Journal of Food Processing & Technology

Manzoor et al., J Food Process Technol 2017, 8:4
DOI: 10.4172/2157-7110.1000669

Research Article OMICS International

Osmotic Dehydration Characteristics of Pumpkin Slices using Ternary Osmotic Solution of Sucrose and Sodium Chloride

Mehnaza Manzoor[1], Shukla RN[2], Mishra AA[2], Afrin Fatima[2] and Nayik GA[3]*

[1]*Department of Food Science and Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, India*
[2]*Department of Food Process Engineering, Sam Higginbottom University of Agriculture, Technology and Sciences, UP, India*
[3]*Department of Food Engineering and Technology, Sant Longowal Institute of Engineering and Technology, Punjab, India*

Abstract

In this study, drying characteristics of osmotically treated pumpkin slices were scrutinized at temperature within range of 30°C to 50°C and at the amalgamation of nine ternary solution (Sugar: Salt) concentration levels (30:5%, 30:10%, 30:15% w/w) (40:5%, 40:10%, 40:15% w/w) and (50:5%, 50:10%, 50:15% w/w). At eight time intervals (30 min, 60 min, 90 min, 120 min, 150 min, 180 min, 210 min and 240 min) moisture loss and solid gain were ascertained at all amalgamation. Sample to Solution ratio of 1:5 w/w was kept invariable from beginning to end of the experiments. The consequence of solution concentration and temperature was examined and it was established that preliminary water loss and solid gain are related to solution concentration and temperature. Both moisture loss and solid gain amplified non- linearly at dissimilar temperatures and at all concentrations. The investigational drying statistics for the pumpkin fruit was used to fit four thin layer drying models Parabolic, Hunderson and Pabis, Page and Logarithmic model. Non-linear regression assessment was used to check the statistical validness of models. The Parabolic model offered preeminent fit for all circumstances of drying, conferring utmost value of R^2 (0.999) and lowest RMSE values (0.004).

Keywords: Pumpkin; Osmotic dehydration; Solid gain; Moisture loss; Mathematical modelling; Microwave drying

Introduction

India being country with varied climate ensures accessibility of all varieties of fresh fruits and vegetables. It is second leading producer of fruits (81.258 million tons) and vegetables (162.19 million tons) in world, with 12.6% fruits and 14.0% vegetables production [1]. Only 4% of vegetable production and 2% of fruit production are being processed while 76% is being utilized in fresh form, out of entire vegetable and fruit production in India. The shortfall and wastage contribute 20% to 22%. Preservation of these vegetables can thus hamper these shortfalls and in the off-season make them promptly accessible at remunerative pay out. Proficient technique of preservation requires to be developed to preserve plant materials in order to obtain superior quality as they are seasonal. "Minimal processing" concept makes the foundation of all modern substitutive food preservation practice. This technique is used to attain products with elevated nutritional value and innate sensory characteristics, with minimum use of preservatives [2]. Pumpkin (*Cucurbita pepo)* contains 92% water and total solid content varying from 7% to 10% [3]. Thus requires to be preserved as being delicate in nature. The process of removal of water from food material mostly vegetables and fruits by drenching it in hypertonic solution of either sugar or salt or sometimes in amalgamation of both these solutes so as to partly dehydrate it by exclusion of moisture and at the same time mounting the solid content of sample is known as Osmotic dehydration process. This process is also known as "dewatering impregnation soaking process" (DISP) as dewatering occurs only after food material in soaked in osmotic solution which is accompanied by impregnation of osmotic solutes in food material from solution. During osmotic dehydration process two major counter-current flows happen at the same time: first is water flow out from food being dehydrated into the osmotic solution and second is simultaneous transport of solute from osmotic solution to food material being dehydrated [4]. Also, a third process: leaching of innate total soluble solutes such as organic acids, sugar, minerals, salts, and so on that trickle into osmotic solution from food being dehydrated [5]. Intermediate moisture foods having water activity varying from 0.65 to 0.90 are produced by osmotic dehydration process, as it trims down the water activity of food material being dehydrated, between 0.95 and 0.90 [6]. The details about drying characteristics of foods during osmotic dehydration process and sketch of operational process are better interpreted by mathematical modeling of mass transfer. At present, no meticulous information on osmotic drying characteristics of pumpkin slices at a mixture of ternary solution concentration levels and at different temperature and osmotic time is accessible, although some text on drying of pumpkin is available [7,8]. In this study, the models that best depict the drying characteristics during the experimental conditions deemed is yet to be done. Drying characteristics of food material are evaluated by theoretical, semi-theoretical or solely empirical thin layer drying models. Various researchers have employed number of semi-theoretical drying models [9-11]. The paper aspires the experimental analysis and modeling on drying characteristics during osmotic dehydration of pumpkin slices.

Materials and Methods

Sample preparation

Fresh and ripe pumpkins purchased from the neighboring market (Allahabad, U.P) on daily basis were used as raw material. Prior to execute each set of experiments, the pumpkins were sorted out visually for color (light green), and no corporal damage. After sorting, the pumpkins were cleansed with tap water and then cut manually into slices of 3-4 mm thickness by very sharp and sterile knife. Finally, to

***Corresponding author:** Nayik GA, Department of Food Engineering and Technology, Sant Longowal Institute of Engineering and Technology, Longowal, Punjab, India, Tel: 91-9478153553; E-mail: gulzarnaik@gmail.com

Received March 14, 2017; **Accepted** April 07, 2017; **Published** April 14, 2017

Citation: Manzoor M, Shukla RN, Mishra AA, Fatima A, Nayik GA (2017) Osmotic Dehydration Characteristics of Pumpkin Slices using Ternary Osmotic Solution of Sucrose and Sodium Chloride. J Food Process Technol 8: 669. doi: 10.4172/2157-7110.1000669

confiscate excess moisture the slices were blotted with absorbent paper. The average initial moisture content of fresh pumpkin samples was revealed by oven drying method [12] and it was found to be 94.211% (wet basis). The value was employed in estimation of moisture loss and solid gain.

Osmotic dehydration of pumpkin slices

Pumpkin slices were partly dehydrated via osmotic dehydration technique. The osmotic agents employed were sucrose and NaCl. Distilled water, commercial sucrose (30%, 40% and 50%), and table salt (5%, 10% and 15%) were used for formulating ternary osmotic solution. Eight 250 ml glass beakers were filled with 100 ml osmotic solution and 30 gm sample was dipped in each beaker. The beakers with sample were then put in water bath. One beaker at times was removed from the water bath after each 30-min interval from the commencement of osmosis. Slices were taken away and blotted tenderly with a blotting paper to take out the surface moisture and then weighed up on an electronic balance. Osmotically dehydrated sample was then employed for determination of moisture loss and solid gain.

Determination of moisture content

Hot air oven method suggested by Ranganna [13] for fruits and vegetables was utilized to calculate the initial and final moisture content of sample.

$$MC(\%) = \frac{(W+W_1)-W_2}{W} \times 100 \quad (1)$$

Where W= Net weight of sample taken (g), W_1 = Weight of petriplate (g), and W_2 = Weight of petriplate plus oven dried sample (g).

Determination of moisture loss and solid gain

The moisture loss (ML %) and solid gain (SG %) were determined by the equations given below.

$$ML(\%) = \frac{(M_0 - M)}{W} \times 100 \quad (2)$$

Where M_o = Wt of initial moisture (g), M = Wt of final moisture (g), and W = Initial wt of sample (g).

$$SG(\%) = \frac{S - S_0}{W} \times 100 \quad (3)$$

Where S = Wt of final solid (g), S_o = Wt of initial solid (g), and W = Initial wt of sample (g)

Mathematical modeling

Four drying models were used to choose an appropriate model for illustrating the drying process of pumpkin slices. XLSTAT-2015 (Addinsoft, New York, USA) was used to fit drying models to the experimental data for each state of osmotic dehydration process.

Henderson and Pabis model

$$MR = a\ exp\ (-k\ t) \quad (4)$$

Page model

$$MR = exp\ \left(-k\ t^n\right) \quad (5)$$

Parabolic model

$$MR = a + bt + ct^2 \quad (6)$$

Logarithmic model

$$MR = a\ exp\ (-k\ t) + c \quad (7)$$

Where M.R = Moisture loss ratio

$$M.R = (M - M_e)\ /\ (M_o - M_e)$$

M_o = Initial moisture content,

M = Moisture content after time t,

M_e = Equilibrium moisture content,

t = Time period, min,

and a, b, n and k are constants.

Results and Discussion

Effect of osmotic dehydration process parameters on moisture loss

Moisture loss from the pumpkin slices versus different process parameters is shown in Figure 1. From Figure 1, it could be depicted that for all process conditions moisture loss increases non-linearly with time, being quicker in beginning of dehydration process. The rate then decreases; because of declining chemical potential gradient of water as moisture keeps moving from sample to solution. Also, elevated turgor pressure gradient produced during initial period of osmosis trigger structural deformation resulting in mass transfer resistance for water. Similar results have been conveyed for osmotic dehydration of apples by Derossi et al. [14]. After 240 min time moisture loss at all process conditions varies between 44.058% to 47.361% (w.b).

In this study, increasing solution concentration at all process temperatures increases moisture loss, because NaCl being ionizable in water has higher water activity lowering power, which along with sucrose increases chemical potential gradient for water and with increase in their concentration moisture loss increases. The results are in agreement of Ozen et al. [15] on behalf of osmotic dehydration of red paparika and green pepper in sucrose-salt combination solution. At 50: 15% (sugar: salt) solution concentration moisture loss is found to be utmost.

Temperature showed prominent effect on moisture loss. It is understandable from Figure 1 that with increase in temperature of osmotic solution moisture loss by pumpkin slices increases. At 50°C temperature, higher moisture loss is perceived at all process conditions. This occurs because at elevated temperature viscosity of osmotic solution decreases which consecutively decreases solution resistance to mass so moisture loss occurs.

Effect of osmotic dehydration process parameters on solid gain

Solid gain from the pumpkin slices at different ternary solution concentration and solution temperatures versus osmosis time is shown in Figure 2. Solid gain also presented non-linearly relation with time at all process conditions. Mass transfer mostly occurs at beginning of osmotic process. At beginning rate of solid gain increases quickly with time than the latter; because of more solids present primarily in solution which then get utilized by sample with time resulting in reduced chemical potential gradient for process. Also as immersion time increases, sucrose comprising more molecular weight than NaCl leads to development of solid barrier at superficial surface of sample, which makes solid gain more intricate thus lowering rate of solid gain.

Solution composition shows substantial influence on solid gain. Solid gain over entire osmotic process Increases with increase in osmotic solution concentration. Maximum value of solid gain is seen

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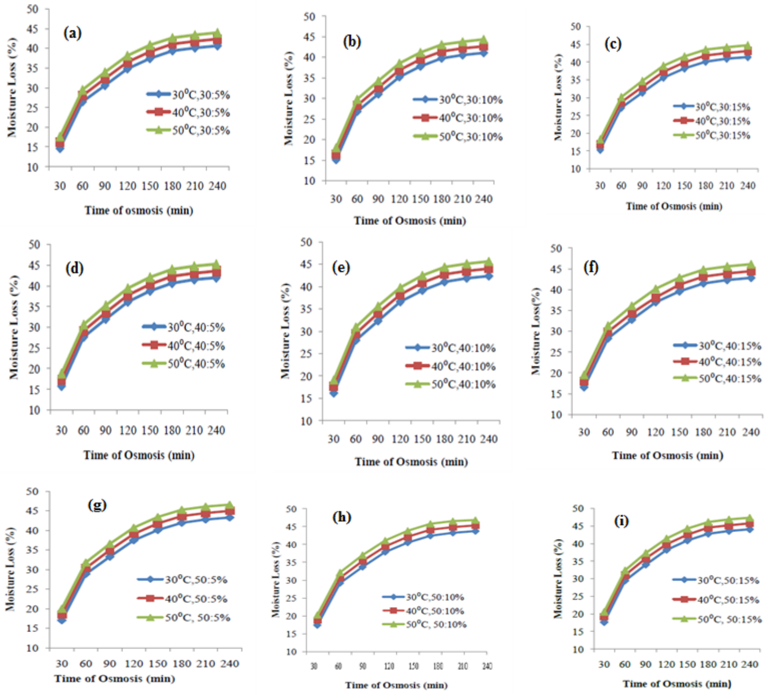

Figure 1: Effect of osmotic solution temperature on moisture loss of pumpkin slices during osmotic dehydration at (a) 30: 5% (b) 30: 10% (c) 30%: 15%(d) 40: 5% (e) 40: 10% (f) 40%: 15% (g) 50: 5% (h) 50: 10% (i) 50: 15% osmotic solution concentration.

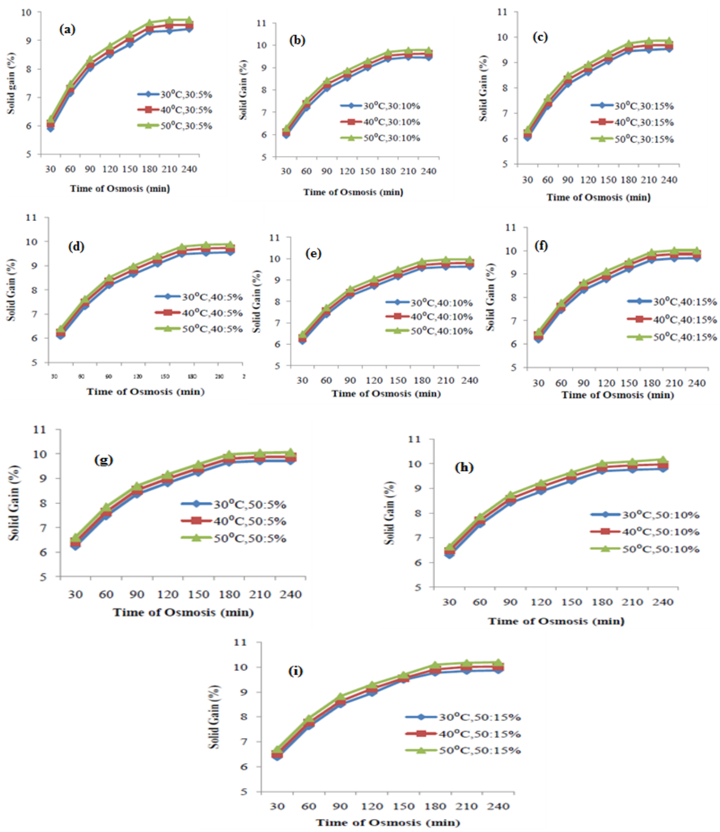

Figure 2: Effect of osmotic solution temperature on solid gain of pumpkin slices during osmotic dehydration at (a) 30: 5% (b) 30: 10% (c) 30%: 15%(d) 40: 5% (e) 40: 10% (f) 40%: 15% (g) 50: 5% (h) 50: 10% (i) 50: 15% osmotic solution concentration.

Model	R^2	RMSE
Henderson and Pabis	0.983	0.022
Page	0.854	0.569
Logarithmic	0.569	0.112
Parabolic	0.999	0.004

Table 1: R^2 and RMSE values of Henderson and Pabis, Page, Logarithmic and Parabolic models for the osmotic dehydration data.

in sample osmosed for 240 min at 50:15% osmotic agents' solution concentration at all process temperatures and its value varies from 6.375 to 10.196%. Temperature also shows immense effect on solid gain as is evident from Figure 2. Increase in solid gain due to increase in solution temperature occurs because of increase in cell membrane permeability to solutes due to swelling and plasticizing of cell membrane. Also, higher temperature reduces viscosity of solution making solute transfer effortless. High temperature of 50°C shows elevated solid gain.

Fitting of drying models

Henderson and Pabis, Page, Logarithmic, and Parabolic models were analyzed by fitting the experimental data using XLSTAT-2015. The R^2 and RMSE values for each of the tested models are given in Table 1 and it is clear from this table that the Parabolic model gives the best values in terms of highest R^2 and lowest RMSE.

Conclusion

From this study it can be concluded that non-linear relation exists between moisture loss and solid gain with osmotic dehydration process parameters. Mass transfers during osmotic dehydration process were mostly influenced by osmotic solution temperature and concentration pursued by immersion time. Parabolic model presents the best fit with utmost values for the coefficient of determination (0.999) and lowest RMSE value followed by Henderson and Pabis model and then by page model. Logarithmic model least illustrated the dehydration process for all temperature and concentration combinations.

Acknowledgments

The author one acknowledges Department of Food Process Engineering, SHIATS for making facilities available and Dr. R. N. Shukla for his valuable suggestions and timely guidance during entire period of research.

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