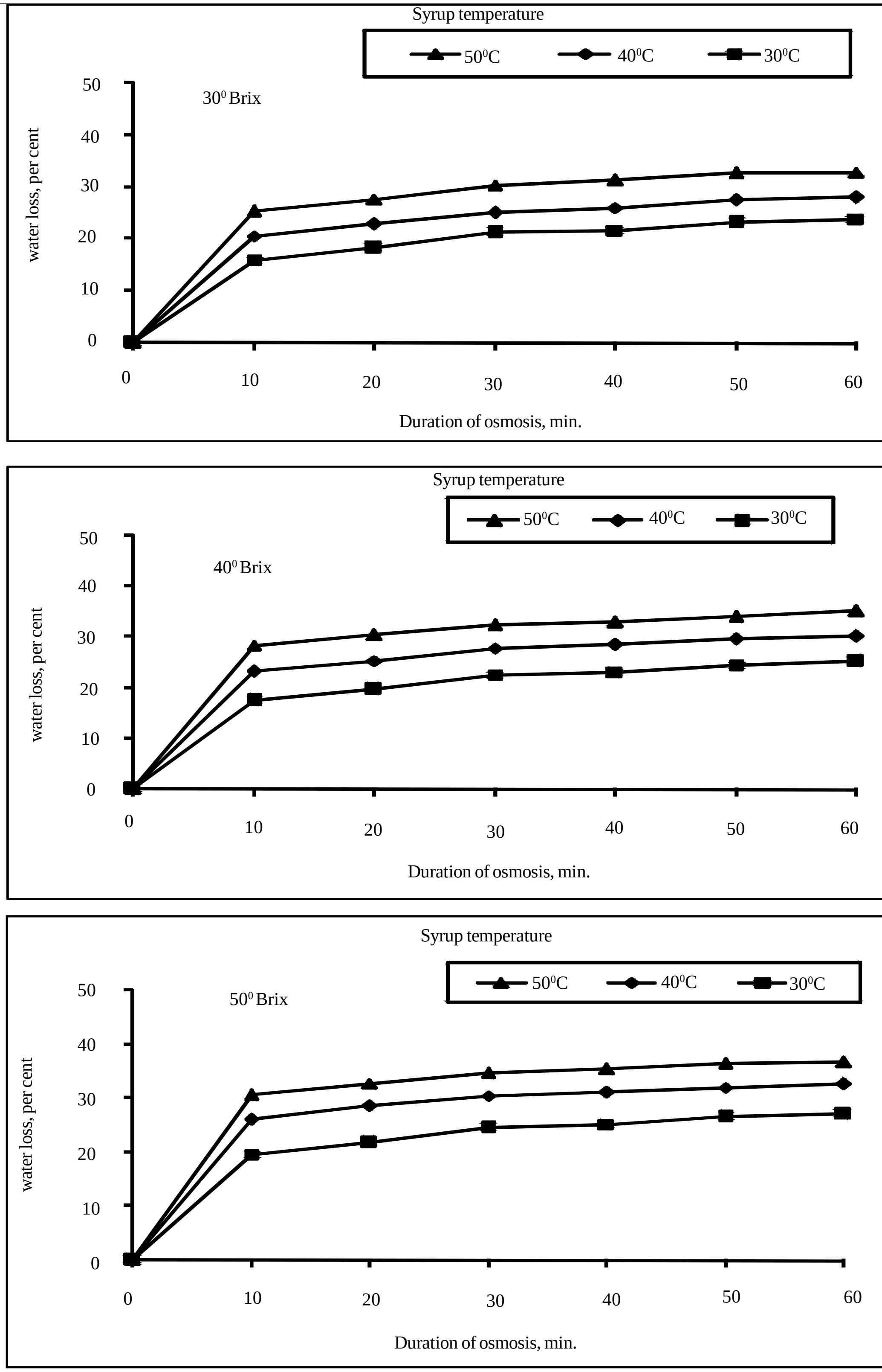

Fig. 2 : **Variation in water loss with syrup concentration at 30,40 and 50^{0}C temperature**

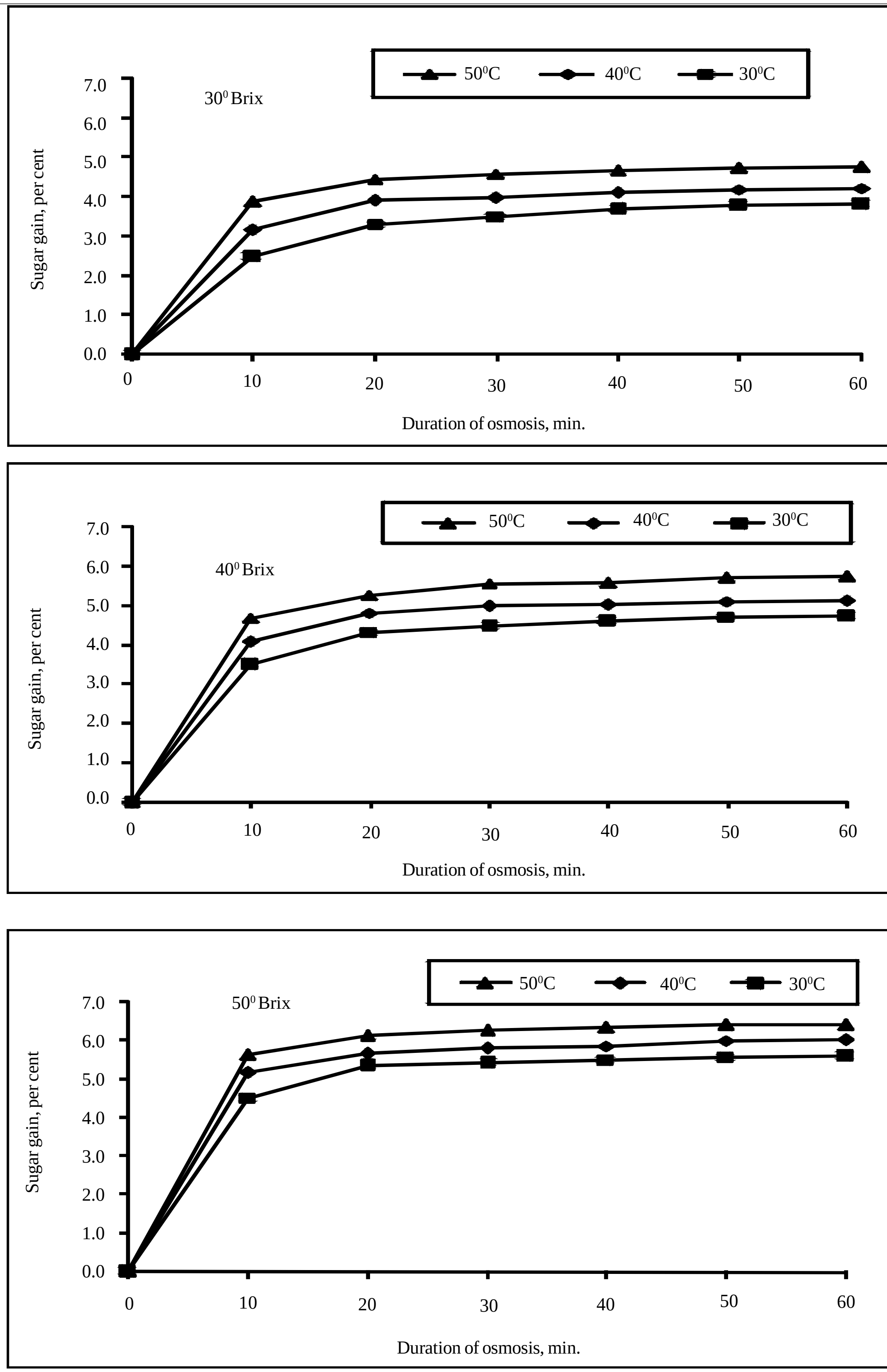

Fig. 3 : Variation in sugar gain with syrup concentration at 30,40 and 50⁰C temperature

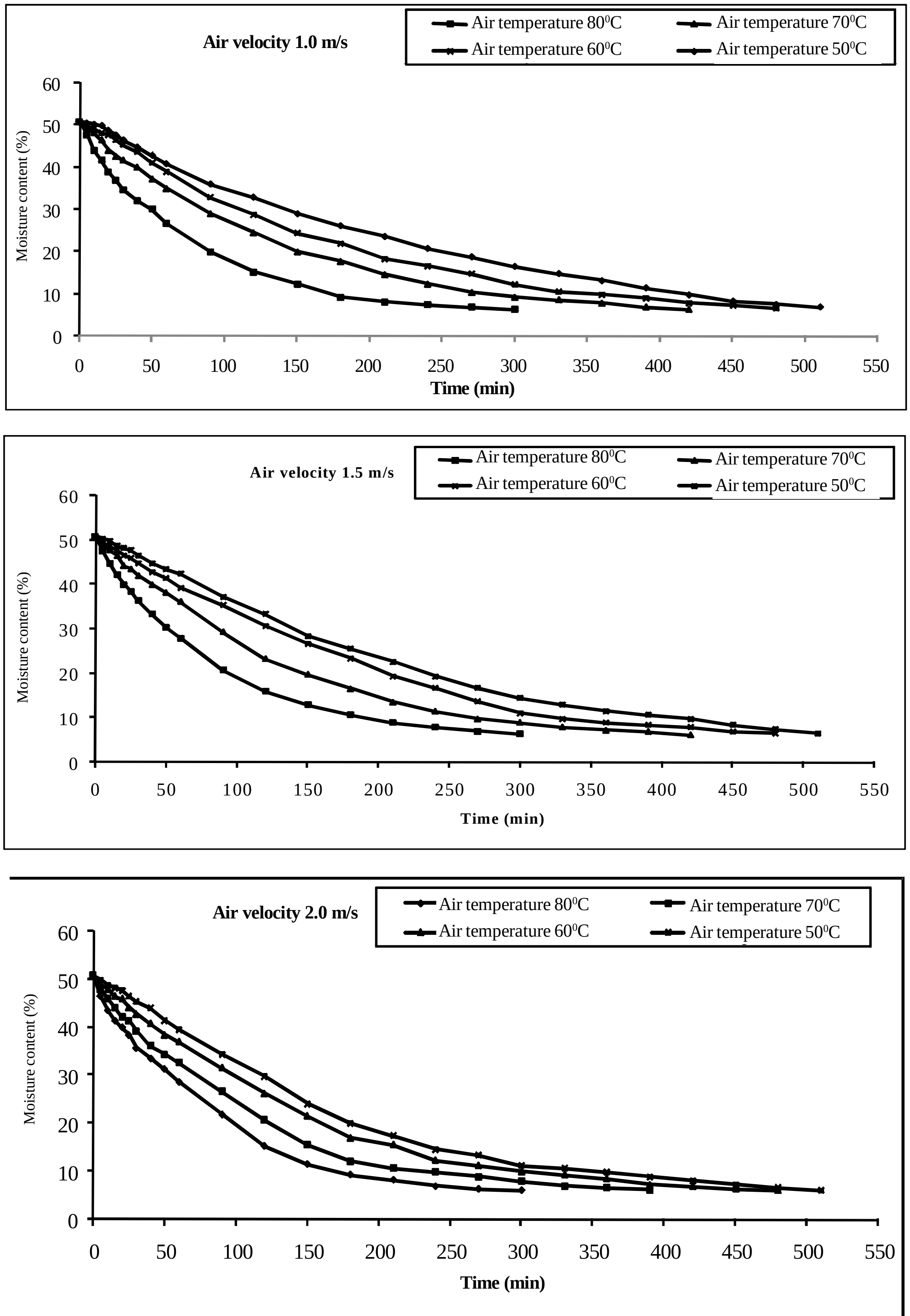

Fig. 4 : **Effect of drying air temperature on moisture content with drying time at various drying air velocities**

adhered water. These osmotically dehydrated sapota slices were then dried in convective dryer at drying temperature 50, 60, 70 and 80°C and 1, 1.5 and 2 m/s air velocity.

The osmo dehydrated samples at 50 °Brix concentrations at 50°C temperature of osmotic solution were dried in the tray drier at air temperature of 50, 60, 70 and 80°C with air velocities of 1.0, 1.5 and 2.0 m/s, respectively are shown in Fig. 4 .

Quality parameters :

Colour :

The colour of dried sapota slices was measured in terms of L-value (brightness/darkness). The L-values of osmo-convectively dried sapota slices at various experimental conditions were ranged between 17.52 to 28.82 (Table 1). As regards individual effect of drying air temperature, it revealed from this table that as the temperature increased L-value of colour was increased that means sample became lighter in colour from 50°C to 70°C and thereafter, decreased at 80°C which may be due to discoloring the sample slightly because of elevated temperature. It is clear with respect to individual effect of temperature, that the sample dried with drying air temperature 70°C was found better and recorded significantly highest colour (L-value=28.82). Increase in velocity also resulted in increased colour (L-value) slightly.

Table 1 : Lightness (L* values) of convective dried sapota slices

Osmo convective dried sapota slices (°C)	Air velocity (m/s)	Colour index L-values
	1	20.73
50	1.5	22.72
	2	24.95
	1	23.08
60	1.5	24.91
	2	26.63
	1	26.28
70	1.5	25.14
	2	28.82
	1	17.52
80	1.5	20.40
	2	20.95

Table 2 : Rehydration ration of convective dried sapota slices

Osmo convective dried sapota slices (°C)	Air velocity (m/s)	Rehydration ratio (RR)				
		Distilled water	5 °Brix	10 °Brix	15 °Brix	20 °Brix
	1	4.571	4.349	4.327	4.124	4.084
50	1.5	3.972	3.932	3.893	3.872	3.852
	2	4.082	4.014	3.946	3.781	3.481
	1	4.229	4.088	4.063	3.948	3.898
60	1.5	3.924	3.809	3.695	3.649	3.599
	2	3.871	3.802	3.790	3.734	3.709
	1	4.019	3.778	3.773	3.538	3.527
70	1.5	4.029	3.997	3.965	3.765	3.565
	2	3.739	3.680	3.622	3.427	3.116
	1	4.113	3.883	3.806	3.653	3.499
80	1.5	3.518	3.509	3.508	3.502	3.494
	2	3.512	3.446	3.431	3.375	3.344

The sample dried with 2 m/s drying air velocity was found significantly superior in recording better colour.

Rehydration characteristics :

The dehydrated products were immersed in water, 5, 10, 15 and 20 °Brix sugar solution and the mass of the products after five hour were measured. The raw data of the re-hydration tests are shown in Table 2. The dehydrated sample absorbed water during rehydration and became soft. From the Table 2 we reveal that the maximum rehydration ratio was obtained for sapota slices immersed in water for 5 h and rehydration ratio was decreased as the concentration of sugar syrup solution increased from 5 to 20 °Brix, for all levels of air velocity.

Water activity :

Water activity was determined as a measure of storage stability using a Hygrolab-3 water activity meter, at a temperature of 24.5°C for all samples. Water activities of osmo-convectively dried samples with all combinations of temperatures and velocities were ranging between 0.263 and 0.471. As regards to individual effect of temperature, it revealed that as the temperature increased water activity decreased significantly. The sample dried at 80°C drying air temperature was having significantly lowest (0.263) water activity. Similarly as air velocity increased water activity decreased significantly but the rate was comparatively less (Brooker *et al*., 1974; Ertekin and Cakaloz, 1996; Ganjyal *et al.*, 2005; Gilly, 1943; Gopalan *et al.*, 1985; Lenart and Flink, 1984; Maguer, 1988; Mastrocola and Dallaglio, 1993; Nsonzi and Ramaswamy, 1998; Pokharkar, 1994, Ranganna, 2000 and Kedarnath *et al*., 2013).

Sensory evaluation :

Sensory evaluation was conducted based on colour, taste, appearance and overall acceptability. The score ranged from 1 to 9 which represented from "Like extremely" to "Dislike extremely". The dried samples were tested by a panel of 12 judges. It was observed that mean sensory score on colour, taste, appearance and overall acceptability was highest for 60°C with 1.5 m/s.

Conclusion :

Osmotic dehydration of sapota samples were influenced by syrup concentration, temperature and duration of osmosis. Water loss and mass reduction both increased with increase in syrup concentration and temperature. 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 °Brix, 30°C) and high levels (50 °Brix, 50°C) of syrup concentration and temperature, respectively. An increase of sugar concentration and temperature of osmosis, increased water loss and solid gain. There was a variation in drying time from 300 to 510 min for the range of drying air temperatures (50-80°C) and air velocities (1-2 m/s) taken for study. Minimum drying time was observed for high air temperature (80°C) and maximum time was recorded for low air temperature (50°C) for all air velocities. The rehydration ratio of the osmo-convective dried sapota samples was in the range of 3.116 to 4.27. Water activities of osmo-convectively dried samples with all combinations of temperatures and velocities were ranging between 0.263 and 0.471. Osmo-convectively dried sapota product at 60°C was highly appreciated by the consumer.

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