RESEARCH PAPER | International Journal of Agricultural Engineering | Volume 8 | Issue 2 | October, 2015 | 160-168
e ISSN–0976–7223 ■ Visit us : *www.researchjournal.co.in* ■ **DOI: 10.15740/HAS/IJAE/8.2/160-168**

Foaming behaviour of sapota pulp

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Received : 25.07.2015; **Revised :** 05.08.2015; **Accepted :** 04.09.2015

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■ **ABSTRACT :** Foaming of sapota pulp was carried out by foaming device at various levels of pectin, egg albumin and methyl cellulose at different levels. The influences of pectin, egg albumin and methyl cellulose concentration on the foaming characteristics in terms of foam expansion and foam stability were subsequently evaluated. Foam expansion and foam stability increased with increasing concentration of pectin and methyl cellulose. The optimum foam expansion of 60.35 per cent and foam stability of 77.13 per cent were obtained with the addition of pectin and methyl cellulose to sapota pulp at optimum concentration of 2.21 per cent and 4.41 per cent, respectively. The foam expansion was very low (25%) with egg albumin. Higher concentration of foaming agents within selected range produced uniform size of air bubbles. Response surface analysis yielded quadratic models that explained the influence of the foaming agents on foam expansion and foam stability.

■ **KEY WORDS :** Sapota pulp, Pectin, Methyl cellulose, Foam expansion, Foam stability

■ **HOW TO CITE THIS PAPER :** Durge, S., Srivastav, P.P. and Jaybhaye, R.V. (2015). Foaming behaviour of sapota pulp. *Internat. J. Agric. Engg.*, **8**(2) : 160-168.

Sapota is one of the most popular tropical fruits besides mango, custard apple, and several others. The total soluble solids (TSS) range from 14 to 20 Brix. Also, sapota fruit contains carotene, rich in vitamins, carbohydrates, fibres, and proteins. Moreover, the ripe sapota fruit needs to be consumed within a couple of days due to the highly perishable nature. Therefore, it is essential to process sapota to increase the shelf-life (Jangam *et al*., 2008) and the best way is to dehydrate peeled sapota (Ganjyal *et al.*, 2005) and prepare powder. The sapota powder is used as natural flavour in jams, ice creams, and milk shakes. Sapota fruit has high fibre content and hence, the powder can be consumed as a fibre supplement for children as well as adults.

Foaming phenomenon and its mechanism is of interest to the food technologist. In foam formation or foam destruction, controlling and maintaining the desired condition is the ultimate goal in producing the desired product characteristics (Karim and Wai, 1999). Foams are inherently unstable systems (Dickinson and Stainsby, 1987) and it is a two-phase system having a dispersed phase (usually air) and a continuous phase (Fig. A). The dispersed phase is larger than the continuous phase (Aubert *et al*., 1989). In foams gas bubbles are dispersed in a relatively small volume of liquid with lower foam densities extending from nearly zero to about 200 kg/m^3.

The foam structure plays a major role in moisture movement during drying and also on subsequent product quality. Most prior works have emphasized on the drying characteristics of foamed foods (Cooke *et al*., 1976; Garcia *et al*., 1988; Karim and Wai, 1999; Sankat and Castaigne, 2004).

Dehydration is the most cost effective and viable method. In foaming the addition of edible foaming agents converts liquid material into stabilized foam. The foaming renders the drying mass extremely porous and more amenable to drying to its inner most layers (Berry *et al.*, 1965; Hart *et al.*, 1963; Morgan *et al.*, 1961;

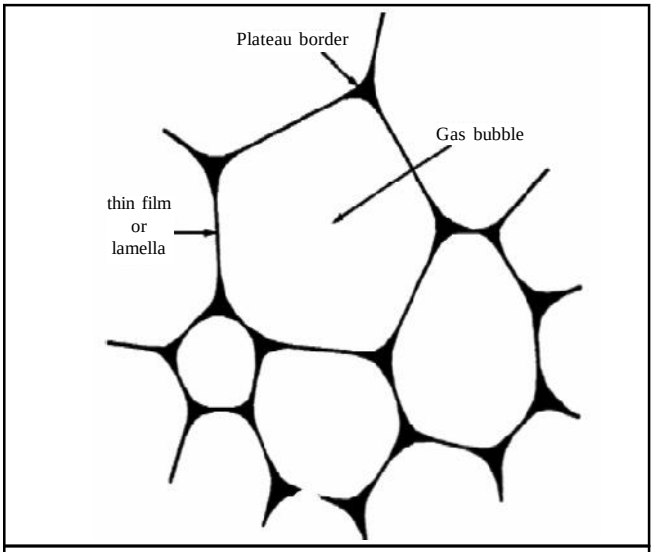

Fig. A : Structure of foam (Wilde and Clark, 1996)

Venkataraman, 1996). In Foam mat drying there is transformation of product from liquid to stable thin porous foam sheet or mat at relatively low temperature to form a free flowing powder (Hart *et al*., 1963; Anjaria and Chivate, 1966).

Rajkumar *et al.* (2007) foamed Alphonso mango pulp and found 1 per cent soy protein, 2 per cent glycerol mono stearate, and 10 per cent egg albumen as optimum concentrations of each foaming agent. The foam mat dried powder at 60 ºC retained a significantly higher ($P<$ 0.05) content of biochemical compounds than at higher temperatures. Addition of Xanthan Gum (0.125%) during foaming reduces the total drying time of foam-mat freeze drying of egg white (Muthukumaran, 2007). The addition of stabilizer also plays an important role in improving the heat and mass transfer. In preparation of mixed vegetable (bitter gourd, tomato and cucumber) juice powder, along with foam expansion and foam stability, the solubility index also increases with increase in concentration of foaming agent and drying temperature (Chandrasekar *et al.*, 2015).

Foam mat drying reduces drying time and dried powder reconstitutes readily. This process is of potential interest for developing countries for its simplicity and economics (Anjaria and Chivate, 1966; Akintoye and Oguntllnde, 1991; Beristain *et al*., 1993). This method offers a wide scope for application in vegetables and fruits juice processing which are difficult to dry, sticky and heat sensitive materials. On a commercial scale, it is finding increasing application and importance in drying of liquids that turn out a high quality concentrate such as milk, fruit juices, soluble coffee, etc. (Chandak and Chivate, 1972; Dodeja and Sharma, 1989). Considering relatively high TSS content of sapota pulp and sticky dried product, the present study was undertaken to prepare a foam mat dried product from sapota pulp and optimise the process parameters.

METHODOLOGY

Sapota pulp :

Fresh sapota (*Achras zapota*) fruits were procured from the local market in Kharagpur (India) and then the fruits were washed in fresh water. The flesh portion of sapota was sliced and pulped using sieve of opening 10 micrometer materials. Pulp was mixed with sodium meta bi-sulphate (1%) and bottled. Bottled pulp was boiled at 100°C and stored at room temperature.

Foaming of sapota pulp :

The sapota fruit pulp was converted into stable foams using a chemical foaming agent. A laboratory model whipping / foaming device having provision for air incorporation was used which was designed and developed using perspex material by Patel (1996) and modified by (Dhamanskar, 2007).

Foaming device :

Foaming device works on the principle of an ordinary turbine agitator. The schematic view of the foaming device used for the foaming of the sapota fruit pulp is shown in Fig. B.

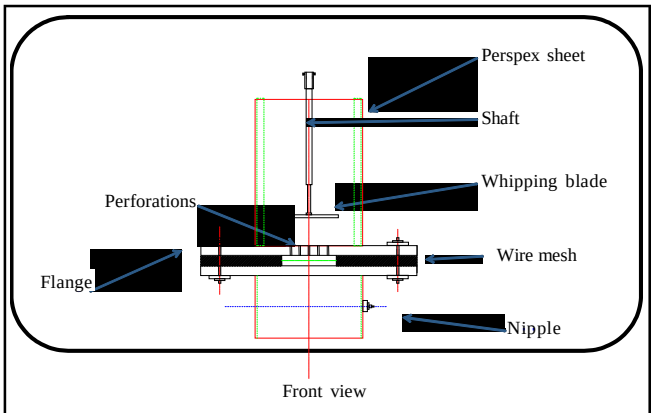

Fig. B : Schematic view of foaming device

It consisted of two sections, a cylindrical vessel or holding tank with flat bottom and an air compression

chamber of equal diameter as that of vessel. The flat bottom of the vessel was extended 30 mm outside around the periphery to serve as a flange. An equal size of flange was also provided on the top of the compression chamber. The two sections were joined together through the flanges with the help of nut and bolts. Perforations of diameter 1 mm were drilled on the bottom plate of the vessel around the periphery of 37 mm radius for air surging. A brass nipple of 5 mm diameter and 35 mm length was provided in the air chamber to connect the unit to air compressor. In between the flanges a fine cloth was placed along with rubber gasket on its top and bottom side. The cloth prevented the material (to be whipped) from passing down the air chamber and at the same time allows the compressor air to pass through. Four measuring scales equally spaced, were provided on the circumference of the vessel to measure the height/ depth of the foamed material in the vessel.

Whipping blade made of stainless steel (1.6 mm thick) with three cutting edges to agitate the material in the vessel. The blade was placed centrally in the vessel and connected to a universal AC/DC electric motor (0.5 kW) through a stainless steel shaft of 12 mm diameter. In order to avoid vortex formation during whipping, four stainless steel baffles were provided on the vessel wall. A variable transformer was connected to motor to control the speed. A stroboscope was used to measure the rotational speed of the whipping blade. A pre-calibrated rotameter was used for monitoring compressed air flow rate.

Selection of foaming agents for preliminary analysis:

Experiments were conducted to investigate the effect of egg albumin, pectin and methyl cellulose (foam inducers and stabilizers) on foaming properties of sapota pulp foam with the view to provide the basis for selection of suitable foaming agent as well as its optimal concentration. Egg albumin and pectin as foam inducers (0.1% to 2% at 0.1% interval), and methyl cellulose (1-5%) as stabilizer to stabilize the foam during the drying operation were used in varying concentration range. It was observed that pectin gives more (double) volume of foam compared to that produced using egg albumin. Therefore, pectin and methyl cellulose were finally selected as independent variables and foam volume and foam stability were taken as dependent variables. The ranges of these variables were selected based on their effectiveness as a foaming and stabilizing agent. Pectin and methyl cellulose prepared at the rate of 0.5 g per 100 g of pulp and 1 g per 100 g of pulp, respectively for 400 g of total sapota pulp. The prepared combinations of samples were foamed followed by spreading on Teflon mat.

Production of foam :

Measured quantity of sample solution was taken into the vessel of the foaming device. A predetermined quantity of foaming agent was dispersed in the added water and mixed thoroughly. The initial height / depth of this mixture were recorded. Compressed air was then allowed to pass through the bottom of the vessel at a controlled rate and the blade was rotated at desired speed. The air flow and the rotation of whipping blade were stopped simultaneously after desired time period of 6 min and the height of the foamed material in the vessel was recorded. All the experiments were done at room temperature.

The foaming properties, such as, foam expansion (overrun) and foam stability were determined using the standard procedure as described by Patel (1996), Chandak and Chivate (1972), Halling (1981) and Rajkumar *et al.* (2007).

Foam expansion :

The per cent foam expansion (FE) was calculated from the height/ depth of material in the vessel before and after whipping using the following formula :

$$\text{Foam expansion (\%)} = \frac{Ha - Hi}{Hi} \times 100 \quad (1)$$

where,

Ha = Height of the material after foaming (cm)

Hi = Initial height of the material (cm)

Foam stability :

The foam was allowed to stand for 60 min at room temperature after which the volume drained out liquid and that of the foam were read directly on the measuring cylinder. The per cent foam stability (FS) was calculated as follows:

$$\text{Foam stability (\%)} = \frac{V_f}{V_i} \times 100 \quad (2)$$

where, V_f = Foam volume at 60 min; V_i =Initial volume of foam including the liquid volume without foaming.

Foam mat drying of sapota pulp :

The sapota pulp foam (10 g) was spread on each aluminum tray with a foam-mat thickness of 2 mm and 3 mm and dried in tray dryer. The drying temperature in dryer was fixed at 50 °C (Chandrasekar *et al.*, 2015) as air at very high temperatures and velocity resulted in collapse of the foam. To monitor weight loss during drying the trays were taken out of the dryer at regular intervals, weighed by using electronic balance and quickly replaced inside the dryer. The experiments were continued till the dried product attained constant weight. Moisture content (% w.b) of the product at different stages of the drying process was calculated.

Experimental design using central composite rotatable design (CCRD) :

In order to determine the effect of independent variables on response variables thirteen experiments were designed using central composite rotatable design. Table A shows the experimental design for two variables pectin and methyl cellulose and expressed in coded values. The experiments were randomized in order to in order to minimize the effect of unexplained variability in the observed responses due to extraneous factors. The centre point was repeated five times to calculate the reproducibility of the method (Montgomery, 2001).

The coded levels and actual values of process variables are given in Table A (Myers, 1971). The actual values at given coded levels are calculated using eq. 3:

$$Ya_{ij} = X_{ij} \times V_i + Ya_3 \quad (3)$$

where,

i = 1 to 2, number of process variables

j = 1 to 5, number of levels

Ya_{ij} = Actual value of i^{th} process variable at given j^{th} coded level

X_{ij} = Coded value of i^{th} process variable at given j^{th} coded level

V_i = interval of variation for i^{th} process variable

Ya_3 = Actual value of i^{th} variable at its central coded level

(Xi_3) = Average of extremities of range of actual values

Sapota pulp foaming and foam mat drying experiments were carried out and RSM was applied to the experimental data using a commercial statistical package, *Design Expert - version 7.0* (Statease Inc., Minneapolis, USA; Stat-Ease, Inc. 2002). The following second order polynomial response surface model (Eq. 4) was fitted to each of the response variable (Y_k) with the independent variables (X_i) :

$$Y_k = b_{k0} + \sum_{i=1}^{4} b_{ki} X_i + \sum_{i=1}^{4} b_{kii} X_i^2 + \sum_{i \neq j=1}^{4} b_{kij} X_i X_j \quad (4)$$

where, b_{k0}, b_{ki}, b_{kii}, and b_{kij} are the constant, linear, quadratic and cross-product regression co-efficients, respectively and X_i's are the coded independent variables of X_1, X_2, X_3 and X_4.

Data analysis :

The response surface models (Eq.4) were fitted the data and statistical significance of the model terms was examined by conducting regression analysis and analysis of variance (ANOVA). The adequacy of the models was determined using model analysis, lack-of fit test and R^2 (co-efficient of determination) analysis as described by Lee *et al.* (2000) and Weng *et al*. (2001) and Pardeshi *et al*. (2014).

Optimization of process parameters :

Optimization of the process parameters and corresponding foam quality parameters *viz*., foam expansion and foam stability was done using *Design Expert 7.0* software. The simultaneous optimization of multiple responses was carried out both numerically and graphically. The desired goals for each factor and response were chosen and different weights were assigned to each goal to adjust the shape of its particular desirability function. The optimization was done for maximizing the foam expansion and maximizing foam stability and the corresponding optimum values of process parameters were selected at maximum desirability by software itself.

Table A : Levels and coded values of independent variables for foaming and drying of sapota pulp

Name of variable	Range (%)	Code (X_i)	Levels					Interval variation
			X_{i1}	X_{i2}	X_{i3}	X_{i4}	X_{i5}	
			-1.4142	-1	0	+1	+1.4142	
Pectin	0.5 – 2.5	X_1	0.5	0.79	1.5	2.21	2.5	0.5
Methyl cellulose	1.0 – 5.0	X_2	1.0	1.59	3.0	4.41	5.0	1.0

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Foam expansion of sapota pulp :

Foam Characteristics of Sapota pulp at different concentrations of additives conducted under the fixed operating parameters of the foaming device are as shown in Table 1 and 2.

Foam expansion increased with increase in concentration of foaming agent. Maximum foam expansion of 50 per cent was obtained with methyl cellulose (1.6%) which was more than 25 per cent expansion obtained with egg albumin (1.6%). This value of methyl cellulose was very higher than 0.5 per cent but near to 2 per cent glycerol mono stearate as optimum concentrations of foaming agents for Alphanso mango pulp reported by Rajkumar *et al.* (2007). The foam expansion values were very less than 94.8 per cent at maximum levels of foaming agent reported by the authors.

Foam stability of sapota pulp :

Foam stability was calculated using the same combinations of stabilizing agent and foaming agent which were used in foam expansion experiment as shown in Table 2. Maximum foam stability of 60 per cent was achieved with the combination of pectin (1.6 %) and methyl cellulose (1.6 %). The result indicated that the combination of pectin (1.6%) and methyl cellulose (1.6%) gave better foam expansion and foam stability as compared to the combination of egg albumin (1.4%) and methyl cellulose (1.4%). Therefore, the combinations of egg albumin and methyl cellulose were deleted for further experiments.

Effect of process variables on foaming behaviour of sapota pulp :

The quality parameters of sapota pulp foam at different process parameters are shown in Table 3. The value of foam expansion varied from 15.0 per cent to 65.23 per cent and that of foam stability varied from 22.45 per cent to 80 per cent at various level combinations of pectin and methyl cellulose. The

Table 1 : Foam expansion of sapota pulp at maximum level of treatment combinations

Foaming agent	Stabilizing agent	Foam expansion (%)
Egg albumin (1.4%)	Methyl cellulose (1.4%)	25
Pectin (1.6%)	Methyl cellulose (1.6%)	50

Table 2 : Foam stability of sapota pulp at maximum level of treatment combinations

Foaming agent	Stabilizing agent	Foam stability (%)
Egg albumin (1.4%)	Methyl cellulose (1.4%)	35
Pectin (1.6%)	Methyl cellulose (1.6%)	60

Table 3 : Sapota pulp foam quality parameters obtained at different treatment combinations

Expt. No.	Independent variables		Response variables	
	Pectin	Methyl cellulose	Foam expansion	Foam stability
1.	1.50	1.01	16.00	22.45
2.	0.79	4.41	45.00	37.00
3.	2.50	3.00	65.23	80.00
4.	1.50	3.00	47.00	55.00
5.	1.50	3.00	50.00	50.00
6.	0.79	1.59	15.00	29.00
7.	0.50	3.00	17.50	45.00
8.	2.21	1.59	39.00	60.00
9.	1.50	3.00	45.00	51.00
10.	1.50	3.00	41.60	48.00
11.	1.50	4.99	50.00	60.00
12.	1.50	3.00	43.20	43.00
13.	2.21	4.41	57.50	75.00

maximum foam expansion of 65 per cent was obtained at combination of 2.5 per cent and 3 per cent level of pectin and methyl cellulose, respectively.

The ANOVA of foam expansion data (Table 4) indicated that the quadratic model could be fitted with high F-value of 22.89. The model terms are significant at $p<0.005$. The linear terms pectin (A) and methyl cellulose (B) were highly significant and contributed more to foam expansion than quadratic term of methyl cellulose (B^2). That means both the process variables have maximum influence on foam expansion.

The high F-value, R^2 value and non-significant lack of fit proved the adequacy of the model. The empirical equation (Eq.1) in terms of coded factors showing relation between foam expansion as a function of two independent process variables is as follows:

$$\text{Foam expansion} = +45.36+13.00\times A+12.25\times B-2.87\times A\times B-1.45\times A^2-5.88\times B^2 \quad (1)$$

The negative co-efficients of first order terms pectin and methyl cellulose indicated that foam expansion decreased with decrease of these variables. The positive co-efficients of first order terms of pectin and methyl cellulose indicated that foam expansion increased with increase of these variables.

The variations of foam expansion at different levels of process parameters were graphically shown in the 3-D surface plot and contour plot (Fig. 1). It is clear from the graph that lower foam expansion resulted at low concentration of pectin and methyl cellulose. Increase in foam expansion with increasing the concentration of pectin and methyl cellulose was found which was due to the formation of air bubbles and foamed structures by incorporation of air. Higher concentration of foaming agents within selected range produced uniform size of

Table 4 : Analysis of variance for foam expansion data

Source	F	p-value	Co-efficient estimate	R-Squared
Model	22.89502	0.0003	45.3600	0.9424
A-Pectin	54.6997	0.0001	13.0000	
B-Methyl cellulose	48.5674	0.0002	12.2496	
AB	1.3376	0.2854	-2.87500	
A^2	0.5912	0.4671	-1.4493	
B^2	9.7370	0.0168	-5.8818	
Lack of fit	4.0126	0.1064		

Std. Dev. = 4.97 Mean = 40.85 C.V. % = 12.17

Table 5 : Analysis of variance for foam stability data

Source	F	p-value	Co-efficient estimate	R-Squared
Model	16.9946	0.0009	49.4000	0.9238
A-Pectin	50.5151	0.0002	14.8121	
B-Methyl cellulose	20.8360	0.0026	9.5129	
AB	0.3525	0.5713	1.7500	
A^2	7.5647	0.0285	6.1468	
B^2	4.0373	0.0845	-4.4906	
Lack of fit	5.0435	0.1124		

Std. Dev. = 5.89 Mean = 50.42 C.V. % = 11.69

Table 6 : Software generated three optimum conditions with corresponding responses for foamed sapota pulp

Pectin	Methyl cellulose	Foam expansion	Foam stability	Desirability
2.21	4.41	60.35	77.13	0.96
2.21	4.39	60.37	77.10	0.96
2.2	4.41	60.25	76.72	0.95

Table 7 : Comparison of experimental and predicted values

Response	Predicted value	Actual value	% Variation
Foam expansion	60.35	59.58	0.013
Foam stability	77.13	74.25	0.037

air bubbles.

Effect of process variables on foam stability of sapota pulp :

Observations of foam stability with different combinations of the process parameters are given in Table 3. The experimental values of foam stability varied between 22.45 per cent and 80 per cent at the experimental levels of process parameters and maximum foam stability was obtained at the pectin level of 2.5 per cent and methyl cellulose level of 3.0 per cent. The maximum value of 80 per cent foam stability was near to the value of 97 per cent for mixed vegetable juice as reported by Chandrasekar *et al.* (2015).

The ANOVA for foam stability (Table 5) indicated that quadratic model could be fitted to experimental data with high model F-value of 16.99. The model was significant at $p<0.005$. The linear terms pectin (A) and methyl cellulose (B) contributed more to the foam stability than quadratic terms of pectin (A^2) and methyl cellulose (B^2). That indicates that pectin and methyl cellulose had maximum influence on stability.

The high F-value, R^2 value and non-significant lack of fit showed the adequacy of developed model. The empirical equation (Eq. 2) in terms of coded factors showing foam stability as a function of two independent process variables pectin (A) and methyl cellulose (B) is as follows:

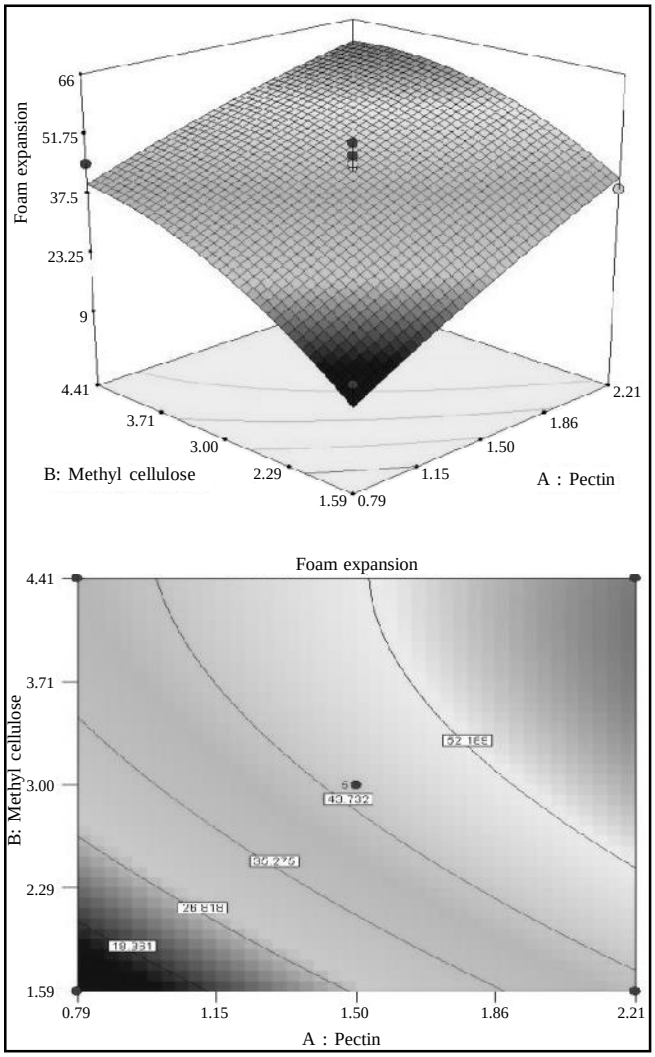

Fig. 1 : Response surface and contour plot for the effect of pectin and methyl cellulose on foam expansion of sapota pulp

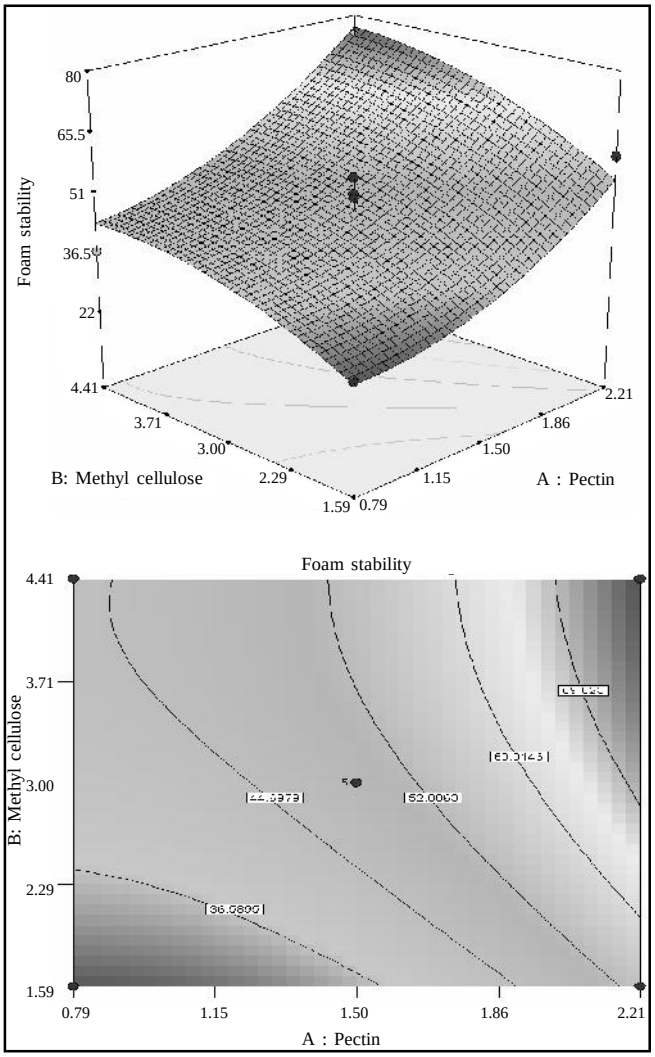

Fig. 2 : Response surface and contour plots for the effect of pectin and methyl cellulose on foam stability of sapota pulp

$$\text{Foam stability} = +49.40 + 14.81 \times A + 9.51 \times B + 1.75 \times A \times B + 6.15 \times A^2 - 4.49 \times B^2 \quad (2)$$

The positive co-efficients of first order terms of pectin and methyl cellulose indicated that foam stability increased with increase of these variables while negative co-efficients of their quadratic term suggested that excessive increase of these variables resulted in decrease of foam stability. The pectin and methyl cellulose indicated that foam stability increased with increase of these variables.

The response surface plot and contour plots are shown in Fig 2. It is clear from the figure that methyl cellulose has more significant effect on stability of foam at higher levels of pectin.

Optimization of process parameters :

In numerical optimization the software generated three optimum conditions of independent variables at which the predicted values of responses for foamed sapota pulp can be obtained. Solution having maximum desirability value was selected as the optimum condition. The maximum foam expansion of 60.35 per cent and foam stability of 77.13 per cent can be achieved at 2.21 per cent and 4.41 per cent level of pectin and methyl cellulose, respectively (Table 6). The foam mat drying temperature of 50^0 C was found suitable as the dried product was stable and good in appearance. This temperature was well close to 55^0 C found suitable for tomato paste and fruit juices by Kudra and Ratti (2006).

Verification of model :

Foaming experiments were conducted at the optimum process condition and the quality attributes of the resulting product were determined. The experimental values (mean of three replication) and values predicted by the equations of the model are presented in Table 7. Percentage variation indicated that the experimental results were sufficiently close to the predicted one.

Conclusion :

The process was developed for preparation of the sapota pulp foam and foam mat dried sapota pulp powder. The effects of concentration of pectin and methyl cellulose on the foaming properties such as foam expansion and foam stability were investigated. The maximum foam expansion of 65.23 per cent and foam stability of 80 per cent was obtained at 2.5 per cent pectin and 3 per cent methyl cellulose level, respectively.

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REFERENCES

Akintoye, O.A. and Oguntllnde, O.A. (1991). Preliminary investigation on the effect of foam stabilizers on the physical characteristic and reconstruction properties of foam-mat dried soymilk. *Drying Technol.*, **9**(1) : 245-262.

Anjaria, B.Y. and Chivate, M.R. (1966). Studies in foam mat drying. *Indian Chemical Engineer's Transactions*, **8**(3) : 64-68.

Aubert, J.H., Kraynik, A.M. and Rand, P.B. (1989). Aqueous foams. *American Scientific J.*, **241**: 74-83.

Beristain C.I., Garcia H.S. and Vazquez A. (1993). Foam-mat dehydration of Jamica (*Hibiscus sabdariffa* L.) instant drink. *Drying Technol.*, **11** : 221-228.

Berry, R.E., Bisset, O.W., Wagner, Jr. C.J. and Veldhuis, M.K. (1965). Foam-mat dried grapefruit juice. Time-temperature drying studies. *Food Technol.*, **19**(3) : 126-128.

Chandak, A.J. and Chivate, M.R. (1972). Recent development in foam mat drying. *Indian Food Packer*, **26**(6) : 26-32.

Chandrasekar, V., Swamy, J., Kannan, G.K. and Sangamithra, A. (2015). Effect of foaming agent concentration and drying temperature on physiochemical and antimicrobial properties of foam mat dried powder. *Asian J. Dairy & Food Res.*, **34**(1): 39-43.

Cooke, R.D., Breag, G.R., Ferber, C.E.M., Best, P.R. and Jones, J. (1976). Studies of mango processing-I. The foam-mat drying of mango (Alphonso cultivar) puree. *J. Food Technol.*, **11**: 463-473.

Dhamanskar (2007). Development of process technology for production of Bael pulp powder using foam mat drying. M.Tech Thesis, Indian Institute of Technology, Kharagpur, W.B. (INDIA).

Dickinson, E. and Stainsby, G. (1987). Progress in the formulation of food emulsions and foams. *Food Technol.*, **41**(9) : 74-81.

Dodeja, A.K. and Sharma, S.C. (1989). Foam mat drying of food product- A review. *J. Agril. Engg.*, **25**(2) : 314-328.

Ganjyal, G.M., Hanna, M.A. and Devadattam, D.S.K. (2005). Processing of sapota (sapodilla): Powdering. *J. Food Technol.*, **3**(3) : 326-330.

Garcia, R., Leal, F. and Rolz, C. (1988). Drying of banana using microwave and air ovens. *Internat. J. Food Sci. & Technol.*, **23** : 73-80.

Halling, P.J. (1981). Protein-stabilised foams and emulsions. *CRC Critical Rev. Food Sci. Nutrit.*, **15** : 155-203.

Hart, M.R., Graham, R.P., Ginnette, L.F. and Morgan, Jr., A.I. (1963). Foams for Foam-mat drying. *Food Technol.*, **17**(10) : 90-92.

Jangam, S.V., Joshi, V.S., Mujumdar, A.S. and Thorat, B.N. (2008). Studies on dehydration of sapota. *Drying Technol.*, **26**(3) : 369-377.

Karim, A. Abd (1999). Characteristics of foam prepared from starfruit puree by using methyl cellulose. *Food Hydrocolloids*, **13** : 203-210.

Karim, A.A. and Wai, C.C. (1999). Foam-mat drying of starfruit (*Averrhoa carambola* L.) puree. Stability and air drying characteristics. *Food Chem.*, **64** : 337-343.

Kudra, T. and Ratti, C. (2006). Foam-mat drying: Energy and cost analyses. *Canadian Biosystems Engg.*, **48**(3) : 27-32.

Lee, J., Ye, L., Landen, W.O. and Eitenmiller, R.R. (2000). Optimization of an extraction procedure for the quantification of vitamin E in tomato and broccoli using response surface methodology. *J. Food Composition & Analysis*, **13** : 45-57.

Montgomery, D.C. (2001). *Design and analysis of experiments* (5th Edn). New York: John Wiley, pp.455-492.

Morgan, A.I., Graham, R.P., Ginnette, L.F. and Williams, G.S. (1961). Recent developments in foam-mat drying. *Food Technol.*, **15** : 37-39.

Muthukumaran, A. (2007). Foam-mat freeze drying of egg white and mathematical modeling. M.Sc. Thesis, Department of Bio-resource Engineering, Macdonald Campus of McGill University, Sainte-Anne-de-Bellevue (QC) H9X 3V9.

Myers, R.H. (1971). *Response surface methodology.* Allyn and Bacon, BOSTON, U.S.A.

Pardeshi, I.L., Chattopadhyay, P.K. and Jaybhaye, R.V. (2014). Optimization of process parameters for hot air puffing of wheat-soy based ready-to-eat (RTE) snacks: A response surface approach. *J. Ready to Eat Food*, **1**(3) : 85-99.

Patel, H. (1996). Development of a process technology for production of tomato powder using foam mat drying techniques, Ph.D Thesis, Indian Institute of Technology, Kharagpur, W.B. (INDIA).

Rajkumar, P., Kailappan, R., Viswanathan, R., Raghavan, G.S.V. and Ratti, C. (2007). Foam mat drying of alphonso Mango Pulp. *Drying Technol.*, **25** : 357-365, DOI: 10.1080/07373930601120126

Sankat, C.K. and Castaigne, F. (2004). Foaming and drying behaviour of ripe bananas. *Lebensmittel-Wissenshaft und-Technologie (LWT)*, **37** : 517-525.

Stat-Ease, Inc. (2002). Design Expert User's Guide; Design Expert Version 7.0, *The Stat-Ease Inc., MN,USA.*

Venkataraman, P.S. (1996). Success and failures in mango pulp processing industries in chitoor district of A.P. *Indian Food Packer*, **51**(1) : 57-58.

Weng W, Liu W and Lin W (2001). Studies on the optimum models of the dairy product Kou Woan Lao using response surface methodology. *AsianAustralasian J. Anim. Sci.*, **14**(10): 1470-1476.

Wilde, P.J. and Clark, D.C. (1996). *Foam formation and stability. Methods of testing protein functionality*. G. M. Hall, Blackie Academic & Professional : 111 - 152.