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EFFECT OF TEMPERATURE AND IMMERSION DURATION ON OSMOTIC DEHYDRATION OF ONION SLICE

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Abstract: Water loss, solid gain, weight loss and moisture content of osmotic dehydrated onion (*Allium cepa L.*) were studied. The effect of temperature and time to onion slices during osmotic dehydration for the onion slices were optimized using response surface methodology (*RSM*). Increase in process temperature and immersion duration increases the solid gain, water loss, weight loss and decrease in moisture content. Process temperature had non-significant effect on solid gain, as well as significant at 5% level significance on water loss, weight loss and moisture content. Optimized values of temperature and time were 42.08°C and 111.13 min, respectively.

Key words*: process temperature, immersion duration, osmotic dehydration, onion*

INTRODUCTION

Onion (*Allium cepa L.*) is an important spice and vegetable crop grown in all over world. Dehydrated bulb or onion powder is in great demand which reduces transportation cost and storage losses. The resulting product has generally better quality than the dried one without pretreatment. As bulk of onion is water (82–87%), reduction of moisture using suitable mechanical means prior to conventional hot air drying can be a simple technique to reduce moisture loading on dryer and hence the energy consumption. Also it is well known fact that each 1% reduction in feed moisture leads to 4% less dryer energy input [3, 15]. Effect of mechanical dewatering prior to hot air drying was investigated on drying time, specific energy consumption, flavor and color of dried product [7]. Osmotic dehydration of pork meat in molasses saved energy ranging from 89157 to 177092 $kJ\cdot kg^{-1}$ [19].

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The most important variable affecting the kinetics of mass transfer during osmotic dehydration is temperature. Increase in temperature of osmotic solution results in increases in water lose, whereas solid gain is less affected by temperature. Higher process temperatures seem to promote faster water loss through swelling and plasticizing of cell membranes, faster water diffusion within the product and better mass (water) transfer characteristics on the surface due to lower viscosity of the osmotic medium. At the same time solids diffusion within the product is also promoted by higher temperatures, only at different rates, mainly dictated by the size of the solute and concentration of the osmotic solution. Dehydration rates of apple slices increase with increase in osmotic pressure and temperature of solution [16].

Talaja Red onion of Sauratshtra Region of Gujarat have higher value for exporting as a row and dehydrated product in Middle East countries. There are about hundreds of dehydrated industry cluster in this region. The objective of this work was to study the osmotic dehydration on onion slice as a function of temperature and immersion time through response surface methodology (*RSM*) in order to identify process conditions for a high water loss at minimal solid uptakes (as an extensive solute uptake is undesirable and the product can no longer as marketed as 'natural') and to optimize the osmotic dehydration as a pre-treatment to further processing.

MATERIAL AND METHODS

The experiment mainly consists of experimental design, preparation of sample, determination of initial moisture content of onion slices, preparation of osmotic solution and osmotic dehydration process.

Preparation of sample and solution. The selected variety of summer onion was peeled and washed with water and unwanted material like dust, dirt, and surface adhering were removed. The onion bulbs were sliced with an electrical slicer of approximate 4 mm ± 0.5 mm thickness. Each slice was weigh and subsequently individually marked by using different color threads, the ratio of solute to onion slices was 7.5:1 w/w.

Measurement of initial moisture content. The moisture content of fresh as well as osmotically dehydrated onion samples was determined by using air oven method and calculated by using following equation [13].

$$Percent\ moisture\ content\ (db) = \frac{w_1 - w_2}{w_1} x100 \qquad (1)$$

Osmotic dehydration process. 100 g onion slices of 4 mm thickness were immersed into a glass jar containing 750 g of concentrated osmotic solution. The glass jars containing immersed samples were kept at five different temperatures i.e., 22, 31, 40, 49 and 58°C. in the *B.O.D.* incubator (Patel Scientific Instrument, Ahmedabad) at five levels of immersion duration i.e., 30, 67.5, 105, 142.5 and 180 min. After completion of immersion duration, the onion slices were removed from the osmotic solution, slices rinsed with clean water to remove the osmotic solution adhered on the surface and then put on a blotting paper to remove surface moisture from the slices. The mass and moisture content of the samples were measured for determination of mass loss, water loss and solid gain.

Experimental design. The Design Expert 8.0.7.1 software was used in making the experimental design for chemical pretreatment prior to osmotic dehydration of onion slices. Response Surface Methodology (*RSM*) was used for designing the experiments. The quadratic model of Central Composite Rotatable Design (*CCRD*) was selected for making experimental design [4].

The effect of four independent variables viz. process temperature, immersion duration, salt concentration and sucrose concentration on water loss, solid gain and weight loss were studied with variables coded as X_1, X_2, X_3 and X_4 respectively. The ranges of parameter values were carefully chosen based on the literature available on the osmotic dehydration of vegetables prior to drying. The ranges and levels of the parameters are shown in Tab. 1. The levels were determined using the code values of -2, -1, 0, +1, +2 as described by Das (2005).

Table 1. Code and actual values of different variables for experimentation

Variables\Code	*-2*	*-1*	*0*	*+1*	*+2*
Process temperature [°C]	*22*	*31.0*	*40*	*49.0*	*58*
Immersion duration [min]	*30*	*67.5*	*105*	*142.5*	*180*
Salt (NaCl) concentration [%]	*5*	*7.5*	*10*	*12.5*	*15*
Sucrose concentration [%]	*40*	*45.0*	*50*	*55.0*	*60*

The quadratic mode of *CCRD* of 4 variables at 5 levels each with 6 centre point combination was used. Altogether, 54 combinations (including 6 replications at the centre point and 2 replications at other points) were chosen according to design.

Process parameters (Factors i.e., four of five levels).

A. Process temperature (X_1) : 22, 31, 40, 49 and 58°C
B. Immersion duration (X_2) : 30, 67.5, 105, 142.5 and 180 min.
C. Salt concentration (X_3) : 5, 7.5, 10, 12.5 and 15%
D. Sugar concentration (X_4) : 40, 45, 50, 55 and 60%

Total number of treatment combinations (Runs).

$$\begin{aligned}
&\mathit{Total}\ \text{no.of treatments combinations} \\
&= [\text{No. of replications x (2) No. of variables}] \\
&+ [\text{No. of replications x } (2 \times \text{No. of variables}) \\
&+ \text{center points} + \text{control} \\
&= (2 \times 2^4) + (2 \times 2 \times 4) + 6 = 54
\end{aligned}$$

Evaluation of osmotic dehydration characteristics. Osmotic dehydration characteristics of onion slices were evaluated on the basis of solid gain, water loss, weight loss and moisture content.

The solid gain is the net uptake of solids by the onion slices. The water loss is the net loss of water from the product on initial mass basis. The weight loss is the net weight loss of the onion slice on initial weight basis. The solid gain, water loss and mass loss was calculated using the equations suggested by Islam and Flink (1982).

$$SG = \frac{W_\theta(1-X_\theta) - W_i(1-X)}{W_i} \times 100 \tag{2}$$

$$WL = \frac{W_i X_i - W_\theta X_\theta}{W_i} \times 100 \tag{3}$$

$$Weight\ Loss = \frac{W_i - W_\theta}{W_i} \times 100 \tag{4}$$

where:
SG [g·100g^{-1}] - solid gain (g/100g initial mass of slices),
WL [g·100g^{-1}] - water loss (g/100 g initial mass of slices),
W_θ [g] - mass of slices after duration θ,
X_θ [g] - water content as a fraction of mass of slices at duration θ,
W_i [g] - initial mass of slices,
X_i [g] - water content as a fraction of initial mass of slices.

Data analysis and optimization. The *CCD* design was used to conduct experiment and the Response Surface Methodology (*RSM*) was applied to the experimental data using a commercial statistical package, Design Expert-version 8.0.7.1 (Stat-ease, 21012). Analysis of variance (*ANOVA*) was conducted for fitting the model represented by equation 1 to examine the statistical significance of the model terms. Model analysis with respect to lack-of-fit test and R^2 (coefficient of determination) was done for determining adequacy of model. The coefficient of variance (*CV*) was calculated to find the relative dispersion of the experimental points from the prediction of the model. Response surfaces were generated and by using the same software, numerical optimization was done. The most commonly used model for optimization using response surface methodology is a second order polynomial equation [2]. The model is of the form:

$$Y_k = b_{k0} + \sum_{i=1}^{4} b_{ki} X_i + \sum_{i=1}^{4} b_{kii} X_i^2 + \sum_{i \neq j=1}^{4} b_{kij} X_i\, X_j \quad (k = 0,1,2,3\ldots) \tag{5}$$

where:
Y_k [-] - response,
b_{k0}, b_{ki}, b_{kii}, b_{kij} [-] - constant, linear, quadratic and corss-product regression coefficients,
X_i’ [-] - coded independent variables.

For optimization purpose the Response Surface Methodology was used.

Numerical optimization technique of the Design-Expert software was used for simultaneous optimization of the multiple responses. The desired goals for each factor and responses were chosen. The goals may apply to either factors or responses. The possible goals are maximize, minimize, target, within range, none (for responses only) and set to an exact value (for factors only). In order to search a solution maximizing multiple responses, the goals were combined into an overall composite function, *D(x)*, called the desirability function [11], which is defined as:

$$D(x) = (Y_1 \times Y_2 \times \ldots \times Y_n)^{1/n} \tag{6}$$

where:

Y_i $(i = 1, 2, \ldots n)$ [-] - responses,

n [-] - total number of responses in the measure.

The optimized solution parameters were used for further study i.e., to examine effect of chemical pretreatment on osmotic dehydration of onion slices.

RESULTS AND DISCUSSION

Initial moisture content of onion slices of freshly harvested Talaja Red variety taken for treatments was 86.12%.

Effect of osmotic dehydration parameters on solid gain. The solid gain varied from 3.90 to 17.02%. The minimum solid gain was found in the treatment having the combination of process temperature of 31°C, 67 minutes and 30 seconds immersion duration, 7.50% salt concentration and 45% sugar concentration, while maximum solid gain was found in the treatment having the combination of process temperature of 40°C, 105 minutes and 15 seconds immersion duration, 15% salt concentration and 50% sugar concentration. This showed that salt concentration and sugar concentration played prominent role than the immersion duration and process temperature on solid gain. Similar observation were given by Alam *et al*. (2013), Ispir and Togrul (2009), Jokie *et al*. (2007).

The model *F*-value of 33.36 implies that the model is significant. There is only 0.01% chance that this much large "Model *F*-Value" could occur due to noise. R^2 and *CV*% value for solid gain was 0.9229 and 11.80% respectively which indicated that the model could fit the data for solid gain very well for all the four variables, i.e. process temperature, immersion duration, salt concentration and sugar concentration.

The response surface equation of second order was obtained in terms of coded factors to predict the variation in solid gain during osmotic dehydration of onion slices with varying levels of processing parameters as Eq. 7.

$$\begin{aligned} Solid\ gain(\%) = {} & 6.52 - (7.253E-003)A + 0.055B + 2.29C + 0.59D - 0.16AB + \\ & 0.066AC - 0.82AD - 0.067BC - 0.016BD + 0.37CD - (9.800E- \\ & 003)A^2 - 0.018B^2 + 0.72C^2 - (9.256E-003)D^2 \end{aligned} \tag{7}$$

where:

A [°C] - process temperature,

B [min] - immersion duration,

C [%] - salt concentration,

D [%] - sugar concentration.

Effect of process temperature and immersion duration on solid gain. The effect of process temperature and immersion duration on solid gain was determined keeping salt concentration and sugar concentration constant at 10% and 50% respectively (Fig. 1). Three dimensional responses for solid gain of osmotic treated samples were generated. It could be observed that with increase in process temperature and immersion duration, there is increase in solid gain and hence solid gain was directly proportional to process temperature and immersion duration. Solid gain rise was more with increase in process temperature as compared to immersion duration. Interaction effect of process temperature and immersion duration on solid gain was found to be non-significant. Results for apricot also showed that solids gain increased with the increase of temperature [10]. Similar results were also obtained by Souraki *et al*. (2012), Alam *et al*. (2013), Jokie *et al*. (2007), Ramallo *et al*. (2004).

Effect of osmotic dehydration parameters on water loss. The water loss varied from 23.94 to 49.28%. The maximum water loss was found in the treatment combination of process temperature of 40°C, 105 minutes immersion duration, 10% salt concentration, 60% sugar concentration, while minimum water loss was found in treatment combination of process temperature of 31°C, 142 minutes and 30 seconds immersion duration, 12.5% salt concentration, and 45% sugar concentration. This shows that sugar concentration, process temperature and salt concentration played prominent role than the immersion duration on water loss. These observations are in line with those reported by Alam *et al.* (2013).

The model *F*-value of 22.55 implies that the model is significant. There is only 0.01% chance that this much large "Model *F*-value" could occur due to noise. R^2 and *CV*% value for water loss was 0.89 and 6.44% respectively which indicated that the mode could fit the data for water loss very well for all the four variables, i.e., process temperature, immersion duration, salt concentration and sugar concentration.

The response surface equation of second order was obtained in terms of coded factors to predict the variation in water loss during osmotic dehydration of onion slices with varying levels of processing parameters as under:

$$\begin{aligned} &Water\ loss(\%) = 34.70 + 1.29A + 0.45B - 0.66C + 4.97D - 0.46AB - 0.18AC \\ &-1.10AD + 0.27BC + (2.160E - 0.003)BD + 0.28CD - 0.90A^2 - 0.67B^2 \\ &-0.28C^2 + 1.25D^2 \end{aligned} \qquad (8)$$

Effect of process temperature and immersion duration on water loss. The effects of process temperature and immersion duration on water loss were determined keeping salt concentration and sugar concentration constant at 10% and 50% respectively (Fig. 2). Three dimensional responses revealed that with increase in process temperature and immersion duration, there was increase in water loss and hence water loss was directly proportional to process temperature and immersion duration. Water was considerably more with increase in process temperature as compared to immersion duration. Interaction effect of process temperature and immersion duration was found to be non-significant on water loss.

Effect of osmotic dehydration parameters on weight loss. The weight loss varied from 16.57 to 42.20%. The maximum weight loss was found in treatment combination of process temperature of 40°C, 105 minutes immersion duration, 10% salt concentration and 60% sugar concentration, while minimum weight loss was found in treatment combination of process temperature of 31°C, 142 minutes immersion duration, 12.5% salt concentration and 45% sugar concentration. This showed that sugar concentration, salt concentration and process temperature played prominent role than the immersion duration on weight loss. These findings are in line with Ozen *et al*. (2002).

The model *F*-value of 21.48 implies that the model is significant. There is only 0.01% chance that this much large "Model *F*-value" could occur due to noise. R^2 and *CV*% value for weight loss was 0.89 and 7.99% respectively which indicated that the mode could fit the data for weight loss very well for all the four variables, i.e., process temperature, immersion duration, salt concentration and sugar concentration.

The response surface equation of second order was obtained in terms of coded factors to predict the variation in weight loss during osmotic dehydration of onion slices with varying levels of processing parameters as under:

$$\begin{aligned} Weight\ loss(\%) &= 28.18 + 1.30A + 0.40B - 1.63C + 4.38D - 0.30AB - 0.25AC \\ &- 1.02AD + 0.34BC + 0.16BD - 0.91CD - 0.89A^2 - 0.66B^2 - 1.00C^2 + 1.24D^2 \end{aligned} \quad (9)$$

Effect of process temperature and immersion duration on weight loss. The effects of process temperature and immersion duration on weight loss were determined keeping salt concentration and sugar concentration constant at 10% and 50% respectively (Fig. 3). Three dimensional responses revealed that with increase in process temperature and immersion duration, there was an increase in weight loss and hence mass loss was directly proportional to process temperature and immersion duration. Weight loss was considerably more with increase in process temperature as compared to immersion duration. Interaction effect of process temperature and immersion duration was found to be non-significant on weight loss. Results for apricot also showed that solids gain increased with the increase of temperature [7, 9].

Effect of osmotic dehydration parameters on moisture content. The moisture content varied from 44.16 to 69.50%. The minimum moisture content was found in treatment combination of process temperature of 40 ^{o}C, 105 minutes immersion duration, 10% salt concentration and 60% sugar concentration, while maximum moisture content was found in treatment combination of process temperature of 31 ^{o}C, 142 minutes and 30 seconds immersion duration, 12.5% salt concentration and 45% sugar concentration. This showed that sugar concentration, salt concentration and process temperature played prominent role than the immersion duration moisture content.

The model F-value of 22.55 implies that the model is significant. There is only 0.01% chance that this much large "Model *F*-value" could occur due to noise. R^2 and CV% value for moisture content was 0.89 and 3.71% respectively which indicated that the mode could fit the data for moisture content very well for all the four variables, i.e., process temperature, immersion duration, salt concentration and sugar concentration.

The response surface equation of second order was obtained in terms of coded factors to predict the variation in moisture content during osmotic dehydration of onion slices with varying levels of processing parameters as under:

$$\begin{aligned} &\textit{Moisture content}\,(\%) = 58.74 + 1.29A + 0.45B - 0.66C - 4.97D + 0.46AB + 0.18AC \\ &+ 1.10AD - 0.27BC - (2.160E - 0.003)BD - 0.28CD + 0.90A^2 + 0.67B^2 \\ &+ 0.28C^2 - 1.25D^2 \end{aligned} \tag{10}$$

Effect of process temperature and immersion duration on moisture content. The effects of process temperature and immersion duration on moisture content were determined keeping salt concentration and sugar concentration constant at 10% and 50% respectively (Fig. 4). It could be observed that with increase in process temperature and immersion duration, there is decrease in moisture content and hence moisture content was inversely proportional to process temperature and immersion duration. Decrease in moisture content was considerably more with increase in process temperature as compared to immersion duration. Interaction effect of process temperature and immersion duration on moisture content was found to be non-significant. It was also found that moisture content 0.6 mm thick slices of pineapple was linearly affected with solute content was independent of temperature up to 600 min of initial dehydration [15].

Optimization of osmotic characteristics during osmotic dehydration of onion slices. Optimization of parameters of osmotic dehydration for maximum water loss and minimum solid gain was done based on analysis of various parameters and statistical data. Numerical optimization found a point that maximizes the desirability function and best combination was selected having the desirability function.

Table 2. Optimized variables and their responses for osmotic dehydration of Talaja Red onion slices

Variable	*Optimized values*	*Responses*	*Predicted values*
Process temperature [°C]	*42.08*	*Water loss [%]*	*40.04*
Immersion duration [min]	*111.13*	*Solid gain [%]*	*5.42*
Salt concentration [%]	*8.03*	*Weight loss [%]*	*34.62*
Sugar concentration [%]	*55.00*	*Moisture content [%]*	*53.39*

From the numerical optimization, 41 solutions were found out of which best combination having desirability of 0.781 was selected. The osmotic dehydration of Talaja Red onion slices should be carried out at 42.08°C temperature and 111.13 minutes immersion duration keeping salt concentration and sugar concentration at 8.03% and 55% respectively. This optimum set of parameters gave the predicted values of osmotic dehydration characteristics i.e. solid gain 5.42%, water loss of 40.04%, weight loss of 34.62% and moisture content of 53.39%. The finding in this study were in line with the results reported by Shamaei *et al*. (2012). The optimum values for different variables and their predicted responses thus obtained are given in Tab. 2.

CONCLUSIONS

It may be concluded that the optimal process temperature and immersion duration for onion slice in 8.03% salt concentration and 55% sugar concentration will be 42.08°C and 111.13 minute respectively for maximum water loss and minimum solid gain during osmotic dehydration.

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UTICAJ TEMPERATURE I VREMENA IZLAGANJA NA OSMOTSKU DEHIDRACIJU REŽNJEVA CRNOG LUKA

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Sažetak: U ovom istraživanju su ispitivani gubitak vode, čvrsti prinos, gubitak mase i sadržaj vlage kod osmotski dehidriranog crnog luka (*Allium cepa L.*). Uticaj temperature i vremena na režnjeve crnog luka tokom osmotske dehidracije je optimiziran korišćenjem metode odgovora površine (*RSM*). Povećanje temperature i vremena izlaganja povećava čvrsti prinos, gubitak vode i gubitak mase, a smanjuje sadržaj vlage. Temperatura nije imala značajan uticaj na čvrsti prinos, a imala je značajan uticaj, na nivou značajnosti od 5%, na gubitak vode, gubitak mase i sadržaj vlage. Optimizirane vrednosti temperature i vremena iznosile su 42.08°C i 111.13 min, redom.

Ključne reči*: temperatura, vreme, osmotska dehidracija, crni luk*

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