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Mass Transfer kinetics during osmotic dehydration of Beetroot Tutti -Frutti

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ABSTRACT

Beetroot and beet juice have been known for their antioxidant, anticancer and anti-diabetic effects as well as being a source of dietary nutrients that reduce blood pressure and may improve athletic performance. Now-a-days, there is an increased interest in fruits and vegetables processing by products due to their nutritive value. The experiment consisted of various combination of sugar syrup temperature (40, 50 and 60°C), concentration (50, 60 and 70°Brix) and duration of osmosis (60,120 and 180 min) for preparation of beetroot tutti-frutti. The results indicated that the quality observations affected by various treatments. As the temperature and concentration of the solution were increased the water loss and sugar gain was also increased with increase in time. The optimized process parameters for osmotic dehydration of beetroot cubes were found to be at 62°Brix syrup concentration, 50°C syrup temperature and 105 min duration of osmosis. The predicted water loss (maximum) and sugar gain (targeted) was 36.12 and 9.80 per cent, respectively at optimized input parameters on the basis of sensory evaluation, texture and overall acceptability.

Keywords: Mass Transfer kinetics during osmotic dehydration

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INTRODUCTION

Fruits and vegetables are important constituents of diet and provide significant quantity of nutrients, especially vitamins, minerals, sugars, and fiber. Beet root commonly known as '*chukander*' are notable for their sweetness, they have the high sugar content. Fresh beetroot also supplies nutritional bonus, their green tops are an excellent source of beta-carotene, calcium, and iron. The beetroot is having tremendous health benefits. However, process of consuming fresh beetroot to meet daily recommended requirement is tedious. The various technologies used for extension of shelf life of the produce include dehydration, osmotic dehydration, intermediate moisture foods, high temperature preservation and low temperature preservation *etc*. In recent years, intermediate moisture foods (IMFs) have become more popular as compared to fully dehydrated foods. Intermediate moisture (IM) fruits and vegetables have advantages over traditionally dried ones, where instead of removing most of the water, just enough water is removed or bound through the addition of a humectant to retard microbial growth (Vibhakara *et al*., 2006).

Osmotic dehydration is a process of partial removal of water by soaking foods, mostly fruits and vegetables, in hypertonic solutions (Shi and Maguer, 2002). Tutti-frutti (from Italian "all fruits", also hyphenated tutti-frutti) is a colourful confection containing various chopped and usually candied fruits, or an artificially created flavouring simulating the combined flavour of many different fruits. Tutti-frutti is also used in cold deserts as toppings for the ice-creams and sundaes. They are also used in sweet pans. The process for making candy product is practically similar to that for preserves in which a whole fruit or its pieces impregnated with sugar or glucose syrup, and afterward drained free of syrup and dried.

Beetroot as a healthy vegetable can be consumed for a long period by converting it in a powder, tuttti-frutti *etc*. Artificial color addition in tutti-frutti may cause health problems. Beetroot is used as a natural colourant in food processing. Beetroot tutti-frutti does not require artificial color addition because of the red pigment betaline present in it. Hence the present study was conducted for process development of beetroot tutti-frutti and assess the quality on the basis of several parameters viz. colour, sugar gain, water activity, water loss and sensory evaluation.

MATERIAL AND METHODOS

Sample and solution preparation

The slicing of fresh beetroot was done with the help of stainless-steel knife to get 10 mm thick cubes. Syrup of desired sugar concentration (50 to 70° Brix) was prepared by dissolving required amount of sugar in water. Sample to sugar syrup ratio was taken as 1:4 (w/w).

Osmosis of beetroot cubes

The prepared samples were weighed approximately 40 g for each experiment and immersed in the sugar syrup (50, 60 and 70ºBrix) contained in a 200 ml glass beaker. The beakers were placed inside the constant temperature water bath. Each beaker was removed from the water bath at the designated time 30, 60, 90, 120, 150 and 180 minutes and the samples were immediately rinsed with water and placed on tissue paper to remove the surface moisture. The samples were weighed and some part of this sample was used for moisture content determination and other is shade dried. The data were utilized for determining sugar gain, water loss and weight reduction. The osmotically dehydrated beetroot tutti-frutti samples were loaded on the trays, weighed and kept in open for moisture removal. After sometime, the sample was come in equilibrium

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with the atmosphere.

Moisture content

The moisture content of the fresh as well as osmotically dehydrated beetroot cubes was determined using AOAC (2000) method. The moisture content of sample was calculated by using following equation:

$$\text{Percent moisture content (db)} = \frac{W_1 - W_2}{W_2} \times 100 \qquad (1)$$

Where,

W_1 = mass of original sample, g

W_2 = mass of the sample after drying, g

Total soluble solids

The total soluble solid of beetroot sample and syrup was determined by digital refractometers of various ranges (0-53 and 45-90ºBrix), which gave the reading directly in Brix (Ranganna, 2000).

Mass Transport in Osmosis

Lenart and Flink (1984) were first to describe terminology, for mass transport data during osmotic dehydration and same has been used by various researchers such as Kaleemullah *et al.*, 2002 and Jain *et al.*, 2011. During osmotic dehydration water loss and solute gain, both take place simultaneously. The weight of the sample undergoes a reduction due to water loss and at same time weight increases due to a solute gain. The terminology is as follows:

Water loss (WL)

The water loss (WL) is defined as the net water loss of the fruit during osmotic dehydration on initial weight basis and was estimated as

$$WL = \frac{W_i X_i - W_\theta X_\theta}{W_i} \qquad (2)$$

Sugar gain (SG)

The sugar gain is the total gain of sugar by the beetroot cubes on initial weight basis. It was determined by using following expression:

$$SG = \frac{W_\theta (1 - X_\theta) - W_i (1 - X_i)}{W_i} \times 100 \qquad (3)$$

Mass reduction (MR)

Mass reduction is difference between water loss and solid gain. Also, it can be determined as the total weight loss of the fruit on initial weight basis.

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

Where,

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

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

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

$_\theta W$ = Mass of beetroot cubes after time θ, g

$_i W$ = Initial mass of beetroot cubes, g

$_\theta X$ = Water content as a fraction of mass of beetroot cubes at time θ,

$_i X$ = Water content as a fraction of initial mass of beetroot cubes, fraction.

RESULTS AND DISCUSSION

Total soluble solids (°Brix)

TSS was determined by using hand refractometer of various ranges (0-32, 28-62 and 58-92ºBrix), which gave the reading directly in Brix. Average of 17 replications was recorded. The maximum and minimum T.S.S. content for beetroot was 7.2 and 6.76°Brix respectively. The average value for T.S.S. content of beetroot cubes was found to be 6.82°Brix.

Moisture content

The initial moisture content of beetroot cubes varied from 85.32 to 86.34 per cent (wb).

Water Loss during Osmotic Dehydration

It was found to be different for different conditions of syrup temperatures and concentrations. The minimum and maximum water loss after osmotic dehydration was 32.29 and 60.52 per cent respectively, corresponding to low levels (50°Brix, 40°C after 180 min) and high levels (70°Brix, 60°C after 180 min) of syrup concentration and temperature. The water loss increased from 0 to 32.29, 35.75 and 48.56 per cent when duration of osmotic dehydration increased from 0 to 180 min for 50° Brix concentration at 40, 50 and 60°C syrup temperatures respectively. Similarly for 60 and 70°Brix concentrations, it varied from 0 to 36.33, 43.61, 52.66 and 42.24, 52.61, 60.52 per cent for 40, 50 and 60°C syrup temperatures, respectively (Fig. 1). Fig. 1 and 2 shows that a low temperature-low concentration condition (40°C-50°Brix) gave a low water loss (32.29 per cent after 180 min of osmosis) and a high temperature-high concentration conditions (60°C-70°Brix) gave a higher water loss (60.52 per cent after 180 min of osmosis).

The statistical analysis revealed that second order polynomial equation could be best fit to the observed values of water loss. The predicted equations with their coefficient of determination values are presented in the Table 1.

$$WL = aX^2 + bX + c \qquad \ldots 5$$

Where,

WL = Water loss in per cent,

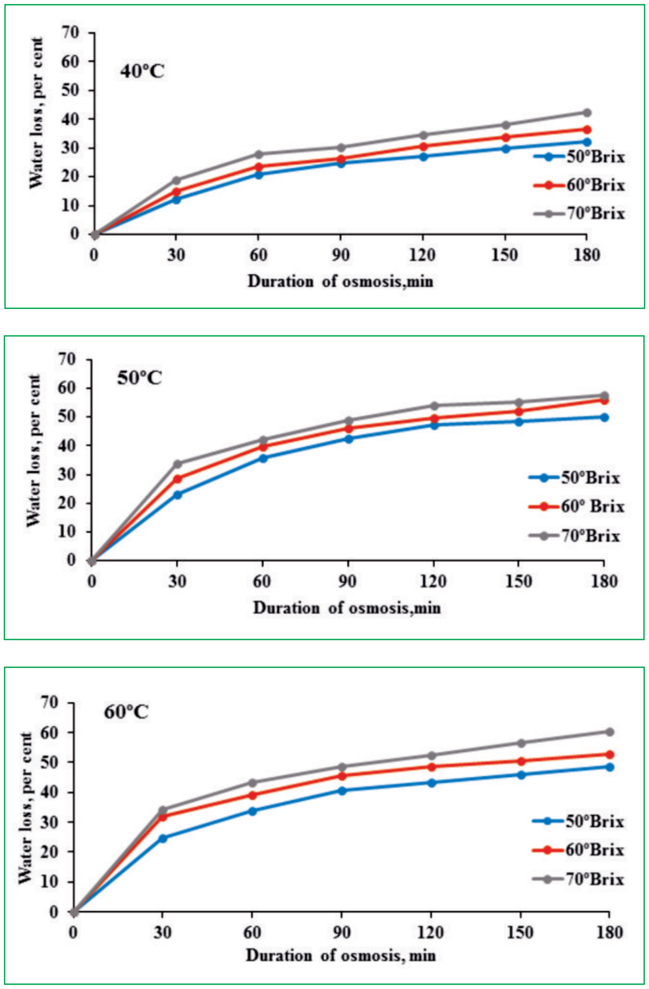
a, b, c = Constants and

X = Duration of osmosis in min.

Table 1: Predicted equations and coefficient of determination values for water loss at 50, 60 and 70ºBrix concentrations and 40, 50 and 60ºC temperature of syrup

Syrup concentration (ºBrix)	Temperature of syrup (ºC)	Equation prediction	R^2
50	40	$y = -0.9638x^2 + 12.641x - 10.308$	0.983
	50	$y = -1.0862x^2 + 13.88x - 9.8336$	0.955
	60	$y = -1.581x^2 + 19.327x - 14.289$	0.966
60	40	$y = -1.0243x^2 + 13.678x - 10.594$	0.976
	50	$y = -1.3116x^2 + 16.69x - 11.787$	0.955
	60	$y = -2.1691x^2 + 24.656x - 16.92$	0.934
70	40	$y = -1.1387x^2 + 15.273x - 10.967$	0.959
	50	$y = -1.4019x^2 + 19.001x - 13.648$	0.965
	60	$y = -2.1405x^2 + 25.494x - 17.009$	0.931

It was observed that the values of coefficient of determination were more than 0.930 for all the experiments which revealed the good co-relation between the predicted and observed data.



1: Variation in water loss with duration of osmosis for 50, 60 and 70ºBrix syrup concentrations at 40, 50 and 60°C syrup temperatures

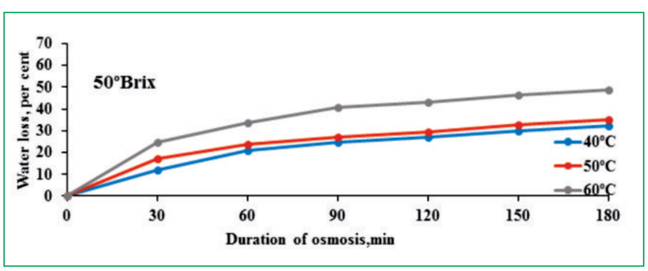


Fig. 2: Variation in water loss with duration of osmosis and 40,50 and 60ºC syrup temperatures for syrup concentrations of 50, 60 and 70 °Brix

Sugar Gain During Osmotic Dehydration

The minimum and maximum sugar gain during osmotic dehydration was found to be 8.66 and 13.42 per cent respectively, corresponding to low levels (50°Brix, 40°C after 180 min) and high levels (70°Brix, 60°C after 180 min) of syrup concentration and temperature. The sugar gain increased from 0 to 8.66, 9.17 and 10.71 per cent when duration of osmotic dehydration increased from 0 to 180 min for 50°Brix concentration at 40, 50 and 60°C syrup temperatures respectively. Similarly, for 60 and 70°Brix concentrations, it varied from 0 to 10.48, 11.30, 12.19 and 11.36, 12.66, 13.42 per cent for 40, 50 and 60°C syrup temperatures, respectively (Fig. 3). Inference can be drawn from Fig. 3 and 4 that a low temperature-low concentration condition (40°C-50°Brix) gives a low sugar gain (8.66 per cent after 180 min of osmosis) and a high temperature-high concentration conditions (60°C-70°Brix) gives a higher sugar gain (13.42 per cent after 180 min of osmosis). The statistical analysis revealed that second order polynomial equation could be best fit to the observed values of sugar gain. The predicted equations with their coefficient of determination values are presented in the Table 2.

$$SG = aX^2 + bX + c \qquad ...6$$

Where,

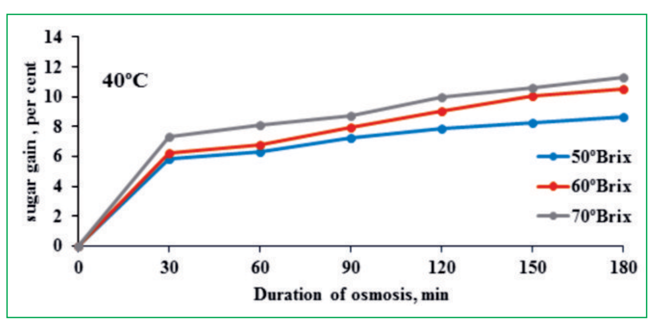
SG = Sugar gain in per cent,

a, b, c = Constants and

X = Duration of osmosis in min.

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

Syrup concentration (ºBrix)	Temperature of syrup (ºC)	Equation prediction	R^2
	40	y = -0.045x² + 0.09948x + 3.9405	0.990
50	50	y = -0.341x² + 3.9324x-2.2898	0.975
	60	y = -0.4011x² + 4.666x -2.9438	0.973
	40	y = -0.318x² + 4.0202x-2.5043	0.917
60	50	y = -0.422x² + 4.8869x-3.0264	0.994
	60	y = -0.466x² + 5.3373x-3.2103	0.985
	40	y = -0.3858x + 4.598x-2.6887	0.986
70	50	y = -0.4479x² + 5.2189x-2.976	0.970
	60	y = -0.4972x² + 5.6787x-3.287	0.977



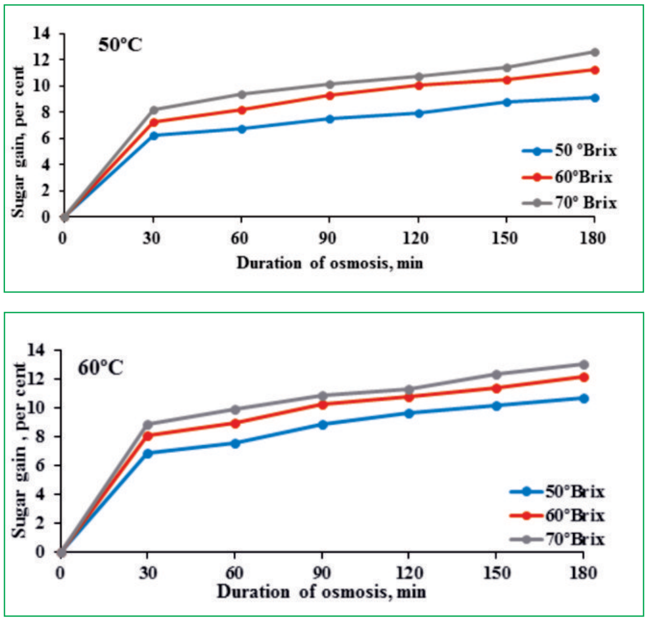


Fig. 3: Variation in sugar gain with duration of osmosis and three different syrup concentrations 50, 60 and 70ºBrix at 40, 50 and 60°C syrup temperatures

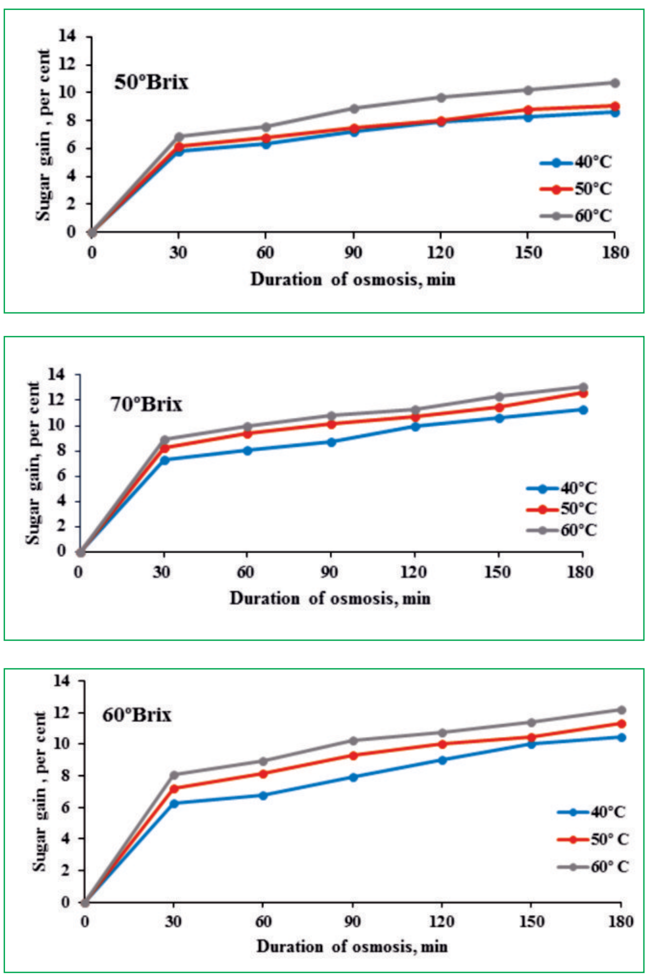


Fig. 4: Variation in sugar gain with duration of osmosis and syrup temperatures 40, 50 and 60ºC for syrup concentrations of 50, 60 and 70°Brix

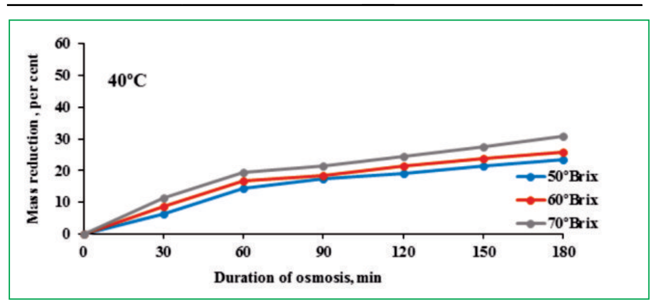
Mass reduction

The minimum and maximum mass reduction after osmotic dehydration was 23.42 and 47.34 per cent respectively, corresponding to low levels (50°Brix, 40°C after 180 min) and high levels (70°Brix, 60°C after 180 min) of syrup concentration and temperature. It can be concluded from Fig. 5 and 6 that a low temperature-low concentration condition (40°C-50°Brix) gives a low mass reduction (23.42 per cent after 180 min of osmosis) and a high temperature-high concentration conditions (60°C-70°Brix) gives a higher mass reduction (47.34 per cent after 180 min of osmosis). High temperature-low concentration of sugar syrup condition 60°C-50°Brix (38.05per cent after 180 min of osmosis) gives higher mass reduction than the low temperature–high concentration condition (40°C-70°Brix) of 30.95 per cent after 180 min of osmosis, which indicates a pronounced effect of temperature on mass reduction (Fig. 3.5). This indicates that mass reduction can be increased by increasing either the syrup concentration or temperature of solution. The predicted equations with their coefficient of determination values are presented in the Table 3.

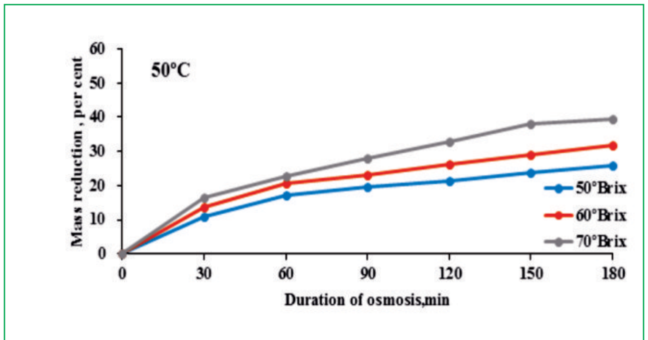
$$MR = aX^2 + bX + c \qquad \text{....7}$$

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

Syrup concentration (ºBrix)	Temperature of syrup (ºC)	Equation predicted	R^2
	40	$y = -0.6277x^2 + 8.7937x - 7.9607$	0.985
50	50	$y = -0.7611x^2 + 9.9533x - 7.6464$	0.972
	60	$y = -1.3955x^2 + 16.756x - 12.94$	0.973
	40	$y = -0.7062x^2 + 9.658x - 8.0893$	0.980
60	50	$y = -0.8896x^2 + 11.803x - 8.7607$	0.697
	60	$y = -1.7027x^2 + 19.319x - 13.71$	0.946
	40	$y = -0.753x^2 + 10.675x - 8.2779$	0.972
70	50	$y = -0.954x^2 + 13.782x - 10.672$	0.981
	60	$y = -1.6433x^2 + 19.816x - 13.722$	0.945



It was observed that the values of coefficient of determination were more than 0.918 for all the experiments which revealed the good co-relation between the predicted and observed data.



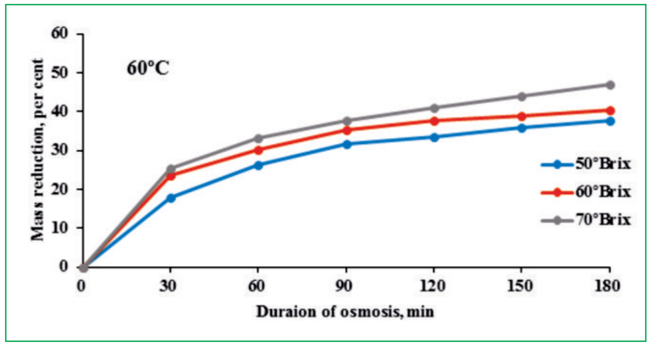
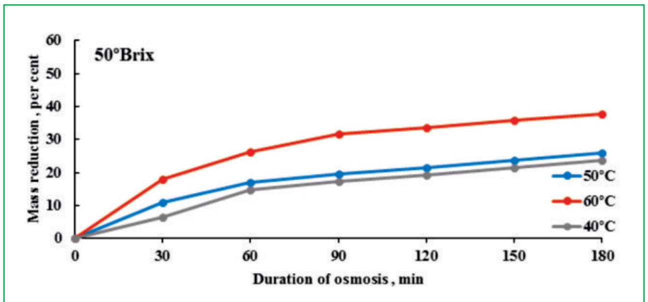
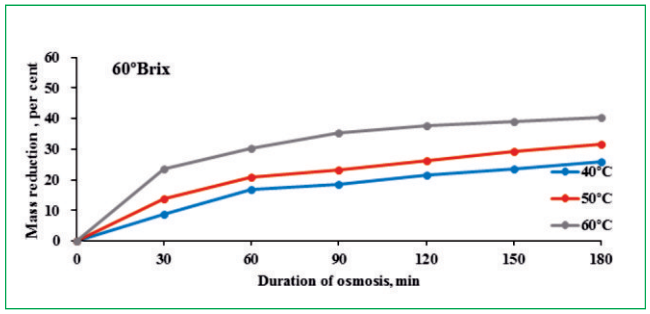


Fig. 5: Variation in mass reduction with duration of osmosis and 50,60 and 70ºBrix syrup concentrations at 40, 50 and 60°C syrup temperatures.





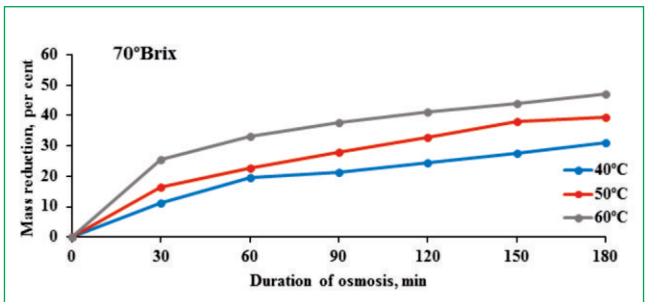


Fig. 5: Variation in mass reduction with duration of osmosis and 40,50 and 60ºC temperatures for syrup concentrations of 50, 60 and 70 °Brix

CONCLUSION

The minimum and maximum mass reduction, water loss and sugar gain after osmotic dehydration were observed in the range of 23.42 to 47.34, 32.29 to 60.52 and 8.66 to 13.42 per cent, respectively corresponding to low levels (50° Brix, 40°C after 180 min) and high levels (70° Brix, 60°C after 180 min) of syrup concentration and temperature, respectively. Taste, colour, texture and overall acceptability of osmotically prepared tutti-frutti at 62°C syrup temperature, 50º Brix syrup concentration was highly appreciable.

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