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Influence of process parameters on the kinetics of the osmotic dehydration of muskmelon (Cucumis melo) using Box Behnken Design

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Abstract: Osmotic dehydration of muskmelon were optimized using response surface methodology with respect to concentration (40-60°Brix), temperature (40-60°C) and immersion time (60-300min) for maximum water loss, maximum weight reduction and minimum solid gain as response variables. Experiments were designed according to Box-Behnken Design with three factors each at three different levels. For each response, a second order polynomial model was developed using multiple linear regression analysis. The osmotic dehydration data was well fitted to the regression model with high correlation coefficient (R^2> 0.90) using Design Expert. The Second order polynomial model for the water loss, solute gain and weight reduction yielded significant and predictive results. Using the desirability function method, optimized conditions were found to be sucrose concentration of 60°B, temperature 40°C and time 257.3 min. At this optimum condition water loss and solid gain were found to be 54.41 % and 10.74% respectively.
Keywords: Muskmelon;Osmotic dehydration;Box-Behnken Design;Model fitting;Optimization

Introduction

Muskmelon (*Cucumis melo*) is a tropical fruit with sweet, fragrant yellow- orange colored flesh. It has a significantly high nutritional value and a good source of β-carotene, vitamin C, dietary fiber and low in saturated fat and cholesterol and provides number of health benefits to the consumer. Muskmelon possesses a high commercial value and appreciated because of its peculiar sensorial and nutritional characteristics, but presents a very short post harvest shelf life at room temperature. Its highly perishable nature results in enormous decomposition at the time of surplus production. The osmotic dehydration is one of the alternative methods to fulfill the above requirements(Shi and Le Maguer 2002).Osmotic dehydration is a process of partial removal of water that involves immersion of the product in a hypertonic solution leading to loss of water through the cell membranes of the product (Sereno et al. 2001).The osmotic dehydration process can be used as a pre-treatment which inhibits enzymatic changes, retains natural color without addition of sulphites, retains volatile compounds during subsequent dryingand improves the nutritional, sensorial and functional properties of food(Fernandes et al. 2006; Singh et al. 2010). The present study aims at the influence of temperature, sugar concentration, and immersion time of osmotic dehydration process on changes in mass of the sample. It also aims at determining the optimum temperature, sugar concentration, and immersion time using response surface methodology in order to identify the process conditions for maximized water loss with minimized solid uptakes.

Experimental

Fresh and ripe muskmelon were washed with water then peeled, seeded and sliced in order to obtain cubes of same dimensions. The osmotic solutions of desired concentration were prepared by dissolving the required amount of sucrose in distilled water. The experiments were carried out with a constant agitation of 100 rpm to maintain constant temperature and concentration throughout the experiments and also to avoid localized dilution of the osmotic solution. The sample to solution ratio was maintained as 1:10 to avoid significant dilution of the medium and further decrease of the driving force during the process. The samples were withdrawn from the solution after specified time, then rinsed in flowing water, blotted gently with a tissue paper to remove adhering water, were weighed using analytical balance (Schimadzu) with an accuracy of ±0.001g and then dried by oven method(AOAC 2000) for the determination of moisture and solid content. All the experiments were repeated three times and the average values have been reported.In order to follow the osmotic dehydration kinetics, the mass transfer parameters such as water loss (WL) and solid gain (SG) were calculated gravimetrically using equations (1) - (2) for each sample and were expressed in percentage of initial composition. (Ozen et al. 2002; Singh et al. 2007). The weight and moisture content data of each sample were used to calculate the response variables.

$$\text{Water loss, \%} = \frac{(W_0 - W_t) + (S_t - S_0)}{W_0} \times 100 \tag{1}$$

$$\text{Solid gain, \%} = \frac{S_t - S_0}{W_0} \times 100 \tag{2}$$

where, W_0 is the initial weight of sample taken for osmotic dehydration (g), W_t is the weight of the sample after osmotic dehydration at any time t(g), S_0 is the initial weight of solids of the sample (g) and S_t is the weight of solids (dry matter) in the sample after osmotic dehydration at any time t. The response surface methodology (Design Expert version 8.0.7.1, Statease Inc, Minneapolis, USA) was used to estimate the optimum processing conditions of concentration (40-60 °Brix), temperature (40-60 °C) and immersion time (60-300 min)at maximized water loss and minimized solid gain.

Results and discussion

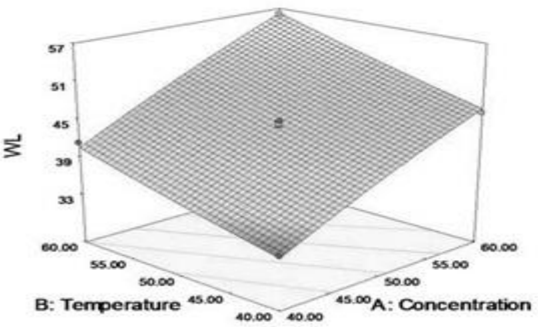
Table 1Coded and un-coded process variables of experimental runs generated by Box- Behnken Design and observed values of response variables

Run	Coded Process Variables			Un-Coded Process Variables			Response Variables					
							Experimental			Predicted		
	Conc. (A)	Temp (B)	Time (C)	Conc. (A)	Temp (B)	Time (C)	WL %	SG %	WR %	WL %	SG %	WR %
1	1	0	-1	60	50	60	35.85	8.10	26.73	35.42	7.98	26.68
2	0	-1	-1	50	40	60	28.95	7.52	21.43	28.67	7.59	20.96
3	0	-1	1	50	40	300	48.07	10.26	37.81	47.83	10.14	37.82
4	-1	-1	0	40	40	180	33.24	8.88	24.36	33.06	8.88	24.30
5	-1	1	0	40	60	180	41.43	11.40	30.03	40.73	11.35	29.51
6	-1	0	1	40	50	300	40.57	10.95	29.62	40.99	11.07	29.67
7	0	1	1	50	60	300	57.11	13.11	44.00	57.39	13.04	44.47
8	0	0	0	50	50	180	44.91	10.09	34.82	44.51	10.08	34.43
9	1	-1	0	60	40	180	46.21	9.52	36.69	46.91	9.57	37.21
10	1	1	0	60	60	180	56.02	11.25	44.77	56.20	11.25	44.83
11	0	0	0	50	50	180	44.88	10.14	34.74	44.51	10.08	34.43
12	0	0	0	50	50	180	44.24	10.04	34.20	44.51	10.08	34.43
13	0	0	0	50	50	180	44.34	10.15	34.19	44.51	10.08	34.43
14	-1	0	-1	40	50	60	27.36	9.02	18.34	27.82	8.95	18.87
15	0	1	-1	50	60	60	35.83	8.71	27.14	36.07	8.83	27.13
16	1	0	1	60	50	300	63.17	12.56	50.61	62.71	12.63	50.08
17	0	0	0	50	50	180	44.18	9.98	34.20	44.51	10.08	34.43

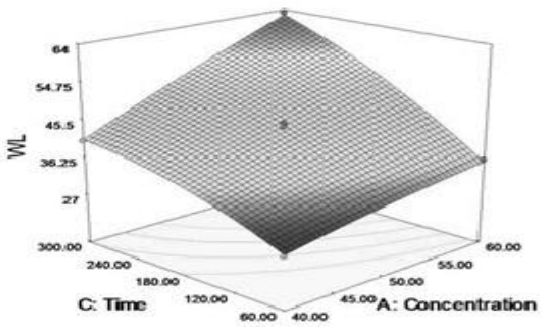
Table 2Analysis of Variance (ANOVA) for response surface quadratic model for the osmotic dehydration of muskmelon

Source	Water Loss			Solid Gain			Weight Reduction		
	CE	**SS**	**P-value**	**CE**	**SS**	**P-value**	**CE**	**SS**	**P-value**
Model	44.51	1467.23	< 0.0001	10.08	34.37	< 0.0001	34.43	1131.97	< 0.0001
A	7.33	429.98	< 0.0001	0.15	0.17	0.0104	7.06	398.33	< 0.0001
B	4.24	143.82	< 0.0001	1.04	8.59	< 0.0001	3.21	82.24	< 0.0001
C	10.12	818.71	< 0.0001	1.69	22.88	< 0.0001	8.55	584.82	< 0.0001
AB	0.41	0.66	0.2262	-0.20	0.16	0.0133	0.60	1.45	0.0572
AC	3.53	49.77	< 0.0001	0.63	1.60	< 0.0001	3.15	39.69	< 0.0001
BC	0.54	1.17	0.1202	0.41	0.69	0.0002	0.12	0.058	0.6644
A^2	-0.52	1.13	0.1247	0.22	0.20	0.0071	-0.87	3.18	0.0120
B^2	0.23	0.23	0.4578	-0.038	0.0059	0.5422	0.40	0.68	0.1643
C^2	-2.25	21.39	0.0001	-0.14	0.086	0.0452	-2.24	21.06	< 0.0001
Lack of Fit		2.10	0.0662		0.081	0.0698		1.56	0.0761
SD		0.61			0.12			0.53	
R^2		0.9982			0.9971			0.9983	
Adj R^2		0.9959			0.9933			0.9960	
Pred. R^2		0.9766			0.9616			0.9775	
Adeq. Precicion		74.537			59.204			76.767	
CV%		1.41			1.19			33.16	

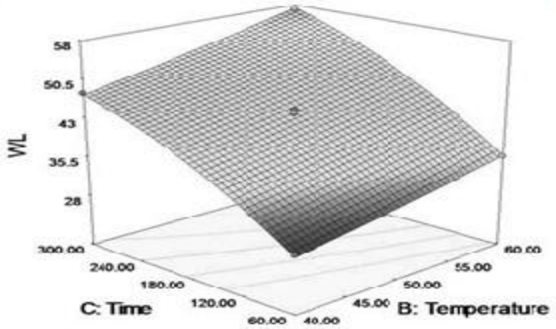
A – Concentration; B – Temperature; C – Immersion Time; CE – Coefficient of Estimate; SS – Sum of Squares; CV – Coefficient of Variance



1.(a)



1 (b)



1(c)

Fig 1.Response surface plots for effect of Temperature - Concentration (1a), Concentration –time (1b) and Time -Temperature (1c) on water loss

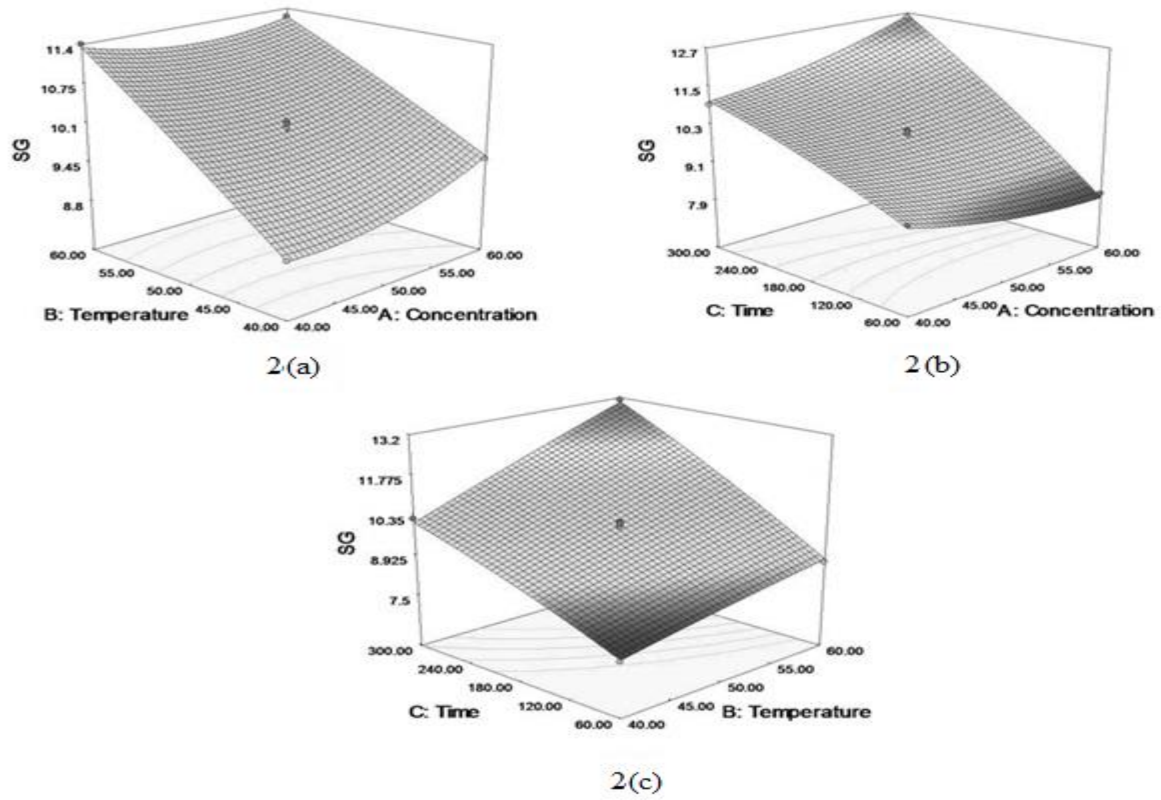


Fig 2.Response surface plots for effect of Temperature - Concentration (2a), Concentration time (2b) and Time -Temperature (2c) on solid gain

Table 1 shows the coded and un-coded process variables of experimental runs generated by Box-Behnken Design and observed values of response variables. Table 2 shows the analysis of variance (ANOVA) model for the osmotic dehydration of muskmelon. The magnitude of P and F values also indicates the maximum positive contribution of time followed by concentration and temperature on the water lossduring osmotic dehydration. The response surface plots for water loss and solid gain has been depicted in Fig. 1 and 2.As the sucrose concentration was increased, water loss was more pronounced with increase in time showing the positive interaction effect of process time and sucrose concentration on WL.It was observed that time had a greater impact on solid gain followed by temperature, whereas concentration has the least effect on solid gain. Predominant increase in solid gain with increase in concentration was also found at an increased immersion time. This effect may be due to the high concentration gradient between the fruit and the osmotic solution. The main criterion for constraints optimization was maximum possible water loss and minimum solute gain. In order to optimize the process parameters during osmotic dehydration of muskmelon, the following constraints have taken sucrose concentration (40-60 °Brix), temperature (40-60 °C) and immersion time (60-300 min), were set for maximum desirability. Applying the desired function, the optimum conditions of various process parameters were found to be sucrose concentration of 60 °Brix, temperature 40 °C and time 257.3 min in order to obtain WL of 54.41% and SG of 10.74%. Therefore, optimum conditions obtained in the model may be recommended for osmotic dehydration of muskmelon.Exposing a product to osmotic dehydration also plays a significant role in improving the energy use efficiency during further drying process. Therefore, osmotic dehydration of muskmelon could effectively be used as a pretreatment prior to conventional drying to remove a large portion of moisture at the low temperature, which is beneficial to maintain the natural property of the product.

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