International Food Research Journal 22(2): 807-811 (2015)

Journal homepage: *http://www.ifrj.upm.edu.my*

Influence of sucrose solution concentration and temperature on mass exchange during osmotic dehydration of eggplant (*Solanum melongena* L.) cubes

*Ganjloo, A. and Bimakr, M.

Department of Food Science and Technology, Faculty of Agriculture, University of Zanjan, Zanjan, Iran

Article history

Received: 12 June 2014
Received in revised form: 29 August 2014
Accepted: 3 September 2014

Keywords

Eggplant
Osmotic dehydration
Mass transfer

Abstract

The purpose of current work was to study the influence of osmotic solution concentration and temperature as process variables on mass transfer during osmotic dehydration of eggplant (*Solanum melongena* L.). The experiments were performed using sucrose as osmotic agent, varying the concentration of the osmotic solution (30-50% (w/w)), temperature (30-50°C) and contact time (0-3 h). The results showed that the mass transfer in terms of weight reduction, solid gain and water loss were influenced by increasing solution sucrose content and temperature over processing time. Weight reduction, solid gain and water loss ranged from 0 up to 25.6%, 0 up to 2.68% and 0 up to 27.9% of the initial sample mass, respectively. The best condition was determined by using WL/SG ratio as sucrose concentration of 30% (w/w) at a temperature of 30°C.

Introduction

Eggplant (*Solanum melongena* L.) is an important economical product which is produced in many tropical and temperate regions of the world. It is a good source of vitamins and minerals, particularly iron, besides appreciable amount of phenolic compounds which contribute to its antioxidant capacity (Cao *et al*., 1996; Kashyap *et al*., 2003). In 2012, China (28800000MT), India (12200000MT) and Iran (1300000MT) were the main producer countries followed by Egypt, Turkey and Indonesia (FAO, 2014). Eggplants are very perishable and have very short shelf life due to rapid enzymatic browning, tissue softening and water loss which limit commercialization of this product (Ghidelli *et al*., 2013). So, there is a need for simple and inexpensive process to offer a way to make this fruit available during off season and for the regions away from production zones. Osmotic dehydration is one the inexpensive process due to the fact that there is no phase change of water from liquid to vapour state (Arballo *et al*., 2012). Osmotic dehydration is a partial water removal process through immersion of cellular materials in a hypertonic solution of one or more soluble solutes. The concentration gradient between the food and the osmotic medium is the driving force for dehydration (Alves *et al*., 2005). Despite of traditional drying (e.g. sun drying, hot air drying) which is usually a long process requiring high temperatures; osmotic dehydration is effective even at ambient temperature leading to save functional, nutritional and sensorial properties of product.

Mass transfer during osmosis process takes place through simultaneous processes of water and solute transfer in opposite directions (Lazarides, 1994; Panades *et al*., 2006). The influence of process variables such as concentration and composition of osmotic solution, temperature, contact time, agitation, nature of food and its geometry, solution to sample ratio on the rate of mass transfer have been described extensively in scientific literatures (Kaymak-Ertekin and Sultanoglu, 2000; Singh *et al*., 2007; Tonon *et al*., 2007). Despite of numerous researches which have investigated the effects of these variables on the mass transfer during osmotic dehydration of different products, no information is available in the literature regarding the osmotic dehydration of eggplant. Therefore, the objective of current work was to study the influence of sucrose concentration and temperature on mass exchange in terms of weight reduction, solid gain and water loss during osmotic dehydration of eggplant (*Solanum melongena* L.).

Materials and Methods

Sample preparation

Fresh eggplants (*Solanum melongena* L.) obtained daily from a local market in Zanjan, Iran. Eggplants were chosen at commercial maturity according to their similarity of color, size and absence of surface defects. Whole fruits were washed with distilled water, peeled and cut into 20±2 mm cubes manually using very sharp stainless steel knife, and gently

*Corresponding author.
Email: *aganjloo@znu.ac.ir*
Tel: +982433052432

blotted with tissue paper to eliminate the excess of surface humidity. Care was exercised to select only cubes that have the same size to minimize the effect of sample size on the experimental data. The dimensions of fruit cubes were measured by Neiko digital caliper (±0.02 mm) (Neiko Tools, TX, USA).

Osmotic dehydration

Eggplant cubes were immersed in sucrose solution which was prepared by mixing commercial grade sucrose and distilled water on a weight-to-weight basis at 30, 40 and 50%. The solution concentration throughout each experiment was monitored by refractometer (Atago CO. LTD., Japan). Experiments were performed at three temperature levels (30, 40 and 50°C) using an agitated water bath (Fan Azma Gostar, Iran) maintained at studied temperatures (±0.5°C). The temperature was monitored by means of a digital thermometer and a thermocouple (KTT-310, KIMO INSTRUMENTS, UK). The sample to sucrose solution ratio was 1:10 w/w to avoid significant dilution of the osmotic solution. Sampling was performed in time intervals of 30, 60, 90, 120 and 180 min, and then the samples rinsed quickly with distilled water (below 20 s) to eliminate the solution from the surface and carefully blotted with tissue paper to remove the excess surface water. All experiments were repeated three times.

Mass transfer determinations

In order to determine mass change, all samples were weighed before and after treatment using Sartorius analytical balance (Cubis® Analytical Balance MSA224S-000-DA, Goettingen, Germany) with accuracy of ±0.0001 g. The fresh and dehydrated eggplant cubes after each contact time were placed in oven (Pars Azma Co., Iran) at 105°C until constant weight (24 h) in order to measure the moisture and solids contents according to AOAC 931.04 (AOAC, 1990). All measurements were performed in triplicate. From these data, weight reduction (WR), solid gain (SG) and water loss (WL) at different times, t, according to the following expressions were determined (Panagiotou *et al*., 1999).

$$\text{WR}(\%\ \text{of initial mass}) = \frac{(M_0 - M)}{M_0} \times 100 \qquad (1)$$

$$\text{WL}(\%\ \text{of initial mass}) = \frac{(M_0 - m_0) - (M - m)}{M_0} \times 100 \qquad (2)$$

$$\text{SG}(\%\ \text{of initial mass}) = \frac{(m - m_0)}{M_0} \times 100 \qquad (3)$$

Where M_0 is initial mass of fresh sample (g), M is the mass of sample after dehydration (g), m_0 is the initial mass of the solids in sample (g), m is mass of the solids in sample after dehydration (g).

Experimental design and statistical analysis

The experimental design applied was a 3 × 3 × 5 factorial design in a frame of Complete Randomized Design (CRD), corresponding to three sucrose solution concentrations, three temperatures and five immersion time intervals. MINITAB Version 16.0 (Minitab Inc., PA, USA) software was used for statistical analysis and significance level was 95%.

Results and Discussion

Typical curves of mass transfer terms during 3 h osmotic dehydration of eggplant with a similar behaviour were showed in Figures 1-3.

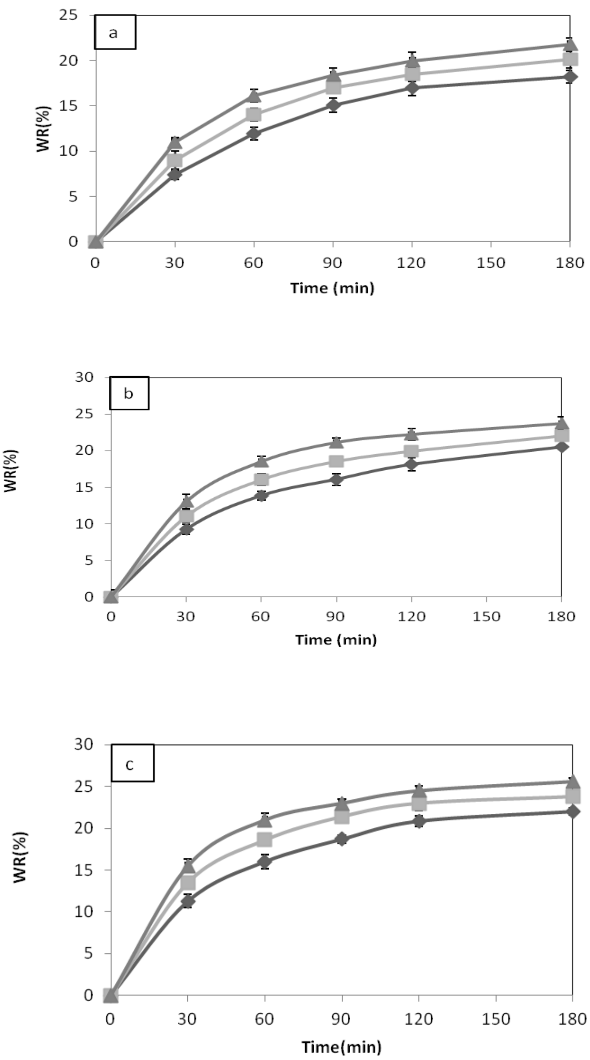

Figure 1. Weight reduction (WR) of eggplant during osmotic dehydration in the sucrose solution (a) 30% (w/w) (b) 40% (w/w) and (c) 50% (w/w) at temperatures of 30 (diamonds), 40 (squares) and 50°C (triangles)

Table 1. Analysis of Variance for weight reduction (WR), solid gain (SG) and water loss (WL) during osmotic dehydration of eggplant using sucrose solution

Source	DF	WR			SG			WL		
		Adj SS	Adj MS	p	Adj SS	Adj MS	p	Adj SS	Adj MS	p
(1)	2	361.49	180.74	0.00	3.47	1.73	0.00	435.77	217.89	0.00
(2)	2	337.11	168.55	0.00	3.95	1.97	0.00	414.07	207.03	0.00
(3)	4	1918.66	479.66	0.00	27.76	6.94	0.00	2407.14	601.78	0.00
(1)×(2)	4	1.25	0.31	0.03	0.17	0.04	0.00	1.03	0.25	0.10
(1)×(3)	8	3.25	0.40	0.00	0.16	0.02	0.00	2.76	0.34	0.01
(2)×(3)	8	4.62	0.57	0.00	0.21	0.02	0.00	4.47	0.55	0.00
(1)×(2)×(3)	16	3.57	0.22	0.03	0.09	0.00	0.00	3.93	0.24	0.02

(1): Sucrose concentration; (2): Temperature; (3): Processing time

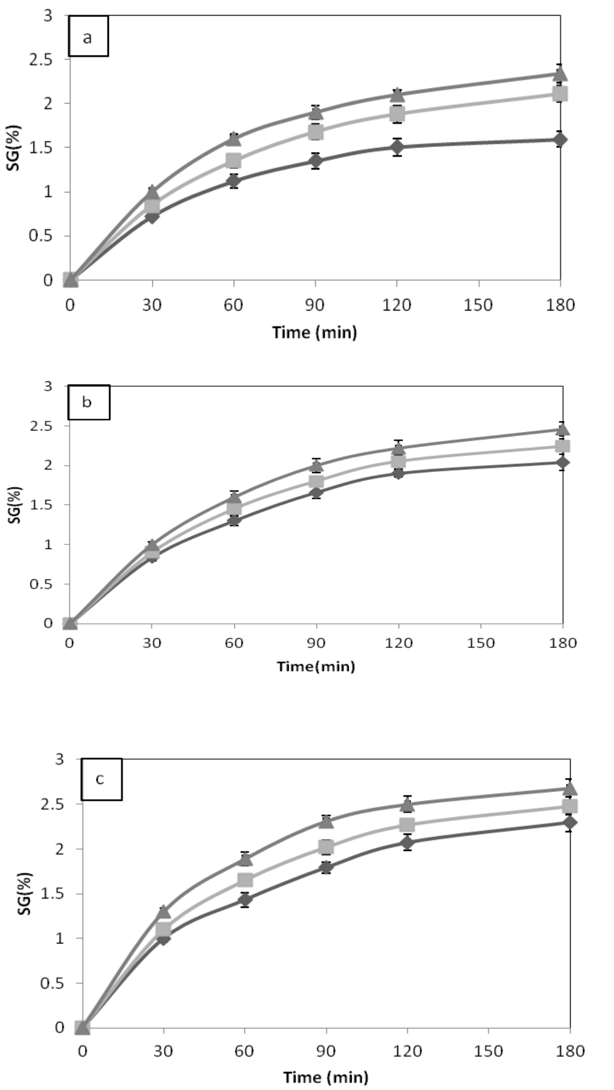

Figure 2. Solid gain (SG) of eggplant during osmotic dehydration in the sucrose solution (a) 30% (w/w) (b) 40% (w/w) and (c) 50% (w/w) at temperatures of 30 (diamonds), 40 (squares) and 50°C (triangles)

It is apparent from Figures 1-3(a-c) that process variables including solute concentration and temperature affect mass transfer in term of weight reduction, solid gain and water loss. In all cases, an initial high rate of water removal and solid gain followed by slower removal and gain in the latter stages was observed. Similar pattern of behaviour is also reported for osmotic dehydration of carrot cubes (Amami *et al*., 2007; Singh *et al*., 2007), pumpkin (Mayor *et al*., 2006), apricot (Ispir and Türk Togrul, 2009) and chestnut (Chenlo *et al*., 2007). The influence of sucrose concentration and temperature on mass transfer terms was assessed using analysis of variance. The results of analysis of variance (Table 1) confirmed that the osmotic solution concentration and temperature had a significant ($p < 0.05$) effect on mass transfer terms during osmotic dehydration of eggplant cubes.

Effect of osmotic solution temperature

As first variable, the effect of temperature in the range of 30-50°C on mass transfer during osmotic dehydration process was analyzed. The experimental results revealed that increasing temperature made intense dehydration by increasing water loss. For example, water loss of eggplant sample attained 19.81% (30% (w/w) sucrose concentration and 30 °C) while it was about 24.60% after 3h of immersion in a sucrose solution with concentration of 30% (w/w) and temperature of 50°C. This variable also affected weight reduction as well as solid gain (See Figures 1 and 2, respectively). Mass transfer acceleration caused by higher temperatures can be associated with the increase in membrane permeability promoting swelling and plasticization of the cell membranes (Lazarides *et al*., 1995). On the other hand, increasing temperature leads to reduction in solution viscosity and reducing external resistance to mass transfer

Table 2. Experimental WL/SG values after 3 h of osmotic dehydration of eggplant

Concentration/Temperature	30°C	40°C	50°C
30%	12.40	10.66	10.51
40%	10.77	10.58	10.48
50%	10.58	10.48	10.41

making easier transport of water and solutes (Tonon *et al*., 2007). In addition, higher temperatures (>50°C) can lead to adverse effects on tissue, color and aroma of product. In contrast, lower temperatures (<30°C) prevent satisfactory mass transfer characteristics due to reduction of the osmotic medium viscosity. Such findings have been reported for osmotic dehydration of carrot (Singh *et al*., 2007), tomato (Tonon *et al*., 2007), Chestnut (Chenlo *et al*., 2007) and apricot (Ispir and Türk Togrul, 2009).

Effect of sucrose concentration

The experimental results of current research confirmed the greater mass transfer caused by increasing solute concentration. According to Figure 1-3, at constant temperature of 30°C, weight reduction, solid gain and water loss were 18.21%, 1.59% and19.81%, respectively. By increasing sucrose concentration from 30% (w/w) to 50% (w/w) at constant temperature of 30° C, these values were 22%, 2.29% and 24.29%, respectively. Rapid loss of water and solid gain in the beginning is apparently due to the large osmotic driving force between the fresh sample and the surrounding osmotic solution (Ispir and Türk Togrul, 2009). Similar curves have published for osmotic dehydration of apricot (Ispir and Türk Togrul, 2009), cherry tomato (Azoubel and Murr, 2004) and pear D'anjou (Park *et al*., 2002). It is worthy to note that considering to viscosity of highly concentrated solutions (>50% w/w) achieving satisfactory mass transfer characteristics is difficult; lower concentration is also inappropriate due to the reduction of driving force for water removal.

Effect of process variables on WL/SG ratio

The WL/SG ratio is a well-known parameter used for assessing the efficiency of dehydration during osmosis process (Sereno *et al*., 2001; Mayor *et al*., 2006) and estimation of relation between the water and solute transfers inside of food (Alves *et al*., 2005; Amami *et al*., 2007). The value of this ratio is higher with better water loss whereas the low values correspond to good solid gain during osmotic dehydration. Several factors namely process conditions including solution concentration, type of osmotic agent, temperature and contact time, and physicochemical properties of raw material such as density and initial moisture content can influence the value of this ratio (Mayor *et al*., 2006). The maximum experimental WL/SG values after 3 h of osmotic dehydration at different sucrose concentrations and temperatures studied are shown in Table 2. The values obtained in this work for eggplant ranged from 10.41 to 12.40. These findings indicate that by choosing a higher concentration medium, some benefits in terms of more water loss due to an increase in the osmotic pressure gradients could be achieved. However, in case of eggplant dehydration, solute gain was more significant. It should be noted that these values (Table 2) are high when they are compared to data for banana and kiwifruit (Panagiotou *et al*., 1998), carrot and apple (Kowalska and Lenart, 2001) and pumpkin (Mayor *et al*., 2006).

According to the values of WL/SG ratio, the optimum operating condition can be achieved by

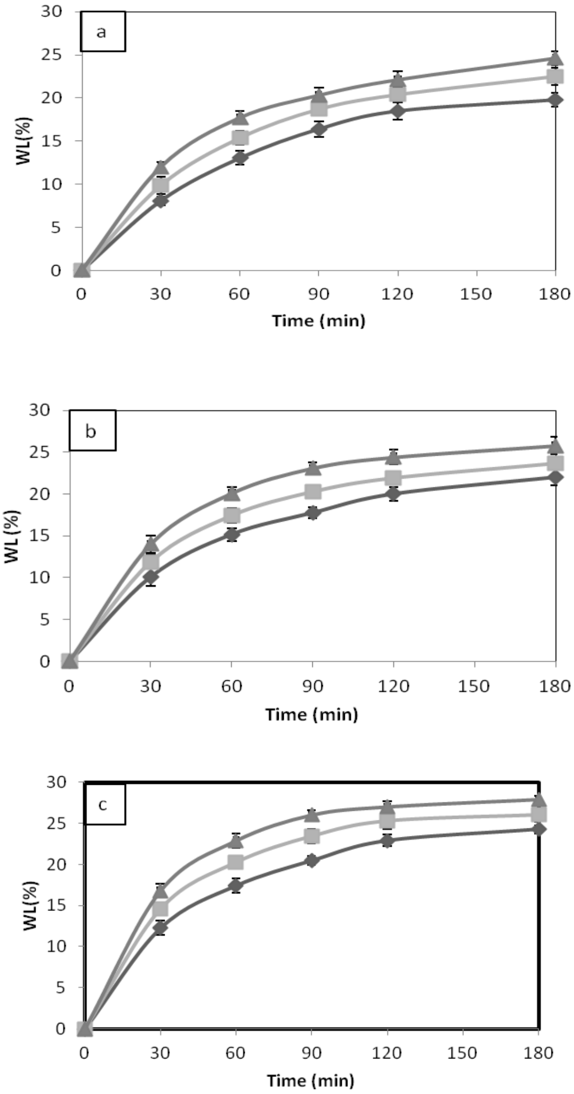

Figure 3. Water loss (WL) of eggplant during osmotic dehydration in the sucrose solution (a) 30% (w/w) (b) 40% (w/w) and (c) 50% (w/w) at temperatures of 30 (diamonds), 40 (squares) and 50°C (triangles)

the use of the 30.0% (w/w) sucrose solution at 30°C because it offers an appreciable water removal without adding too much solute to the eggplant tissue. In addition, working at nearly ambient temperature (30°C) could be more advantageous due to the fact that there is no addition of thermal energy to the system.

Conclusion

In current research, the effects of osmotic solution concentration and temperature on mass transfer in terms of weight reduction, solid gain and water loss during osmotic dehydration of eggplant cubes were studied. The results revealed that mass transfer terms affected significantly ($p<0.05$) by temperature and sucrose concentration led to higher water and solid mass transfer. From values of WL/SG ration can be concluded that the best condition for osmotic dehydration of eggplant cubes was sucrose solution with 30% (w/w) concentration at a temperature of 30°C.

References

Alves, D.G., Barbosa, J.L., Jr., Antonio, G.C. and Murr, F.E.X. 2005. Osmotic dehydration of acerola fruit (*Malpighia punicifolia* L.). Journal of Food Engineering 68: 99-103.

Amami, E., Fersi, A., Vorobiev, E. and Kechaou, N. 2007 Osmotic dehydration of carrot tissue enhanced by pulsed electric field, salt and centrifugal force. Journal of Food Engineering 83: 605-613.

AOAC. 1990. Official methods of analysis. Washington: Association of Official Analytical Chemists.

Arballo, J.R., Bambicha, R.R., Campanone, L.A., Agnelli, M.E. and Mascheroni, R.H. 2012. Mass transfer kinetics and regressional desirability optimisation during osmotic dehydration of pumpkin, kiwi and pear. International Journal of Food Science and Technology 47: 306–314.

Azoubel, P.M. and Murr, F.E.X. 2004. Mass transfer kinetics of osmotic dehydration of cherry tomato. Journal of Food Engineering 61: 291-295.

Cao, G., Sofic, E. and Prior, R.L. 1996. Antioxidant capacity of tea and common vegetables. Journal of Agriculture Food Chemistry 44: 3426-3431.

Chenlo, F., Moreira, R., Fernández-Herrero, C. and Vázquez, G. 2007. Osmotic dehydration of chestnut with sucrose: Mass transfer processes and global kinetics modelling. Journal of Food Engineering 78: 765-774.

FAO – Food and Agriculture Organization of the United Nations. Statistical databases, Rome, access: 04. 2014.

Ghidelli, C., Mateos, M., Rojas-argudo, C. and Pérez-gago, M.B. 2013. Effect of antioxidants on enzymatic browning of eggplant extract and fresh-cut tissue. Journal of Food Processing and Preservation 1-10.

Ispir, A. and Türk Togrul, I. 2009. Osmotic dehydration of apricot: Kinetics and the effect of process parameters. Chemical Engineering Research and Design 87: 166-180.

Kashyap, V., Vinod kumar, S., Collonier, C., Fusari, F., Haicour, R. and Rotino, G.I. 2003. Biotechnology of eggplant. Science Horticulture 97: 1-25.

Kaymak-Ertekin, F. and Sultanoglu, M. 2000. Modeling of mass transfer during osmotic dehydration of apples. Journal of Food Engineering 46: 243-250.

Kowalska, H. and Lenart, A. 2001. Mass exchange during osmotic pretreatment of vegetables. Journal of Food Engineering 49: 137-140.

Lazarides, H.N. 1994. Osmotic preconcentration: Developments and prospects. In Singh, R. P. and Oliveira, F. A. (Eds), Minimal processing of foods and process optimization. CRS Press Inc.

Lazarides, H.N., Katsanidis, E. and Nickolaidis, A. 1995. Mass transfer kinetics during osmotic preconcentration aiming at minimal solid uptake. Journal of Food Engineering 25: 151-166.

Mayor, L., Moreira, R., Chenlo, F. and Sereno, A.M. 2006. Kinetics of osmotic dehydration of pumpkin with sodium chloride solutions. Journal of Food Engineering 74: 253-262.

Panades, G., Fito, P., Aguiar, Y., Nunez de Villavicencio, M. and Acosta, V. 2006. Osmotic dehydration of guava: Influence of operating parameters on process kinetics. Journal of Food Engineering 72: 383–389.

Panagiotou, N., Karathanos, V. and Maroulis, Z. 1999. Effect of osmotic agent on osmotic dehydration of fruits. Drying Technol 17, 175-189.

Panagiotou, N.M., Karathanos, V.T. and Maroulis, Z.B. 1998. Mass transfer modelling of the osmotic dehydration of some fruits. International Journal of Food Science and Technology 33: 267-284.

Park, K.J., Bin, A., Brod, F.P.R. and Park, T.H.K.B. 2002. Osmotic dehydration kinetics of pear D'anjou (*Pyrus communis* L.). Journal of Food Engineering 52: 293-298.

Sereno, A.M., Moreira, R. and Martinez, E. 2001. Mass transfer coefficients during osmotic dehydration of apple in single and combined aqueous solutions of sugar and salt. Journal of Food Engineering 47: 43-49.

Singh, B., Kumar, A. and Gupta, A.K. 2007. Study of mass transfer kinetics and effective diffusivity during osmotic dehydration of carrot cubes. Journal of Food Engineering 79: 471–480.

Tonon, R.V., Baroni, A.F. and Hubinger, M.D. 2007. Osmotic dehydration of tomato in ternary solutions: Influence of process variables on mass transfer kinetics and an evaluation of the retention of carotenoids. Journal of Food Engineering 82: 509-517.