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Mass transfer kinetics during osmotic dehydration of banana in different osmotic agent

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■ **ABSTRACT :** In this study, osmotic dehydration of banana was carried out on the basis of the mass transfer kinetics. During osmotic dehydration of banana, three concentration levels (40, 50 and 60 %) of osmotic agents such as sucrose, fructose and maltodextrin were used at three different levels of osmotic solution temperature (40, 50 and 60 °C). The samples to solution ratio were taken at three levels *i.e.*, 1:4, 1:5 and 1:6 for all the experiments. Full factorial design was employed to determine the number of experiments for osmotic dehydration of banana. Osmotic solutions were prepared by dissolving different levels of sucrose, fructose and maltodextrin in distilled water (w/w). A magnetic stirrer was used to dissolve the content. Fresh osmotic solution was prepared for every run. The surface moisture was removed by using blotting paper. Osmotic dehydration was carried out from 10 to 240 min with varying time intervals to investigate the osmotic kinetics at each experimental condition. All the experiments were replicated thrice. The initial moisture content of banana samples and moisture content of osmosed samples (10, 20, 30, 40, 50, 60, 90, 120, 150, 180, 210 and 240 min) were determined by hot air oven method. The moisture loss and solid gain were computed on the basis of mass balance. The effect of osmotic agents, concentration of osmotic solution, temperature of osmosis, sample to solution ratio and osmotic time on moisture loss and solid gain during osmotic dehydration of banana were studied. Determination of the moisture and solid change in banana samples during osmotic dehydration under different treatments is a function of drying time. In each case, the best fit was selected and the kinetic rate constant and other statistical parameters at each process were determined. The moisture loss and solid gain increased with increasing the sucrose solution concentration at constant sample to solution ratio and temperature of solution. The moisture loss was found to be higher for samples osmosed in maltodextin compared to those osmosed in sucrose and lower than the sample osmosed in fructose at the same concentration, temperature of solution and sample to solution ratio. The solid gain was higher for samples osmosed in fructose compared to those osmosed in maltodextrin and sucrose at the same concentration and temperature of solution with the same sample to solution ratio, because solid uptake is inversely correlated with the molecular size of the osmotic agents. Zero-order and first-order kinetic models were used for the mass transfer kinetics during osmotic dehydration of banana samples in sucrose, fructose and maltodextrin solution. The mass transfer kinetic studies reveal that the data for moisture loss and solid gain were accurately fitted by zero-order kinetic model compared to a first-order kinetic model with high values for the corresponding co-efficients of determination (R^2) and low value of root mean square error (RSME).

■ **KEY WORDS :** Banana, Osmotic dehydration, Osmotic agent

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Banana is one of the oldest tropical fruits cultivated by man from prehistoric time in India with great socio-economic significance, interwoven in the cultural heritage of the country. It is also fourth important food crop in terms of gross value after paddy, wheat and milk products and it is an important crop for subsistence farmers. The important banana growing states of India are Tamil Nadu, Karnataka, Madhya Pradesh, Kerala, Assam, U.P., Maharashtra, West Bengal, Himachal Pradesh, Bihar, Gujarat etc. It is a rich source of vitamin C and minerals, and makes healthy and salt-free diet. In India, banana contributes 35.33 per cent of the total fruit production. The total production is estimated at 26.5 million tonnes (Indian Horticulture Database, 2013). India is the largest producer of banana in the world.

Since ancient time, dehydration has been one of the most common natural and reliable methods for food preservation. Although reaction rates are generally reduced by dehydration, undesirable changes due to reactions such as enzymatic browning may result in quality changes (Kouassi and Roos, 2001). Sugar, honey and salt have been used as aids in the drying of fruits and vegetables at various times in the past (Woodroof, 1986). Recently, much attention has been given to the quality of dehydrated products. Drying methods and physicochemical changes that occur during dehydration seem to affect colour, texture, density, porosity and sorption characteristics of dehydrated product (Lewicki and Lukaszub, 2000 and Telis *et al.*,2000). One of the techniques being widely used is osmotic dehydration. The osmotic process can be used to obtain fruits and vegetables with distinctive characteristics and an extended shelf-life, ready-to-eat, or as a prior step to a further process such as drying, freezing, pasteurization, canning or frying.

Osmotic dehydration is a water removal technique, which is applied to horticultural products, such as fruits and vegetables, to reduce the water content, while increasing soluble solid content. The semi final product obtained is not stable from the point of view of conservation. The chemical composition and organoleptic characteristics of osmodehydrated fruits and vegetables result in high quality products that can undergo subsequent freezing, dehydrofreezing, air drying or vacuum drying. Using the osmotic dehydration combined with subsequent drying, good organoleptic quality products can be obtained. Osmotic dehydration also named de-watering and impregnation soaking process. Osmotic dehydration has generally been applied to fruit and vegetables (Ponting *et al*., 1966) and recently to meat and fish (Collegoan and Raoult-Wack, 1992). Mass transfer phenomena taking place between the product and the osmotic medium are strongly affected by the nature of the raw material (*i.e.* species, variety, maturity level, shape and size, pretreatment) and the process variables (*i.e.* composition/ concentration of osmotic medium, medium/product ratio, temperature, contact time).

In light of above discussion the objective of this work are to investigate the mass transfer kinetics of banana during osmotic dehydration in solution of different osmotic agents having different concentration at different temperature with different sample to solution ratio.

■ METHODOLOGY

Experiments were conducted to study the mass transfer kinetics of osmotic dehydration of banana. The fresh, uniform size and good quality banana was procured from fruits and vegetables mandi. The osmotic agents sucrose, fructose and maltodextrin were procured from Delhi market. Muslin cloth and tissue paper were used to absorb surface moisture after blanching and osmosis. Properly cleaned and dry beakers were used for whole osmotic dehydration experiments and Petri plates were used for moisture loss and solid gain calculation of osmotically dehydrated banana slices. Based on preliminary experiments and review of literature, three concentration levels (40, 50 and 60%) of osmotic agents sucrose, fructose and maltodextrin, three sample to solution ratio levels (1:4, 1:5 and 1:6) were used at three different levels of osmotic solution temperature (40, 50 and 60 °C) (Sagar, 2001) with agitation. Full factorial design was employed to determine the number of experiments for osmotic dehydration of banana. The osmotic dehydration was carried out from 10 to 240 min with varying time interval to investigate the osmotic kinetics at each experimental condition. All the experiments were replicated thrice. The initial moisture content of samples and moisture content of osmosed samples (10, 20, 30, 40, 50, 60, 90, 120, 150, 180, 210 and 240 min) were determined by hot air oven method. The moisture loss and solid gain were computed on the basis of mass balance. All reported results were average values of the three replications. Osmotic solutions were prepared by dissolving the different levels of sucrose, fructose and maltodextrin in the distilled water (w/w). A magnetic stirrer was used to dissolve the contents. An electronic balance with 1 mg least count was used to weigh the osmotic agents. Fresh osmotic solution was prepared for every run.

The banana was peeled manually and cut into the round slices of thickness 10 mm with a knife. The surface of the banana samples were gently blotted with absorbent paper. The sample was then subjected to osmotic dehydration at different osmosis condition. A flask shaker was used for the osmotic dehydration of banana samples. The temperature and agitation were controlled during overall osmotic dehydration time. During osmotic dehydration twelve 500 ml beakers were filled with osmotic solution in sample to solution ratio of 1:4, 1:5 and 1:6.The prepared 30 g banana samples were immersed in each beaker. One beaker at a times taken out from the shaker after 10, 20, 30, 40, 50, 60, 90, 120, 150, 180, 210 and 240 min from the beginning of osmosis and banana samples taken out from the beakers. The samples were withdrawn, rinsed quickly in water, blotted gently with a tissue paper in order to remove adhering water and weighed on an electronic balance.

The initial and final moisture content of sample was determined by using hot air oven method recommended by Ranganna (2001) for fruits and vegetables.

$$\text{M C (\% w. b)} = \frac{\text{(Initial weight – Final weight)}}{\text{Initial weight}} \text{x 100} \quad ....(1)$$

The moisture loss (ML) per cent was measured by the following equation suggested by (Lenart and Flink, 1994 and Hawkes and Flink, 1978).

$$\text{M L (\%)} = \frac{\text{(Wt of initial moisture, g - Wt of final moisture, g)}}{\text{Initial wt of the samaple in g}} \text{x 100} \quad .(2)$$

The solid gain (SG %) was measured by the following equation suggested by (Lenart and Flink, 1994: Hawkes and Flink, 1978).

$$\text{SG (\%)} = \frac{\text{(Wt of fomal solid, g - Wt of initial solid, g)}}{\text{Initial wt of the samaple in g}} \text{x 100} \quad ....(3)$$

Mass transfer kinetic :

In order to determine the moisture and solid gain of banana during osmotic dehydration under different treatment, as a function of drying time, generally, the rate of change of a mass transfer factor C can be represented by

$$\frac{dC}{dt} = -kC^n \quad .....(4)$$

where k is the kinetic rate constant, C is the concentration of a mass transfer factor at time t, and n is the order of reaction. For the majority of foods, the time-dependence relationships appear to be described by zero-order (Maskan,2000 and Chen and Ramaswamy, 2002) or first-order kinetic models (Maskan, 2000 and Chen and Ramaswamy, 2002). By integrating eq. (4), zero-order eq. (5) and first-order kinetic models eq. (5) can be derived as:

$$C = C_0 \pm kt \quad .....(5)$$

$$C = C_0 \exp(\pm kt) \quad .....(6)$$

where, C_0 is the initial value of mass transfer parameter and C is the mass transfer value at a specific time. In the equations, (±) indicates gain and loss of any mass transfer parameter. The order of reaction for the mass transfer parameters during osmotic dehydration of banana was determined by the adjustment of the experimental data to the integrated eqs. (5) and (6) by using linear regression analysis. In each case, the best fit was selected and the kinetic rate constant and other statistical parameters at each process were determined.

■ RESULTS AND DISCUSSION

The osmotic dehydration of banana was carried out to investigate the mass transfer kinetics for different experimental condition. The moisture loss and solid gain of banana during osmotic dehydration were calculated by mass balance. The average initial moisture content of the banana sample was found to be 77 per cent (wb). The calculated moisture loss and solid gain after 4 hour osmotic dehydration ranged between 38.21 - 50.26 per cent and 5.963 – 7.795 per cent of initial weight of banana samples, respectively.

Effect of temperature, processing time, sample to solution ratio and concentration of sucrose, fructose and maltodextrin on moisture loss of banana :

The moisture loss was increased in non-linear manner with time at all concentration of sucrose, fructose and maltodextrin at different temperature. An initial high rate of moisture loss followed by slower removal in later stage was observed. Rapid moisture loss in the beginning is apparently due to large osmotic driving force between

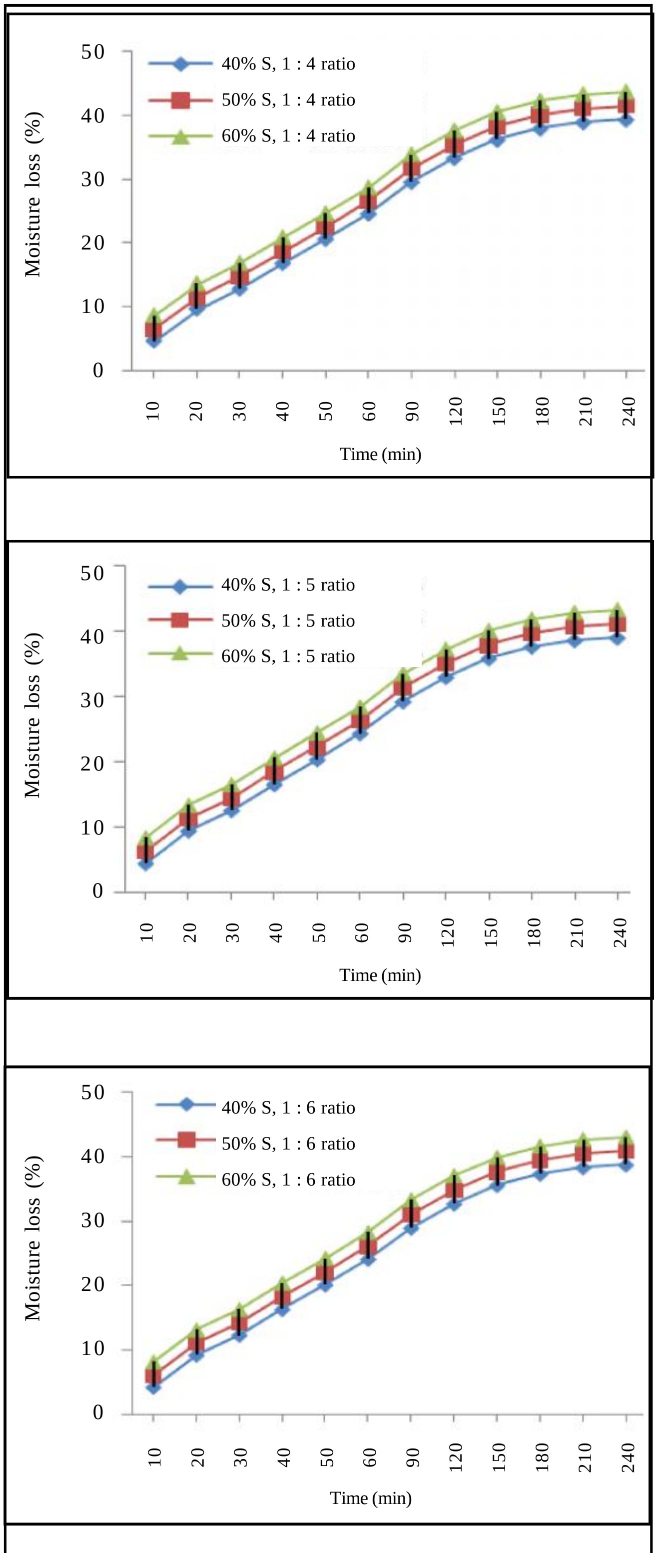

Fig. 1 : Effect of osmotic concentrations of sucrose on moisture loss of banana at 40 °C and 1:4, 1:5 and 1:6 samples to solution ratio

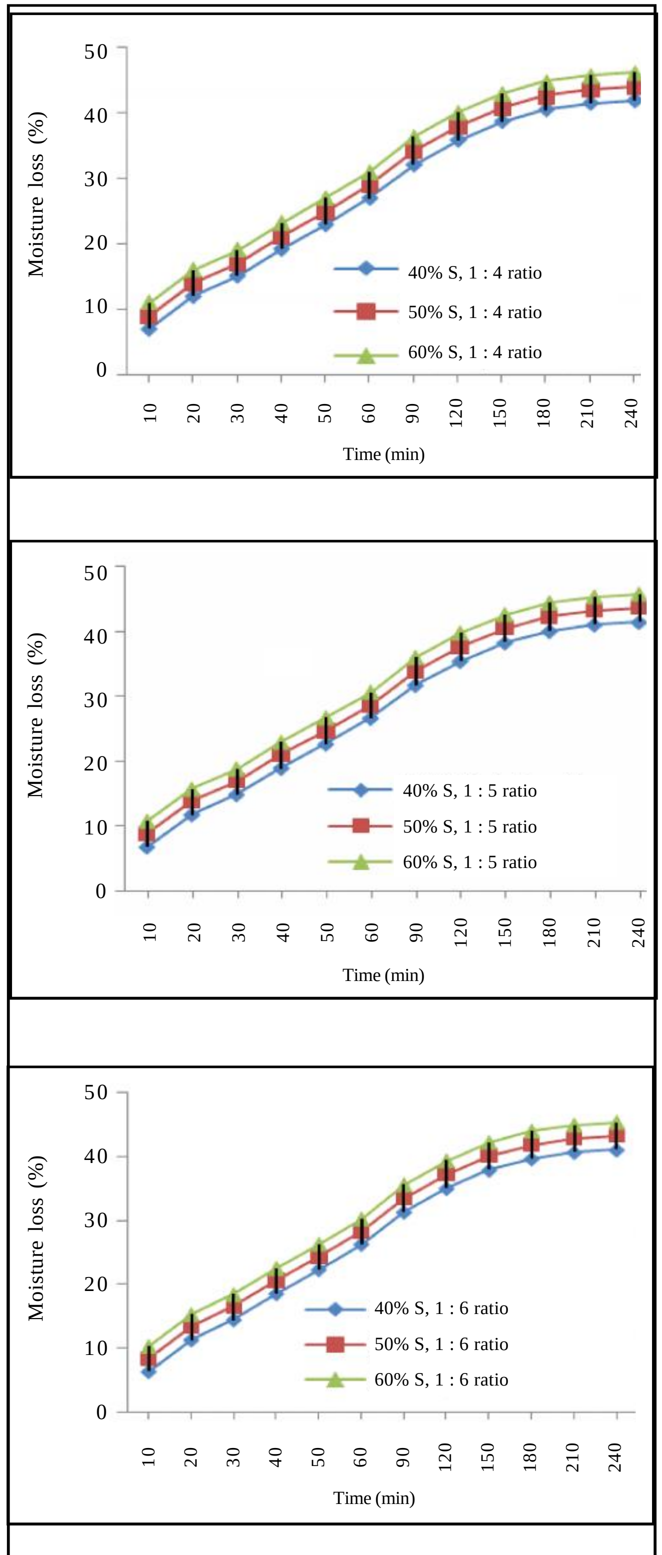

Fig. 2 : Effect of osmotic concentrations of sucrose on moisture loss of banana at 50 °C and 1:4, 1:5 and 1:6 samples to solution ratio

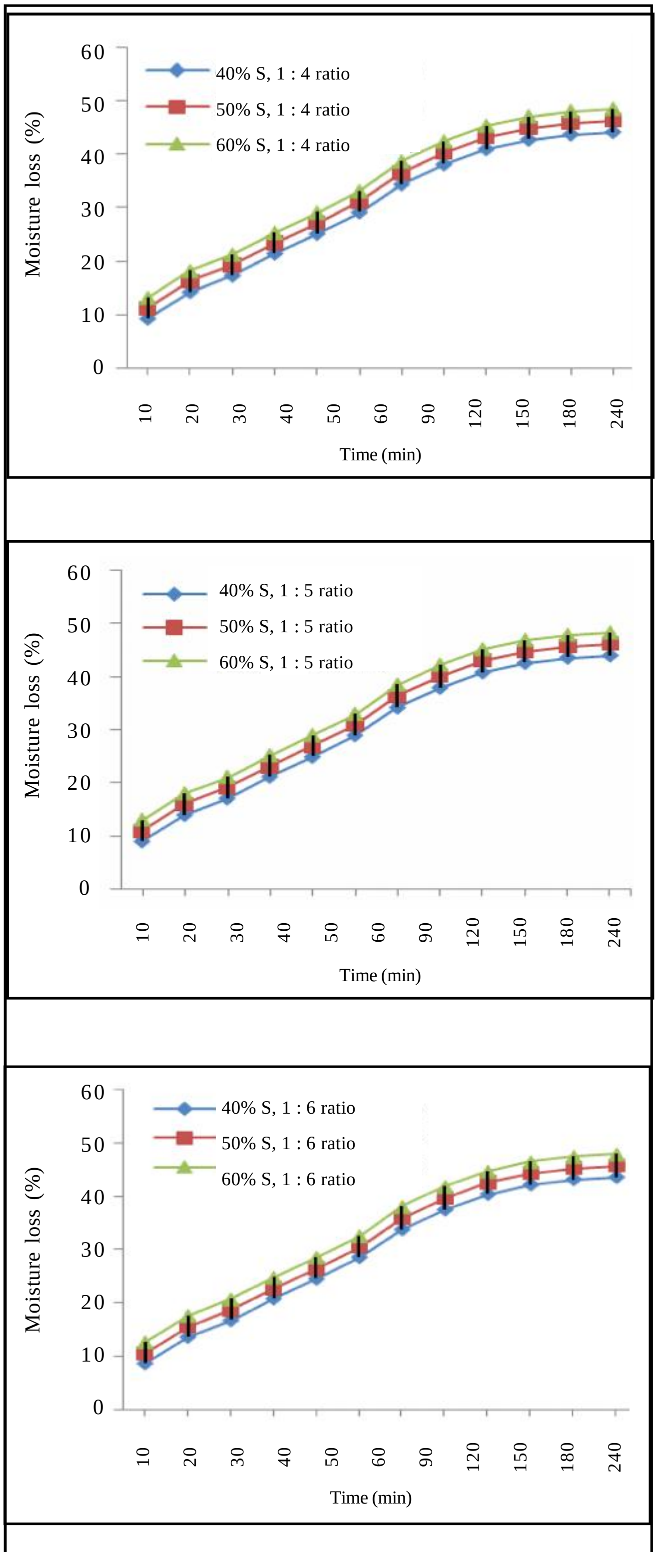

Fig. 3 : Effect of osmotic concentrations of sucrose on moisture loss of banana at 60 °C and 1:4, 1:5 and 1:6 samples to solution ratio

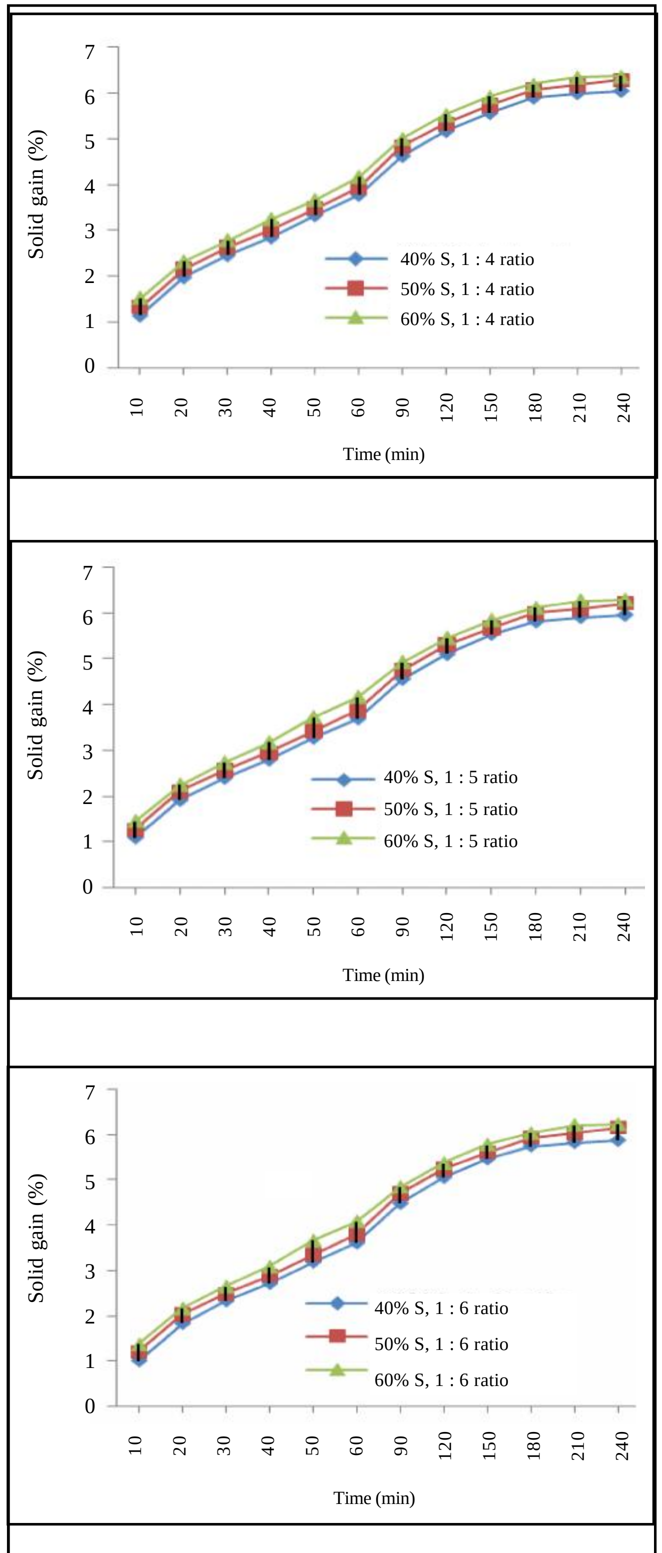

Fig. 4 : Effect of osmotic concentrations of sucrose on solid gain of banana at 40 °C and 1:4, 1:5 and 1:6 samples to solution ratio

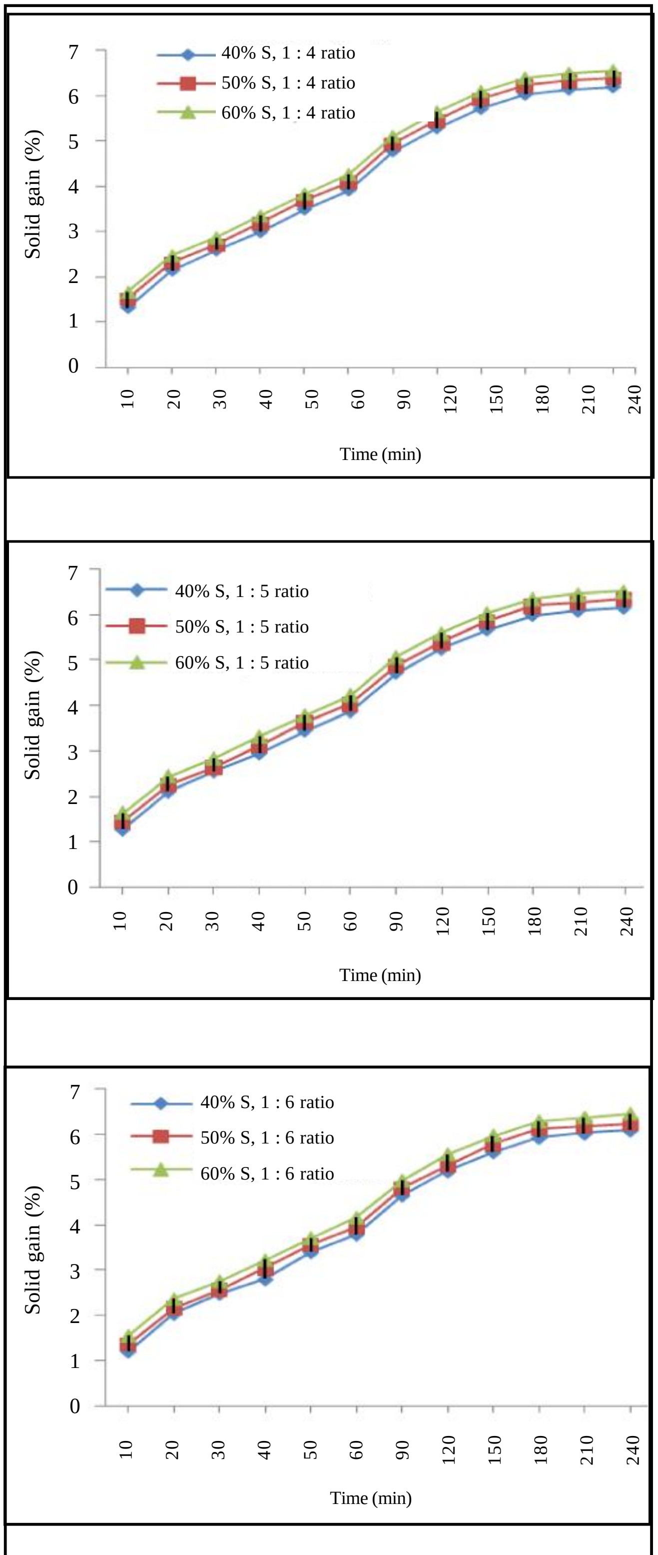

Fig. 5 : Effect of osmotic concentrations of sucrose on solid gain of banana at 50 °C and 1:4, 1:5 and 1:6 samples to solution ratio

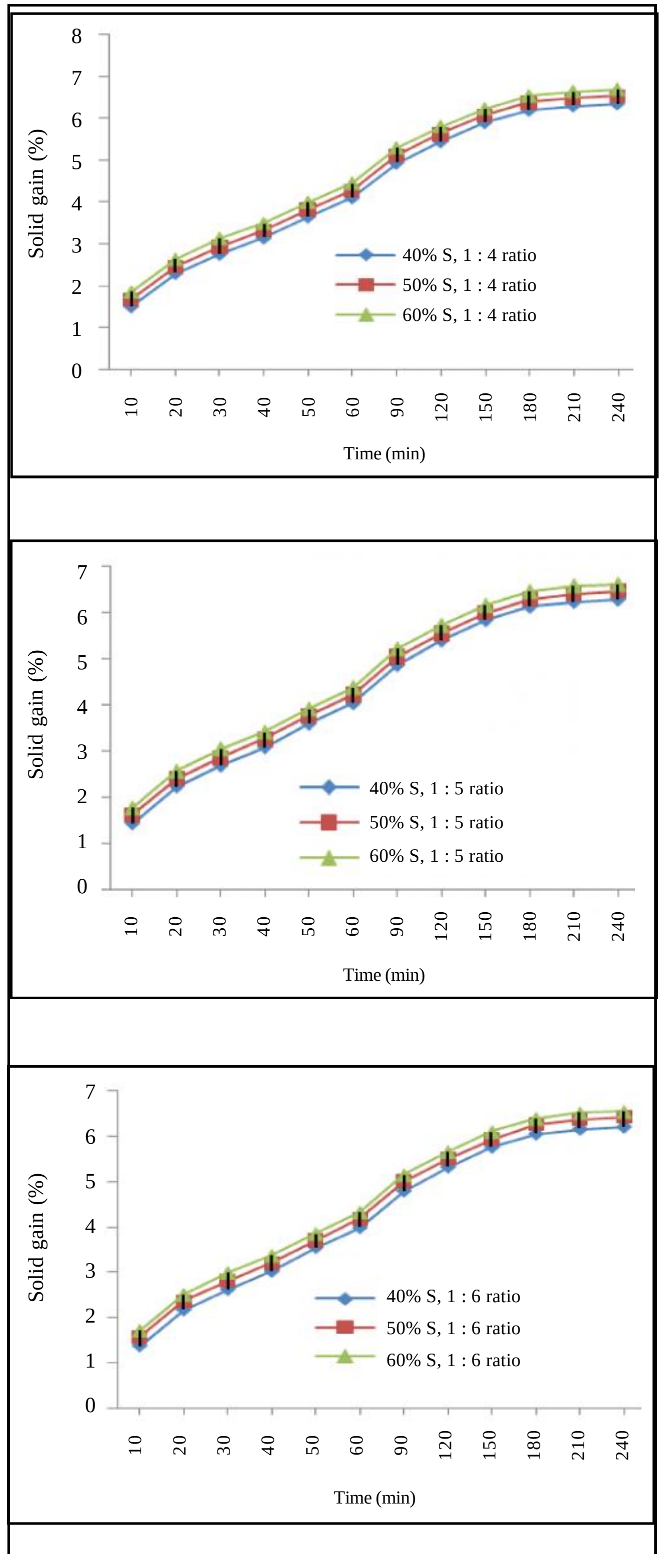

Fig. 6 : Effect of osmotic concentrations of sucrose on solid gain of banana at 60 °C and 1:4, 1:5 and 1:6 samples to solution ratio

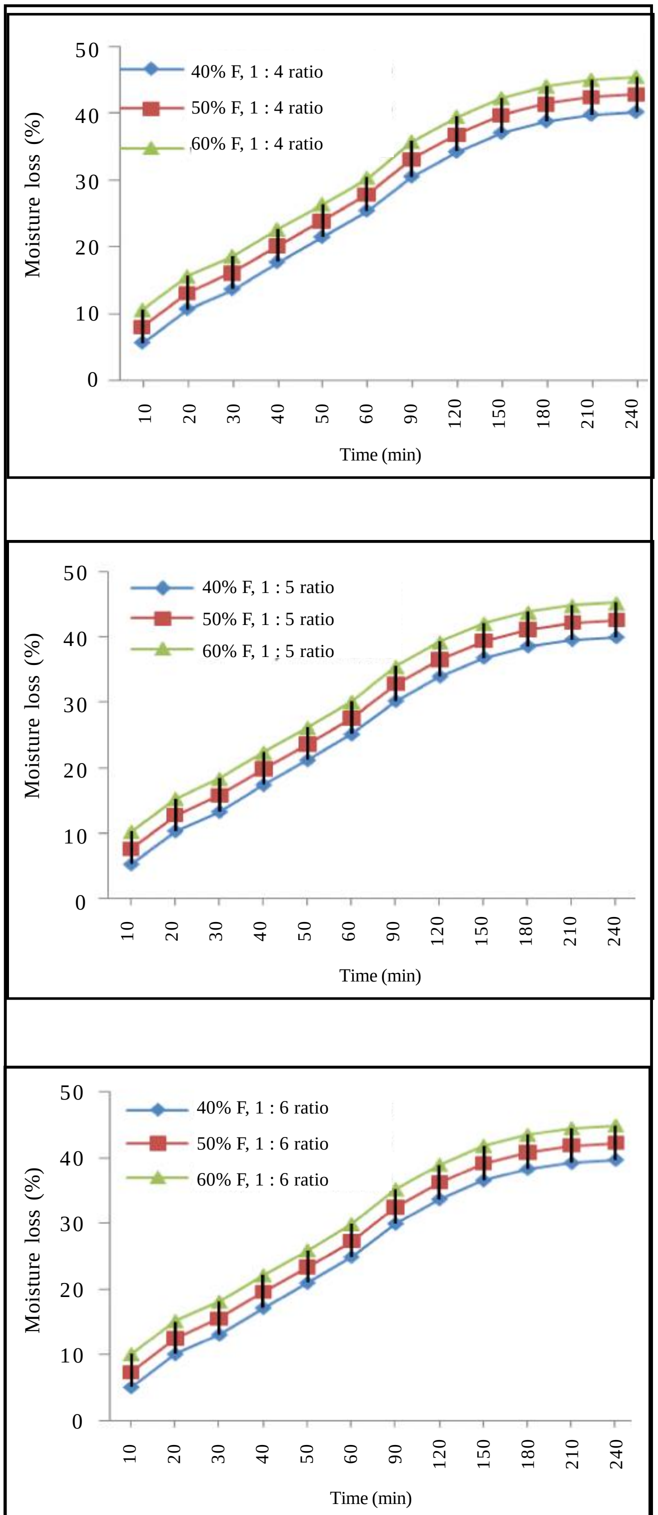

Fig. 7 : Effect of osmotic concentrations of fructose on moisture loss of banana at 40 °C and 1:4, 1:5 and 1:6 samples to solution ratio

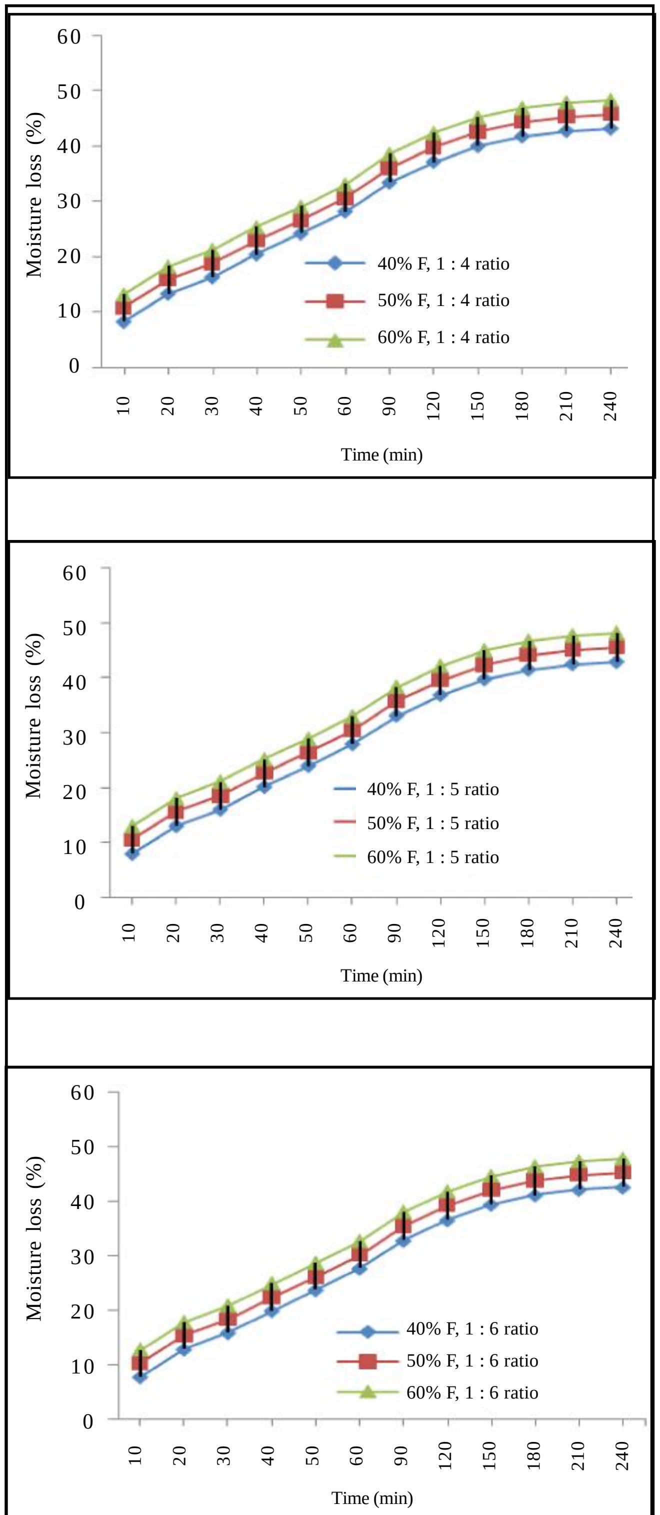

Fig. 8 : Effect of osmotic concentrations of fructose on moisture loss of banana at 50 °C and 1:4, 1:5 and 1:6 samples to solution ratio

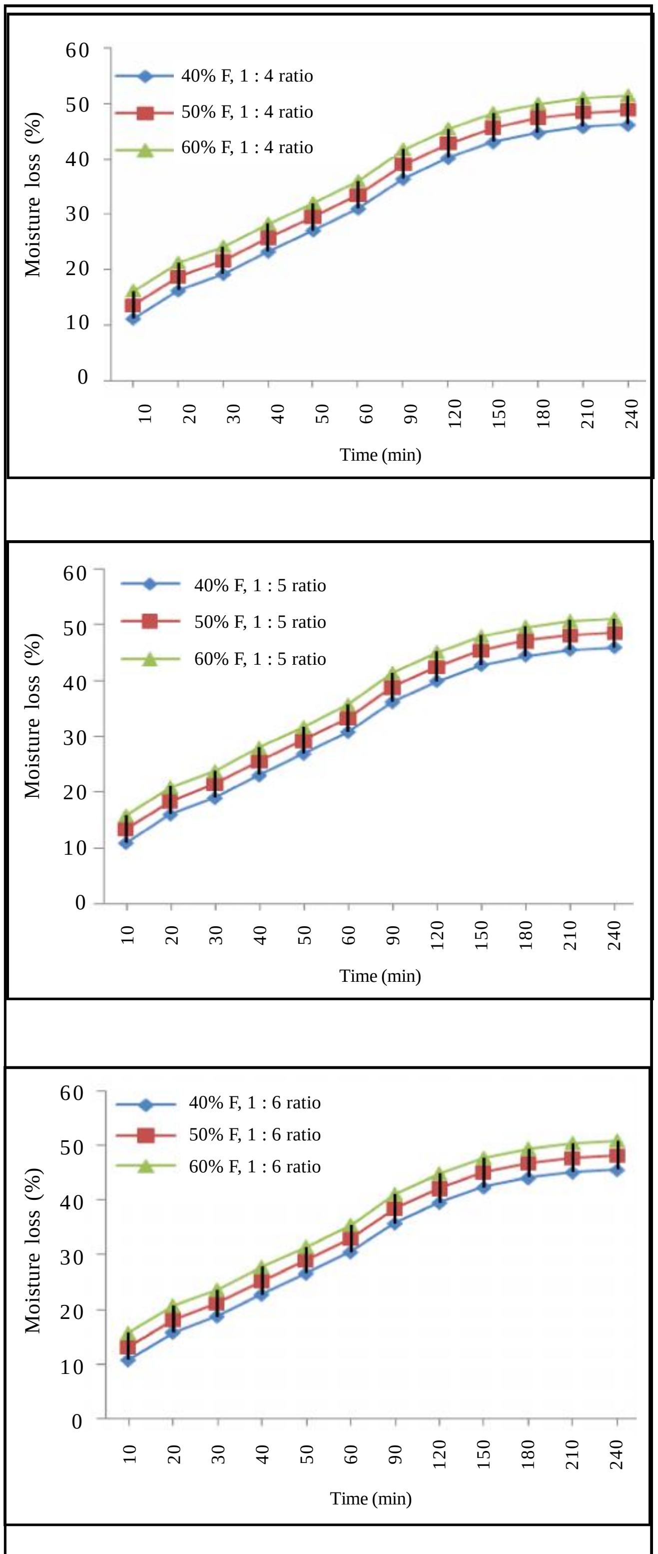

Fig. 9 : Effect of osmotic concentrations of fructose on moisture loss of banana at 60 °C and 1:4, 1:5 and 1:6 samples to solution ratio

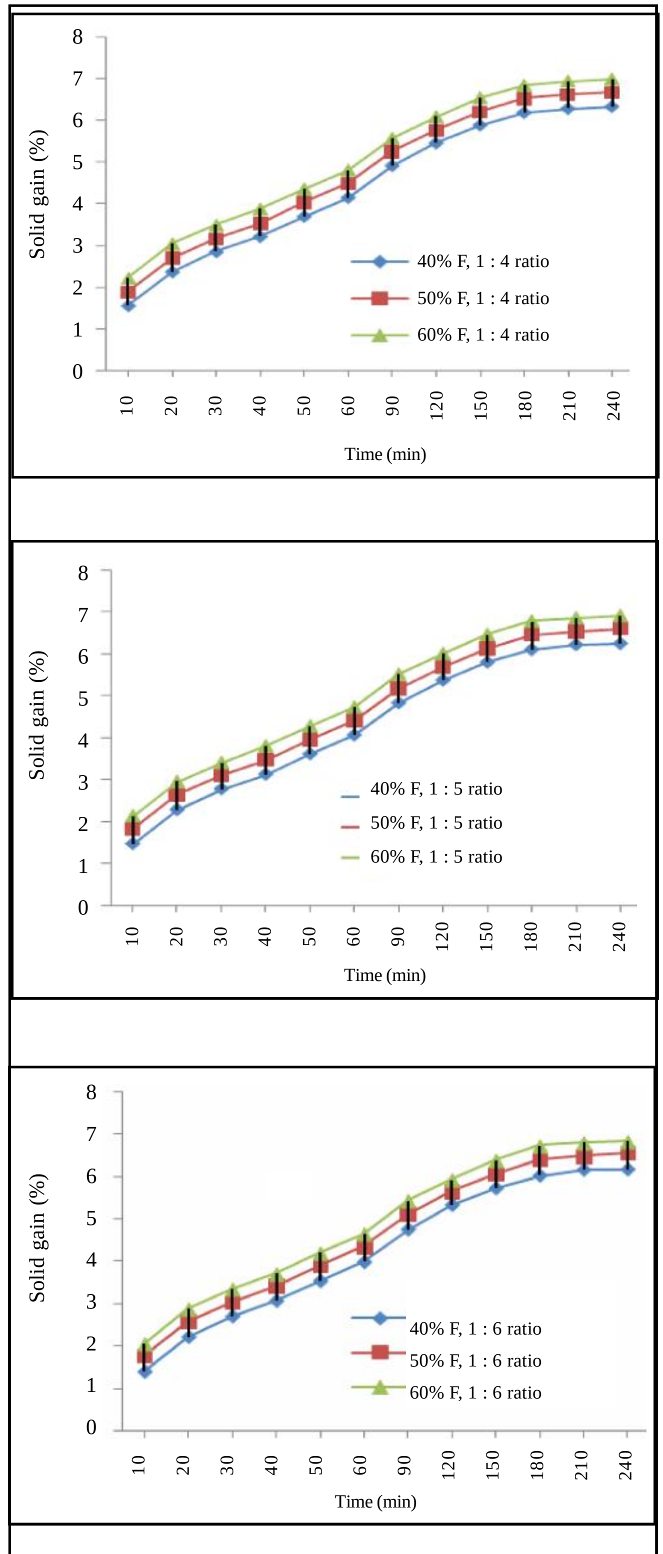

Fig. 10 : Effect of osmotic concentrations of fructose on solid gain of banana at 40 °C and 1:4, 1:5 and 1:6 samples to solution ratio

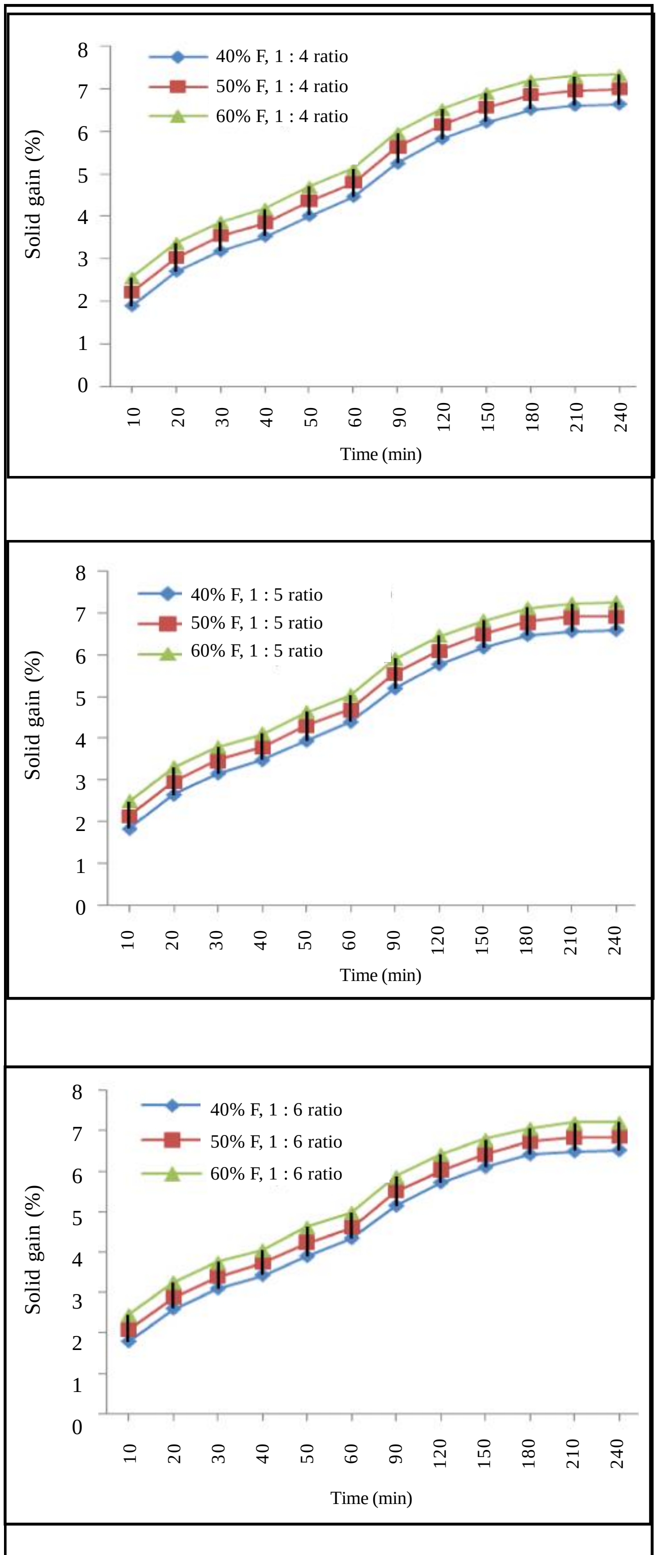

Fig. 11 : Effect of osmotic concentrations of fructose on solid gain of banana at 50 °C and 1:4, 1:5 and 1:6 samples to solution ratio

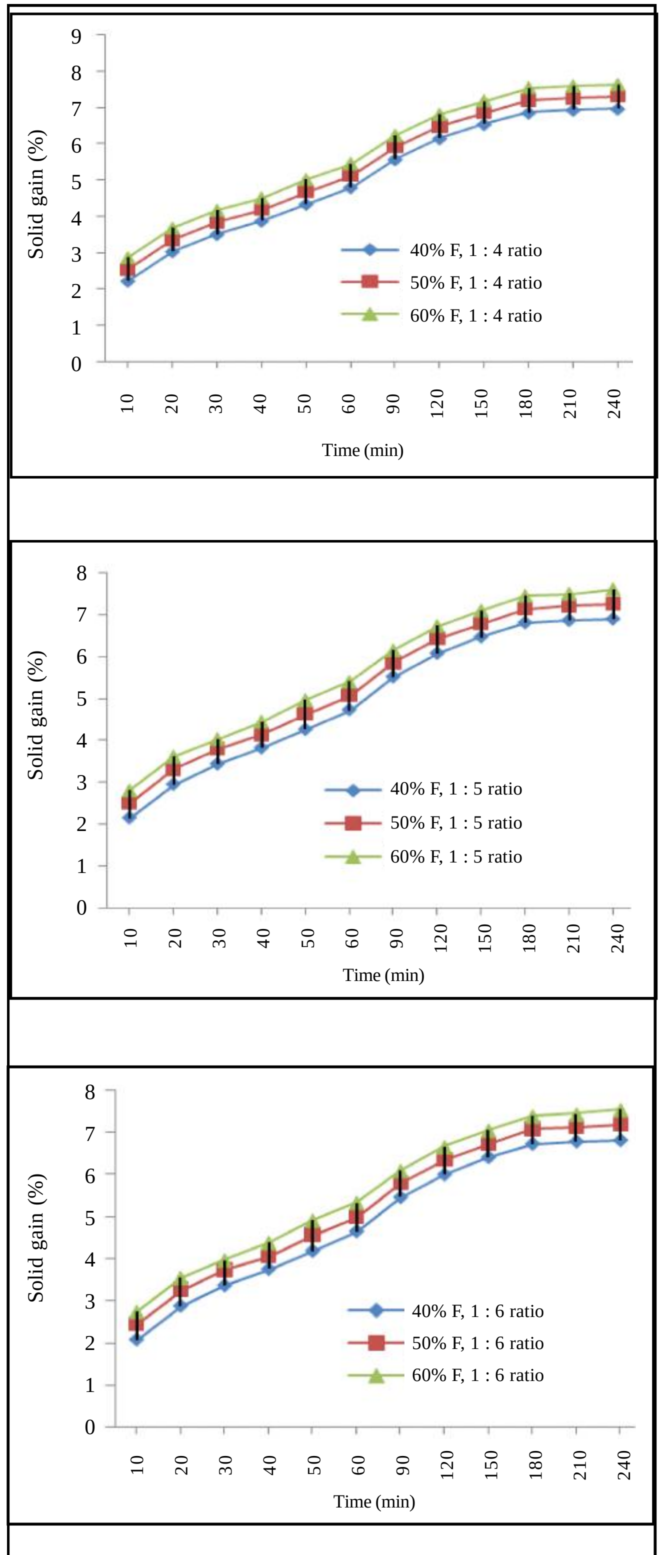

Fig. 12 : Effect of osmotic concentrations of fructose on solid gain of banana at 60 °C and 1:4, 1:5 and 1:6 samples to solution ratio

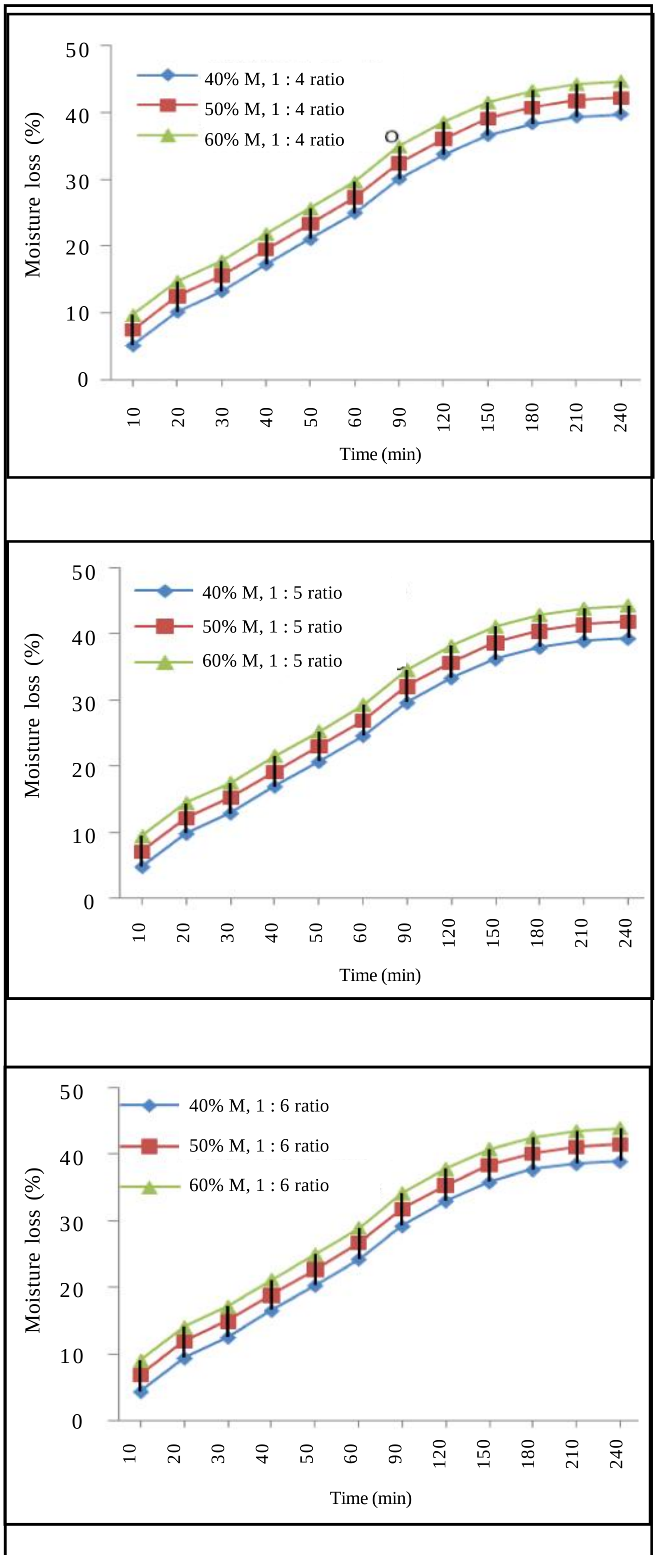

Fig. 13 : Effect of osmotic concentrations of maltodextrin on moisture loss of banana at 40 °C, and 1:4, 1:5 and 1:6 samples to solution ratio

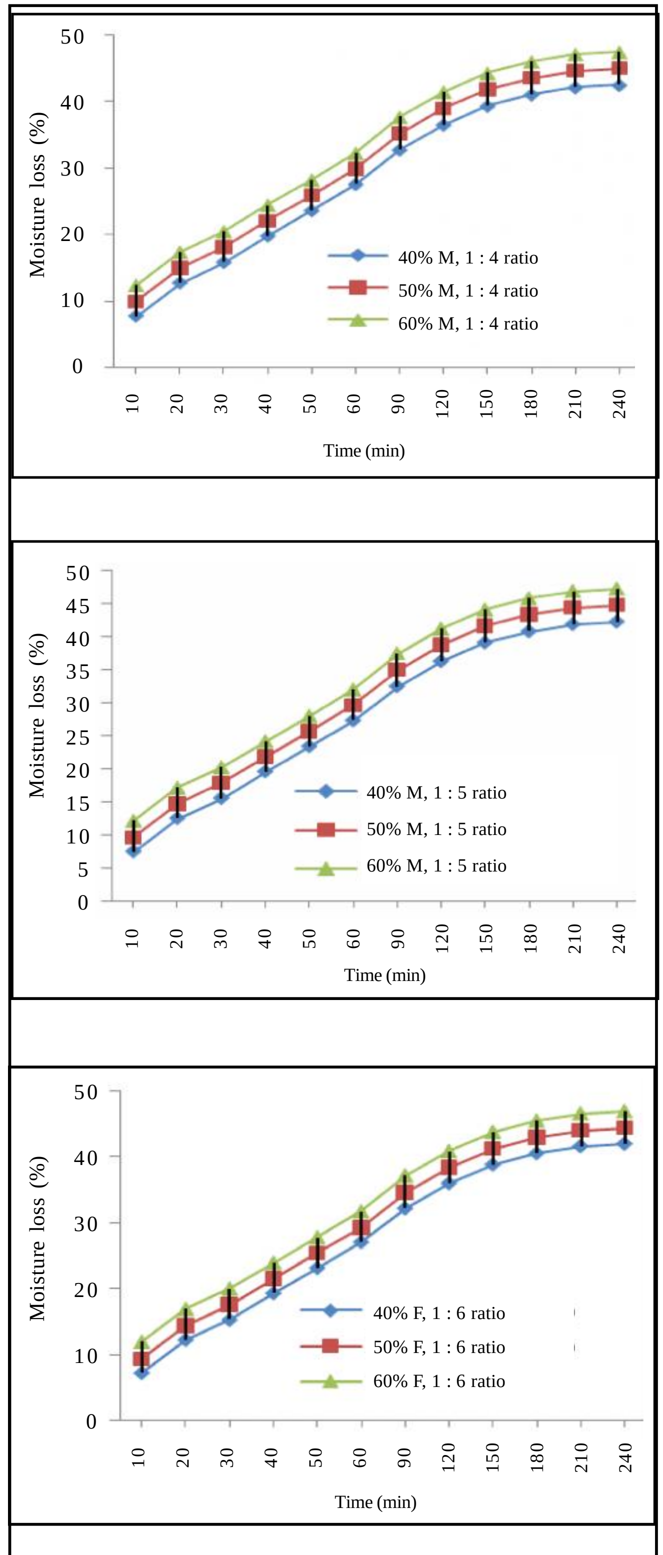

Fig. 14 : Effect of osmotic concentrations of maltodextrin on moisture loss of banana at 50 °C, and 1:4, 1:5 and 1:6 samples to solution ratio

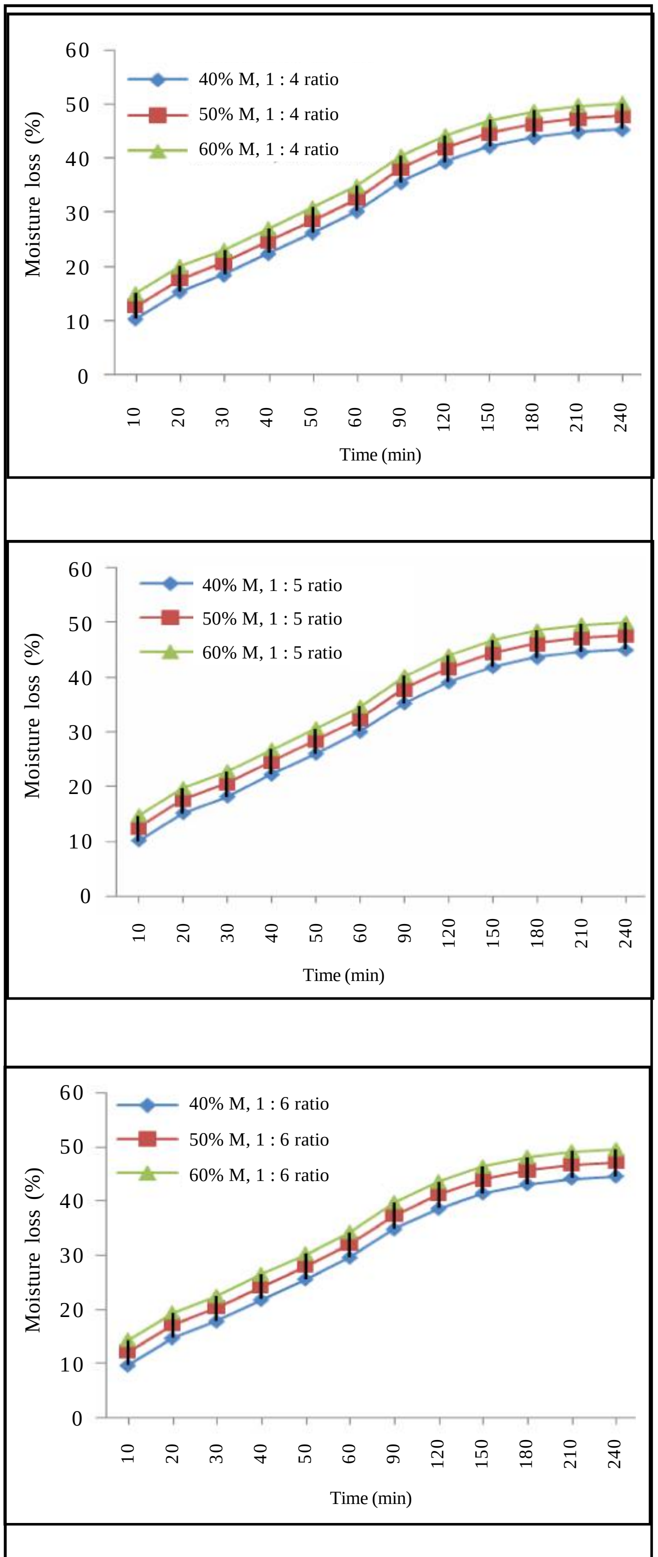

Fig. 15 : Effect of osmotic concentrations of maltodextrin on moisture loss of banana at 60 °C, and 1:4, 1:5 and 1:6 samples to solution ratio

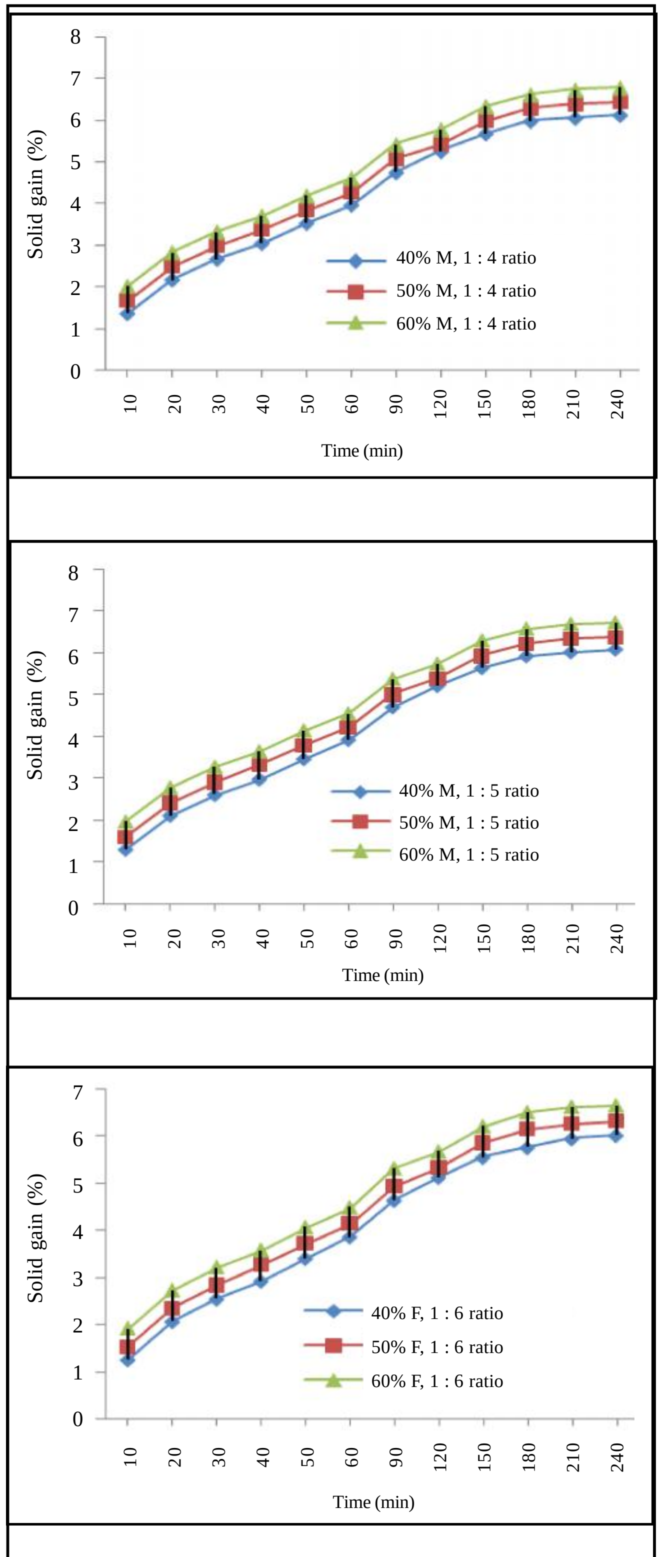

Fig. 16 : Effect of osmotic concentrations of maltodextrin on solid gain of banana at 40 °C, and 1:4, 1:5 and 1:6 samples to solution ratio

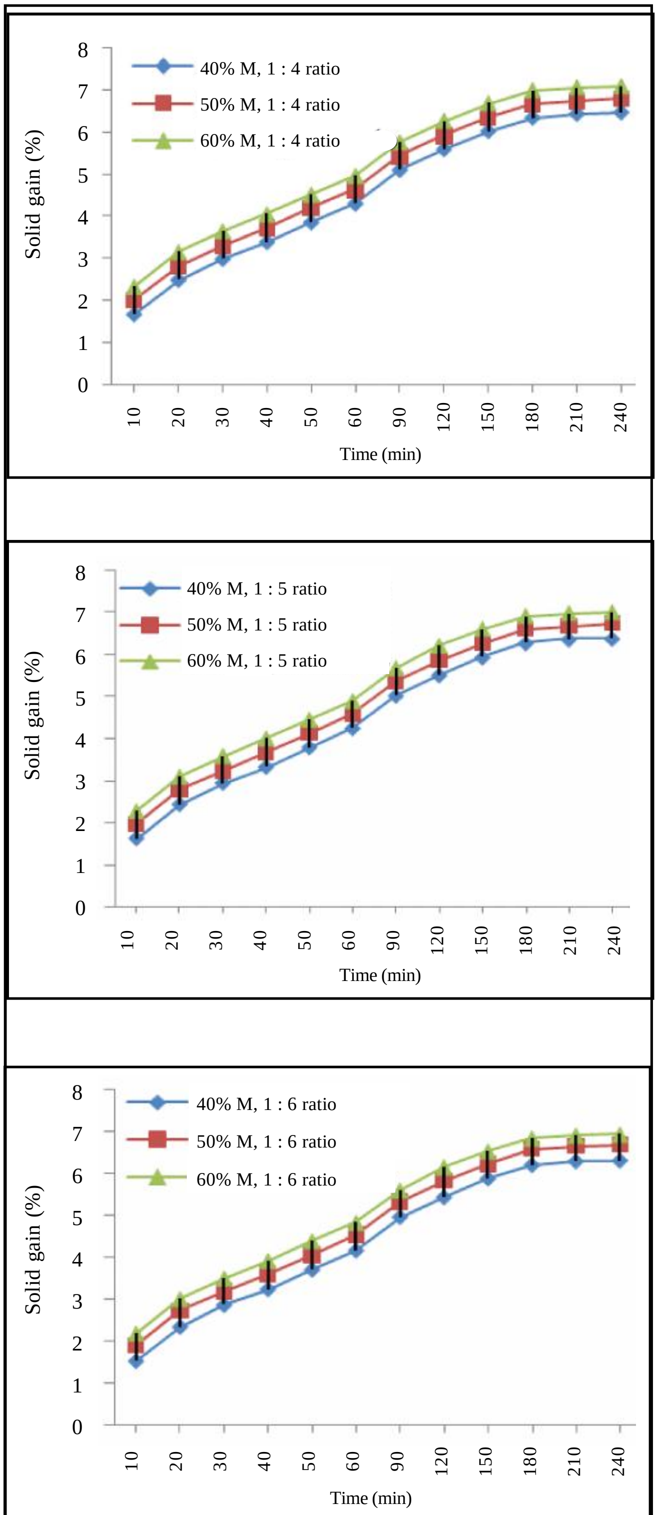

Fig. 17 : Effect of osmotic concentrations of maltodextrin on solid gain of banana at 50 °C and 1:4, 1:5 and 1:6 samples to solution ratio

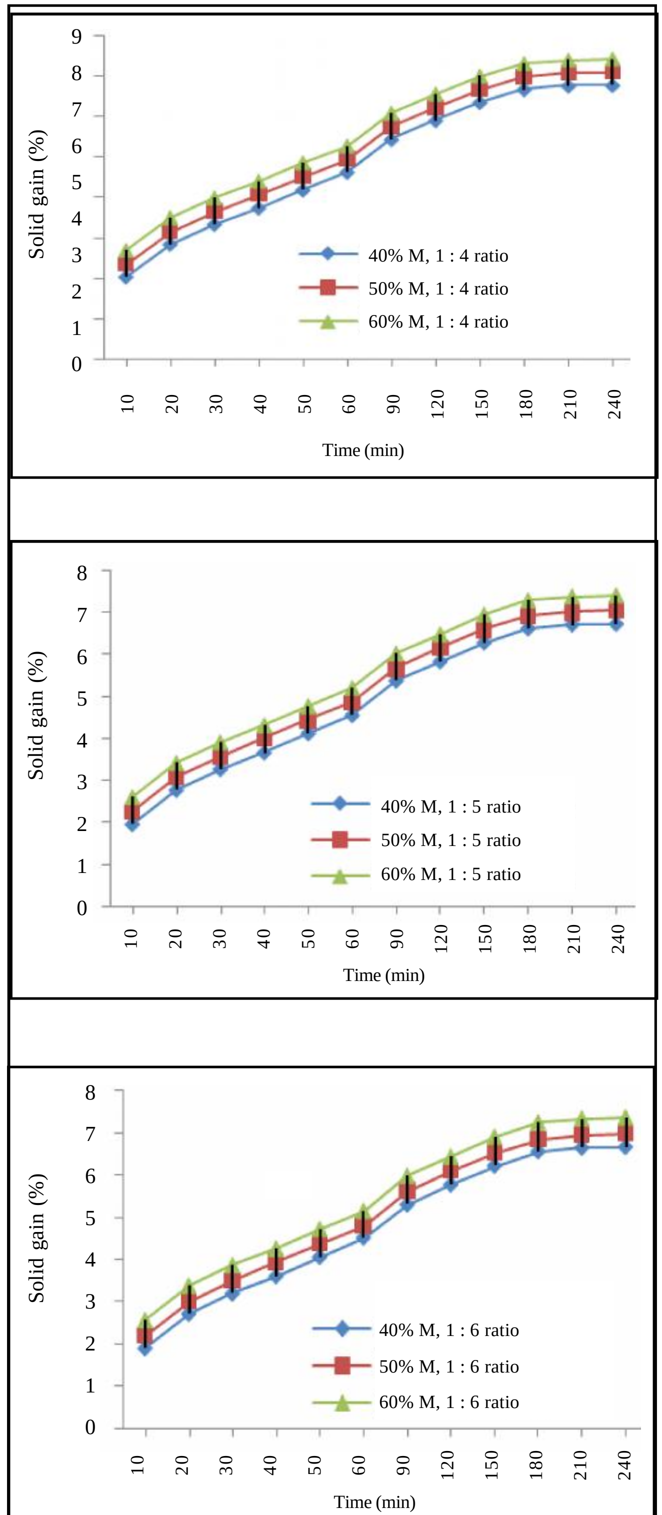

Fig. 18 : Effect of osmotic concentrations of maltodextrin on solid gain of banana at 60 °C and 1:4, 1:5 and 1:6 samples to solution ratio

the sucrose, fructose and maltodextrin solution and fresh banana sample. Similar results were obtained by Kowalska and Lenart (2001) and Azoubel and Marr (2004). After some period of osmotic dehydration the rate of moisture loss was reduced, because of faster gain of solid at initial period in the banana slices that filled the path of evaporation hence restricting the loss of moisture. From Fig. 1-18 it is clear that the moisture loss was increased with increasing the osmotic agent concentration at constant sample to solution ratio and temperature of solution. The moisture loss was higher at concentration of 60 per cent It was also observed that the moisture loss of banana slices increased with increasing the temperature of the osmotic solution. The moisture loss was higher at 60°C temperature of the osmotic solution, above which enzymatic browning and flavour deterioration begin to take place. This is due to rise on fruit membrane permeability caused by higher temperatures which promotes swelling and plasticization of cell membrane, favouring mass transfer. The higher moisture loss were obtained by fructose compared to those osmosed in maltodextrin and sucrose at same concentration, temperature of solution and sample to solution ratio. Because monosaccharide such as fructose has low molecular weight, has a more profound effect on water activity depression than polysaccharides such as maltodextrin and sucrose. Molecular size may also influence the permeability and mobility of the molecule. Similar results were found by Karathanos *et al.* (1995) and Lerici *et al.* (1985). Sample to solution ratio also influenced the osmotic dehydration process. Moisture loss after 240 min osmotic dehydration in sucrose, fructose and maltodextrin solution ranged between 38.66 - 48.57 per cent, 39.62 - 51.54 per cent and 39.02 - 50.34 per cent, respectively of initial weight of banana samples.

Zero-order and first-order kinetic models were used for the mass transfer kinetics during osmotic dehydration of banana sample in sucrose, fructose and maltodextrin. In case of zero order mass transfer kinetic model for moisture loss, the co-efficient of determination values (R^2) increased from 0.861-0.8664 for sucrose, 0.862-0.864 for fructose and 0.862-0.864 for maltodextrin and RMSE values changed from 4.752-4.856 for sucrose, 4.775-4.873 for fructose and 4.775-4.882 for maltodextrin solution and in case of first order mass transfer kinetics R^2 values ranged from 0.764 to 0.786 for sucrose, 0.764 to 0.792 for fructose and 0.760-0.789 for maltodextrin and RMSE values ranged between 6.111-6.294 for sucrose, 6.050-6.294 for fructose and 6.096-6.489 for maltodextrin solution. The mass transfer kinetic studies showed that the data for moisture loss was accurately fitted to a zero-order kinetic model compared to a first-order kinetic model with high values for the corresponding co-efficients of determination (R^2) and low value of root mean square error (RMSE). The kinetic rate constant for moisture loss was varied from 0.144-0.148 min^{-1} for zero orders and 0.004-0.005 min^{-1} for first order mass transfer kinetics in sucrose, 0.145-0.149 min^{-1} for zero order and 0.003-0.005 min^{-1} for first order kinetic model in fructose and 0.145– 0.149 min^{-1} for zero order and ranged between 0.004-0.005 min^{-1} for first order mass transfer kinetics in maltodextrin solution.

Effect of temperature, processing time, sample to solution ratio and concentration of sucrose on solid gain of banana:

Solid gain after 240 min osmotic dehydration ranged from 5.874-6.689 per cent, 6.141-7.629 per cent and 6.002 - 7.441 per cent, respectively in sucrose, fructose and maltodextrin solution of initial weight of banana samples. The data depicts that as the temperature, osmotic agents concentration and sample to solution ratio increases the solid gain increased. Increase in solution concentration resulted in an increase in the osmotic pressure gradients and hence, higher solid gain values throughout the osmotic dehydration period were obtained. The solid gain increased in non-linear manner with time at all concentration of osmotic agents, temperature of osmotic solution and sample to solution ratio. Solid gain was faster in the initial period of osmotic dehydration and then the rate decreased. Because osmotic driving potential for solid transfer will keep on decreasing with time as the solids keeps moving from solution to sample. Further more solid uptake would result in the formation of high solid subsurface layer, which would interfere with the concentration gradients across the sample-solution interface and act as a barrier against uptake of solids. The solid gain in banana slices increased with increasing the temperature of the osmotic solution. The solid gain was higher at 60°C temperature of the osmotic solution, above which enzymatic browning and flavour deterioration begin to take place. In addition, increasing temperature caused a reduction on solution viscosity, lowering external resistance to mass transfer and making water and solute transport easier. Similar results were obtained by Corzo and Gomez (2004); Lombard *et al*. (2008) and Mundada *et al*. (2010) in osmotically dehydrated cantaloupe cylinders, mango slices and pomegranate arils, respectively. The solid gain were higher for sample osmosed in fructose compared to those osmosed in maltodextrin and sucrose at same concentration and temperature of solution with same sample to solution ratio, because, solid uptake is inversely correlated with the molecular size of the osmotic agents.

The mass transfer kinetics studies of banana showed that the calculated data for solid gain in sucrose, fructose and maltodextrin solution was also fitted to a zero-order kinetic model compared to a first-order kinetic model with high values of co-efficients of determination (R^2) ranged between 0.867 - 0.882 for sucrose, 0.864 - 0.885 for fructose and 0.788 - 0.878 for maltodextrin, and low value of root mean square error (RMSE) varies between 0.618-0.649 for sucrose, 0.609-0.672 for fructose and 0.607-0.666 for maltodextrin solution. For solid gain the kinetic rate constant varied from 0.020 - 0.021 min^{-1} for zero orders and 0.004 min^{-1} for first order mass transfer kinetics in sucrose, 0.020 min^{-1} for zero order and 0.002-0.004 min^{-1} for first order kinetic model in fructose and 0.020- 0.023 min^{-1} for zero order and ranged between 0.003 - 0.004 min^{-1} for first order mass transfer kinetics in maltodextrin solution.

Conclusion :

In osmotic dehydration process of banana the moisture loss and solid gain were increased in non linear manner with time at all concentration of sucrose, fructose and maltodextrin solution at different temperature. The moisture loss and solid gain were increased with increasing the osmotic solution concentration, temperature of osmotic solution and sample to solution ratio. It was higher at concentration of 60 per cent osmotic agents, 60°C temperature of the osmotic solution and 1:4 samples to solution ratio. The moisture loss and solid gain were found higher for sample osmosed in maltodextin compared to those osmosed in sucrose and lower than the sample osmosed in fructose at same concentration, temperature of solution and sample to solution ratio. In kinetic study of osmotic dehydration process of banana the moisture loss and solid gain was accurately fitted to a zero-order kinetic model compared to a first-order kinetic model with high values for the corresponding co-efficients of determination (R^2) and low value of root mean square error (RSME).

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REFERENCES

Azoubel, P. M. and Marr, F. E. X. (2004). Mass transfer kinetics of osmotic dehydration of cherry tomato. *J. Food Engg.*, **61**: 291-295.

Chen, C. R. and Ramaswamy, H. S. (2002). Colour and texture change kinetics in ripening banana, *LWT- Food Sci. & Technol.*, **35** : 415-419.

Collignan, A. and Raoult-Wack, A.L. (1992). Dewatering through immersion in sugar/salt concentrated solutions at low temperature. An interesting alternative for animal foodstuffs stabilization, In: Drying 1992. Majumdar AS (Ed.). Elsevier Science Publication. pp. 187.

Corzo, O. and Gomez, E. R. (2004). Optimization of osmotic dehydration of cantaloupe using desired function methodology. *J. Food Engg.*, **64** : 213-219.

Hawakes, J. and Flink, J. M. (1978). Osmotic concentration of fruit slices prior to freeze dehydration. *J. Food Process. & Preserv.*, **2** : 265-283.

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

Kouassi, K. and Roos, H. Y. (2001). Glass transition and water effects on sucrose inversion in non-crystalline carbohydrate food systems. *Food Res. Int.*, **34**: 895-901.

Kowalska, H. and Lenart, A. (2001). Mass exchange during osmotic pre-treatment of vegetables. *J. Food Engg.*, **49**(2): 137-140.

Lenart, A. and Flink, J. M. (1994). Osmotic dehydration of potato. *J. Food Technol.*, **19** : 65-89.

Lerici, C. R., Pinnavai, G., Rosa, M. D. and Bartoucci, L. (1985). Osmotic dehydration of fruits: Influence of osmotic agents on drying behaviour and product quality. *J. Food Sci.*, **50**: 1217-1226.

Lewicki, P. P. and Lukaszub, A. (2000). Effect of osmotic dewatering on rheological properties of apple subjected to convective drying. *J. Food Engg.*, **45**: 119-126.

Lombard, G. E., Oliveira, J. C., Fito, P. and Andres, A. (2008).

Osmotic dehydration of pineapple as pre-treatment for further drying. *J. Food Engg.,* **85**: 277-284.

Maskan, M. (2000). Microwave/air and microwave finish drying of banana. *J. Food Engg.*, **44** : 71–78.

Mundada, M., Hathan, S.B. and Maske, S. (2010). Mass transfer kinetics during osmotic dehydration of pomegranate arils. *J. Food Sci.,* **76** : 31-39.

Ponting, J. D., Walters, G. G., Forrey, R. R., Jackson, R. and Stanley, W. L. (1966). Osmotic dehydration of fruits, *Food Technol.,* **20** : 125-128.

Ranganna, S. (2001). *Handbook of analysis and quality control of fruit and vegetable products*, 3rd Ed., Tata McGraw-Hill Publ.Co., 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.

Telis, V. R. N., Gabas, A.L., Menegalli, F. C. and Telis-Romero, J. (2000). Water sorption thermodynamic properties applied persimmon skin and pulp. *Thernochimica Acta.*, **343** (1-2): 49-56.

Torreggiani, D. (1993). Osmotic dehydration of fruits and vegetable processing. *Food. Res. Int.,* **26** : 59-68.

Woodroof, J. G. (1986). *History and growth of fruit processing.* Woodroof J G, LuhSHiun B (Eds.) (2ndEd). AVI Publishing Company Inc., Westport, Connecticut, USA. 1-24.

WEBLOGRAPHY

Indian Horticulture Database (2013) Ministry of Agriculture Government of India, *www.nhb.gov.in.*