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Optimizing Osmotic Dehydration Conditions For Cantaloupe Using Response Surface Methodlogy

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ABSTRACT: The present study was conducted to investigate the process of osmotic dehydration for Golden melon. Response surface methodology was used to optimize the osmotic dehydration conditions to obtain a product with higher desirability on the basis of nutritional composition and sensorial properties. The sample to osmotic solution ratio was maintained as 1:10. Size of the fruit pieces (2.5-7.5mm), blanching time (3min -7min), concentration of osmotic solution (25ºB-55ºB) and dipping time (90min-270min) were used as an independent response variables. Different experiments were carried out to determine the effect of independent variables on phenolic content, antioxidant activity, vitamin C content, sugar content, rehydration ratio and also on sensorial properties of osmotically dehydrated golden melon. The optimal conditions for 80% desirability of the final product were size of fruit pieces (4mm), blanching time (5min),concentration of sucrose solution(35ºB)and dipping time(270min).

Key words: Osmotic dehydration, response surface methodology, Golden melon, sucrose solution, optimization

INTODUCTION

Fruits are an important part of human's healthy diet because they are the richest source of vitamins and minerals, which are very much required for maintaining good health. Fruits being rich in vitamin C, thiamine, niacin, pyridoxine, folic acid, minerals and dietary fibre helps in lowering blood pressure, reduce risk of heart diseases and also prevents cancer (Wargovich,2000).The World Health Organisation of Food and Agriculture department of the united nation reports recommend adults to consume at least five servings of fruits per day (Crawford et al., 1994).

The diverse climatic conditions of India favours the availability of different varieties of fruits of which cantaloupe (*Cucumis melo L.*) is one of the most popular delicious seasonal fruit of family “Cucurbitaceae” (Gene,1997 ; Bailey, 1976). It is liked and consumed all around the world because of its sweetness, pleasurable aroma and health benefits (Lester,2008). The fruit is available in many different verities like golden melon, canary melon, honeydew etc. It contains many health promoting nutrients like phosphorus, calcium, potassium, magnesium, iron, copper, folic acid, pyridoxine, nicotinamide and dietary fibre (Gene, 1997; Lester and Hodges, 2008). It has been observed that the high antioxidant activity of golden melon is due to presence of vitamin A and C that prevents the oxidative damages by free radicals and helps in lowering down the aging process (Phisut, 2013). Golden melon is one of the best fruit for obsessed persons because of having low fat content. Consumers preference for this fruit is due to its medicinal properties like antibiotic, anitfertility, anticancer as well as to reduce chronic diseases and stimulating immune system (Nishadh *et al*., 2014).

One of the main problem associated with this fruit is its post harvest deterioration due to its high moisture content in order to reduce the post harvest losses and to extend the shelf. It is necessary to apply a suitable preservation techniques like drying, freezing, rehydration, osmotic dehydration (Konopacka *et al*., 2009; Bala *et al*.,2009). Most of the drying techniques used for fruits and vegetables are responsible for nutrient losses and results in unacceptability of the product. Among various preservation techniques osmotic dehydration is considered to be one of the most efficient technique because of lesser loss of nutritive compounds, colour and flavour. (Sagar and Suresh Kumar,2009; Sablani and Rahman, 2003). The osmotic dehydration process depends on some factors such as osmotic agent, concentration of solute, time temperature combination, size of fruit pieces and the most important factor is sample to solution ratio (Singh *et al*., 2010;Lombard *et al*., 2008).To optimize the osmotic dehydration conditions as well as to study the effect of different processing variables on the final product some statistical designs can be used one such design is response surface methodology.

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Vol-22-Issue-16-August-2019

It is an effective design expert in building models, designing the experiments and also in optimizing the conditions for desirable final product by evaluating the effects of different independent variables on various responses during various food processes including osmotic dehydration (Corzo and Gomez ,2004). The most beneficial property of Response surface methodology is it reduces the number of experiments which provide us statistically valid results (Yadav *et al* ., 2012; Ozdemir *et al*.,2008 ; Singh *et al* ., 2010).The main aim of this study was optimization of osmotic dehydration conditions for cantaloupe using response surface methodology and also to study the effect of various in -dependent process variables like size of the fruit pieces, blanching time, concentration of osmotic solution, dipping time on nutritional as well as on sensorial properties of osmotically dried cantaloupe.

MATERIAL AND METHODS

Sample preparation:

Fresh Golden melons of good quality were purchased from local market of Jalandhar. The Golden melons were then washed, hand peeled and cut into pieces of different sizes with the help of knife and the thickness was maintained with the help of skin fold calliper for different treatments of RSM. Sugar and water were used as base material to prepare osmotic solution of diferent concentrations. The fruit to osmotic solution ratio was maintained as 1:10. The experiments were conducted at a temperature of 60ºC.

Experimental design

Experiments were designed with the help of Response surface methodology (RSM) to investigate the main effect of osmotic dehydration process on sensory and nutritional quality of golden melon. The design was formulated by taking in to consideration different variables as independent where sugar concentration ranges from (15°B- 55°B), immersion time is from (90min-360min) and selected size ranges between 2.5mm-10mm as shown in Table 1.

Physico and Phyto-Chemical Analysis:

Moisture and Ash content of Golden melon samples was determined by using the standard methodology as prescribed by AOAC, 1990. Drying was continued until a constant weight is reached and percentage moisture content was determined and ashing was done in muffle furnace at 550°C for 6-8 hrs. Pre weighed piece of each sample was dipped in sufficient amounts of water for 8 – 10hr to calculate the rehydration ratio (Singh *et al* .,2006). Folin Ciocalteu reagent was used for total phenol estimation (Bray and Thorpe, 1954) and the results were expressed as mgGAE/g taking Gallic acid as a standard at 650nm. Percent antioxidant activity was measured as given by Brand-Williams *et al*.,1995 and the absorbance was recorded at 515 nm. Reducing sugars were measured by Lane and Eynon method1923. For ascorbic acid estimation a calibrated curve of L ascorbic acid was used to quantify vitamin C content (Guimaraes *et al.,* 2010).

Results and Discussions

30 different treatments with varying combinations of blanching time, size of fruit pieces, dipping time and concentration of sugar syrup were obtained by using Response surface methodology. The fruit pieces treated with these 30 treatments were further analysed for the physico chemical properties which were considered as response variables or dependent variables. The results of analysis of physico chemical properties of 30 treatments were shown in (Table.2).ANOVA was also calculated for these treatments to see the effect of independent variables on all the dependent variables (Table.3). It was observed by analysing the results that all the model for dependent variables were statistically significant from each other

For testing the fitting of the model for different responses like phenols, antioxidant activity, vitamin C, rehydration ratio, reducing sugars and sensory evaluation the sum of squares of the model was also analysed by considering the four factors i.e the linear effect, the regression of the response, the linear effects and the quadratic effects of the responses (X_1, X_2, X_3, X_4, X_5, X_6)(Table.3).

Model F-value of 47.40, 12.67, 11.97, 10.10, 12.54, 23.95 for X_1, X_2, X_3, X_4, X_5, X_6 respectively indicating that the model is significant 0.01% chance that a “Model F-Value” this large could due to noise. The degree of fitness of model was checked by the value of coefficient of determination r^2.The value of this coefficient for all the responses was calculated to be 0.9779(X_1), 0.9220(X_2), 0.9179(X_3), 0.9041(X_4), 0.9213(X_5), 0.9565(X_6) which are satisfactory and showing proper fitting of the model. The value of predicted R^2 for responses was 0.93(X_1), 0.78(X_2), 0.69(X_3), 0.74(X_4), 0.72(X_5), 0.84(X_6) found in reasonable agreement with the “Adjusted R-squared” which were having the values 0.95, 0.84, 0.84, 0.81, 0.84, 0.87 respectively for the same responses. All these values were discussed in table.3.

Effect of independent variables on response variables :

The 3D graphs for response variable indicates that all the independent variables significantly affects all the response variables.

1) **Effect of Blanching time on response variables:** It was revealed from the results that with the significant increase in blanching time up to 7min the nutritional components i.e phenols, antioxidants and vitamin C was slightly decreased(Fig 1a,b-3a,b) and it might be due to leaching of these nutrients which occurs because of their solubility in water. The highest amount of phenols (1.94mgGAE/g), Antioxidants(52.19%)and vitamin C(32.33mg/100g) was found in the treatments which are having minimum blanching time(3min). Taiwo *et al*., 2010 had also observed the same decreasing trend of ascorbic acid in case of apple slices which were blanched before drying. A.Korus, 2011;Amin *et al*.,2006;Howard *et al*.,1999 and Selman in 1994 have also found similar results in their studies on blanching treatments of different fruits and vegetables and showed a good agreement with the results of the present study. In case of rehydration ratio, reducing sugars and sensorial acceptability a significant increasing trend was observed with increase in blanching time. Blanching treatment results in the destruction of fruit tissue structure which promotes the solid uptake and significantly increase mass transfer process during osmotic dehydration leads the increase in reducing sugars(Fig 5a,b). Kowalska *et al*., 2008 has been studied the effect of blanching on mass transfer process of pumpkin during osmotic dehydration process and observed same results. Sensory score was also found highest in the treatments with more blanching time because it improves the texture and also retain the colour of the final product(Fig6 a,b). Agiriga *et al*., 2015 have also observed that the sensory acceptability of blanched carrots was high the un blanched carrots.

2) **Effects of size of fruit pieces on response variables:**

   Size of fruit slices also showed a significant effect on dependent variables as the size of the fruit pieces increase the leaching of the nutrient was decreased which means that the fruit pieces with larger size have the capability to retain the nutrients and due to this reason phenols, antioxidants and vitamin C content have shown an increasing trend with the increase in the size of the fruit pieces (Fig 1a,b-3a,b). Rehydration ratio was also increased with increase in size of fruit pieces (Fig 4a,b) whereas the 3D graph for reducing sugars (Fig 5a,b) showed a slight decrease due to lesser permeability of cell membrane of fruit. Sensory score was also not found good for the fruit pieces having higher size which was probably due to less crispiness and lesser absorbance of sugar syrup(Fig6a,b).

3) **Effects of dipping time on response variables :**

Dipping time affects the dependent variables i.e phenols, antioxidants activity and vitamin C in the same manner as blanching time(fig 1-3a,b). According to Device *et al*., 2010 and Vijayakumari *et al*., 2007 the higher dipping of fruits in osmotic solution results in loss of natural solutes. In case of rehydration ratio no significant effect of dipping time has been observed on rehydration ratio(fig 4a,b). In the initial phase of osmotic dehydration reducing sugars were increased significantly but as the time increase the effect of dipping time on reducing sugars was also reduced because the osmotic driving force for mass transfer keeps on decreasing with increase in dipping time(fig 5a,b). The solute gain and water loss process was at the highest rate at the initial stage of osmotic dehydration (Hawkes *et al*., 1978). Sensory acceptability was also deceased because of the absorption of sugar syrup was occurred properly which contribute to the flavour of the final product(fig 6a,b).

4) **Effect of concentration of osmotic solution of response variables :**

Concentration of osmotic solution was showing increasing trend as a concentration of osmotic solution increased in case of phenols, antioxidants and vitamin C (Fig 1a,b-3 a,b).which was due to the increase in the concentration of osmotic solution. The deposition of sugar layer on the surface of the product will occur which results in resistance to mass transfer process and reduce the permeability of cells which leads to the lesser leaching of nutrient (Lazarides *et al*., 1995; Motuska *et al*., 2006). Reducing sugar was also increased slightly it might be due to higher concentration of sugar syrup leads to increase in solid uptake (Fig 5a,b) (Azoubel amd Murr, 2004;Mundada et al., 2011)and inversion of sucrose was also responsible for increase in reducing sugars (Phisut *et al*., 2013). Sensory score was decreased

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Vol-22-Issue-16-August-2019

with increase in concentration of osmotic solution which might be due to excessive sweetness and over flavour of sugar in the final product(Fig 6a,b).

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Vol-22-Issue-16-August-2019

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Vol-22-Issue-16-August-2019

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ISSN:0971-1260
Vol-22-Issue-16-August-2019

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Table :1 Different independent process variables using response surface methodology

30 different experiments were generated on account of independent variables based on response surface methodology. These 30 treatments are having different

ISSN:0971-1260
Vol-22-Issue-16-August-2019

combinations of blanching time, size of fruit pieces, dipping time and concentration of osmotic solution

Independent Parameters of Response Surface Methodology				
Run	Size(mm)	Blanching time(min)	TSS(ºB)	Dipping time(min)
1	2.50	3.00	45.00	270.00
2	7.50	7.00	25.00	90.00
3	5.00	9.00	35.00	180.00
4	2.50	3.00	25.00	90.00
5	7.50	3.00	25.00	270.00
6	7.50	3.00	45.00	270.00
7	7.50	7.00	45.00	270.00
8	2.50	3.00	25.00	270.00
9	2.50	3.00	45.00	90.00
10	5.00	5.00	35.00	180.00
11	5.00	5.00	15.00	180.00
12	5.00	5.00	35.00	180.00
13	2.50	7.00	45.00	270.00
14	5.00	1.00	35.00	180.00
15	5.00	5.00	35.00	180.00
16	2.50	7.00	25.00	270.00
17	7.50	3.00	35.00	90.00
18	0.00	5.00	35.00	180.00
19	10.00	5.00	45.00	180.00
20	7.50	7.00	55.00	90.00
21	5.00	5.00	35.00	180.00
22	5.00	5.00	35.00	180.00
23	5.00	5.00	35.00	180.00
24	5.00	5.00	35.00	180.00
25	2.50	7.00	45.00	90.00
26	5.00	5.00	35.00	360.00
27	7.50	3.00	45.00	90.00

28	7.50	7.00	25.00	270.00
29	5.00	5.00	35.00	0.00
30	2.50	7.00	25.00	90.00

Table.2. Nutritional composition of fresh Golden melon per 100g

Analysis	**Mean values**
Moisture	90.66 ± 1.52 %
Ash	0.76 ± 0.05 %
Phenols	2.33 ± 0.03 mg GAE/g
Antioxidant activity	50.41 ± 0.04 %
Vitamin C	43±0.05mg/100g
Total dietary fiber	0.043±0.03g
Reducing sugars	8.89±0.03 %
pH	6.59±0.11

*All values are mean significant value

Table 3: Analysed results of the responses variables for the 30 treatments

The treatments obtained by using response surface methodology were analysed for their physico chemical properties or response variables to check the effect of different treatments on the nutritive and sensorial properties of osmotically dehydrated golden melon. All the treatments were compared with each other on the basis of these analysis to get a final treatment with higher acceptability and lesser loss of nutrients.

30 Treatmets of Response Surface Methodology										
Run	Size	Blanching time	TSS	Dipping time	Phenols	A.O	Rehydration ratio	Ascorbic acid	Sugar	Sensory analysis
1	2.50	3.00	45.00	270.0	0.59	36.32	0.32	25.21	11.97	5.800
2	7.50	7.00	25.00	90.00	0.39	36.11	0.22	22.71	9.39	4.3.00
3	5.00	9.00	35.00	180.0	0.25	30.43	0.28	21.02	10.45	5.7.00
4	2.50	3.00	25.00	90.00	1.82	44.57	0.18	29.93	8.81	6.0.00
5	7.50	3.00	25.00	270.0	0.72	41.98	0.26	26.54	10.51	4.7.00

ISSN:0971-1260
Vol-22-Issue-16-August-2019

6	7.50	3.00	45.00	270.0	0.21	35.97	0.62	21.02	9.74	4.1.00
7	7.50	7.00	45.00	270.0	0.38	26.44	0.35	22.51	9.68	4.5.00
8	2.50	3.00	25.00	270.0	0.72	30.63	0.16	26.49	11.78	6.0.00
9	2.50	3.00	45.00	90.00	1.94	48.59	0.17	32.33	10.14	6.1.00
10	5.00	5.00	35.00	180.0	0.57	32.98	0.24	24.02	9.86	4.9.00
11	5.00	5.00	15.00	180.0	0.88	37.96	0.21	28.63	10.21	4.9.00
12	5.00	5.00	35.00	180.0	0.57	33.78	0.24	24.02	9.86	4.9.00
13	2.50	7.00	45.00	270.0	0.61	33.29	0.27	28.63	11.87	5.1.00
14	5.00	1.00	35.00	180.0	1.64	52.01	0.31	29.82	10.02	5.9.00
15	5.00	5.00	35.00	180.0	0.57	33.57	0.19	24.02	9.89	4.9.00
16	2.50	7.00	25.00	270.0	0.49	34.46	0.21	24.04	11.14	5.2.00
17	7.50	3.00	35.00	90.0	1.83	52.19	0.32	30.02	8.85	3.6.00
18	0.00	5.00	35.00	180.0	0.93	38.62	0.19	28.42	11.01	6.2.00
19	10.0	5.00	45.00	180.0	0.46	34.46	0.32	23.62	9.01	4.0.00
20	7.50	7.00	55.00	90.00	0.41	29.85	0.24	23.12	10.32	4.4.00
21	5.00	5.00	35.00	180.0	0.72	30.43	0.32	25.24	12.11	4.2.00
22	5.00	5.00	35.00	180.0	0.21	32.44	0.24	21.02	9.86	4.9.00
23	5.00	5.00	35.00	180.0	0.34	32.32	0.22	21.89	9.09	4.4.00
24	5.00	5.00	35.00	180.0	0.42	31.86	0.22	23.15	9.76	4.8.00
25	2.50	7.00	45.00	90.00	0.94	36.49	0.21	28.77	11.06	5.6.00
26	5.00	5.00	35.00	360.0	0.21	30.43	0.36	19.18	9.57	4.8.00
27	7.50	3.00	45.00	90.00	1.47	50.07	0.34	29.01	9.24	3.7.00
28	7.50	7.00	25.00	270.0	0.21	31.09	0.21	19.16	8.93	4.9.00
29	5.00	5.00	35.00	0.00	1.61	44.07	0.22	29.14	9.29	3.6.00
30	2.50	7.00	25.00	90.00	0.35	38.56	0.23	22.14	9.31	5.4.00

Table :4 Analysis of variance for response surface quadratic model for osmotic dehydration of golden melon:

The coefficients of variance for response surface quadratic model which was used in second order polynomial equation for all the response variables. Second order polynomial model was fitted to the experimental data (eqn 1):

$$У_1=\beta_0+\beta_1x_1+\beta_2x_2+\beta_3x_3+\beta_{12}x_1x_2+\beta_{13}x_1x_3+\beta_{23}x_2x_3+\beta_{11}x_1^2+\beta_{22}x_2^2+\beta_{33}x_2^2+e \quad (1)$$

ISSN:0971-1260
Vol-22-Issue-16-August-2019

In the above equation y is representing the response variable, β_0 is a content term and $\beta_{11,}$ β_{22},$\beta_{33}$are representing the quadratic coefficients as well as β_{12},β_{13},β_{23} representing the interaction coefficients,x_1,x_2,$x_{3,}$$x_4$,$x_5$,$x_6$ representing the independent variables where as A,B,C,D are coded value for size of fruit pieces, blanching time, TSS of syrup, dipping time respectively.

Coefficients	X1	X2	X3	X4	X5	X6
A(β_1)	-0.12	-0.73	0.045	-0.87	-0.56	-0.63
B(β_2)	-0.35	-4.13	0.020	0.47	0.063	-0.041
C(β_3)	-0.013	-0.90	0.040	0.23	0.38	-0.10
D(β_4)	-0.33	-3.48	0.032	0.78	0.38	0.15
AB(β_{12})	-0.010	-1.89	-6.038	0.12	-0.44	0.29
AC(β_{13})	-0.086	-1.22	0.022	-0.55	-0.17	-0.053
AD(β_{14})	3.750E-003	0.67	9.375E-003	-0.011	-0.40	0.21
BC(β_{23})	0.11	-1.36	-0.021	0.15	-0.19	0.024
BD(β_{24})	0.28	1.55	-0.013	-0.39	-0.34	-0.078
CD(β_{34})	-0.045	-0.36	0.044	-0.45	-0.22	-0.12
A2(β_{11})	0.059	0.80	6.354E-003	0.065	0.066	0.087
B2(β_{22})	0.12	1.47	0.016	0.13	0.12	0.25
C2(β_{33})	0.085	0.21	8.854E-003	0.51	0.35	-0.061
D2(β_{44})	0.11	0.98	0.051	-0.27	-0.079	-0.41

3D graphs and second order polynomial equations of all the response variables:

Phenols(X_1):

The mathematical expression showing the second order polynomial equation by analysing the data for all the 30 treatments of RSM for phenolic content

$2.37-0.12 \times A-0.35 \times B-0.013 \times C-0.33 \times D-0.010 \times A \times B -0.086 \times A \times C + 3.750E-003 \times A \times D- 0.11 \times B \times C - 0.28 \times B \times D -0.045 \times C \times D + 0.059 \times A^2 + 0.12 \times B^2+ 0.085 \times C^2 + 0.11 \times D^2$

Phenols (X_1): $2.37-0.12 \text{ x } A- 0.35 \text{ x } B-0.013 \times C- 0.33 \text{ x } D- 0.01 \text{ x } A \times B - 0.086 \text{ x } A \times C + 3.75E - 003 \text{ x } A \times D- 0.11 \text{ x } B \text{ x } C - 0.28 \text{ x } B \text{ x } D - 0.045 \text{ x } C \times D + 0.059 \text{ x } A^2 + 0.12 \text{ x } B^2 + 0.085 \text{ x } C^2 + 0.11 \text{ x } D^2$

ISSN:0971-1260
Vol-22-Issue-16-August-2019

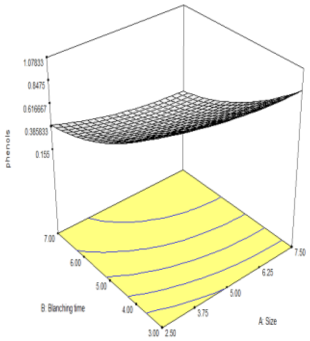


fig 1(a)

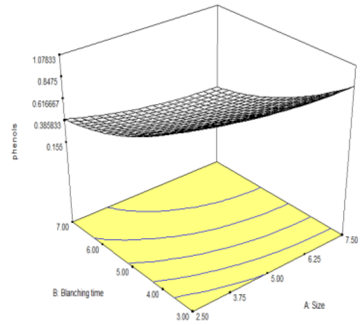


fig (b)

Figure:1(a,b): Response surface and contour graphs showing the effect of blanching time, size, dipping time and TSS of syrup on phenolic content of osmotically dehydrated golden melon

Antioxidants(X_2): $33.67-0.73\times A-4.13\times B-0.90\times C-3.48\times D-1.89\times A\times B-1.22\times A\times C-0.67\times A\times D$ $1.36\times B\times C+1.55\times B\times D-0.36\times C\times D+0.80\times A^2+1.47\times B^2+0.21\times C^2+0.98\times D^2$

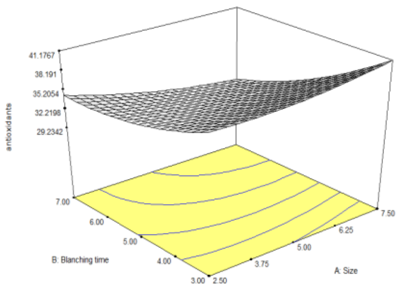


fig 2(a)

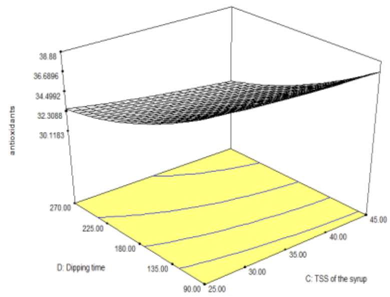
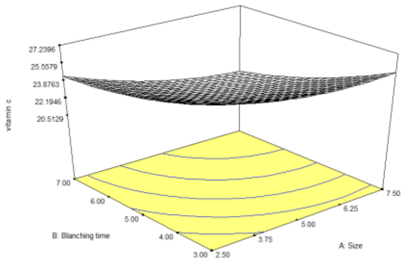


fig 2(b)

Fig:2(a,b): Response 3D graph and contour plots showing the effect of blanching time , size of fruit pieces , dipping time and TSS of syrup on antioxidant activity content of osmotically dehydrated golden melon

Vitamin C (X_3): $23.01 - 1.39 \times A - 1.97 \times B + 0.13 \times C - 1.87 \times D + 0.53 \times A \times B - 0.96 \times A \times C - 0.41 \times A \times D - 0.41 \times B \times C + 1.26 \times B \times D + 1.25 \times C \times D - 0.47 \times A^2 + 0.77 \times B^2 + 0.62 \times C^2 + 0.031 \times D^2$

ISSN:0971-1260
Vol-22-Issue-16-August-2019



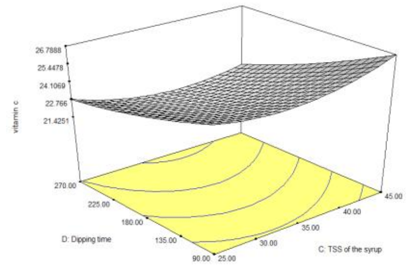
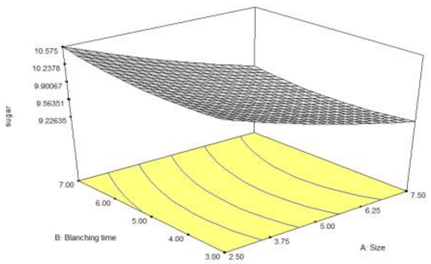


fig 3(a) **fig 3(b)**

Fig:3(a,b) : Response 3D graph and contour plots showing the effect of blanching time , size of fruit pieces , dipping time and TSS of syrup on vitamin C content of osmotically dehydrated golden melon

Reducing sugars (X_4): 9.72- 0.56 x A + 0.063 x B + 0.38 x C + 0.38 x D- 0.44 x A x B-0.17 x A x C+ 0.40 x A x D + 0.19 x C- 0.34 x B x D- 0.22 x C x D + 0.066 x A^2 + 0.12 x B^2+ 0.35 x C^2- 0.079 x D^2



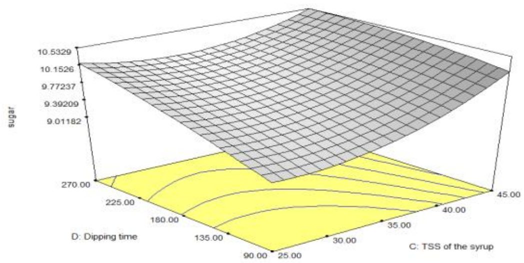
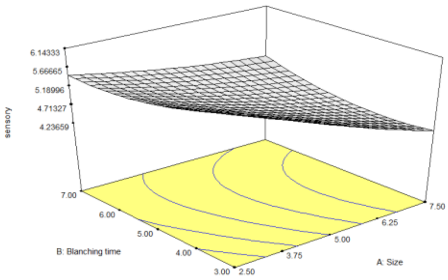


fig 4(a) fig 4(b)

Fig 4 (a,b): Response 3d graph and contour plots showing the effect of blanching time, size of fruit pieces, dipping time and TSS of syrup on reducing sugars of osmotically dehydrated golden melon

Sensory evaluation (X_5): 4.84 - 0.63 x A - 0.041 x B- 0.10 x C + 0.15 x D + 0.29 x A x B - 0.053 x A x C + 0.21 x A x D - 0.078 x B x D - 0.12 x C x D + 0.087 x A^2 + 0.25 x B^2 - 0.061 x C^2 - 0.4

ISSN:0971-1260
Vol-22-Issue-16-August-2019



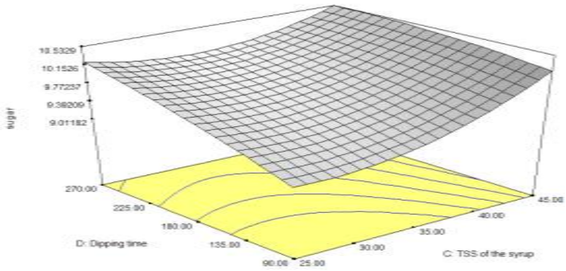


fig 5(a) fig 5(b)

Fig 5 (a, b): Response 3D graph and contour plots showing the effect of blanching time, size of fruit pieces, dipping time and TSS of syrup on acceptability of osmotically dehydrated golden melon.

ISSN:0971-1260
Vol-22-Issue-16-August-2019

Fig. 6. Osmotically dehydrated cantaloupe conditions optimized with RSM

Fresh fruit

↓

Washing, slicing

↓

Preparation of sugar syrup of different concentrations

↓

dipping into osmotic solutions of different concentrations for different time

↓

Air drying at 60^0 C Temperature

Fig. 7. Flow sheet for the preparation of osmotically dried cantaloupe