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OSMOTIC DEHYDRATION OF MANGO SLICES IN SUGAR SOLUTION USING RESPONSE SURFACE METHODOLOGY

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Abstract:-
The response surface methodology (RSM) was applied to optimize the effects of immersion time (01, 02 and 03 hr), temperature (40, 50 and 60 ºC) and concentration of sucrose solution (40, 50 and 60ºBrix) in osmotic dehydration of mango fruit slices (3mm thickness). Box-Behnken Design was used with water loss (WL, %), solid gain (SG, %), and weight reduction (WR, %) as responses. The models obtained for all the responses were significant ($P \leq 0.05$) without a significant lack of fit. The optimum conditions were temperature (50°C), immersion time (2hr), concentration of sucrose solution (56.756ºBrix) in order to obtain WR of(32.75 g/100g initial sample), SG of (18.799g/100g initial sample) and WL of (51.551g/100g initial sample), respectively.

Keywords: - ***"****Optimization, osmotic dehydration, mango, response surface methodology****"***

I. INTRODUCTION

In developing countries such as Myanmar, agro-food processing efforts making the agricultural industrialization have been strongly supported to diversity its economy. Mangoes are the popular fruit in Myanmar and are grown in Sagaing Region, Mandalay Region and central part of the country. In Myanmar, the consumption of fresh green mango is quite popular, and is consumed with salt, sugar or saccharin and chili powder. The acidity, color, and texture of the green fruit, provides to the consumers, agreeable taste. However, its high humidity content (0.83 ± 0.03 wb) and high water activity (aw), (0.983 ±0.005) [1], makes of mango a highly perishable fruit, thus requiring conservation alternatives [2]. It is widely used as a fresh fruit, ripe, and in processed products as ingredient in fruit salad, ice cream, jam, yoghurt, and cakes, among others [3]. However, green mango is also used as a fresh and processed product. In some countries, mango is used to prepare different processed products as drinks, cocktails, candy, processed meats and vinegar (chutney) and powered products [4,5].

Osmotic dehydration is a partial dehydration method applied to fruits and legumes. It consists in immerging the entire or piece of products in highly concentrated solutions [6, 7]. During osmotic dehydration, two simultaneous phenomena occur [7]: (i) important leave of water from food to solution that water diffusion is due to concentration gradient between the food and the solution through food cellular membrane; (ii) Solute transfer from solution to food.

In the processing of dehydrated foods, osmotic dehydration (OD) is one of most important complementary treatment and food preservation technique, since it has some benefits such as reducing the damage of heat to the flavor, color, inhibiting the browning of enzymes and decrease the energy costs [8]. Rastogi and Raghavararo (1997) reported that osmotic dehydration reduced up to 50% weight of fresh vegetables and fruits [9]. The different types of osmotic agents such as glucose, sorbitol, sucrose and salts are used according to the final products [10]. However combination of different solutes can be used [11]. Water loss from vegetables and fruits took place in first two hours and maximum sugar gain within 30 minutes [12]. Temperature and concentration of osmotic syrups increased the rate of water loss during osmotic dehydration. Although higher temperature has the significant effect on the structure of tissues [13] and also cause deterioration of flavour and enzymatic browning at temperature above 45°C. The osmotic agents are sugars (e.g. sucrose, glucose, sorbitol) and salts according to expected final product quality, however, different solutes can be combined [14]-[18].

The response surface methodologies (RSM) are very useful techniques for optimization and applied in different food processes among that is osmotic dehydration [19][23]. The main advantage is that they reduce the number of experiments needed to obtain statistically valid results and are faster and more informative than traditional assessments which evaluate one variable at a time [22].

The objective of this work was to study the osmotic dehydration of mango slices as a function of sugar concentration, temperature and immersion time through Response surface methodology (RSM) in order to identify process conditions for a high water loss at maximum solid uptakes and to optimize the osmotic dehydration as a pretreatment.

II. MATERIALS AND METHODS

The methodology involved osmotic dehydration with different concentration of sucrose solution, determination of water loss, solid gain, weight reduction and optimization of response parameters with RSM.

2.1 *Sample preparation and Experimental method*

Good, sound and unmature mango fruit (*Mangifera indica L*. Myanmar variety) grown in Hmawbi Township, Yangon Region, Myanmar were used. They were washed, peeled with a sterile knife and cut in to uniform slices (0.5mm thickness) and steam blanched for 1minute. Then the slices were dipped in the 0.1% potassium sorbate solution for 5 minutes and drained. Osmotic dehydration was done in sucrose solution with different concentrations such as 40, 50 and 60 °Brix. The sample to solution ratio was constant 1:5 (w/w). The mango slices were weighed and submerged in sugar solution solution at 40, 50 and 60°C. The temperature was maintained constant using a hot water bath and the samples were removed from the solution at different time intervals of 1, 2 and 3 hr. In each of the experiments, fresh osmotic solutions were used. After removing from the sugar solution, the samples were drained and the excess solution at the surface was removed with filter paper for subsequent weight measurement. After dehydration the samples were dried in hot air oven at 60°C about 5 hours until equilibrium moisture content was obtained. All experiments were done triplicates and the average value was taken for calculation.

2.2 *Water Loss, Solid gain and Weight Reduction*

Water Loss (WL), Solid Gain (SG) and Weight Reduction (WR) were calculated and given in Equations (1,2and 3) [24].

$$\text{Water Loss} = \text{Solid Gain} + \text{Weight Reduction} \quad \text{---------(1)}$$

$$\text{Solid Gain} = \frac{(m - m_o)}{M_o} \times 100 \quad \text{---------(2)}$$

$$\text{Weight Reduction} = \frac{(M_o - M)}{M_o} \text{ x } 100 \quad \text{---------(3)}$$

Where, Mo- Initial mass of the samples (g)
M-Mass of sample after dehydration (g)
mo- Initial mass of the solids in sample(g)
m- Mass of the solids in the sample after dehydration (g)

2.3 *Design of Experiment*

The Response Surface Methodology (RSM) is a statistical modeling technique applied for multiple regression analysis using quantitative data obtained from properly designed experiments. The Box-Behnken Design (BBD) of three variables and seventeen trials were used for designing the experiments of osmotic dehydration [25].

Table 1: Codes and actual levels of the independent variables for the design of experiment

Independent Variables	Notations	Coded Levels		
		-1	0	+1
Sugar Concentration (°Brix)	C	40	50	60
Temperature of solution (°C)	B	40	50	60
Duration of osmosis (hr)	A	1	2	3

The response surface methodology assumes that there is a polynomial function that relates the responses to the independent variables namely Duration of osmosis (A), Temperature of the solution (B) and Sugar concentration (C) in the process. Therefore, the experimental data obtained from the design (Table. 1) were fitted to a polynomial of the form found in equation 4 [26].

Response (Y) = $a_0 + a_1A + a_2B + a_3C + a_{11}A^2 + a_{22}B^2 + a_{33}C^2 + a_{12}AB + a_{13}AC + a_{23}BC$…… (4)
where the response (Y) is (WL, SG and WR %), the a_n are constants and A, B, C are independent variables.

2.4 Optimization

Optimization was carried by attempting to combine various factors that simultaneously satisfy the requirements placed on each of the response and factors. There are several response variables describing the quality characteristics and performance measurements of the system, are to be maximized while some are to be minimized. RSM was applied to determine the optimum conditions for producing a model for osmotic dehydration of mango slices with maximum water loss, weight reduction and minimum solid gain.

III. RESULTS AND DISCUSSION

3.1 *Effect of variables on water loss, solid gain and weight reduction*

The effects of variables such as osmotic solution temperature, osmotic solution concentration and duration on water loss, solid gain and weight reduction were studied and a second order polynomial equation was fitted with the experimental data.

3.2 *Statistical analysis on model fitting*

The experimental responses as a function of process variables such as Time(A), Temperature(B) and Sugar Concentration (C) during osmotic dehydration of mango slices are shown in Table 2.

Table 2. The Box-Behnken Design for Osmotic Dehydration of Mango Fruit Slices

Run	Factor 1	Factor 2	Factor 3	Response 1	Response 2	Response 3
	A:time	B:Temp	C:Sugar	WR	SG	WL
1	50	50	2	35.11	20.91	56.02
2	40	40	2	21.93	10.71	32.64
3	50	60	3	39.62	25.83	64.96
4	50	50	2	35.15	21.13	56.28
5	50	40	3	31.96	20.34	52.30
6	50	50	2	35.21	20.94	56.15
7	50	50	2	35.17	20.89	56.06
8	50	50	2	35.14	20.93	56.07
9	60	50	1	29.32	13.73	43.05
10	50	40	1	30.65	19.77	50.42
11	40	50	3	30.27	10.94	41.21
12	60	60	2	30.29	19.36	49.65
13	50	60	1	36.36	26.61	62.97
14	40	50	1	28.47	18.27	46.74
15	60	40	2	24.66	13.38	38.14
16	60	50	3	32.36	20.56	52.92
17	40	60	2	29.73	17.84	47.37

The value of weight reduction (%), solid gain (%) and water loss (%) were within the ranges of 21.93-39.62, 10.71- 26.61 and 32.64-64.96 respectively. Regression analysis and ANOVA results are shown in Table 3. The model F values of three responses such as WR, SG and WL were 8045.20, 1127.12 and 4328.07 implying that the model is significant. At the same time WR, SG and WL showed that they possess non -significant lack- of- fit. These values indicated that the models were fitted and reliable. The adequacy of the model is further checked by Coefficient of determination (R^2) was found to be 0.9999, 0.9993 and 0.9998 for WR, SG and WL respectively. As the calculated R^2 was found to be approximately equal to 1 it was considered to be high enough for predication purposes and the predicted R^2 for WR, SG and WL of 0.9987, 0.9906 and 0.9977 were in reasonable agreement with adjusted R^2 of 0.9998, 0.9987 and 0.9996. The values of R^2 and adjusted R^2 obtained in the study implied that the predicted values are in good agreement with the experimental values. The values of Adeq precision are 349.8281, 117.1812 and 243.9962 for WR, SG and WL respectively. The values of Adeq precision obtained in this study are greater than 4.0 indicating that these responses had better precision and reliability. The values of coefficient of variation (C.V %) were 0.2069, 0.9423 and 0.3412 for WR, SG and WL

Table 3. Regression coefficients for osmotic dehydration of mango slices

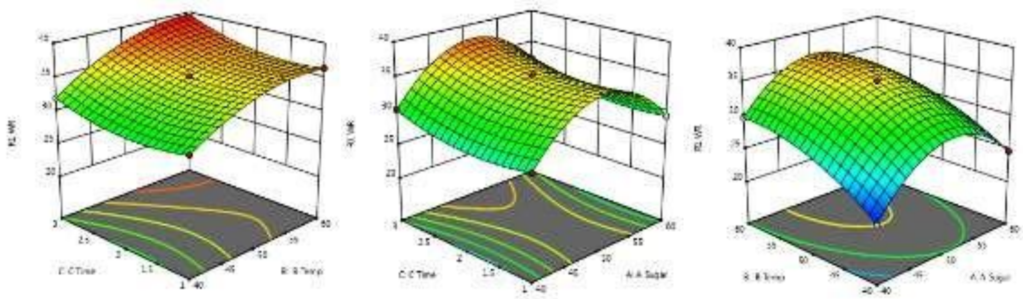
Variables/ Factor	DF	Weight (%) Reduction		Solid Gain (%)		Water Loss (%)	
		Sum of Squares	F-value	Sum of Squares	F-value	Sum of Squares	F-value
Model	9	314.40	8045.20	323.42	1127.12	1168.27	4328.07
A-time	1	4.85	1117.33	10.74	336.92	31.20	1040.44
B-Temp	1	89.78	20676.43	80.90	2537.45	330.89	11032.48
C-Sugar	1	11.07	2549.09	0.0630	1.98	8.43	280.92
AB	1	1.18	271.12	0.3306	10.37	2.59	86.43
AC	1	0.3844	88.53	50.13	1572.24	59.29	1976.85
BC	1	0.9506	218.93	0.4556	14.29	0.0030	0.1009
A^2	1	179.16	41259.79	175.17	5494.25	703.31	23449.82
B^2	1	16.52	3803.49	2.78	87.18	6.49	216.47
C^2	1	9.12	2101.11	7.85	246.07	32.73	1091.42
Lack of Fit		0.0249		0.1856		0.1674	
R^2		0.9999		0.9993		0.9998	
Adjusted R^2		0.9998		0.9984		0.9996	
Predicted R^2		0.9987		0.9906		0.9977	
Adeq precision		349.8281		117.1812		243.9962	
Std. Dev.		0.0659		0.1786		0.1732	
Mean		31.85		18.95		50.76	
C.V. %		0.2069		0.9423		0.3412	

3.3 Effect of process variables on weight reduction

During the osmotic dehydration process, weight reduction indicates the amount of water lost by the sample. *WR* is a parameter including the net balance of flow of water loss and solute gains along the osmotic process. Therefore, the sum of these two countercurrent flows leads to the net mass variation of the dehydrated samples [27]. The regression model of weight reduction as a function of process parameters are given in equation (7)

Weight reduction = $+35.16 +0.7788*A + 3.35*B + 1.18*C -6.52*A^2 - 1.98*B^2 + 1.47*C^2 -0.5425*A*B + 0.31*A*C + 0.4875 *B*C$--- (5)

The presence of positive interaction term between A, B and C indicated that increase in their level increased weight reduction. The positive values of quadratic terms of process variables of osmosis indicated that higher values of these variables reduced weight reduction. The response surface plot indicated in Figure 1 represents weight reduction as a function of time, temperature and concentration of the osmotic solution. Weight reduction increases with increase in sugar concentration, temperature and time as shown in Figure 1. The reason was that the viscosity of osmotic solution was lowered and the diffusion coefficient of water increases at high temperature. Figure 1 (b) and (c) revealed that sugar concentration had significant effect on weight reduction than others.

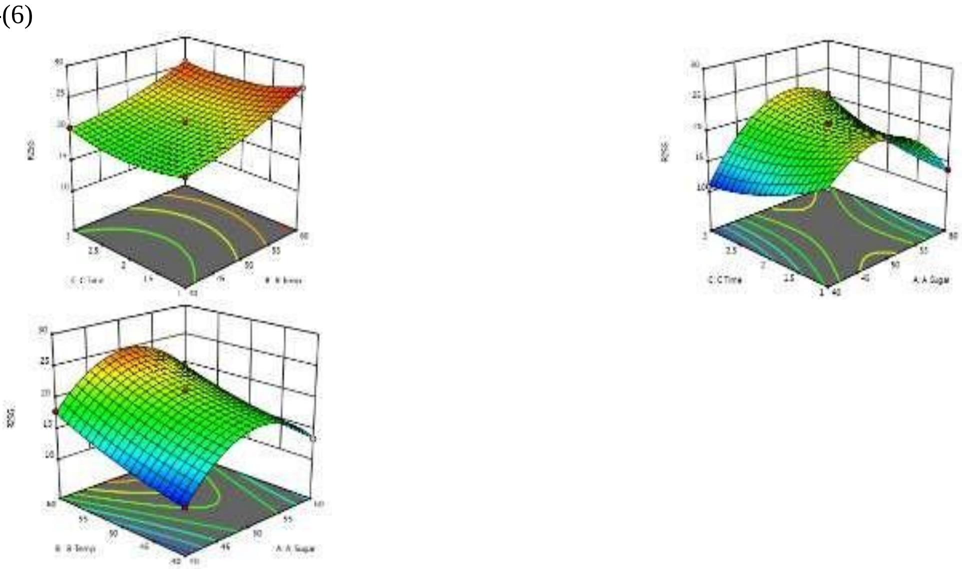


(a) Immersion time and temperature (b) sugar concentration and time (c) sugar concentration and temperature
Figure 1. Weight reduction during osmotic dehydration of mango slices as a function of:

3.4 Effect of process variables on Solid Gain

The response surface plot indicated in Figure 2 represents solid gain as a function of time, temperature and concentration of the osmotic solution. As shown in Figure 2a the solid gain increases with immersion temperature and immersion time up to a level at a specific sucrose concentration and after it decreased. The present results are also in agreement with findings of Baljeet Singh Yadav, et.al [28] obtained during the optimization of the osmotic dehydration of peach slices. The increase in SG was more pronounced to increase in temperature and sugar concentration (Fig. 2b and c). This positive interaction between process time and osmotic agent concentration was also reported by Manivannan and Rajasimman [29] during the osmotic dehydration studies on beetroot in salt solution. The regression model of solid gain as a function of process parameters are given in equation (6). The presence of positive interaction term between A, B and C indicated that increase in their level increased solid gain. The negative values of quadratic terms of process variables of osmosis indicated that higher values of these variables affected solid gain.

$\text{Solid Gain} = +20.96 + 1.16*A+3.18*B - 0.0888*C - 6.45*A^2 + 0.8125*B^2 + 1.36*C^2 - 0.2875*A*B + 3.54*A*C - 0.3375*B*C$---(6)

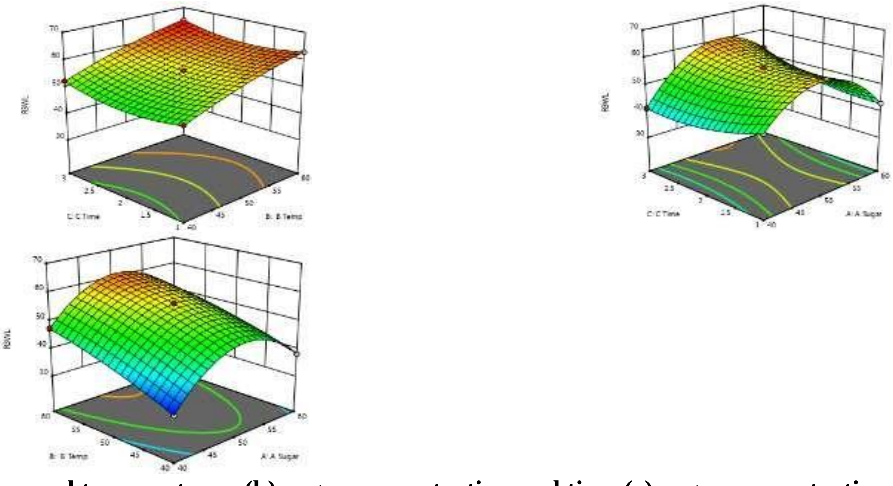


(a) Immersion time and temperature (b) sugar concentration and time (c) sugar concentration and temperature
Figure 2. Solid gain during osmotic dehydration of mango slices as a function of:

3.5 Effect of process variables on water loss

Figure (3) shows that the water loss increased with increased time and sugar concentration. Water loss is an important parameter in osmotic dehydration and indicates the amount of moisture diffused from the sample to solution. The regression model of water loss as a function of process parameters is given in equation (5). The negative value of term B indicated that increase in its level decreased water loss. The quadratic terms of sugar concentration have negative effect, and processing time and temperature have positive effect on water loss. An increase in the sugar concentration and temperature favored water loss from the product because of the greater osmotic pressure gradient in the product/solution interface [30,31].

$\text{Water loss} = + 56.12 + 1.97*A + 6.43*B + 1.03*C - 12.92*A^2 - 1.24B^2 +2.79C2-0.8050*A*B + 3.85*A*C + 0.0275*B*C$--- (7)



(a) Immersion time and temperature (b) sugar concentration and time (c) sugar concentration and temperature
Figure 3. Water loss during osmotic dehydration of mango slices as a function of:

3.6 Numerical optimization of process parameters:

The criteria variables were set such that the independent variables (Time, Temperature and Concentration) would be minimum from an economical point of view [32]. The main responses for optimization were maximum possible water loss and weight reduction. The desired goals for each factor and response are shown in Table 4. In order to optimize the process parameters for osmotic dehydration process by numerical optimization which finds a point that maximize the desirability function; equal importance of `3' was given to all the three process parameters and three responses.

Table 4. Criteria and output for numerical optimization of process parameters

Criteria	Goal	Lower limit	Upper limit	Importance	Output
A:Sugar Concentration	is target = 60	40	60	3	56.756
B:Temperature	is target = 50	40	60	3	50
C:Time	is target = 2	1	3	3	2
Weight reduction (%)	maximize	10.71	39.62	3	32.70 5
Solid Gain (%)	minimize	2.87	26.61	3	18.799
Water loss (%)	maximize	32.64	64.96	3	51.55 1
Desirability					0.726

3.7 Verification of the model for osmotic dehydration of mango slices

Osmotic dehydration experiments were conducted at the optimum process condition (A= 56.756 ºBrix, B=50°C and C=2hr) for testing the adequacy of the model equations for predicting the response values. The observed experimental values (mean of three experiments) and values predicted by the equations of the model are presented in Table 5. The experimental values were found to be very close to the predicted values for weight reduction, solid gain and water loss. Therefore, it could be concluded from above discussion that model are quite adequate to assess the behavior of the osmotic dehydration of mango slices.

Table 5. Predicted and experimental values of response at optimum process conditions for osmotic dehydration of mango slices

Response	Predicted Value	Observed Value
Weight Reduction (%)	32.7049	32.75
Solid Gain (%)	18.799	18.9
Water loss (%)	51.5515	51.65

IV. CONCLUSION

It was concluded from this study that the solution temperature and immersion time were the most pronounced factors affecting solid gain and water loss of mango slices during osmotic dehydration followed by sugar concentration. Response surface methodology was effective in optimizing process parameters for the osmotic dehydration of mango slices in osmotic aqueous solution of sugar having concentration in the range of 40-60 ºBrix, temperature 40-60°C and process duration 1-3hr. The regression equation obtained in this study can beused for optimum conditions for desired responses within the range of conditions in the study.

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