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Research Article

DEVELOPMENT AND STUDY ON QUALITY PARAMETERS OF FOAM MAT DRIED BANANA POWDER

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Abstract- The independent variables selected for this study were carboxy methyl cellulose (0.5-2.5%) as foam stabilizer, egg albumin (3-11%) as foaming agent, temperature (60-80ºC) and whipping time (6-12min). Foam were prepared by incorporating carboxy methyl cellulose and egg albumin into the puree, the foam were then dried in cabinet air drier and finally grinded into powder. The dependent variables measured were flowability time, solubility, hygroscopicity and degree of caking. The study shows that the minimum value of flowability time was 6.5 s and maximum value was 13.56 s. Solubility of banana powder ranges from 59.1 to 98.5%, hygroscopicity varied from 1.25 to 4% and degree of caking was in the range of 1.89 to 4.5 %.

Keywords- Banana powder, flowability time, solubility, hygroscopicity, degree of caking

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Introduction

Banana with its scientific name *Musa spp.* is regarded as one of the important fruit among all ages of people owing to its availability year round, affordability, taste, nutritive and medicinal value. It is called a champion fruit due to infinite health benefits such as it helps in reducing risk of heart diseases when used regularly consumed and is recommended for patients suffering from high blood pressure, arthritis, ulcer, gastroenteritis and kidney disorders. India occupy first position in the world in banana production. In Uttarakhand, Great Naine varieties are mostly grown but cultivation and production of banana is negligible. The major banana producing belts in Uttarakhand are Haridwar and Kotdwar. Though India is the largest producer of banana, but the processing of banana is less than 2 % and the post harvest losses of banana are estimated to be more than 25 %. Banana is available throughout the year in tropical countries, like India, so there is avast need to utilize for proper processing techniques [1]. Conversion of this highly perishable fruit into value added products which retain its colour, flavour and nutrients with longer shelf life is the only way to combat the losses. The most important methods, drying and dehydration are widely practiced for fruits and vegetables because of considerable reduction in volume and saving in time during packaging and storage [1]. Due to the dense tissue structure of banana drying is one of the most critical steps as it consume large amount of energy which leads to poor quality of the dried products [2-5]. The most relevant method to overcome this problem is foam mat drying from fruit pulps to produce a free flowing and fine powder which gives a good reconstitutions characteristic [6]. The foaming agents used here is egg albumin as it induces and increases foam from 6 to 8 times the volume and carboxy methyl cellulose as foam stabilizer which acts as thickening agents, binders, emulsifiers, stabilizers, suspension aids, reduces stickiness of powder and produces a non sticky, free flowing powder.

Foam mat drying, originally develop by Morgan *et al.*, 1961 [7], is a process in which the liquid or semi food is converted to form stable foam by cooperation with foaming agents or stabilizing agents. The foam is then spread into a thin sheet and dried by using hot air at lower temperature compared to other drying techniques such as spray drying and steam drying. Mass transfer is enhanced leading to shorter dehydration times due to the porous structure of the foamed materials (Sharada, 2013) [6]. The dried and dehydrated product can be converted into powder later using grinding process. Finally, the banana powder will be packed in an air tight sealed pouches to extend the shelf life of the products as well as to prevents the deterioration of the product by micro-organism, bacteria, yeast, etc. during the long-term storage. Foam mat drying technique are mostly used for heat sensitive, sticky, viscous and high sugar content food products [8-10].

Banana powder are used as the first baby food and used in cake, bread, cookies, ice-cream, flavoured milk, chocolates etc. However, one of the challenges of producing fruit powders is to lessen the stickiness of the powder for safe handling and storage. They are also very hygroscopic in their amorphous state and loose their free-flowing nature at high moisture content. To reduce the stickiness of fruit powders, drying aid such as carboxy methyl cellulose is added to produce non-sticky and free flowing powders (Jaya and Das, 2006) [11]. Foam mat drying has produce a wide variety of powders from different fruits such as mango [12], star fruit [13], papaya [14], banana [15] and tomato [16, 17].

Box-Behnken of response surface methodology (Balasubramanian *et al*., 2012; Jaya and Das, 2006; Chand and Pandey, 2012) [18, 11, 19] is a statistical and mathematical techniques used for developing, improving, optimizing and to find out the effect of variable on the responses. In view of the above, present studies were undertaken to check the quality parameters (flowability time, solubility, hygroscopicity and degree of caking) of banana powder and to study the effect of variables on these parameters.

Materials and methods

Sample preparation

Banana of the variety Great Naine were procured from local market at Pantnagar, Uttarakhand. The fresh and fully ripened banana selected for the study were firstly peeled, sliced into pieces and then pre-treated by immersing them in 1% (w/w) sodium metabisulphite for 2min and then rinsed them with distilled water for 30s to prevent discoloration. The pre-treated banana was then grinded in a food processor for 1 min to make puree, the ingredients such as egg albumin powder as foaming agent and carboxy methyl cellulose (CMC) as stabilizer at a concentration of 3, 7 and 11% and 0.5, 1.5 and 2.5% respectively [20-22] were added to the puree and then was whipped by Orpat hand blender for 6, 12 and 18min to mix the ingredients uniformly and to incorporate air for foaming. The mixture was then spread evenly on a petridish and dried in a batch type cabinet drier at a temperature of 60, 70 and 80ºC [3, 5]. The obtained dried samples were finely grinded in grinder to powder.

Quality analytical methods

Flowability time

Flowability time was expressed as time in seconds necessary for the powder to leave the rotary steel drum. The apparatus used for flowability time measurement consisted of stainless steel drum of diameter 120mm and length 90mm. One end of the drum is fitted with lid, while its other end is rigidly fixed to shaft of motor. The drum has two slots, each having 4mm width and 70mm length on the surface of drum. Powder sample of known moisture content weighing 25 times of its bulk density in gm/cc is kept in the drum. The drum is rotated at 30rpm by geared motor and powder can fall through the slits. The time required to all the powder to come out of the slits provided on the drum is noted [11].

Solubility

For the determination of solubility, 100ml of distilled water was transferred into the blended jar. The powder sample (1g, db) was cautiously added into the blender operating at high velocity for 5min. The solution was placed in tube and centrifuged at 3000 rpm for 5min. An aliquot of 25ml of the supernatant was transferred to pre-weighed petridishes and instantly oven-dried at 105^{0}C for 5hr. Then the solubility (%) was calculated by weight difference [23].

Hygroscopicity

Hygroscopicity was expressed final moisture content attained after exposing the powder in humid air having 85.11% relative humidity. For measurement of hygroscopicity apparatus (Plate 3.14) used consisted of saturated solution of potassium chloride salt (equilibrium relative humidity= 85.11±2% at 20^{0}C) which was kept in glass wash bottle having two passages for air inlet and outlet. The powder sample of 0.5g is spread uniformly on filter paper. The diaphragm type vacuum pump is used to suck air through salt solution and sample at the flow rate of 300-400ml per minute. Increase in weight of sample for every 15 minute is noted. This measurement was continued till difference between two successive weighing did not exceed by 0.5%. The hygroscopicity of powders calculated by using the below equation,

$$HG = \frac{\frac{b}{a_h} + W_t}{1 + \frac{b}{a_h}} \quad \text{... [1]}$$

Where, b(g) is increase in weight of sample, a_h (g) is the amount of powder taken for measurement, W_t (%, wb) is the free water present in the powder before allowing into the humid air environment (Jaya and Das, 2006) [11].

Degree of caking

After the determination of hygroscopicity, the wet sample obtained at the end of the hygroscopicity measurement was placed along with the Gooch filter in a drying oven set at 102^{0}C±2^{0}C for one hour to measure the degree of caking. After cooling the dried sample, it was weighed and transferred into a sieve of 500µm size. The sieve was then vibrated for 5min in a shaking apparatus. The weight of the powder remaining in the sieve was measured. Degree of caking, DC (%) was calculated by using the following equation.

$$DC = \frac{c}{d} \times 100 \quad \text{... [2]}$$

Where, d (g) is the amount of the powder used for sieving, c (g) is amount of the powder left on the sieve after sieving. Normally the degree of caking between 5 to 20% is called as 'slightly caking' powder [11, 24].

Experimental design

The Box-Behnken designs (BBD) of response surface methodology with four levels were used for the study and the process were optimized based on four input variables whose interactions were studied as four major responses. On the basis of preliminary single factor experiments the levels of input variables were determined and are as follows: concentration of egg albumin: 3, 7 and 11% (w/w), concentration of carboxy methyl cellulose: 0.5, 1.5 and 2.5 % (w/w), temperature: 60, 70 and 80^0 C, whipping time: 6, 12 and 18 min. Twenty-nine runs were carried out to select the best combination of input variables which could result in most suitable form. The test factors were coded according to the following equation:

$$x_i = \frac{X_i - X_0}{\Delta X_i} \times 100 \quad \text{.... [3]}$$

Where,

x_i = dimensionless value of an independent variable,

X_i = level or value of controllable factor *i* in original units of measurement,

X_0 = midpoint of the range of values for factor *i*,

ΔX_i = range of values over the factor *i* will vary.

Low and high levels of each factor were coded as −1 and +1 keeping 0 as mid-point. The experimental design with its coded value are given in [Table-1] below. Since the various responses were the result of various interactions of independent variables, therefore the following second order polynomial regression equation was fitted to the experimental data of all responses.

$$y = \beta_0 + \sum_{j=1}^{k} \beta_j X_j + \sum_{j=1}^{k} \beta_{jj} X_j^2 + \sum_{x-1}^{j=1} \sum_{j=2}^{k} \beta_{ij} X_i X_j + \in \text{.... [4]}$$

Where,

y = predicted response, β_0 = a constant, β_i = linear coefficient, β_{ii}= squared coefficient, β_{ij}= interaction coefficient, X_i and X_j are the independent variables and $\in$ is noise or error.

Statistical analysis

Full second order model was fitted in various responses and independent variables using least square regression analysis. Regression analysis and analysis of variance (ANOVA) was used for fitting the models represented by Equation (4) and to examine the statistical significance of the model terms. Testing the adequacy of the model at 1% and 5% level of significance were done based on coefficient of determination (R^2) and Fisher's F-test. If the model was adequate, then the effects of independent variables on responses were interpreted. Design-Expert 8.0.7.1 software was used for process optimization based on the powder properties [25-28].

Results and Discussion

Effect of influencing factors on various responses

Effect of influencing factors i.e. carboxy methyl cellulose, egg albumin, temperature and whipping time on the responses i.e. flowability time, solubility, hygroscopicity and degree of caking were determined, statistically analyzed and are discussed below. Result of regression analysis of foam mat dried banana powder is given in [Table-2] and is discussed in detail below:

Table-1 *Experimental design with its coded value*

Expt No.	Coded Levels				Real values			
	X_1	X_2	X_3	X_4	Carboxy Methyl Cellulose (%)	Egg Albumin (%)	Temperature (ºC)	Whipping time(min)
1	-1	-1	0	0	0.5	3	70	12
2	1	0	0	-1	2.5	7	70	6
3	0	0	0	0	1.5	7	70	12
4	1	1	0	0	2.5	11	70	12
5	-1	1	0	0	0.5	11	70	12
6	0	0	-1	1	1.5	7	60	18
7	1	0	1	0	2.5	7	80	12
8	0	0	0	0	1.5	7	70	12
9	0	0	0	0	1.5	7	70	12
10	0	1	-1	0	1.5	11	60	12
11	1	-1	0	0	2.5	3	70	12
12	0	-1	0	-1	1.5	3	70	6
13	0	0	0	0	1.5	7	70	12
14	0	-1	1	0	1.5	3	80	12
15	0	1	0	-1	1.5	11	70	6
16	0	1	0	1	1.5	11	70	18
17	0	0	1	1	1.5	7	80	12
18	0	0	1	-1	1.5	7	80	6
19	1	0	-1	0	2.5	7	60	12
20	-1	0	0	-1	0.5	7	70	6
21	0	0	-1	-1	1.5	7	60	6
22	1	0	0	1	1.5	7	70	18
23	0	-1	0	1	1.5	3	70	18
24	-1	0	-1	0	0.5	7	60	12
25	-1	0	1	0	0.5	7	80	12
26	-1	0	0	1	0.5	7	70	18
27	0	-1	-1	0	1.5	3	60	12
28	0	0	0	0	1.5	7	70	12
29	0	1	1	0	1.5	11	80	12

Table-2 *Result of regression analysis of foamed banana powder*

Cons.	Flowability time		Solubility		Hygroscopicity		Degree of caking	
	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)
	9.72	0.01*	84.47	0.01*	2.8	0.01*	3.54	0.01*
X_1	2.24	0.01*	16.96	0.01*	0.55	0.01*	-0.98	0.01*
X_2	-1	0.06*	-9.35	0.01*	-0.18	1.27**	0.19	2.7**
X_3	0.54	0.29*	2.71	13.46	0.66	0.01*	0.19	3.12**
X_4	-0.15	55.22	-0.016	99.27	-0.025	74.3	0.0033	96.66
X_1X_2	-0.15	28.68	-1.44	63.36	-0.085	33.76	0.21	14.38
X_1X_3	-0.19	9.4***	3.2	29.63	-0.5	0.06*	-0.08	56.46
X_1X_4	0.59	18.21	-0.22	94.03	-0.02	68.54	0.0025	98.56
X_2X_3	0.38	56.83	3.19	29.78	-0.09	90.3	-0.03	82.81
X_2X_4	0.0025	95.9	0.1	97.28	0.013	98.38	0.008	99.01
X_3X_4	0.053	71.97	0.57	84.83	0.0073	64.16	0.012	92.79
X_1^2	0.0049	25.84	-7.56	0.57*	0.2	5.49***	-0.17	13.36
X_2^2	0.38	24.17	0.11	96.27	0.031	37.22	-0.29	0.0162
X_3^2	0.014	75.71	0.028	99.06	-0.29	1.74*	-0.17	13.89
X_4^2	0.32	29.68	-1.04	66.01	0.068	39.66	-0.041	70.71
R^2	94		91.24		92.54		92.85	
F	15.669 (1% 3.698)		10.42 (1% 3.698)		12.401 (1% 3.698)		12.988 (1% 3.698)	
LOF	NS		NS		NS		NS	

*,** and *** Significant at 1, 5 and 10% level of significance respectively
Coeff. = Coefficient, NS= Non significant, Cons.= Constant, LOF= Lack of Fit
X_1= Carboxy methyl cellulose, X_2 = Egg albumin, X_3 = Temperature and X_4 = Whipping time

Fitting of second order polynomial equations for various responses

Second order regression was fitted into the responses such as flowability time, solubility, hygroscopicity and degree of caking data obtained from various experimental conditions and the results of the regression analysis was given in [Table-2]. Regression analysis and analysis of variance (ANOVA) was used for fitting the models in the second order predictive quadratic equation and to examine the statistical significance of the model terms. Regression coefficient, R^2 indicates how much of the observed variability in the data was accounted by the model while R^2 –adj modifies R^2 by considering the number of covariate or predictors in the model. The regression coefficient, R^2 for flowability time, solubility, hygroscopicity and degree of caking were found to be 0.94, 0.9124, 0.9254 and 0.9285 which indicates that the regression model represented 94, 91.24, 92.54 and 92.85% respectively of the experimental results, representing a good fit of the response. The lack of fit were found non- significant and the model was found to be highly significant (p<0.01) as F_{cal} value was greater than F_{tab} (3.698) for all the responses at 1% level of significance, hence the model can be used to navigate the design. The following equations are the equation generated in coded terms for each response according to Box-Behnken experimental design.

a) Flowability time

Second order predictive quadratic equation for flowability time (s) is given below:

$Y=10.02-2.2X_1+0.72X_2-0.6X_3+0.1X_4+0.32X_1X_2+0.52X_1X_3-0.4X_1X_4-0.17X_2X_3-0.015X_2X_4-0.1X_3X_4-0.27X_1^2-0.28X_2^2+0.071X_3^2+0.24X_4^2$

Significant predictive equation for flowability time (s) is given below:

$Y=10.02-2.2X_1+0.72X_2-0.6X_3+0.52X_1X_3$

b) Solubility

Second order predictive quadratic equation for solubility (%) is given below:

$Y=84.47+16.96X_1-9.35X_2+2.71X_3-0.016X_4-1.44X_1X_2+3.2X_1X_3-0.22X_1X_4+3.19X_2X_3+0.1X_2X_4+0.57X_3X_4-7.56X_1^2+0.11X_2^2+0.028X_3^2-1.04X_4^2$

Significant predictive equation for solubility (%) is given below:

$Y=84.47+16.96X_1-9.35X_2-7.56X_1^2$

c) Hygroscopicity

Second order predictive quadratic equation for hygroscopicity (%) is given below

$Y=2.53-0.49X_1+0.2X_2-0.62X_3+0.023X_4-0.12X_1X_2+0.53X_1X_3+0.05X_1X_4-0.015{:}\ X_2X_3+0.0025X_2X_4-0.057X_3X_4-0.2X_1^2-0.087X_2^2+0.26X_3^2-0.083X_4^2$

Significant predictive equation for hygroscopicity (%) is given below:

$Y=2.53-0.49X_1+0.2X_2-0.62X_3+0.53X_1X_3-0.2X_1^2+0.26X_3^2$

d) Degree of caking

Second order predictive quadratic equation for degree of caking (%) is given below:

$Y=3.54-0.98X_1+0.19X_2+0.19X_3-0.0033X_4+0.21X_1X_2-0.08X_1X_3-0.0025X_1X_4-0.03X_2X_3-0X_2X_4+0.012X_3X_4-0.17X_1^2-0.29X_2^2-0.17X_3^2-0.041X_4^2$

Significant predictive equation for degree of caking (%) is given below:

$Y=3.54-0.98X_1+0.19X_2+0.19X_3-0.29X_2^2$

Where

Y is flowability time (s), solubility (%), hygroscopicity (%) and degree of caking (%) for each responses

X_1, X_2, X_3 and X_4 are coded variables for carboxy methyl cellulose, egg albumin, temperature and whipping time.

Statistical analysis of dependent variables

Effect of influencing factors on flowability time

It was found that minimum value of flowability time was 6.5 s and maximum value was 13.56 s [Table-3] exhibit the effect of influencing factors at linear, quadratic and interaction levels. The effects on flowability time at linear level of all influencing factor was highly significant at 1% level of significance (p<0.01).

Table-3 *ANOVA for flowability time*

Source	DF	SS	MS	Fcal
Model	14	72.11621	5.151158	15.66868*
Linear	4	68.65	17.163	57.096*
Quadratic	4	1.373	0.343	1.142
Interactive	6	2.265	0.378	1.258
Error	14	4.602572	0.328755	
Total	**28**	**76.719**		

*, ** and *** Significant at 1, 5 and 10% level of significance respectively

From [Fig-1], it was reported that flowability time decreases with increase in regressor of CMC. Minimum flowability time was found because of carboxy methyl cellulose. At linear level [Fig-2], it was observed that flowability time increases with increase in regressor of egg albumin. Maximum flowability time was found because of egg albumin. [Fig-3] convey that at linear level the flowability time increases with increase in regressor of temperature. [Fig-4] shows the variation of flowabilty time with carboxy methyl cellulose and temperature at interactive level of the model. The flowability time of banana powder decreases with increase in the level of temperature from -1(60^{0}C) to 1(80^{0}C) and carboxy methyl cellulose from -1(0.5%) to 1(2.5%). Maximum flowability time was found at the highest level (13.56 sec) of 2.5% of carboxy methyl cellulose

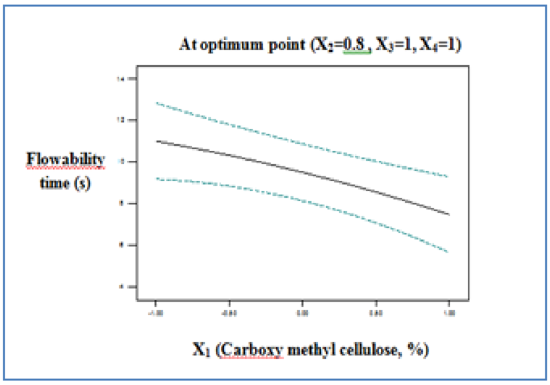

Fig-1 Effect of Carboxy methyl cellulose (%) on Flowability time (s)

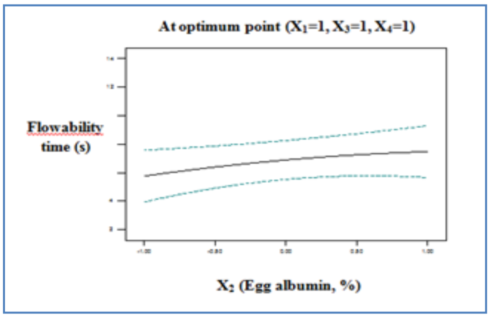

Fig-2 Effect of Egg albumin (%) on Flowability time (s)

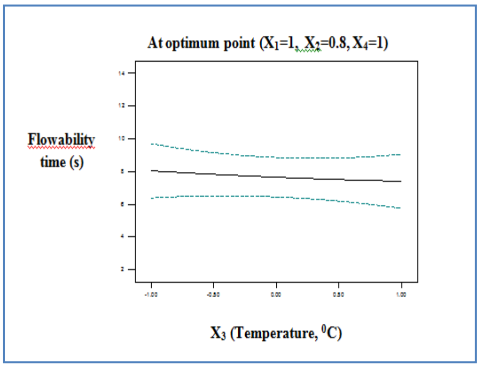

Fig-3 Effect of Temperature (ºC) on Flowability time (s)

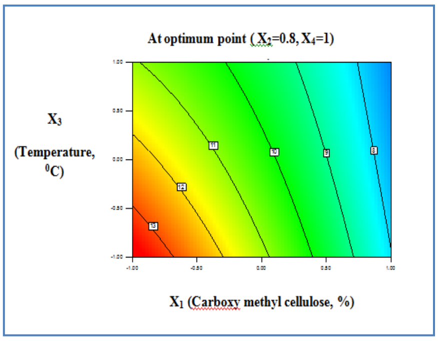

Fig-4 Variation of Flowability time (s) with Temperature (ºC) and Carboxy methyl cellulose (%)

Effect of influencing factors on solubility

The solubility of banana powder ranges from 59.1 to 98.5%. It can be seen from [Table-4] that the effects on solubility of all influencing factor at linear level is highly significant at 1% level of significance (p<0.01), while interactive is significant at 10% level of significance (p<0.1).

Table-4 *ANOVA for solubility*

Source	DF	SS	MS	Fcal
Model	14	5077.67	362.69	10.42*
Linear	4	4589.223	1147.31	32.96*
Quadratic	4	377.934	94.484	2.714***
Interactive	6	91.492	15.249	0.44
Error	14	487.3112	34.81	
Total	**28**	**5564.98**		

*, ** and *** Significant at 1, 5 and 10% level of significance respectively

The effect of carboxy methyl cellulose on solubility at linear level was shown in [Fig-5] was observed that solubility increases with increase in regressor of carboxy methyl cellulose. Maximum solubility was found due to the highest effect of carboxy methyl cellulose. At linear level [Fig-6], shows the effect of egg albumin on solubility and it can be observed that the solubility decreases with increase in regressor of egg albumin. Minimum solubility was found because of egg albumin.

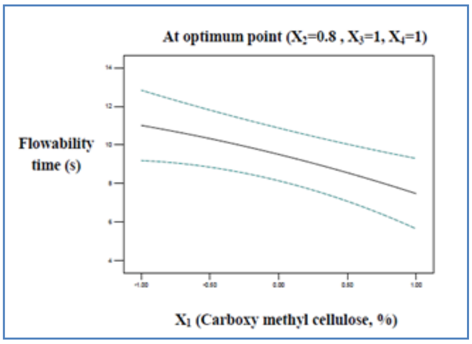

Fig-5 Effect of Carboxy methyl cellulose (%) on Solubility (%)

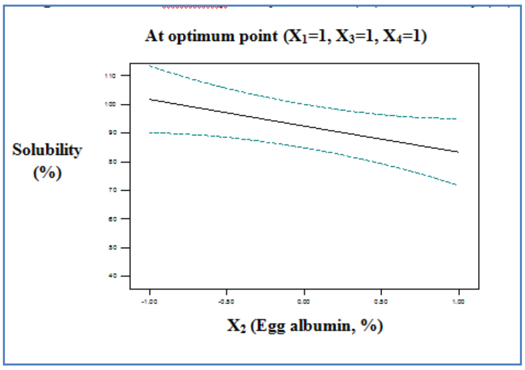

Fig-6 Effect of Egg albumin (%) on Solubility (%)

Effect of influencing factors on hygroscopicity

The value of hygroscopicity found to varied from 1.25 to 4%. Effect of ingredients at linear, quadratic and interaction levels was presented in [Table-5]. It shows that the effect of ingredients on hygroscopicity at linear was highly significant at 1% level of significance (p<0.01), while quadratic and interactive were significant at 5% level of significance (p<0.05).

Table-5 *ANOVA for hygroscopicity*

Source	DF	SS	MS	Fcal
Model	14	10.14495	0.72464	12.401*
Linear	4	7.9965	1.999	34.211*
Quadratic	4	0.775	0.1938	3.3167**
Interactive	6	1.202	0.2003	3.428**
Error	14	0.818049	0.058432	
Total	**28**	**10.963**		

*, ** and *** Significant at 1, 5 and 10% level of significance respectively

From [Fig-7], it was observed that hygroscopicity decreases with increase in regressor of carboxy methyl cellulose. At linear level [Fig-8], it revealed that hygroscopicity increases with increase in regressor of egg albumin. It was observed at linear level from [Fig-9] that hygroscopicity decreases with increase in regressor of temperature at the centre and after it, increases but lesser than the starting point. The variation of hygroscopicity with carboxy methyl cellulose and temperature was shown in [Fig-10]. The hygroscopicity of banana powder decreases with increase in the level of carboxy methyl cellulose from -1 (0.5%) to 1 (2.5%) temperature from -1(60°C) to 1(80°C). Maximum hygroscopicity was found at the highest level (4%) of 0.5% of carboxy methyl cellulose and 60°C.

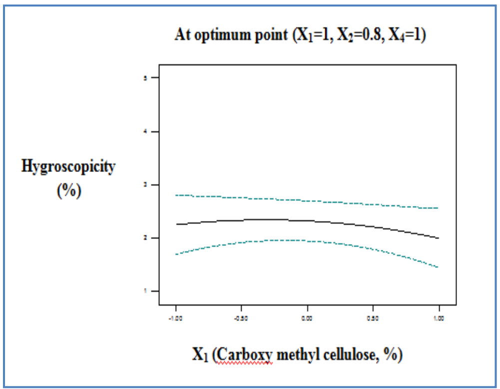

Fig-7 Effect of Carboxy methyl cellulose (%) on Hygroscopicity

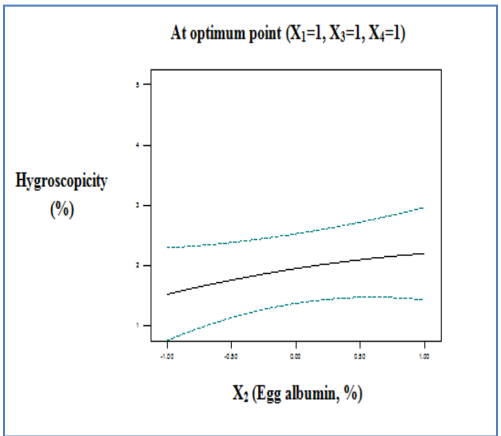

Fig-8 Effect of Egg albumin (%) on Hygroscopicity (%)

Effect of influencing factors on degree of caking

The degrees of caking were found to be in the range of 1.89 to 4.5 %. The effect of variables at linear, quadratic and interaction levels is reported in [Table-6]. It shows that the total effect of variables on degree of caking at linear was highly significant at 1% level of significance (p<0.01), while quadratic level was significant at 5% level of significance (p<0.05). The F_{cal} (12.988) was found greater than F_{tab} (3.698) which indicate that the model was significant at 1% level of significance.

Table-6 *ANOVA for degree of caking*

Source	DF	SS	MS	Fcal
Model	14	13.37261	0.955187	12.988*
Linear	4	12.45	3.113	42.327*
Quadratic	4	0.931	0.233	3.168**
Interactive	6	0.2163	0.0361	0.491
Error	14	1.029642	0.073546	
Total	**28**	**14.402**		

*,** and *** Significant at 1, 5 and 10% level of significance respectively

The effect of carboxy methyl cellulose on degree of caking was given in [Fig-11]. At linear level, it was observed that degree of caking decreases with increase in regressor of carboxy methyl cellulose. Minimum degree of caking was found due to the highest effect of carboxy methyl cellulose. At linear level [Fig-12], shows the effect of egg albumin on degree of caking and was found that degree of caking increases slightly with increase in regressor of egg albumin. [Fig-13] shows the effect of temperature on degree of caking at linear level and it was seen that the degree of caking increases very slightly (negligible) with increase in regressor of temperature.

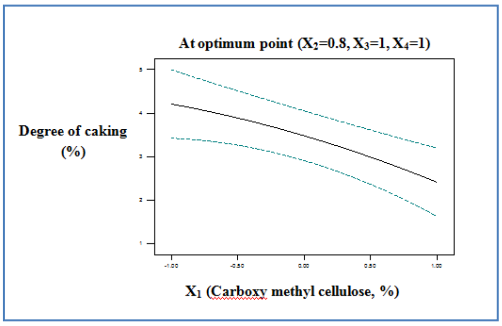

Fig-11 Effect of Carboxy methyl cellulose (%) on Degree of caking (%)

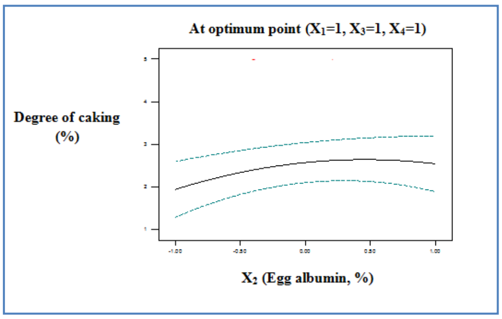

Fig-12 Effect of Egg albumin (%) on Degree of caking (%)

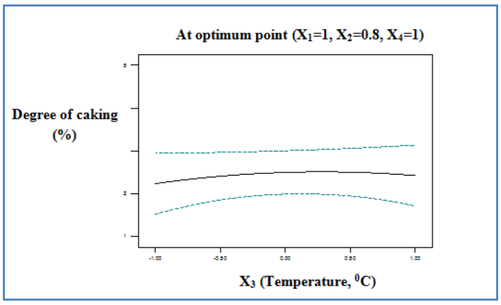

Fig-13 Effect of Temperature (°C) on Degree of caking (%)

Conclusion

From this experimental study for the quality evaluation of foamed mat dried banana powder, flowability time keep on decreases with increase in carboxy methyl cellulose and temperature while it increases with increase in egg albumin. Rise of flowability time may be due to coagulation of egg protein at higher temperature which result in thickening or jelly like texture. Solubility increases with increase in carboxy methyl cellulose from 0.5 to 2.5% but decreases with increase in egg albumin from 3 to 11%. This may be due to coagulation of proteins i.e. surface denaturation when it lose their native, soluble structure and hence become insoluble. Hygroscopicity increases with increase in carboxy methyl cellulose (0.5-2.5%) and temperature (60-80ºC) while it decreases slightly with increase in egg albumin (3 to 11%). Degree of caking increases with increase in egg albumin (3 to 11%) while it decreases with increase in carboxy methyl cellulose (0.5-2.5%). This study serve to check the important quality parameters of the finished product. Further research can also be done in the future for checking the other quality parameters like storage studies, bulk density of powder, sensory analysis, etc to make more effective powder for producing numerous products.

Application of research

The banana powder can be used for producing functional and fortified foods such as baby food, instant beverages premixes, milk shakes, ice-cream premixes, cakes, biscuits, flavoured milk, chocolate, cookies, etc.

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Author contributions

All authors equally contributed by working hard, cooperating, encouraging and suggesting in performing experiment and writing the paper.

Abbreviations

Abbreviation	Particular
ANOVA	Analysis of Variance
Anonymous	Anon.
CMC	Carboxy methyl cellulose
DC	Degree of caking
^0C	Degree Centigrade
et al	and others
F	F- value
FL	Flowability Time
Fig.	Figure
g	gram
min	minute
MS	Mean square
w.b.	Wet basis
R^2	Coefficient of Determination
R^2 adj	R adjusted value
SS	Sum of square
rpm	revolution per minute
/	per
%	percent
Y	Response
X	Independent variable
KCl	Potassium chloride
s	Seconds
β	Beta
β_0	Regression coefficient
L*, a*, b*	Colour parameters
tab	tabulated
cal	calculated
FD	Foam density
FE	Foam expansion
SL	Solubility
HG	Hygroscopicity
DC	Degree of caking
cm	centimeter
µm	micrometer
BBD	Box benhken design
etc	Et cetera
MT/ ha	Million Tones/ hectare
Kcal	Kilocalorie
IU	International Unit
mcg	microgram
N/mm	Newton/ millimeter
ppm	part per million
mm	millimeter
mg/kg	milligram/kilogram
m	meter
Pa s	Pascal second
W	Watt
ml	mililiter

Conflict of Interest: None declared

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