International Journal of Food Science and Nutrition
ISSN: 2455-4898
Impact Factor: RJIF 5.14
www.foodsciencejournal.com
Volume 3; Issue 4; July 2018; Page No. 44-51

Process optimization for the preparation of bael (*Aegle marmelos correa*) fruit powder by spray drying

Apurba Saha[1*], Navdeep Jindal[2]

[1] Department of Fish Processing Technology, College of Fisheries, Central Agricultural University, Lembucherra, Tripura, India

[2] Department of Food Engineering and Technology, Sant Longowal Institute of Engineering and Technology, Longowal, Dist- Sangrur, Punjab, India

Abstract

Aim of this work was to optimize the process parameters for the production of spray dried fruit powder from bael fruit (*Aegle marmelos correa*). The independent variables for spray drying were maltodextrin concentration (10 to 20%), feed concentration (10 to 15°brix) and inlet air temperature of spray drier (130 to 190°C). The operating parameters like feed flow rate (30ml/min) and blower speed (2400 rpm) were kept constant for the study. A central composite rotatable design was used to optimize the conditions for spray drying of bael fruit. The independent variables significantly affected the physico-chemical and functional properties of the spray dried bael fruit powder. The optimized condition for spray drying of bael fruit powder was 16.11% maltodextrin concentration, 14.96 °brix feed concentration and 166.39°C inlet air temperature.

Keywords: bael fruit powder, spray drying, process optimization, maltodextrin, antioxidant and physicochemical properties

1. Introduction

The bael fruit is popular for its characteristic flavour and also for its soothing and refreshing effect. During the summer season it is consumed in the form of sarbat (bael pana). Bael have been used in ethno medicine to exploit its medicinal properties including astringent, antidiarrheal, antidysenteric, demulcent, antipyretic, anti-inflammatory and anti-allergenic activity (Maity *et al*., 2009, Getha and Varalakshmi, 2001) [31, 24], antidiabetic activity (Kamalakkanan and Prince, 2005) [27], antiulcer activity (Bandyopadhyay *et al*., 2002, Sachs *et al*., 2002, Dhuley, 2004) [18, 33, 21], antioxidant activity (Kamalakkannan *et al*, 2003) [28], radio protective activity (Jagetia *et al*., 2003, 2004) [25, 26], antibacterial activity (Singh *et al*, 1983) [34], antiviral activity (Fenner *et al*., 1993, Dhar *et al*., 1968, Babbar *et al*., 1982) [23, 20, 17]. Phytochemical constituents isolated from bael are alkaloids (Farooq, 2005, Manandhar *et al*., 1978) [22, 32], coumarins (Farooq, 2005, Kokate *et al*., 2002) [22], Polysaccharides (Basak *et al*., 1982), Carotenoids (Farooq, 2005, Ali and Pervez, 2004), antioxidants (Karakaya, 2004) [22, 16] and steroids.

The extracted pulp of bael fruit undergoes deterioration at room temperature due to exposure to atmospheric conditions like oxygen, atmospheric temperature and microorganisms (Rastogi *et al*., 2005) [9]. So for the preservation of the bael fruit pulp, dehydration is the best feasible method.

Spray drying is the simplest and most widely used industrial process for transforming fruit juices into powder form. The optimization of the spray drying process involves the evaluation of various parameters of the constituents of the feed solution (Wendel and Celik, 1997) [15]. The spray drying is a continuous process in which almost all liquid juices can be converted into powdered form. In spray drying, hot air used in a very high temperature above 1000C for few seconds. Due to less exposure time the powder is produced without heat degradation. Spray drying technique is very much suitable in case of heat sensitive products (Mermelstein, 2001) [7].

The spray dried fruit powder has some advantages like good keeping quality with low water activity and feasible for easier transport. The physicochemical properties of the spray dried fruit powder depends on the various conditions such as viscosity, particle size, flow rate of liquid feed, the inlet and outlet temperature of the air and concentration of the carrier agent used. So it is very much important to monitor the crucial state of process and formulate the liquid feed to optimize the drying process to obtain the fruit powder having good sensory and nutritional quality.

So the present study was undertaken to optimize the parameters of spray drying process viz maltodextrin concentration, feed (pulp) concentration and inlet air temperature of spray drier to produce a spray dried powder of good quality.

2. Practical application

Production of bael fruit powder by conventional tray or sun drying results colour degradation and loss of most volatile compounds. Bael fruit powder ensures longer storage life and easier storage. It can be used in preparation of soft drink, fruit juices, jams, jellies, candies, chocolates, milk based drinks, ice cream, etc. Bael fruit powder which retains the natural flavour, besides good keeping quality, would lead to greater convenience and increased consumption.

3. Materials and Methods

3.1 Materials

3.1.1 Raw Materials

Fully ripe bael fruits were purchased from the local market of

Agartala (India). The greenish yellow colored bael fruits were selected which were free from any dark spots and mechanical injuries.

3.1.2 Carrier agent

Maltodextrin (DE20) manufactured by Himedia laboratories was used as carrier agent.

3.2 Methods

3.2.1 Pulp Extraction Process

Fresh and fully ripened bael fruit was selected for the extraction of the pulp. Fruits were washed in cold tap water and graded. The hard rind of the fruit was broken manually. The pulp was extracted along with seeds and gums. The bael pulp was extracted by addition of distilled water (1:1 w/w) to facilitate the extraction process as well as removal of seeds (Roy and Singh 1979). The pulp was passed through the 20 mesh stainless steel sieve to remove the fibers, seeds and extraneous materials. This clear pulp was further ground in a juicer mixer grinder to get fine pulp which was stored in PET jars under refrigeration condition (4–7°C) for further study.

3.3 Experimental Design and Data Analysis for Spray drying process of bael fruit powder.

For preparation of spray dried bael fruit powder a central composite rotatable design was used to optimize the variables needed during the spray drying process and the ranges of the variables were chosen in accordance with references for spray drying of fruit juice (Rastogi *et al*., 2005) [9]. The independent variables considered were maltodextrin concentration (%; X1), feed mixture concentration (°Brix; X2), and inlet temperature (°C; X3). The independent variables and their levels of variation are shown in Table no 1. The level of every variable was determined by the data found in literatures and preliminary trial experiments. The total outline of experimental design with the coded and actual levels is shown in Table 2. Dependent variables were water activity, WSI, bulk density, moisture content, beta carotene and antioxidant activity as product responses. Response surface methodology (RSM) was applied to experimental data using commercial statistical software Design- Expert version 6.0.10 for the generation of response surface plots. This software was also used for statistical analysis of experimental data. The first step in RSM was to find a suitable approximation for the true functional relationship between the response (y) and the set of independent variables (X1, X2, and X3). The polynomial of higher degree such as the second-order model (Eq. 1) can be used for the study of responses.

$$Y = b0 + b1X1 + b2X2 + b3X3 + b4X12 + b5X22 + b6X32 + b7X1X2 + b8X1X3 + b9X2X3 \quad (1)$$

Where, y is the response. b0, b1, b9 are regression equation coefficients.

A blend of 1000 ml of bael fruit pulp and maltodextrin was prepared. Maltodextrin solution was prepared in warm water (about 50°C) with constant stirring followed by addition of measured amount of extracted bael fruit pulp to make the solution according to the design.

Pilot plant Spray-dryer (S.M. Scientech, India) with a concurrent air flow was used for the preparation of bael fruit powder. The blower speed was set at 2400 rpm for all the samples. Distilled water was pumped into the dryer at a set flow rate at 10 rpm (10 rpm = 30 ml/min) to achieve the inlet/outlet temperatures. All the parameters were selected by trial and error and in accordance with references. The dryer was run at the specified conditions for about 10 min before every feed sample was introduced. The product was collected in a pre-weighed, insulated glass bottle connected at the end of cyclone collector.

3.4 Physicochemical analysis of bael fruit and powder.

Freshly extracted pulp and spray dried bael powder was used for the analysis of the different physicochemical properties such as water activity, WSI, bulk density, moisture content, beta carotene and antioxidant activity. The procedures followed are discussed as follows.

3.4.1 Water activity

A water activity meter (COLE PARMER make) was used to measure water activity of the spray dried bael fruit powder.

3.4.2 Water solubility index (WSI)

The WSI of the bael fruit powder was determined using the method described by Anderson *et al*., (1969). Spray-dried bael fruit powder (2.5 g) and distilled water (30 ml) were vigorously mixed in a 100 ml centrifuge tube, incubated in a 37°C water bath for 30 min and then centrifuged for 20 min at 10,000 rpm in a J2-MC Centrifuge (Beckman, USA). The supernatant was carefully collected in a pre-weighed beaker and oven dried at a temperature of 105 ± 2°C. The WSI was calculated as the percentage of dried supernatant with respect to the amount of the original 2.5 g bael fruit powder.

3.4.3 Bulk density

Bulk density (g/ml) was determined by the method described by Goula *et al*. (2004) and slightly modified. 2 g of bael fruit powder was gently filled into an empty 10 ml graduated cylinder and held on a vortex vibrator machine for duration of 1 min. The ratio of mass and volume determines the bulk density of powder,

3.4.4 Moisture content

The moisture content of the bael fruit powder was determined as per AOAC, (1990) [1]

3.4.5 Total beta carotene

The carotenoid content of bael fruit powder was measured by the method described by Tran *et al*., (2008) [13] with some modification. Approximately 0.1g of bael fruit powder was weighed in a beaker and then extracted with 10 ml of the mixed solvent. The mixed solvent was prepared by a combination of n-hexane and acetone (3:2 v/v). The residue was further extracted several times using a magnetic stirrer until colorless, each time with 5 ml of the mixed solvent. The extracts were collected and washed twice to remove acetone each time with 25 ml of distilled water in a separating funnel. A few drops of saturated NaCl solution were added to the funnel to facilitate phase separation. The supernatant was collected to measure total carotenoid content. Pure carotene solution (0.0005-0.01 mg/ml) was used to construct the standard curve for the determination of total carotenoid content. Total carotenoid content of the bael fruit powder was spectrophotomatricaly determined at 473 nm and expressed based on carotene equivalents (mg/g of powder).

3.4.6 Total antioxidant activity

Antioxidant capacity was determined according to the method of Lai *et al*. (2001) with some modifications. Approximately 0.1 g of bael fruit powder was mixed with 0.9mL of 100mM Tris- HCl buffer (pH 7.4) to which 1mL of DPPH (0.500mM in ethanol) was added. The control sample was prepared in a similar way by adding 0.1g of maltodextrin instead of bael fruit powder. The mixtures were shaken vigorously and left to stand for 30 min. Absorbance of the resulting solution was measured at 517 nm using a spectrophotometer. The reaction mixture without DPPH (2, 2 Di Phenyl 1- Pecryl Hydrazyl) was used for the background correction. The antioxidant activity was calculated using following equation

% antioxidant activity = [1- (A sample / A control)] X 100 %

Where a sample and a control are the absorbance values of the sample and control at 517 nm, respectively.

4. Result and Discussion

In the present investigation efforts were made to standardize the process for the preparation of bael fruit powder from bael fruit. Effects of process parameters (maltodextrin concentration, concentration of feed and inlet air temperature) on physicochemical properties of bael fruit powder at constant operating parameters (feed flow rate and blowers speed) were studied.

4.1 Effect of spray drying parameters on physicochemical properties of bael fruit powder

The effect of process parameters on the physicochemical properties of the spray dried bael fruit powders have been shown in Table 2

4.1.1 Water activity

The average water activity of the spray dried powders in this study varied from 0.168 to 0.258. Thus bhel fruit powder was quite microbiologically stable. The water activity of the bael fruit powder decreased with the increase in the inlet air temperature, feed concentration and maltodextrin concentration.

The equation of the model fitted for the water activity of the sample in actual form of process variables after eliminating the non-significant terms was-

$$\text{Water activity} = +0.23-0.010 * X1-0.013 * X2-0.022 * X3-3.843E-003 * X12-3.135E-003 * X22-2.959E-003 * X32-3.625E-003 * X1 * X2+3.125E-003 * X1 * X3-7.375E-003 * X2\ X3 \quad (2)$$

Where X1, X2, X3 are the coaded values of % malto dextrin, feed concentration (°brix) and inlet air temperature respectively. An inverse relationship between these variables with water activity was obseved. Among these variables X3(inlet air temperature) is the dominating variable and is most significant than maltodextrin concentration and concentration of feed. Similar results were reported by Quek *et al*. (2007) [8] for the water activity of the spray dried melon powder.

4.1.2 Water Solubility Index (WSI)

The results showed that WSI of the bael fruit powder increased with the increase in the maltodextrin concentration.

The equation of the model fitted for the WSI of the sample in actual form of process variables after eliminating the non-significant terms was-

$$WSI = +86.64+2.59 * X1+1.40 * X2+1.21 * X3+1.19 * X12+0.50 * X22+0.94 * X32+0.51 * X1 * X2+0.26 * X1 * X3-1.11 * X2 * X3 \quad (3)$$

A positive coorelation between all the independent variable with WAI was observed and X1 (maltodextrin concentration) was the dominating variable and was most significant than feed concentration and inlet air temperature.

Similar results of increase in water solubility index with increase in maltodextrin concentration were observed in spray dried ginger juice powder. Water solubility index and yield increased with increasing drying aids (Maltodextrin) concentration. (Singhanat and Anong, 2010) [12].

4.1.3 Bulk density

Results showed that the bulk density of bael fruit powder decreased with the increase in maltodextrin concentration, increase in feed concentration and increase in inlet air temperature (table:2).

The equation of the model fitted for the bulk density of the sample in actual form of process variables after eliminating the non-significant terms was-

$$\text{Bulk Density} =+0.64-0.045 * X1-0.013 * X2-0.043 * X3-0.016 * X12-0.019 * X22+0.031 * X32-0.0095 * X1 * X2-0.013 * X1 * X3+0.022 * X2 * X3 \quad (5)$$

An inverse relationship between the independent variables with bulk density was observed Among these variables X1 (maltodextrin concentration) was the dominating variable and was most significant than feed concentration and inlet air temperature.

Abadio *et al*., 2004 [2] also reported similar results in case of spray dried pineapple (Ananas comosus) juice powder. This might be due to the lower moisture content of the powders and increase in void spaces. Higher inlet air temperature might have resulted in higher drying rates with less shrinkage of droplets and powder with increased internal voids, so powder had less bulk density.

4.1.4 Moisture content

Results showed decreased in moisture content with increase in maltodextrin concentration and temperature.

The equation of the model fitted for the moisture content of the sample in actual form of process variables after eliminating the non-significant terms was-

Moisture content = +3.54-0.42*X1-0.028*X2-0.22*X3-0.014 * X12 + 0.060 * X22 - 1.700E – 03 * X32 +0.074 * X1*X2+0.13* X1*X3-0.024* X2 * X3 (6)

An inverse relationship between the independent variables with moisture content was observed. Among these variables X1 (maltodextrin concentration) was the dominating variable and was most significant than feed concentration and inlet air temperature.

Abadio *et al*., 2004 [2] reported that same trend of decrease in the moisture content with the increase in maltodextrin concentration was observed in spray dried pineapple in which increase in the maltodextrin concentration resulted in decrease in the moisture content.

4.1.5 Beta carotene

The β-carotene content found decreased with the increase in the maltodextrin concentration and increase in inlet air temperature but increased with the increase in the feed concentration.

The equation of the model fitted for the beta carotene of the sample in actual form of process variables after eliminating the non-significant terms was-

Beta Carotene =+47.30-4.64 * X1+0.63* X2-0.39 * X3-0.37 * X12-2.14 * X22-1.68 * X32-0.58 * X1* X2+0.56* X1 * X3+0.44 * X2 * X3 (7)

An inverse relationship between co-efficients of X1, and X3 with beta carotene was observed. Whereas variable X2 had the positive co-relation. Among these variables X1 (maltodextrin concentration) was the dominating variable and is most significant than feed concentration and inlet air temperature.

Same effects were observed by Siew, *et al*., 2006 in spray dried gac aril powder. They observed that total carotenoid content (TCC) was significantly affected by maltodextrin concentration.

4.1.6 Antioxidant activity

DPPH radical scavenging capacity of spray dried bael fruit powder was significantly influenced by maltodextrin concentration. Result showed that with the increase in the maltodextrin concentration the DPPH radical scavenging capacity decreased. DPPH radical scavenging capacity also significantly decreased with the increase in the inlet air temperature of the spray dryer. But there is increase in the DPPH radical scavenging capacity with the increase in the concentration of the feed.

The equation of the model fitted for the DPPH scavenging of the sample in actual form of process variables after eliminating the non-significant terms was-

DPPH scavenging =+87.10-7.36 * X1+2.87 * X2-4.21 * X3-5.78 * X12-6.64 * X22-6.03 * X32 +0.80 * X1 * X2+0.47 * X1 * X3+0.67 * X2 * X3 (8)

An inverse relationship of co-efficient X1, and X3 with DPPH radical scavenging capacity was observed whereas co-efficient of X2 had the positive relationship. Among these variables X1 (maltodextrin concentration) was the dominating variable and was most significant than feed concentration and inlet air temperature. Similar trend was observed by Tuyen *et al*., 2010 for spray dried Gac fruit aril powder. They reported that when maltodextrin concentration were increased the antioxidant activity of Gac fruit aril powder decreased.

Table 1: Process variables used in central composite rotatable design for three independent variables

Independent variables	Code	Independent variables				
		-1.68	-1	0	1	1.68
Maltodextrin (%)	X_1	6.6	10	15	20	23.4
Feed concentration (° Brix)	X_2	8.3	10	12.5	15	16.7
Temperature(˚C)	X_3	109.5	130	160	190	210.5

Table 2: The central composite rotatable design employed for Effects of process parameters on physicochemical and quality characteristics of bael fruit powder

Coded variables				Responses					
Exp. No	X_1	X_2	X_3	aw	MC (%)	WSI (%)	Bulk density g/cm3	Beta carotene mg/100g	DPPH scavenging (%)
1	-1	-1	-1	0.255	4.44	83.813	0.744	47.35	79.84
2	1	-1	-1	0.237	3.19	87.204	0.694	38.53	61.67
3	-1	1	-1	0.253	4.26	87.562	0.686	49.19	82.35
4	1	1	-1	0.218	3.34	93.632	0.614	37.51	68.44
5	-1	-1	1	0.222	3.77	87.583	0.628	45.45	68.51
6	1	-1	1	0.214	3.06	92.659	0.544	38.32	53.28
7	-1	1	1	0.188	3.53	87.542	0.674	48.48	74.78
8	1	1	1	0.168	3.08	94.005	0.536	39.59	61.67
9	-1.6818	0	0	0.236	4.21	85.784	0.674	54.28	82.45
10	1.68179	0	0	0.201	2.81	94.305	0.516	38.33	58.58
11	0	-1.6818	0	0.242	3.76	85.842	0.611	40.28	63.53
12	0	1.68179	0	0.199	3.68	90.363	0.561	42.35	72.64
13	0	0	-1.6818	0.258	3.9	87.283	0.797	43.95	76.78
14	0	0	1.68179	0.184	3.19	91.424	0.656	41.25	62.85
15	0	0	0	0.23	3.56	85.998	0.652	47.39	86.75
16	0	0	0	0.227	3.52	86.593	0.635	47.54	87.45
17	0	0	0	0.238	3.55	86.699	0.663	47.77	86.88
18	0	0	0	0.222	3.54	87.233	0.629	46.65	87.34
19	0	0	0	0.232	3.58	86.639	0.647	47.37	86.8
20	0	0	0	0.227	3.51	86.684	0.628	47.05	87.49

Table 3: Analysis of variance table for response surface quadratic models

	Water activity		WSI		Bulk density		Moisture content		Beta carotene		DPPH scavenging	
Source	**Sum of square**	**F -value**	**Sum of square**	**F -value**	**Sum of square**	**F -value**	**Sum of square**	**F -value**	**Sum of square**	**F -value**	**Sum of square**	**F -value**
Model	0.011045	80.68	182.2524	191.9535	0.086114	75.53712	3.263042	719.651	405.4813	163.859	2476.904	1012.62
X_1	0.001432	*94.17*	91.40086	866.3942	0.027222	214.9031	2.366112	4696.53	293.8113	1068.59	740.5217	2724.7
X_2	0.0022	*144.6*	26.67173	252.8229	0.002481	19.59007	0.010828	21.4922	5.417247	19.7025	112.8691	415.293
X_3	0.006392	*420.21*	20.0374	189.9357	0.02576	203.3673	0.652031	1294.23	2.041999	7.42674	241.9882	890.378
X_1 2	0.000213	*13.99*	20.35767	192.9715	0.003585	28.30256	0.002855	5.66638	2.026393	7.36998	481.8446	1772.91
X_2 2	0.000142	*9.31*	3.630775	34.41633	0.005178	40.87422	0.052178	103.569	65.94944	239.858	635.6663	2338.89
X_3 2	0.000126	*8.29*	12.84871	121.7937	0.0136	107.3668	4.17E-05	0.08267	40.91191	148.796	523.9739	1927.92
X_1X_2	0.000105	*6.91*	2.066544	19.5889	0.000722	5.699872	0.043513	86.3686	2.66805	9.70369	5.08805	18.7211
$X_1 X_3$	7.81E-05	*5.14*	0.53976	5.116422	0.00125	9.868199	0.127513	253.101	2.5088	9.12449	1.74845	6.43329
X_2X_3	0.000435	*28.61*	9.839048	93.26492	0.003872	30.56773	0.004512	8.95692	1.5138	5.50568	3.61805	13.3124
Residual	0.000152		1.054957		0.001267		0.005038		2.749522		2.717816	
Lack of Fit	4.78E-06	*0.032*	0.283523	*0.37*	0.000287	*0.29*	0.001705	*0.51*	1.973172	*2.54*	2.126732	*3.6*
Pure Error	0.000147		0.771434		0.000979		0.003333		0.77635		0.591083	
R-Squared	0.9864		0.9942		0.985504		0.998458		0.993265		0.998904	
Adj R-Squared	0.9742		0.9891		0.972457		0.997071		0.987203		0.997917	
Std. Dev.	0.0039		0.32		0.011255		0.022445		0.524359		0.521327	
Mean	0.22255		88.44		0.63945		3.574		44.4315		74.504	

Table 4: The predicted and actual values of the responses for optimized product

Process variables	Coded	Uncoded	Responses	Predicted value	Actual value	Variation (%)
Maltodextrin (%)	0.03	16.11	Water activity	0.205	0.209	1.95
Feed concentration (° brix)	0.81	15	WSI	89.33	91.452	2.37
Temperature (°C)	0.26	166.39	Bulk Density	0.594	0.571	3.39
			Moisture content	3.45	3.624	4.80
			Beta Carotene	44.62	44.03	1.32
			DPPH scavenging	79.82	78.34	1.86

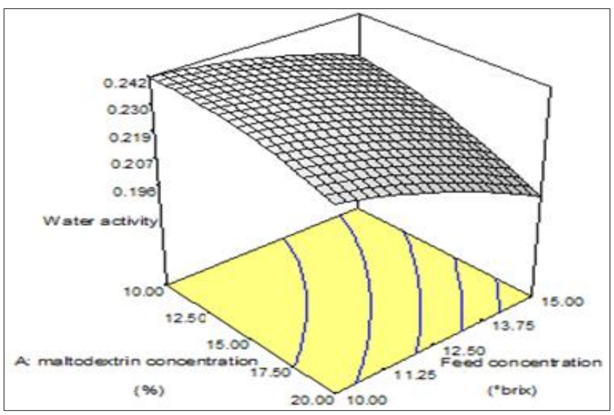

Fig 1: Response surface plot for the variation of water activity of spray dried bael powder as a function of maltodextrin concentration and feed concentration.

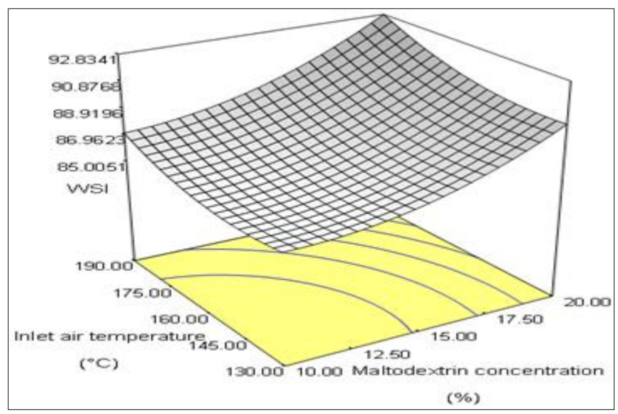

Fig 3: Response surface plot for the variation of WSI of spray dried bael powder as a function of maltodextrin concentration and inlet air temperature.

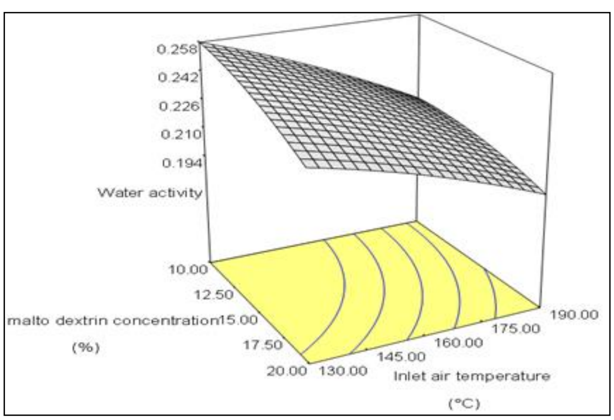

Fig 2: Response surface plot for the variation of water activity of spray dried bael powder as a function of maltodextrin concentration and inlet air temperature

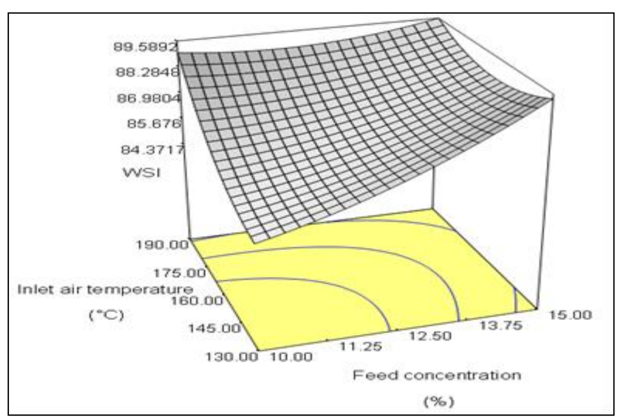

Fig 4: Response surface plot for the variation of WSI of spray dried bael powder as a function of inlet air temperature and feed concentration

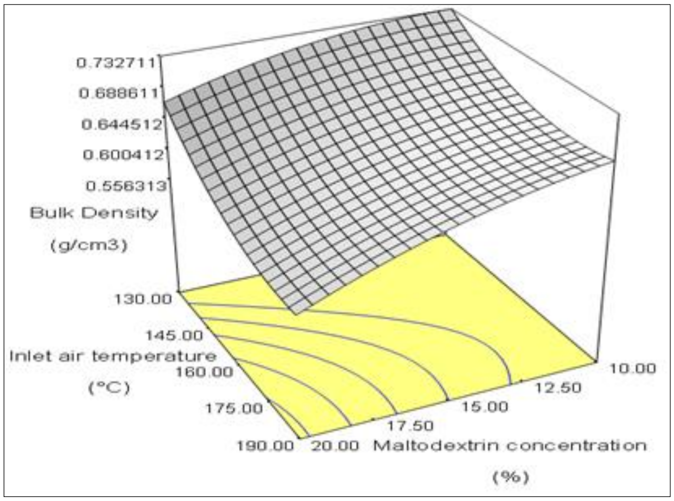

Fig 5: Response surface plot for the variation of bulk density of spray dried bael powder as a function of maltodextrin concentration and inlet air temperature.

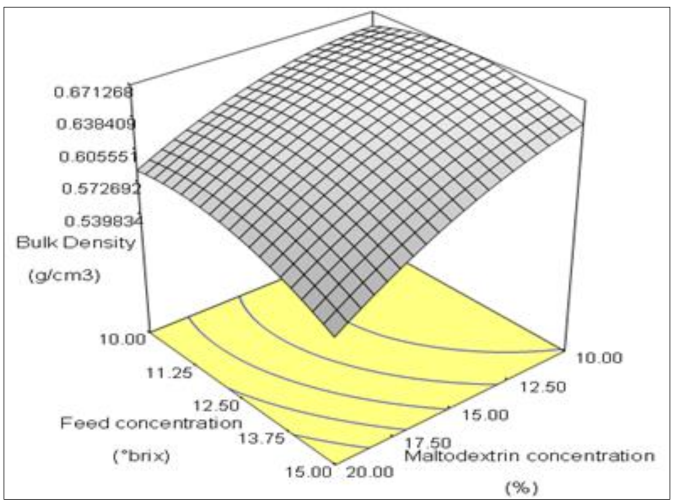

Fig 6: Response surface plot for the variation of bulk density of spray dried bael powder as a function of maltodextrin concentration and feed concentration

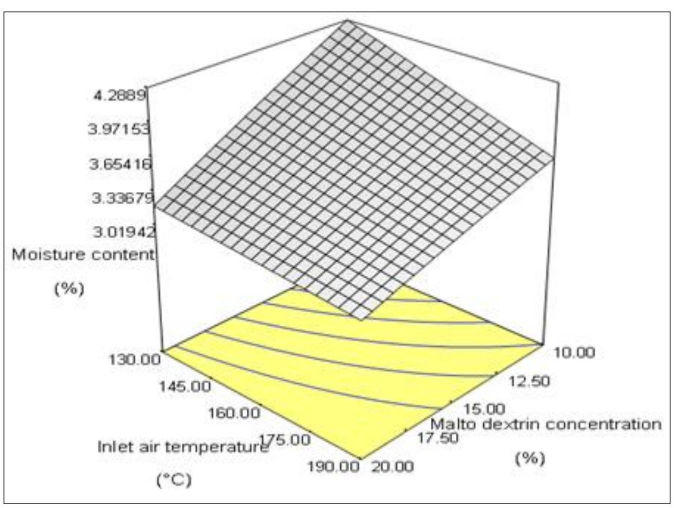

Fig 7: Response surface plot for the variation of moisture content of spray dried bael powder as a function of maltodextrin concentration and inlet air temperature.

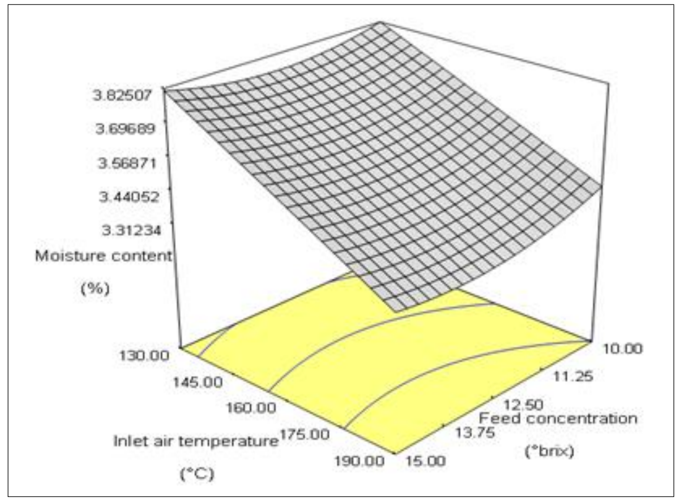

Fig 8: Response surface plot for the variation of moisture content of spray dried bael powder as a function of inlet air temperature and feed concentration

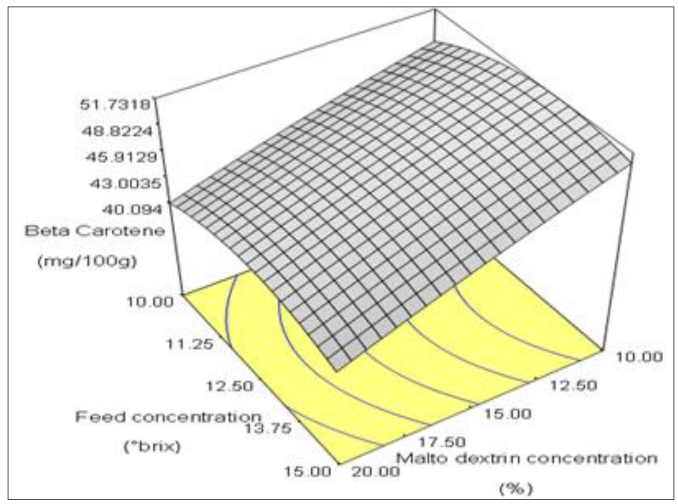

Fig 9: Response surface plot for the variation of beta carotene of spray dried bael powder as a function of maltodextrin concentration and feed concentration

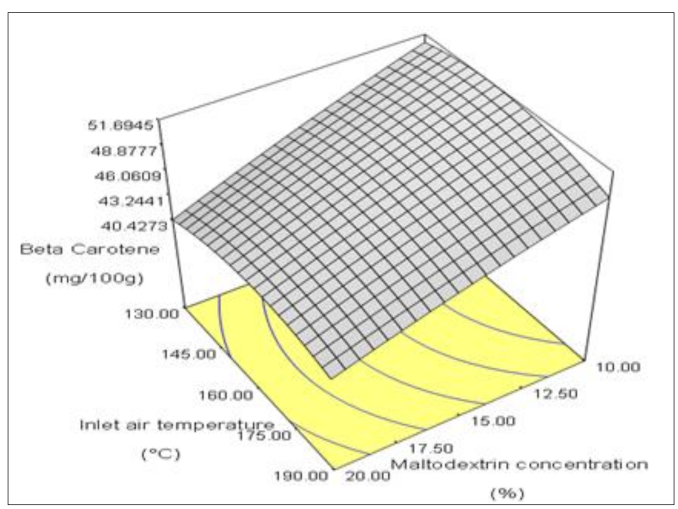

Fig 10: Response surface plot for the variation of beta carotene of spray dried bael powder as a function of maltodextrin concentration and inlet air temperature

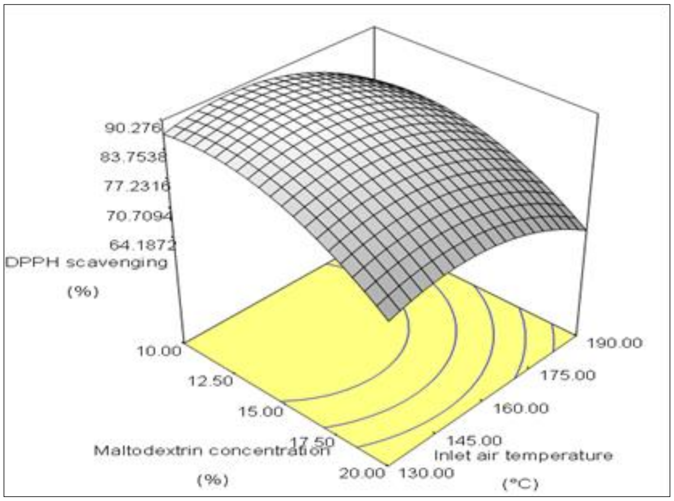

Fig 11: Response surface plot for the variation of DPPH radical scavenging of spray dried bael powder as a function of maltodextrin concentration and inlet air temperature

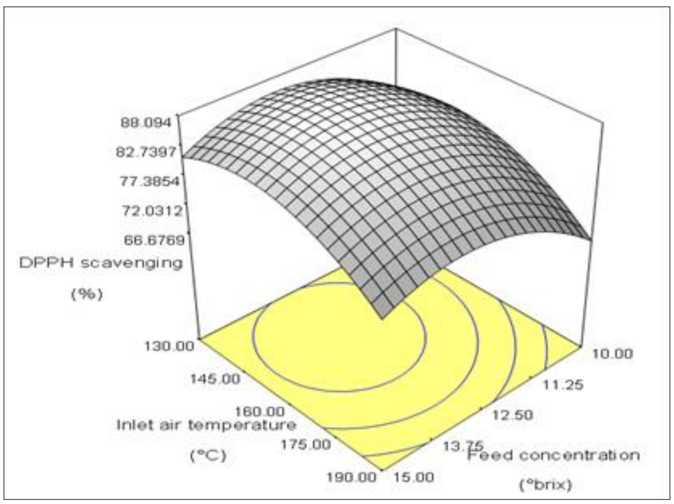

Fig 12: Response surface plot for the variation of DPPH radical scavenging of spray dried bael powder as a function of inlet temperature and feed concentration

5. Conclusions

The independent variables chosen for the study had significant effect on the various physicochemical and quality characteristics of the bael fruit powder. A good quality bael fruit powder can be produced by spray drying. The optimized condition of spray drying of bael fruit powder was found to be 16 % maltodextrin concentration, 15° brix of feed and 166 °C inlet air temperature.

With the increase in maltodextrin concentration from 10% to 20%, the antioxidant activity decreased from 85.65% to 69.06%. The moisture content of spray dried bael fruit powder decreased from 4.44 to 3.19%. The bulk density decreased from 0.744 to 0.694 g/cm3. Water Solubility Index of bael fruit powder increased from 83.81 to 87. Total carotene content decreased from 47.35mg/100g to 38.53mg/100g.

Increase in Inlet air temperature from 130°C to 190°C the antioxidant activity decreased from 85.65% to 68.51%, moisture content on wet basis decreased from 4.44 to 3.77%, the bulk density decreased from 0.744 to 0.628 g/cm3, the water solubility index increased from 83.81 to 87.58, the carotenoid content decreased from 47.35mg/100g to 45.45mg/100g bael powder.

With the increase in the concentration of feed from 10°brix to 15°brix, the antioxidant activity increased from 79.84 to 82.35, bulk density decreased from 0.744 to 0.686 g/cc.

6. References

1. AOAC. Official methods of analysis. Association of Official Analytical Chemists. 15th Edition Washington D, 1990, C.
2. Abadio fDB, domingues M, borges, SV, oliveira VA. Physical properties of powdered pineapple (ananas comosus) juice-effect of maltodextrin concentration and atomization speed. J Food eng. 2004; 64:285-287.
3. Anderso RA, conway Hf, pfeifer VF, griffin JR. Gelatinization of corn grits by roll and extrusion cooking. Cereal sci. Today. 1969; 14(1):4-11.
4. Goula, AM, adamopoulos KG, kazakis NA. Influence of spray drying conditions on tomato powder properties. Dry. Technol. 2004; 22(5):1129-1151.
5. Grabowsk JA, truong VD, daubert CR. Spray-drying of amylase hydrolyzed sweet potato puree and physicochemical properties of powder. J Food sci. 2006; 71(5):209-217.
6. Lai lS, chou ST, chao WW. Studies on the antioxidative activities of hsian-tsao (mesona procumbenshemsl) leaf gum. J Agr. Food chem. 2001; 49:963-968.
7. Mermelstein NH. Spray drying. Food technol. 2001; 55 (4):92-96.
8. Quek SY, chok NK, swedlund P. The physicochemical properties of spraydried watermelon powder. Chem. Eng. Process. 2007; 46(5):386- 392.
9. Rastogi NK, hebbar HU, subramanian R, jayaprakashan SG, shivakumara M.. Process for the preparation of bael fruit powder. Pat. Pub, 2005, No.wo2005063055
10. Roy SK, singh RN. Bael fruit (aegle marmelos)—a potential fruit for processing. Econ. Bot. 1979; 33(2):203-212.
11. Siew YQ, ngan KC, peter S. The physicochemical properties of spray-dried watermelon powders, chem. Eng. Process. 2006; 46:386-392.
12. Singhanat P. Anong S. Spray-drying of ginger juice and physicochemical properties of ginger powders, sci. Asia, 2010; 36:40-45.
13. Tran TH, nguyen MH, zabaras DYU. Process development of gac powder by using different enzymes and drying techniques. J Food eng. 2008; 85(3):359-365.
14. Tuyen CK, minh HN, paul DR. Effects of spray drying conditions on the physicochemical and antioxidant properties of the gac (momordica cochinchinensis) fruit aril powder, j Food eng. 2010; 98:385-392.
15. Wendel SC, celik M. An overview of spray drying applications, pharm. Technol. 1997; 21(10):124-156.
16. Ali MS, pervez MK. Marmenol: a 7-geraniloxy coumarin from the leaves of aegle marmelos corr. Nat. Prod. Res. 2004; 18:141-146.
17. Babbar OP, joshi MN, madan AR. Evaluation of plants for antiviral activity, indian j med res, 76
18. Bandyopadhyay U, Biswas K, chatterjee R,

bandyopadhyay D, chattopadhyay I, ganguly CK, *et al*. Gastroprotective effect of neem (azadirachta indica) bark extract: possible involvement of h (+)-k (+)-atpase inhibition and scavenging of hydroxyl radical, life sci. 2002; 71:2845.
19. Basak RK, mandal PK, mukherjee AK. Investigation on the structure of a hemicellulose fraction isolated from the trunk of young bael tree. Corbohydr. Res. 1982; 104:309-317.
20. Dhar ML, Dhar MM, Dhawan BN, Mehrotra BN, Ray C. Screening of indian plants for biological activity, part i, indian j exp boil. 1968; 6:232.
21. Dhuley JN. Investigation on the gastroprotective and antidiarrhoeal properties of aegle marmelos unripe fruit extract, hindustan antibiot bull, 2004, 45-46.
22. Farooq S. medicinal plants. Field and laboratory manual, international book distributors, dehradun, 555, 40-42.
23. Fenner FJ, gibs EPJ, Murphy RA, Rott R, Studdart MJ, white D. veterinary virology. 2nded. (academic press inc) London, uk, 2005-1993, 301.
24. Geetha T, varalakshmi P. Anti-inflammatory activity of lupeol and lupeol linoleate in rats, j.ethnopharmacol, 2001, 76 -77.
25. Jagetia GC, venkatesh P, baliga MS. Evaluation of the radioprotective effect of aegle marmelos (l) correa in cultured human peripheral blood lymphocytes exposed to different doses of gamma-radiation: a micronucleus study, mutagenesis, 2003; 18:387.
26. Jagetia GC, venkatesh P, baliga MS. Fruit extract of aegle marmelos protects mice against radiation-induced lethality, integr cancer ther. 2004; 3:323.
27. Kamalakkannan N, prince PS. The effect of aegle marmelos fruit extract instreptozotocin diabetes: a histopathological study. J herb pharmacother. 2005; 5:87-96.
28. Kamalakkannan N, prince SM. Effect of aegle marmelos correa. (bael) fruit extract on tissue antioxidants in streptozotocin diabetic rats. Indian j exp boil. 2003; 41:1285-1288.
29. Karakaya S. bioavailability of phenolic compounds, crit rev food sci nutr, 2004; 44:453.
30. Kokate CK, purohit AP, gokhale SB. Drugs containing glycosides. Pharmacog. 2002; 21:158-239.
31. Maity P, hansda D, bandyopadhyay U, mishra DK. Biological activities of crude extracts and chemical constituents of bael, aegle marmelos (l.) Corr. Indian j exp boil. 2009; 47:849-861.
32. Manandhar MD, shoeb A, kapil RS, popli SP. New alkaloids from aegle marmelos. Phytochemistry. 1978; 17:1814-1815.
33. Sachs G, shin JM, vagin O, munson K, weeks D, scott DR, voland P. Current trends in the treatment of upper gastrointestinal disease, best pract res clin gastroenterol. 2002; 16:835.
34. Singh KV, bhatt SK, sthapak JK. Antimicrobial and anthelmintic properties of the seeds of aegle marmelos, fitoterapia. 1983; 54:261.