OPTIMUM PROCESS PARAMETERS FOR DEVELOPMENT OF SWEET AONLA FLAKES

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ABSTRACT

To develop a product 'sweet aonla flakes' of high consumer acceptability, the aonla slices of 2mm thickness were first osmotically pretreated and than convectively dried at constant air temperature of 60°C to safe moisture level of 10% wet basis. Different experimental combinations of osmotic process parameters i.e sugar concentration, solution temperature, solution to fruit ratio and immersion time were tried using Box and Behnken design of experiments. Response surface methodology (RSM) was used to investigate the effect of sugar concentration (50-70°B), solution temperature (30-60°C), solution to fruit ratio (4:1-8:1) and immersion time (60-180 min) on the water loss, solute gain, vitamin-C loss and overall acceptability of osmo-convectively dried aonla slices having moisture content of 10% w.b. An analysis of variance (ANOVA) revealed that among the process variable temperature has remarkable effect on responses. In comparison to solution to fruit ratio the sugar concentration, solution temperature and immersion time showed significantly higher effect on all the quality responses. Optimization of the osmotic dehydration process was performed to result maximum water loss, solute gain, overall acceptability and minimum vitamin-C loss. The optimum process parameters obtained by computer generated response surfaces, canonical analysis and contour plot interpretation were: 70^0B of sugar concentration, 60°C of solution temperature, 6.8:1 of solution to fruit ratio and 72 min of immersion time. The sweet aonla flakes developed under optimized condition were of high consumer acceptability and were in close agreement to the predicted quality values.

Keywords: *Aonla, Flakes; Optimization; Osmosis; Response surface methodology*

1. INTRODUCTION

Aonla (*Phyllanthus emblica* L.) or Indian gooseberry, an important fruit, is highly valued among indigenous medicines. The main cultivated varieties are Banarasi, Bansi Red, Chakaiya, Desi, Krishna, Kanchan (NA-4), Francis (Hathijool), NA-6, NA-7, NA-8, NA-9, NA-10 and Pink tinged (Rakesh et al 2004). Aonla fruits are a natural source of vitamin-C and work better than synthetic ascorbic acid in cure of deficiency diseases. The fresh aonla fruits are not popular as a table fruit due to their high astringency and its storability after harvesting is also limited due to its high perishable nature (Kumar and Nath 1993). The other methods of extending shelf life are by cold storage, sun drying and hot air drying or by processing to murabba, pickle, juice syrup, squash and dehydrated powder (Kalra 1988). Among these processes, dehydration offers many advantages, such as reduced weight, inexpensive packaging, dry shelf stability and negligible deterioration in quality due to enzymatic changes. Among various drying methods available, open sun drying and solar drying have been exploited to some extent and has the limitations of high solar radiations (Bhatia et al 1959,Ramasastri 1975, Sethi 1986, Verma and Gupta 1996). The climatic adversities, contamination by insects and dust, quality loss i.e. vitamin-C loss, browning, lower consumer acceptability are some of the important reasons to look for some simple and inexpensive alternate process, which may be energy intensive and require low capital investment but also offer a way to save highly perishable products and enhance the quality and availability of the produce. The osmotic dehydration is one of these new methods (Shi and Maguer 2002).

Osmotic dehydration is a process of partial removal of water by soaking foods, mostly fruits and vegetables, in hypertonic solutions. The driving force for the diffusion of water from the plant tissue into the solution is difference between osmotic pressures of hypertonic solution and plant tissue. The diffusion of water is accompanied by simultaneous counter diffusion of solutes from the solution into the tissue (Lazarides et al 1995). Leakage of the natural solutes from the plant tissue occurs because the cell membranes of plant tissue responsible for osmotic transport, is not perfectly selective but this flow is negligible, although it may be important for the organoleptic and nutritional properties of the product (Heng et al 1990, Mizrahi et al 2001). Osmotic dehydration, which is effective even at ambient temperature and saves the colour, flavour and texture of food from heat, is used as a pretreatment to improve the nutritional, sensorial and functional properties of food. The food which has been osmotically dehydrated, can be further processed by freezing, freeze drying vacuum drying and air drying (Nanjundaswamy et al 1978). Sugar, glucose, fructose, corn syrup and sodium chloride are the common osmotic agents and out of this sodium chloride solution is commonly used for vegetables and sucrose solution for the fruits. Only limited efforts have so far been made to process aonla into dehydrated product (Palodkar et al 2003). An expanding interest currently exists for osmo-convective dehydrated products in the domestic and world markets. No attempt has been made to optimize the osmotic process parameters for osmo-convectively dehydrated product of aonla. The purpose of the present work was to study the effect of osmotic process parameters (sugar concentration, solution temperature, solution to fruit ratio and immersion time) on quality responses (water loss, solute gain, vitamin-C loss and overall acceptability) and also to optimize these parameters for developing a new product 'Sweet aonla flakes' of higher quality.

2. MATERIALS AND METHODS

2.1 Experimental design: Response Surface Methodology or RSM is a collection of mathematical and statistical techniques that are useful for modeling and analysis of problems in which the response is influenced by several variables. It is reported to be an efficient tool for optimizing a process when the independent variables have the joint effect on the responses (Mudahar et al 1989). It has been applied in optimizing food-processing operations by several investigators (Floros and Chinnan 1987, Madamba and Lopez 2002, Ramos et al 1998, Rai et al 2004, Dhingra and Paul 2005). Hence, response surface methodology (RSM) was used to design the experiments. The Box- Behnken design of four variables and three levels each with three-center point combination was used (Box and Behnken 1960). This design was taken as it fulfills most of the requirements needed for optimization of the pretreatment (osmotic dehydration) process prior to convective drying. In the above design X_1, X_2, X_3, X_4 are the coded variables, which are related to un-coded variables using the following relation

$$X_i = 2(\xi_i - \bar{\xi}_i)/d_i \qquad (1)$$

where, ξ_i is variable value in actual units of the ith observation, $\bar{\xi}_i$ is the mean of highest and lowest variable value of ξ_i. and d_i is the difference between the highest and lowest variable value of ξ_i.
Based on the above relationship, the independent osmotic process variables and their levels in the form of coded variables for four-factor three level response surface analyses are given in Table 1. The independent process variables were sugar concentration, osmotic solution temperature, solution to fruit ratio and immersion time. The low level and high level in the actual (un-coded) form were 50-70^{0}B sugar, 30-60^{0}C, 4:1–8:1(w/v) and 60-180 minutes for osmotic solution concentration, temperature, solution to fruit ratio and immersion time, respectively (Azoubel and Murr 2004, Biswal et al 1991, Kar and Gupta 2001, Kar and Gupta 2003,Ozen et al 2002). Mostly sucrose is used as osmotic agent for fruits and salt for vegetables.
The experiment was conducted according to the requirements of response surface methodology for analyzing the data. A second order Box-Behnken design was conducted to work out the range of osmotic process variables for osmo-convective dehydration of aonla slices.

Table 1. Process variables and their levels

Independent variables	Symbol		Levels	
	Coded	Un-coded	Coded	Un-coded
Sugar Concentration (°B)	X1	C	1	70
			0	60
			-1	50
Temperature (°C)	X_2	T	1	60
			0	45
			-1	30
Solution to fruit ratio	X_3	STFR	1	8
			0	6
			-1	4
Immersion time (min)	X_4	t	1	180
			0	120
			-1	60

2.2 Sample preparation: Fresh aonla fruits of variety 'Francis' were procured from New Orchard, Punjab Agricultural University, Ludhiana, India. The fruits were sorted for uniform size, colour and physical damage, washed with fresh water and then wiped with a muslin cloth. As the aonla fruit waxy skin represents a high resistance to mass transfer, mechanical treatment was given to aonla with sharp stainless steel knife resulting sheet shape aonla slices of 2mm thickness. The initial moisture content of the fresh aonla slices was 87.78 % (w.b).

2.3 Osmotic agent concentrations: Sugar, the osmotic agent, was purchased from local market. The osmotic solutions of different concentrations (50°B, 60°B and 70°B) were prepared by dissolving required amounts of sugar in distilled water using magnetic stirrer. Concentrations were checked by HRN-18 hand refractrometer.

2.4 Osmotic dehydration: For each experiment, known weight of aonla slices were put in the stainless steel containers having calculated volume of osmotic solutions of different concentrations pre set at the desired temperature by water bath. During experimentation, it was assumed that the amount of solid leaching out of aonla slices during osmosis was negligible (Biswal and Bozorgmehr 1992, Lazarides et al 1995). At the specified times the aonla slices were removed from the osmotic solutions and rinsed with water to remove surplus solvent adhering to the surfaces. These osmotically dehydrated aonla slices were then spread on the absorbent paper to remove the free water present on the surface. A proportion of the pretreated aonla slices (5-8 gm) were used for determination of dry matter by oven method (AOAC 2000). The remaining part of each sample was dried to final moisture content of 10 % (wet basis) using a hot air drier preset at 60°C air temperature. The dried samples were cooled in a desiccators containing silica gel for half an hour, packed in HDPE bags and kept at ambient condition for quality analysis.

2.5 Measurement of water loss and solute gain: The mass transfer parameters i.e water loss and solute gain reflecting as one of the quality attributes of aonla were calculated by the equations given by Ozen et al (2002), Singh et al (2007):

$$\% WL = \text{water loss /100g fresh fruit}$$

$$= \frac{(W_0 - W_t) + (S_t - S_0) \times 100}{W_0} \qquad (2)$$

$$\% SG = \text{solute gain /100g fresh fruit}$$

$$= \frac{S_t - S_0}{W_0} \times 100 \qquad (3)$$

The other quality parameters i.e. vitamin-C and overall acceptability were evaluated by the procedure mentioned below:

2.6 Sensory evaluation of sweet aonla flakes: Organoleptic quality of developed product was determined with the help of a ten-member consumer panel using a 9-point hedonic scale following standard procedure. The aspects considered were colour, appearance, taste, flavour and overall acceptability. Overall acceptability was evaluated as an average of colour, appearance, taste and flavour score and is expressed in percentage. The average scores of all the 10 penalists were computed for different characteristics.

The vitamin-C content in fresh and dried samples was determined by the 2,6- dichlorophenolindophenol xylene extraction method (AACC 1969).

2.7 Optimization of process parameters: Response surface methodology was applied to the experimental data using a commercial statistical package, Design-Expert version 7.1.1 (Statease Inc, Minneapolis, USA, Trial version). The same software was used for the generation of response surface plots, superimposition of contour plots and optimization of process variables. The response surface and contour plots were generated for different interaction for any two independent variables, while holding the value of other two variables as constant (at the central value). Such three-dimensional surfaces could give accurate geometrical representation and provide useful information about the behavior of the system within the experimental design (Cox and Cochran 1964, Montgomery 2004). The optimization of the osmotic dehydration process aimed at finding the levels of independent variables viz. osmotic solution concentration, temperature, solution to fruit ratio and immersion time, which could give maximum possible water loss, solute gain and overall acceptability; and minimum vitamin-C loss.

3. RESULTS AND DISCUSSION

The value of various responses at different experimental combination for coded variables is given in Table 2. A wide variation in all the responses was observed for different experimental combinations i.e. 31.99 to 49.24% for water loss, 4.79 to 18.93% for solute gain, 68.42 to 91.12 % for vitamin-C loss and 71.99 to 89.90 % for overall acceptability. The maximum consumer acceptance was witnessed for the sample pretreated at experimental condition of 60^0B, 45^0C, 4:1 and 60 min immersion time.

Table 2. Experimental data for the four-factor three level response surface analyses

Coded				Un-coded				Responses			
X_1	X_2	X_3	X_4	C (^{0}B)	T (^{0}C)	STFR	t (min.)	WL (Y1)	SG (Y2)	VCL (Y3)	OA (Y4)
-1	-1	0	0	50	30	6	120	45	11.11	85.98	71.99
1	-1	0	0	70	30	6	120	39.96	18.93	85.47	72.69
-1	1	0	0	50	60	6	120	32	18.21	79.7	80.03
1	1	0	0	70	60	6	120	49.24	12.14	78.46	89.81
0	0	-1	-1	60	45	4	60	43.11	4.8	76.5	89.9
0	0	1	-1	60	45	8	60	42.78	6.31	74.88	84.26
0	0	-1	1	60	45	4	180	48.65	10.61	80.54	88.89
0	0	1	1	60	45	8	180	48.86	11.9	89.02	85.65
0	0	0	0	60	45	6	120	41.14	10.18	73.27	79.52
-1	0	0	-1	50	45	6	60	43.75	10.95	75.13	78.01
1	0	0	-1	70	45	6	60	47.53	12.32	68.42	81.02
-1	0	0	1	50	45	6	180	40.12	14.63	81.26	78.94
1	0	0	1	70	45	6	180	48.87	14.22	87.04	86.57
0	-1	-1	0	60	30	4	120	48.43	12.51	91.12	73.38
0	1	-1	0	60	60	4	120	37.81	5.27	82.4	88.89
0	-1	1	0	60	30	8	120	45.5	10.2	87.01	75
0	1	1	0	60	60	8	120	38.73	12.63	80.32	81.94
0	0	0	0	60	45	6	120	39.12	8.37	74.44	79.87
-1	0	-1	0	50	45	4	120	41.17	11.89	87.32	73.41
1	0	-1	0	70	45	4	120	48.39	9.26	88.32	80.32
-1	0	1	0	50	45	8	120	42.42	11.65	78.05	76.16
1	0	1	0	70	45	8	120	43.85	10.26	80.04	81.94
0	-1	0	-1	60	30	6	60	45.39	11.39	75.62	80.33
0	1	0	-1	60	60	6	60	43.67	9.12	71.51	89.81
0	-1	0	1	60	30	6	180	47.58	11.43	83.5	85.19
0	1	0	1	60	60	6	180	44.42	16.55	82.96	86.57
0	0	0	0	60	45	6	120	40.21	9.73	72.29	81.57

The data was analyzed employing multiple regression technique to develop a response surface model. A linear model and a second order model with and without interaction terms were tested for their adequacies to describe the response surface and R^2 values were calculated. A second order polynomial of the following form was fitted to the data of all the responses and results are given in Table 3.

$$y_k = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \beta_{ii} x_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \beta_{ij} x_i x_j \qquad (4)$$

Where β_i , β_{ii} , β_{ij} are constant coefficient and χ_i χ_j are coded independent variables.

All the four models were tested for their adequacy using ANOVA technique. *F*-values for the lack of fit were non-significant ($p < 0.01$) thereby confirming the validity of the models. Analysis of experimental values for responses revealed that water loss, solute gain, vitamin-C loss and overall acceptability could be treated with 0.864, 0.925, 0.889 and 0.896 coefficient of determination, respectively.

Table 3. Analysis of variance of process variables as linear, quadratic and interactive terms on response Variables

Source	Degree of freedom	Sum of Squares			
		Water loss (%)	Solute gain (%)	% Vitamin C loss	% Overall acceptability
Model	14	399.947***	265.187***	842.146***	724.716***
Linear	4	164.148***	56.306***	439.440***	394.604***
Quadratic	4	115.791***	98.388***	446.736***	185.092***
Cross product	6	142.984***	86.384***	69.176***	62.533***
Residual					
Lack of Fit	10	60.789	19.607	102.039	81.969
Pure Error	2	2.040	1.760	2.317	2.411
Total error	12	62.829	21.368	104.356	84.380
Coefficient of determination (R^2)		0.864	0.925	0.889	0.896

*** Significant at 1% level

Table 3 shows that the combined effect of all the process variables was significant at linear and quadratic and interaction level ($p < 0.01$) for all the responses. Further statistical analysis for overall effect of the process variables on all the responses was performed. In simple terms, the values obtained gives factor wise analysis of variance i.e. the contribution of each independent variable to the total sum of squares are separated. The results revealed the higher influence of concentration, temperature and time in comparison to solution to fruit ratio irrespective of the responses. The concentration showed most significant effect on WL and SG; temperature has most significant effect on OA; immersion time showed significantly higher effect on all the responses ($p < 0.01$) (Table 4).

Table 4. Analysis of variance for the overall effect of the process variables on four responses

Process variables	df	Sum of Squares			
		Water loss (%)	Solute gain (%)	% Vitamin- C loss	(%)Overall acceptability
Concentration	5	238.748***	102.042***	123.002***	169.572***
Temperature	5	186.425***	115.587***	234.049***	340.642***
STFR	5	37.734***	44.450***	276.052***	30.168**
Time	5	103.0***	65.382***	391.426***	164.380***

** Significant at 5% level, *** Significant at 1% level

The full second order model of the form was fitted to data and regression coefficients were computed the results of which are reported in Table 5.

Table 5. Regression coefficients (un-coded variables) from quadratic model and their significance

Term	Regression coefficient	Water loss (k=1)	Solute gain (k=2)	% Vitamin-C loss (k=3)	(%) Overall acceptability (k=4)
Constant	β_0	207.26	95.92	387.21	-9.58
Concentration	β_1	-2.59798***	-2.73930	-5.39273	3.0477***
Temperature	β_2	-2.75143***	-0.30191	2.3606***	0.07544***
STFR	β_3	-3.70052	0.81457*	-24.24269	1.21012
Time	β_4	-0.35996	-0.04233***	-0.42075***	-0.36840
Concentration* Temp	β_{12}	0.03714***	-0.02314***	-0.00121	0.01515
Concentration* STFR	β_{13}	-0.07245	0.01533	0.01234	-0.01406
Concentration * Time	β_{14}	0.00207	-0.00074	0.0052*	0.00193
Temperature * STFR	β_{23}	0.03205	0.0806***	0.01701	-0.07137
Temperature * Time	β_{24}	-0.00040	0.00205**	0.00099	-0.00225
STFR * Time	β_{34}	0.00111	-0.00046	0.02107	0.00501
Conc * Conc	β_{11}	0.01159	0.03139***	0.03959***	-0.02996**
Temp * Temp	β_{22}	0.00260	0.01057***	0.0225***	0.00043
STFR * STFR	β_{33}	0.5204*	-0.41227**	1.6254***	0.15287
Time * Time	β_{44}	0.0011***	0.00013	0.0001	0.0014***

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level

The sign and magnitude of the coefficients indicate the effect of the variable on the response. Negative sign of the coefficient means decrease in response when the level of the variable is increased while positive sign indicated increase in the response. Significant interaction suggests that the level of one of the interactive variable can be increased that of other decreased for constant value of the response (Montgomery, 2004).

3.1 Effect of variables on water loss: Fig. 1 shows that the water loss decreased with increase in temperature but increased with increase in concentration whereas, it showed initial decrease followed by increase with the immersion. The maximum value of water loss was observed for combination of lower temperature and solution to fruit ratio. Among the process variable studied the concentration witnessed maximum affect on water loss (Table 4). It was also affected by the interaction of concentration and temperature as shown in Table 5. It can be seen that water loss was found to be significantly affected by concentration, temperature individually followed by concentration: temperature and time: time interaction ($p < 0.01$) whereas, lower affect of solution to fruit ratio: solution to fruit ratio interaction was observed ($p < 0.1$).

3.2 Effect of variables on solute gain: In Fig. 1 the solute gain increases with increase in immersion time whereas, maximum solute gains were observed for higher temperature lower concentration and for lower temperature higher concentration combinations. Moreover, solute gain was highly affected by solution temperature followed by concentration (Table 4). It can be seen from Table 5 that solute gain was found to be significantly affected by time ($p < 0.01$) and solution to fruit ratio ($p < 0.1$) individually followed by interaction of concentration and temperature; quadratic terms of concentration and temperature ($p < 0.01$) and solution to fruit ratio ($p < 0.05$).

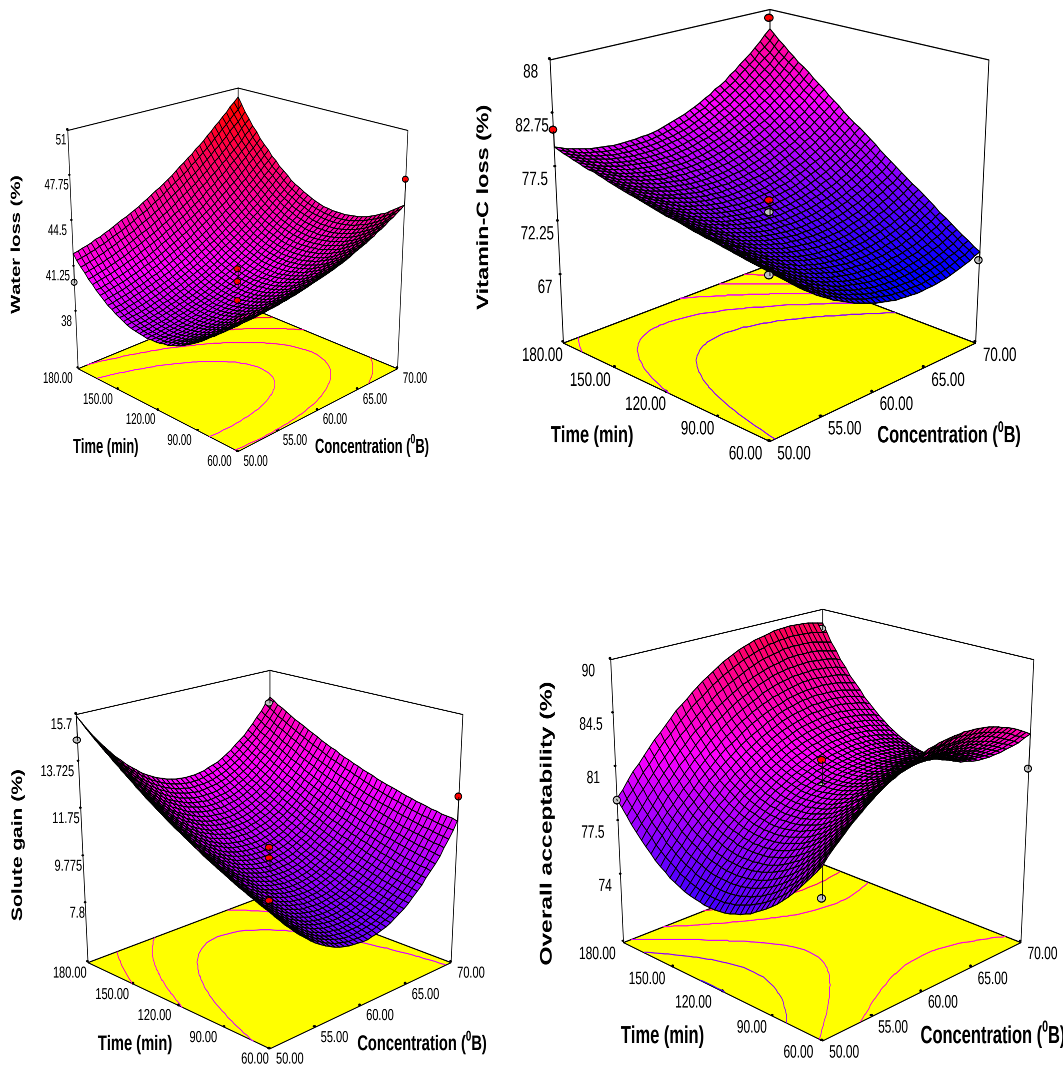

Figure 1 Response surface plots for water loss, solute gain, vitamin C loss and overall acceptability

3.3 Effect of variables on vitamin-C loss: The vitamin-C loss decreases with increase in all the process variables except immersion time. The minimum vitamin-C loss was observed for the temperature above 35^0C, solution to fruit ratio above 5.5 and concentration above 55^0B with the condition that immersion time should be less than 100 minutes (Fig. 1). The immersion time showed significantly higher affect on vitamin-C loss in comparison to other process variables (Table 4). From Table 5 it can be seen that vitamin-C loss was significantly affected by temperature, time individually followed by quadratic terms of concentration, temperature and solution to fruit ratio ($p < 0.01$). Moreover, the concentration: time interaction also influenced the vitamin-C loss ($p < 0.1$).

3.4 Effect of variables on overall acceptability: The overall acceptability of the dehydrated product increased with increase in all the process variables except with the increase of solution to fruit ratio. The maximum acceptance was noticed for the product osmotically dehydrated under process condition of high temperature, high concentration and low solution to fruit ratio with the condition that immersion time should be either less than 90 minutes or more than 150 minutes (Fig. 1). The solution temperature witnessed significantly higher affect on overall acceptability in comparison to other process variables (Table 4). It is clear from statistically analyzed data presented in Table 5 that individually concentration, temperature (p<0.0 1) significantly affected the overall acceptability whereas, the interaction terms was found to have non-significant effect on overall acceptability. Moreover, the quadratic terms of immersion time (p<0.01) and sugar concentration (p<0.05) also significantly affected the acceptability of the product.

3.5 Optimization of osmo-convective dehydration process: Graphical multi-response optimization technique was adopted to determine the workable optimum conditions for the osmotic dehydration of aonla slices. The contour plots for all the responses were superimposed and regions that best satisfy all the constraints were selected as optimum conditions. The main criteria for constraints optimization were maximum possible water loss, solute gain, overall acceptability and minimum vitamin-C loss (Themelin et al 1997, Ade-Omowaye et al 2002). These constraints resulted in "feasible zone" of the optimum conditions (shaded area in the superimposed contour plots). Superimosed contour plots having common superimposed area of all the responses for osmo-convective dehydration in sugar solution are presented from Fig. 2. The optimum range of process parameters obtained for osmo-convective dehydration of aonla slices for developing the product sweet aonla flakes were: 66 to 70 ^{0}B of osmotic solution concentration, 54 to 60^{0}C of osmotic solution temperature, 6.5:1 to 7.9:1 of solutions to fruit ratio and 60 to 93 minutes of immersion time.

Table 6. Optimum values of process parameters and responses

Process parameters	Target	Experimental range		Importance	Optimum values	Desirability
Concentration (^{0}B)	is in range	50	70	3	70	
Temperature (^{0}C)	is in range	30	60	3	60	
STFR	is in range	4	8	3	6.8	
Time (min)	is in range	60	180	3	72	
Responses					Predicted values	0.763
Water loss (%)	maximize	31.999	49.243	3	49.05	
Solute gain (%)	maximize	4.798	18.932	3	9.96	
Vitamin-C loss (%)	minimize	68.416	91.120	3	72.31	
Overall acceptability (%)	maximize	71.991	89.904	5	89.28	

In order to optimize the process conditions for osmotic dehydration process by numerical optimization technique, equal importance of '3' was given to all the four process parameters (viz. osmotic solution concentration, solution temperature, solution to fruit ratio and immersion time). However, based on their relative contribution to quality of final product, the importance given to different responses was 3, 3, 3, and 5 for water loss, solute gain, vitamin-C loss and overall acceptability, respectively. Maximum importance was given to the overall acceptability, because it includes a number of parameters like appearance, texture, colour, flavour and taste. The optimum operating condition for osmotic solution concentration, temperature, solution to fruit ratio and immersion time was 70 ^{0}B, 60 ^{0}C, 6.8:1 and 72 minutes, respectively. Corresponding to these values of process variables, the value of water loss is 49.05 g water/ 100g fresh fruit, solute gain 9.96 g/100g fresh fruit, vitamin-C loss 72.31% and overall acceptability 89.28% (Table 6). The overall desirability was 0.763. The conditions were experimentally verified with deviation of $\pm$ 0.15%.

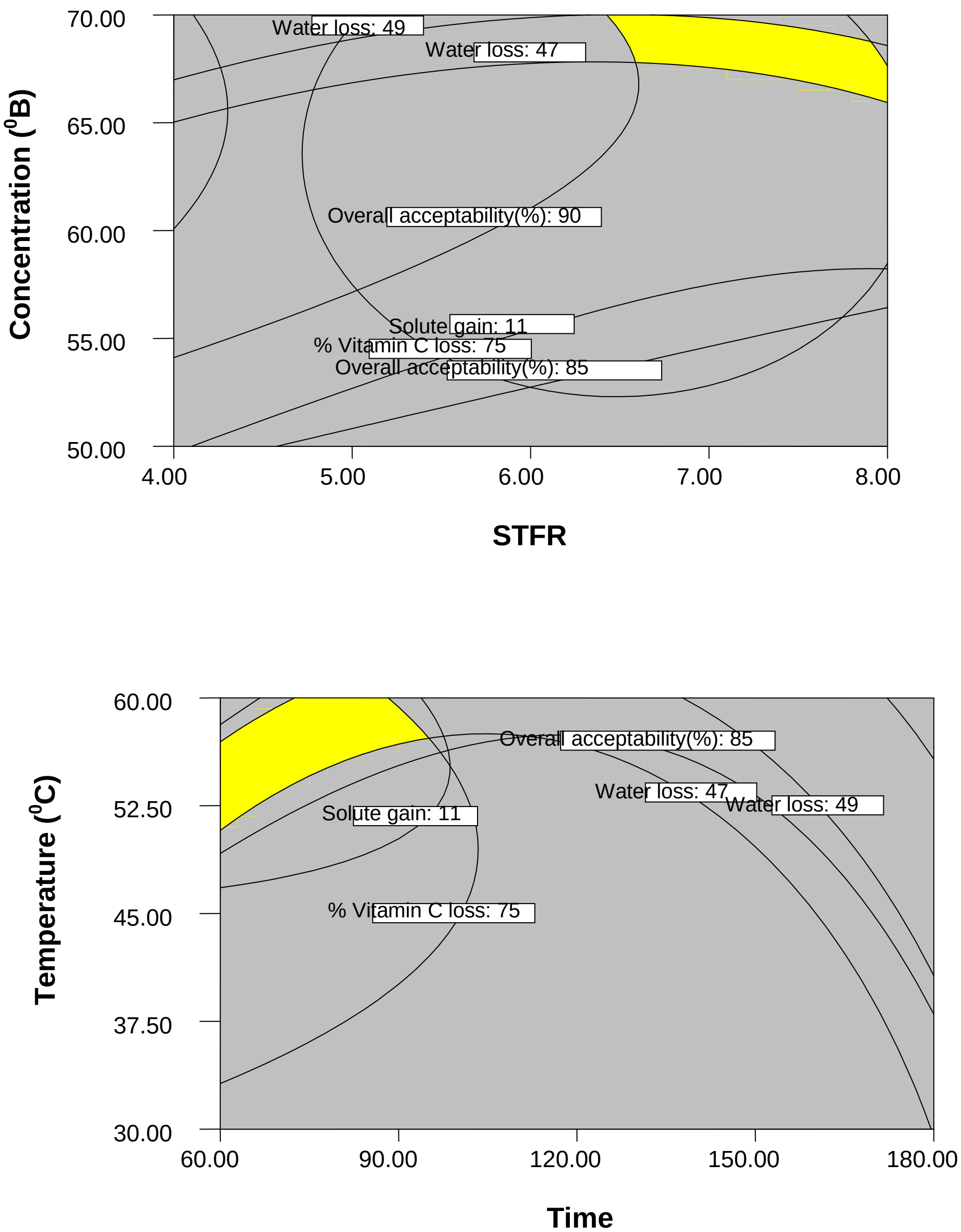

Figure 2 Overlaid contours of different responses for optimization of process parameters

4. CONCLUSIONS

Response surface methodology was effective in optimizing process parameters for osmotic dehydration of aonla slices in osmotic aqueous solution of sugar having concentration in the range of 50 to 70^{0}B sugar, temperature 30 to 60^{0}C, solution to fruit ratio 4:1 to 8:1 and immersion time 60 to 180 minutes. The regression equations obtained in this study can be used for optimum conditions for desired responses within the range of conditions applied in this study. Graphical techniques, in connection with RSM, aided in locating optimum operating conditions, which were experimentally verified and proven to be adequately to be reproducible. Optimum solutions by Numerical optimization obtained was 70 ^{0}B sugar solution concentration, 60 ^{0}C osmotic solution temperature, 6.8:1 solution to fruit ratio and 72 minutes of immersion time to get maximum possible water loss, solute gain, overall acceptability and minimum vitamin-C loss. The model equation for the response variables predicted values under the identified optimum conditions, which were experimentally verified to be in general agreements with the model.

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NOMENCLATURE:

C	concentration (^{0} Brix)
OA	overall acceptability (%)
R^2	coefficient of determination
S_0	initial dry matter of fruit (g)
S_t	dry matter of fruit after osmotic dehydration for any time t (g)
SG	solute gain (%)
STFR	solution to fruit ratio
T	temperature (^{0}C)
t	immersion time (min)
VCL	vitamin-C loss (%)
WL	water loss (%)
W_0	initial weight of fruit taken for osmotic dehydration (g)
W_t	weight of fruit after osmotic dehydration at any time t (g)
X_1	coded independent variable for sugar concentration
X_2	coded independent variable for solution temperature
X_3	coded independent variable for solution to fruit ratio
X_4	coded independent variable for immersion time
β_i	regression coefficients for linear terms
β_{ii}	regression coefficients for quadratic terms
β_{ij}	regression coefficients for interactive terms