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OPTIMIZATION OF OSMOTIC DEHYDRATION OF TODDY FRUIT 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 (60,90and 120min), temperature (35, 45 and 55ºC) and concentration of sucrose solution (30, 40 and 50ºBrix) in osmotic dehydration of toddy fruit slices (2mm 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≤0.05) without a significant lack of fit. The optimum conditions were temperature (45°C), immersion time (109.336min), concentration of sucrose solution (40ºBrix) in order to obtain WL of (29.331g/100g initial sample), SG of (4.265g/100g initial sample) and WR of 25.224 g/100g initial sample, respectively.

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

I. INTRODUCTION

Palmyra Palm, sugar palm or toddy palm (Borassus flabellifer Linn.) is commonly available in the Africa, South Asian (e.g. Sri Lanka and India), Southeast Asia (e.g. Myanmar, Cambodia, Malaysia, Indonesia, Vietnam and Thailand)[1][2]. The mesocarp or pulp ripe is sweet with abundant carotenoid. It had yellow orange as it becomes ripe and can be used for foods such as cakes, jelly, ice cream, jams, cordials, beverages and toffee (Chakraborty et al., 2011) [3].

The important sources of digestible and indigestible minerals, carbohydrates and certain vitamins, particularly vitamins A and C are contained in fruits. The moisture in most of the fruits above 75% and fruits are prone to spoilage by molds and yeasts and this moisture content of fruits are prone to spoilage by molds and yeasts [4].

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 [5]. The increased in shelf-life, little bit loss of aroma in dried and semidried food stuffs, lessening the load of freezing and without causing unnecessary changes in texture of freezed dried food due to osmotic dehydration [6]. Rastogi and Raghavararo (1997) reported that osmotic dehydration reduced up to 50% weight of fresh vegetables and fruits [7]. The different types of osmotic agents such as glucose, sorbitol, sucrose and salts are used according to the final products [8]. However combination of different solutes can be used [9]. Water loss from vegetables and fruits took place in first two hours and maximum sugar gain within 30 minutes [10]. 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 [11] and also cause deterioration of flovour and enzymatic browning at temperature above 45°C.

The response surface methodologies (RSM) are very useful techniques for optimization and applied in different food processes among that is osmotic dehydration [12]-[16]. The main advantage is that they reduce the number of experiments needed to obtain statistically valid results [15] and are faster and more informative than traditional assessments which evaluate one variable at a time [15].

The objective of this work was to study the osmotic dehydration of toddy fruit 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 toddy fruits grown in Thanlyin Township, Yangon Region, Myanmar were used. They were washed, peeled with a sterile knife and cut in to uniform slices (2mm thickness) and steam blanched for 1minute. The initial moisture content was determined by using oven method at 70°C for 18h [17]. Osmotic dehydration was done in sucrose solution with different concentrations such as 30, 40 and 50 °Brix. The sample to solution ratio was constant 1:5 (w/w). The toddy fruit slices was weighed and submerged in salt solution at 35, 45 and 55°C. The temperature was maintained constant using a hot water bath and the samples were removed from the solution at different time intervals of 60, 90 and 120 min. 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 dryer at 45°C about 15 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) [18].

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

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

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

Where, M_o- Initial mass of the samples (g)

M-Mass of sample after dehydration (g)

m_o- 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 [19].

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

Independent Variables	Notations	Coded Levels		
		-1	0	+1
Duration of osmosis (min)	A	60	90	120
Temperature of solution (°C)	B	35	45	55
Sugar Concentration (°Brix)	C	30	40	50

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 Salt 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 [20].

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 toddy 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 variation in water loss, solid gain and weight reduction were studied by changing the osmotic solution temperature, osmotic solution concentration and duration 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 toddy fruit slices are shown in Table 2.

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

Run	Factor 1	Factor 2	Factor 3	Response 1	Response 2	Response 3
	A:time	B:Temp	C:Sugar	WL	SG	WR
1	90	45	40	24.8	3.8	21
2	90	35	30	24	3.17	20.83
3	120	45	50	32.8	4.7	28.1
4	120	35	40	31.3	4.1	27.2
5	120	55	40	34.3	4.5	29.8
6	90	55	30	22.7	2.87	19.83
7	60	45	50	18.5	3.47	15.03
8	90	45	40	24.7	3.8	20.9
9	90	35	50	24.7	3.2	21.5
10	90	55	50	23.87	3.66	20.21
11	120	45	30	29.5	3.98	25.52
12	90	45	40	24.7	3.83	20.87
13	90	45	40	24.8	3.8	21
14	60	55	40	18.2	3.2	15
15	90	45	40	24.73	3.9	21.83
16	60	45	30	19.5	3.3	16.2
17	60	35	40	23.2	3.5	19.7

The value of water loss (%), solid gain (%) and weight reduction (%) were within the ranges of 18.2-34.3, 2.87-4.7 and 15.029.8 respectively. Regression analysis and ANOVA results are shown in Table 3. The model F values of three responses such as WL, SG and WR were 7125.74, 333.02 and 329.67 implying that the model is significant. At the same time WL, SG and WR 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, 0.9977 and 0.9976 for WL, SG and WR 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 WL, SG and WR of 0.9987, 0.9922 and 0.9952 were in reasonable agreement with adjusted R^2 of 0.9998, 0.9947 and 0.9946. 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 289.9872, 68.3254 and 62.6777 for WL, SG and WR 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 0.2891, 0.9489 and 1.44 for WL, SG and WR respectively which showed that the deviations between experimental and predicted values are low.

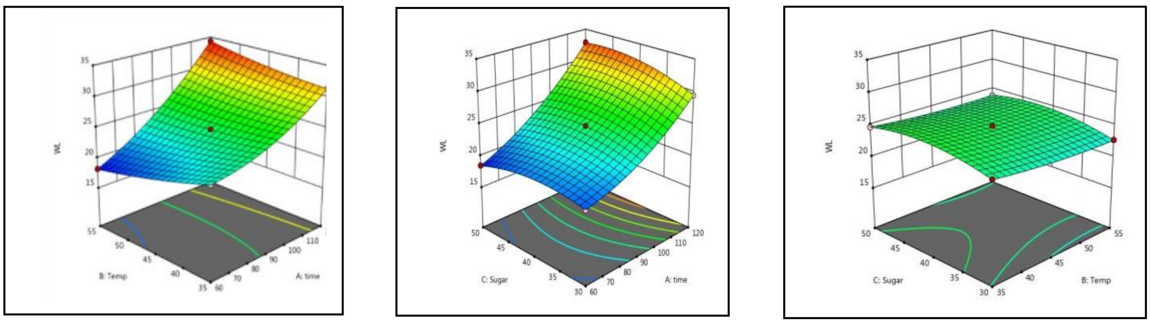
Table 3. Regression coefficients for osmotic dehydration of toddy fruit slices

Variables/ Factor	DF	Water Loss (%)		Solid Gain (%)		Weight Reduction (%)	
		Sum of Squares	F-value	Sum of Squares	F-value	Sum of Squares	F-value
Model	9	337.10	7125.74	3.68	333.02	282.09	329.67
A-time	1	294.03	55937.46	1.81	1477.79	249.65	2625.82
B-Temp	1	2.13	405.62	0.0084	6.88	2.41	25.34
C-Sugar	1	2.17	413.52	0.3655	297.68	0.7564	7.96
AB	1	16.00	3043.89	0.1225	99.77	13.32	140.13
AC	1	4.62	879.40	0.0756	61.59	3.52	36.98
BC	1	0.0552	10.51	0.1444	117.60	0.0210	0.2211
A^2	1	11.20	2130.20	0.4265	347.32	6.19	65.11
B^2	1	0.5866	111.60	0.4291	349.50	1.48	15.55
C^2	1	7.13	1357.38	0.3342	272.22	5.28	55.55
Lack of Fit		0.0265		0.0011		0.0217	
R^2		0.9999		0.9977		0.9976	
Adjusted R^2		0.9998		0.9947		0.9946	
Predicted R^2		0.9987		0.9922		0.9952	
Adeq Precision		289.9872		68.3254		62.6777	
Std. Dev.		0.0725		0.0350		0.3083	
Mean		25.08		3.69		21.44	
C.V. %		0.2891		0.9489		1.44	

3.3 *Effect of process variables on water loss*

Figure (1) shows that the water loss increased with increasing 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.

$$\text{Water loss} = +24.75 + 6.06*A - 0.5162*B + 0.5212*C + 1.63*A^2 + 0.3732B^2 - 1.30C^2 + 2.00*A*B + 1.07*A*C + 0.1175*B*C \quad \text{-----(5)}$$



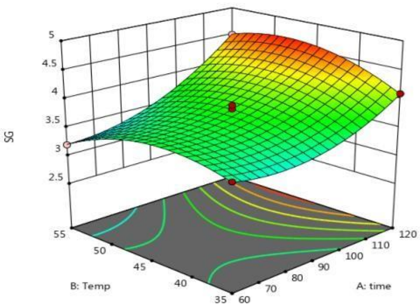
(a) Immersion time and temperature (b) sugar concentration and time (c) sugar concentration and temperature

Fig 1. Water loss during osmotic dehydration of toddy fruit slices as a function of:

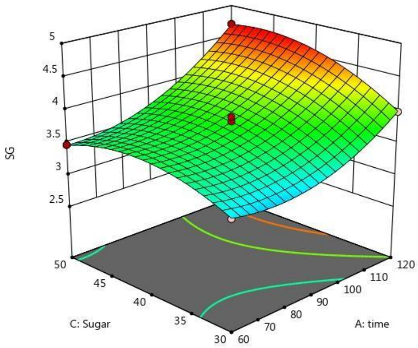
3.4 *Effect of process variables on Solid Gain*

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 [21] 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 [22] 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.

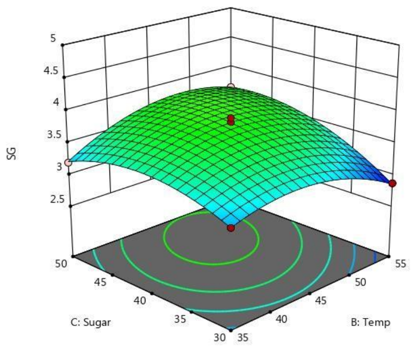
$$\text{Solid Gain} = +3.83+0.4763*A+0.0325*B+0.2138*C+0.3182*A^{2} -0.3193*B2-0.2817*C2+0.175*A*B+0.1375*A*C+0.19*B*C \text{---(6)}$$



(a) Immersion time and temperature



(b) sugar concentration and time



(c) sugar concentration and temperature

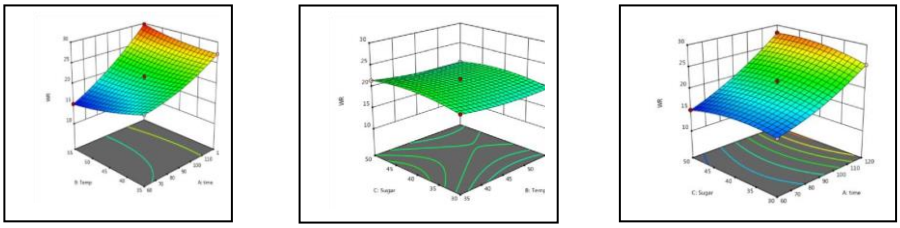
Fig 2. Solid gain during osmotic dehydration of toddy slices as a function of:

3.5 *Effect of process variables on weight reduction*

Weight reduction indicates the amount of water lost by the sample during the osmotic dehydration process. The regression model of weight reduction as a function of process parameters are given in equation (7)

$$\text{Weight reduction} =+21.12+5.59*A-0.5488*B+0.3075*C+1.21*A^{2}+0.5925*B^{2}-1.12C^{2} +1.83*A*B+0.9375*A*C -0.0725*B*C \text{ ---------(7)}$$

The presence of negative interaction term between A, B and C indicated that increase in their level decreased 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 3 represents weight reduction as a function of time, temperature and concentration of the osmotic solution. Weight reduction increases with increase in sugar concentration and time as shown in Figure 3. The reason was that the viscosity of osmotic solution was lowered and the diffusion coefficient of water increases at high temperature.



(a) Immersion time and temperature (b) sugar concentration and time (c) sugar concentration and temperature

Fig 3. Weight reduction during osmotic dehydration of toddy 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 [23]. The main criteria for constraints 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:Time	is target = 120	60	120	3	109.336
B:Temp	is target = 45	35	55	3	45
C:Sugar	is target = 40	30	50	3	40
Water loss (%)	maximize	18.2	34.3	3	29.331
Solid Gain (%)	minimize	2.87	4.7	3	4.265
Weight reduction (%)	maximize	15	29.8	3	25.224
Desirability					0.673

3.7 Verification of the model for osmotic dehydration of toddy slices

Osmotic dehydration experiments were conducted at the optimum process condition (A= 109.336 min, B=45°C and C=40%) 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 water loss, solid gain and weight reduction. Therefore, it could be concluded from above discussion that model are quite adequate to assess the behavior of the osmotic dehydration of toddy slices.

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

Response	Predicted Value	Observed Value
Water loss (%)	29.331	29.2
Solid Gain (%)	4.265	4.1
Weight reduction (%)	25.224	25.1

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 toddy slices during osmotic dehydration followed by sugar concentration. Response surface methodology was effective in optimizing process parameters for the osmotic dehydration of toddy slices in osmotic aqueous solution of sugar having concentration in the range of 30-50, temperature 35-55°C and process duration 60-120min. The regression equation obtained in this study can be used for optimum conditions for desired responses within the range of conditions in the study.

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