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Original Research Article

Effect of Extrusion Cooking on Colour (L*, a*, b*) of Germinated Buckwheat-Corn Based Snacks

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A B S T R A C T

The present work was undertaken to study the utilization of corn flour (*Zea mays*) and germinated buckwheat (*Fagopyrum esculentum*) flour in preparation of extruded product using central composite rotatable design. The experiments were randomized in order to minimize the effects of unexplained variability in the observed responses due to extraneous factors. The effect of different extrusion parameters i.e. Feed rate (4 kg/h), Feed composition (Germinated Buckwheat: Maize:: 90:10, 80:20, 70:30, 60:40, 50:50 respectively), feed moisture (13–17%), screw speed (250– 350 rpm), and barrel temperature (100–140°C) on colour (L*, a*, b*) of an expanded buckwheat-corn snack was observed. Increasing feed moisture increasing the brightness (a*) but decrease the feed moisture increase the blueness (b*) of extrudate product. Decreasing the feed composition and screw speed and increases in extrusion temperature results in increases the brightness (L*) of extrudates products. Screw speed increase redness will be decreases but blueness increase of the extrudate product. L* value varied between 40.68 to 58.74, a* value ranged from 0.73 to 6.89 and b* value varied from 4.22 to 16.88 of extruded product.

Keywords

Colour, Extrusion, Corn, Buckwheat, RSM

Introduction

Extrusion cooking is an important and popular food processing technique classified as a high temperature-short time process to produce fiber rich products (Gaosong and Vasanthan, 2000). In the extruder, food mix is thermo mechanically cooked to high temperature, pressure and shear stress which is generated in the screw-barrel assembly. The cooked melt is then texturized and shaped in the die (Arhaliass *et al.*, 2003). In extrusion technology nutrient losses are low than other thermal processing methods (Kharat, *et al.*, 2015).

Cereal grains are generally used as major raw material for development of extruded snack foods due to their good expansion characteristics because of their high starch content. Buckwheat is a pseudocereal, in India two species of buckwheat are cultivated in the Himalayas (*F.esculentum* and *F. tataricum*). It is high in lysine, vitamins (B1, B2 and niacin) and mineral (zinc, copper and potassium) (Anonymous, 2002, Pomeranz, 1983, De Francischi *et al.*, 1994). Buckwheat contains many flavonoid compounds which are known in reducing the

blood cholesterol, keeping capillaries and arteries strong and flexible and assisting in prevention of high blood pressure. The germinated buckwheat flour used because of reduced the antinutritional factor and provides the high nutritive value.

Maize (*Zea mays*) is another important food providing many nutrients for humans and animals. With its high content of carbohydrates, fats, proteins and some of the important vitamins and minerals; maize acquired a well-deserved reputation as a 'poor man's diet.

Maize has become an attractive ingredient in the extrusion industry due to its attractive yellow colour and great expansion characteristic as expansion is an important parameter in the production of a cereal-based extruded snack food in terms of the functional properties of the final product (Tahnoven *et al.,* 1998). Maize grits are widely used to elaborate expanded products by extrusion cooking.

The fast changing life style of the consumer demands convenience in terms to save time and labour and to provide hygienic products of standard and uniform quality with enhanced shelf life. The present study was conducted to develop the extrudates product by application of maize flour and germinated buckwheat flour blends. The extrudates products obtained were analysed for their effect on colour (L*, a*, b*) properties.

Materials and Methods

The study was carried out in the Department of Food Engineering and Technology, SLIET, Longowal, Punjab. The experiment was consisting of varying proportion of maize flour and germinated buckwheat flour for development of extruded snack product. Buckwheat and maize were procured from the local market of Sangrur, Punjab. These grains were freshly harvested having good germination capacity. The grains were cleaned in unit operation laboratory by using instruments like aspirator & sieving etc.

Preparation of sample

Ingredient formulations for preparation of extruate products were blend at different levels mentioned in Table 1. The moisture was adjusted by sprinkling the distilled water in all the dry ingredients. All the ingredients were weighed and then mixed in the Food Processor with mixer attachment for 20 min.

This mixture was then passed through a 2 mm sieve to reduce the lumps formation due to addition of moisture. After mixing samples were stored in polyethylene bags at room temperature for 24h (Stojceska *et al.,* 2008). The moisture content of all the samples was estimated using the Hot air oven method (Ranganna, 2003).

Extrusion of samples

The co-rotating twin screw extruder (7.5HP motor, 440V, 3ph, 50cycles, Make: Basic Technology Pvt. Ltd. Kolkata, India) was kept running for suitable period of time to stabilize the set temperatures and samples were then poured in to feed hopper and the feed rate was adjusted to 4 kg/h for easy and non-choking operation. The die diameter of 4 mm was selected for the preparation of extrudate. The product was collected at the die end and packed in already numbered zipped lock packs and kept for proper storage. All the extrudate were kept in high precision (+ 0.1°C) incubator (Macro Scientific works, New Delhi) at 60°C for 12 hour duration for the stabilization of moisture.

Evaluation of Colour (L*, a*, b*) extrudates product

The colour of the extrudates were measured by using Color Spectrophotometer (Hunter's color lab, GretagMacbethTM, model – color i.5, CH-8105 Regensdort, Switzerland.) (Ranganna, 2003).

Experimental design

Response surface methodology (RSM) was adopted in the experimental design as it emphasizes the modeling and analysis of the problem in which response of interest is influenced by several variables and the objective is to optimize this response (Montgomery 2001). The main advantage of RSM is reduced number of experimental runs needed to provide sufficient information for statistically acceptable results. A five-level, four-factor central composite rotatable design was employed. The variables and their levels were chosen by taking trials of samples.

Statistical analysis of responses

The responses (color) for different experimental combinations were related to the coded variables (xi, i=1, 2, 3 and 4) by a second degree polynomial equation

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{44} x_4^2 + \beta_{12} x_1.x_2 + \beta_{13} x_1.x_3 + \beta_{14} x_1.x_4 + \beta_{23} x_2.x_3 + \beta_{24} x_2.x_4 + \beta_{34} x_3.x_4 + \varepsilon$$

The coefficients of the polynomial were represented by β_0 (constant), β_1, β_2, β_3, β_4 (linear effects); β_{12}, β_{13}, β_{14} β_{23}, β_{24}, β_{34} (interaction effects); β_{11}, β_{22}, β_{33}, β_{44} (quadratic effects); and ε (random error). Data were modeled by multiple regression analysis and the statistical significance of the terms was examined by analysis of variance for each response

Analysis of data

Design Expert 6.0 (version 6.0, by STAT-EASE Inc., USA) was used for optimization of selected parameters.

Results and Discussion

Extruded snack product was developed from corn flour and germinated buckwheat flour as per the experimental design. Design experiments were conducted to study the effect of incorporation of corn flour into germinated buckwheat flour on color of extrudate.

Diagnostic checking of fitted model and surface plots of experiment

Effect of process variables on product color (L* value)

Color of germinated buckwheat flour and corn flour extrudate varied between 40.68 to 58.74. Tables 2 and Table 3 shows the coefficient of the model and other statistical attributes of L* value. The Model F-value of 18.94 implies the model is significant ($P < 0.0001$).

Lack of fit F-value is 5.61 indicating that lack of fit is not significant. In this case x_1, x_2, x_3, x_1^2, x_3^2, x_4^2, x_1x_2, x_2x_3 and x_2x_4 are significant model terms at ($P<0.05$). R^2 0.9465, Adj R^2 0.8965 and Adeq precision is 14.643 confirms that the developed model can be explored for optimization of process parameters.

$$L^* = 42.54 - 1.77.x_1 - 128.x_2 - 1.31.x_3 + 0.49.x_4 + 3.25.x_1^2 + 0.33.x_2^2 + 1.17.x_3^2 + 2.82.x_4^2 + 1.17.x_1.x_2 - 1.60.x_1.x_3 - 0.34.x_1.x_4 - 1.91.x_2.x_3 + 0.97.x_2.x_4 + 0.039.x_3.x_4 \quad (1)$$

Where, x_1, x_2, x_3, and x_4 *are* the coded values of Feed composition (%), moisture content (%), screw speed (rpm) and temperature (^{0}C) respectively.

From equation (1) we observe that the coefficient of x_1, x_2 and x_3 are negative, therefore as geminated buckwheat flour of feed composition decreases brightness increases.

Increase in extrusion temperature increase in L* value i.e. the intensity of brightness. Similar result was observed in extruded snacks made from sour cassava and flaxseed flour (Mesquita *et.al*, 2013).

F-value for the interaction term x_1x_2 is 15.84 which is significant (P <0.0012). In this case the coefficient of the interaction term is positive, so L* value will show concave shaped variation with the change in value of variables. From the Fig. 1 we can observe that L* value increases with increase in feed moisture and with blend composition.

F-value for the interaction term $x_2.x_3$ is 19.77 which is significant (P <0.0005). In this case the coefficient of the interaction term is negative, so L* value will show convex shaped variation with the change in value of variables. From the Fig. 2 we can observe that L*value increases as screw speed and moisture content decreases. F-value for the interaction term $x_2.x_4$ is 5.13 which is significant (P <0.0388). In this case the coefficient of the interaction term is positive, so L* value will show concave shaped variation with the change in value of variables.

From the Fig. 3 we can observe that L* value increases as temperature and moisture content increases. Similar result was observed under high moisture and high barrel temperature conditions, there was less darkening of the extruded cassava starch, i.e. greater L* value (Leonel *et. al*., 2009)

Effect of process variables on product colour (a* value)

Color (a*) is the important physical characteristics of extrudate products and directly related to the acceptability of food products. Color (a*) of germinated buckwheat flour and corn flour extrudate varied between 0.73 and 6.89. Tables 4 and Table 5 show the coefficient of the model and other statistical attributes of Color (a* value). The Model F-value of 6.71.

In this case x_1, x_4, x_1^2, x_2^2, and x_3^2 are significant model terms at (P<0.05). The "Lack of Fit F-value" of 2.49 implies the Lack of Fit is not significant. R^2 0.8623, Adj R^2 0.7338 and Adeq precision is 8.391 confirms that the developed model can be explored for optimization of process parameters.

$$a^*=1.34+0.61.x_1+0.100.x_2+ 0.25x_3-.11x_4+0.77.x_1^2+0.52.x_2^2+0.0.88.x_3^2+0.26.x_4^2-0.063.x_1.x_2 -0.074.x_1.x_3-0.066.x_1.x_4 -0.21.x_2.x_3 +0.15.x_2.x_4 +0.29.x_3.x_4 \quad (2)$$

Where, x_1, x_2, x_3, and x_4 are the coded values of Feed composition (%), moisture content (%), screw speed (rpm) and temperature (^{0}C) respectively.

From equation (2), it is evident that the coefficient of x_1, x_2 are positive, therefore as corn flour increases a*value increase and increase in moisture content will also increase a*value i.e. the intensity of redness increases as feed composition and moisture content increases. Coefficient of x_3 is positive and x_4 is negative indicating that as of the extrusion temperature decreases a* increase and screw speed of feed increase a* value of product decrease.

Table.1 Experimental combination in Coded and Uncoded levels for preparation of extrudate snacks

Sr No.	Coded variables				Uncoded variables			
	x_1	x_2	x_3	x_4	X_1 Feed Proportion (Germinated buckwheat flour:corn flour)	X_2 Moisture content (%)	X_3 Screw speed (rpm)	X_4 Temperature (^{0}C)
1	-1	-1	-1	-1	80:20	14	275	110
2	1	-1	-1	-1	60:40	14	275	110
3	-1	1	-1	-1	80:20	16	275	110
4	1	1	-1	-1	60:40	16	275	110
5	-1	-1	1	-1	80:20	14	325	110
6	1	-1	1	-1	60:40	14	325	110
7	-1	1	1	-1	80:20	16	325	110
8	1	1	1	-1	60:40	16	325	110
9	-1	-1	-1	1	80:20	14	275	130
10	1	-1	-1	1	60:40	14	275	130
11	-1	1	-1	1	80:20	16	275	130
12	1	1	-1	1	60:40	16	275	130
13	-1	-1	1	1	80:20	14	325	130
14	1	-1	1	1	60:40	14	325	130
15	-1	1	1	1	80:20	16	325	130
16	1	1	1	1	60:40	16	325	130
17	-2	0	0	0	90:10	15	300	120
18	2	0	0	0	50:50	15	300	120
19	0	-2	0	0	70:30	13	300	120
20	0	2	0	0	70:30	17	300	120
21	0	0	-2	0	70:30	15	250	120
22	0	0	2	0	70:30	15	350	120
23	0	0	0	-2	70:30	15	300	100
24	0	0	0	2	70:30	15	300	140
25	0	0	0	0	70:30	15	300	120
26	0	0	0	0	70:30	15	300	120
27	0	0	0	0	70:30	15	300	120
28	0	0	0	0	70:30	15	300	120
29	0	0	0	0	70:30	15	300	120
30	0	0	0	0	70:30	15	300	120

Code '0' is for centre point of the parameter range investigated, '$\pm$1' for factorial points and '$\pm$2' for star points

Table.2 Analysis of variance table for Color (L* value)

Source	Coefficient of model terms	Sum of Squares	Df	Mean Square	F – Value	Prob > F
Model	42.54	779.37	14	55.67	18.94	< 0.0001***
x_1	-1.77	74.94	1	74.94	25.50	0.0001***
x_2	-1.28	39.40	1	39.40	13.40	0.0023**
x_3	-1.31	41.06	1	41.06	13.97	0.0020**
x_4	0.49	5.73	1	5.73	1.95	0.1829
x_1^2	3.25	289.06	1	289.06	98.35	< 0.0001
x_2^2	0.33	3.03	1	3.03	1.03	0.3257
x_3^2	1.17	37.63	1	37.63	12.80	0.0027**
x_4^2	2.82	218.14	1	218.14	74.22	< 0.0001
$x_1.x_2$	1.71	46.55	1	46.55	15.84	0.0012**
$x_1.x_3$	-1.60	40.86	1	40.86	13.90	0.0020**
$x_1.x_4$	-0.34	1.84	1	1.84	0.63	0.4408
$x_2.x_3$	-1.91	58.10	1	58.10	19.77	0.0005**
$x_2.x_4$	0.97	15.07	1	15.07	5.13	0.0388**
$x_3.x_4$	0.039	0.025	1	0.025	8.440E-003	0.9280

*Significant at P < 0.1, **Significant at P < 0.05, ***Significant at P < 0.001 df: degrees of freedom

Table.3 Analysis of variance results of equation 1

Response	Source	Sum of Squares	Df	Mean Squares	F-value	P-value
L*	Regression	779.37	14	55.67	18.94	< 0.0001***
	Lack of fit	40.48	10	4.05	5.61	0.0655
	Pure error	3.61	5	0.72		
	Residual	44.09	15	2.94		
	Total	823.46	29			
	R^2-value	0.9465				
	Adjusted R^2	0.8965				
	Adeq. Precision	14.643				

*significant at P < 0.05, df: degrees of freedom

Table.4 Analysis of variance table for Color (a* value)

Source	Coefficient of model terms	Sum of Squares	Df	Mean Square	F – Value	Prob > F
Model	1.34	49.43	14	3.53	6.71	0.0004**
x_1	0.61	8.92	1	8.92	16.95	0.0009**
x_2	0.100	0.24	1	0.24	0.45	0.5114
x_3	0.25	1.54	1	1.54	2.92	0.1082
x_4	-0.11	0.31	1	0.31	0.58	< 0.0001***
x_1^2	0.77	16.31	1	16.31	31.00	0.0020**
x_2^2	0.52	7.34	1	7.34	13.96	< 0.0001***
x_3^2	0.88	21.42	1	21.42	40.71	0.0842*
x_4^2	0.26	1.80	1	1.80	3.42	0.7326
$x_1.x_2$	-0.063	0.064	1	0.064	0.12	0.7326
$x_1.x_3$	-0.074	0.089	1	0.089	0.17	0.6875
$x_1.x_4$	-0.066	0.069	1	0.069	0.13	0.7225
$x_2.x_3$	-0.21	0.69	1	0.69	1.32	0.2690
$x_2.x_4$	0.15	0.34	1	0.34	0.64	0.4345
$x_3.x_4$	0.29	1.36	1	1.36	2.59	0.1283

*Significant at P < 0.1, **Significant at P < 0.05, ***Significant at P < 0.001 df: degrees of freedom

Table.5 Analysis of variance results of equation 2

Response	Source	Sum of Squares	Df	Mean Squares	F-value	P-value
a*	Regression	49.43	14	3.53	6.71	< 0.0004**
	Lack of fit	6.57	10	0.66	2.49	0.1627
	Pure error	1.32	5	0.26		
	Residual	7.89	15	0.53		
	Total	57.32	29			
	R^2-value	0.8623				
	Adjusted R^2	0.7338				
	Adeq. Precision	8.391				

*significant at P < 0.05, df: degrees of freedom

Table.6 Analysis of variance table for Color (b* value)

Source	Coefficients of model terms	Sum of Squares	Df	Mean Square	F – Value	Prob > F
Model	5.37	357.82	14	25.56	9.59	< 0.0001***
x_1	-0.34	2.76	1	2.76	1.04	0.3249
x_2	-0.20	0.96	1	0.96	0.36	0.5574
x_3	0.13	0.43	1	0.43	0.16	0.6947
x_4	-0.53	6.78	1	6.78	2.55	0.1315
x_1^2	1.62	72.15	1	72.15	27.07	0.0001***
x_2^2	0.91	22.74	1	22.74	8.53	0.0105**
x_3^2	2.68	197.28	1	197.28	74.02	<0.0001***
x_4^2	1.97	106.38	1	106.38	39.92	< 0.0001***
$x_1.x_2$	0.000	0.000	1	0.000	0.000	1.0000
$x_1.x_3$	-0.16	0.042	1	0.042	0.16	0.6983
$x_1.x_4$	0.59	5.64	1	5.64	2.12	0.1663
$x_2.x_3$	-1.54	37.88	1	37.88	14.21	0.0019**
$x_2.x_4$	0.33	1.78	1	1.78	0.67	0.4263
$x_3.x_4$	0.29	1.32	1	1.32	0.50	0.4920

*significant at P < 0.1, **significant at P < 0.05, ***significant at P < 0.001 df: degrees of freedom

Table.7 Analysis of variance results of equation 3

Response	Source	Sum of square Squares	Df	Mean Squares	F-value	P-value
b*	Regression	357.82	14	25.56	9.59	< 0.0001*
	Lack of fit	36.12	10	3.61	4.68	0.0511
	Pure error	3.86	5	0.77		
	Residual	39.98	15	2.67		
	Total	397.79	29			
	R^2-value	0.8995				
	Adjusted R^2	0.8057				
	Adeq. Precision	9.524				

*significant at P < 0.05 df: degrees of freedom

Fig.1 Effect of feed moisture: blend composition on colour (L) value

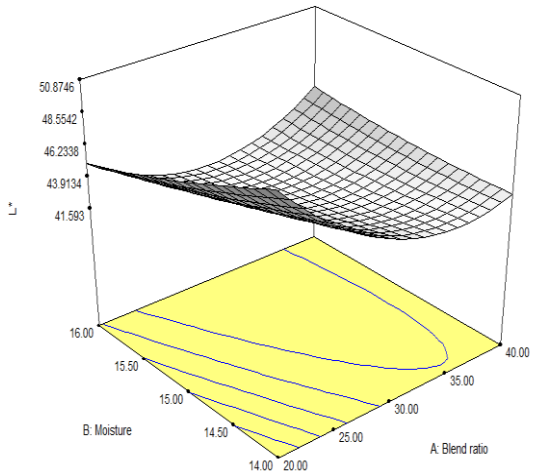


Fig.2 Effect of screw speed: feed moisture on colour (L) value

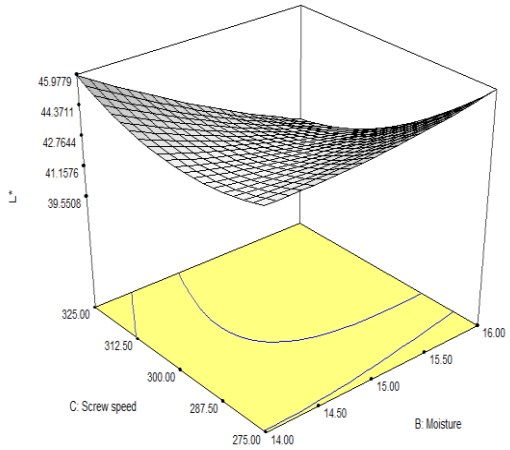


Fig.3 Effect of temperature: feed moisture on colour (L) value

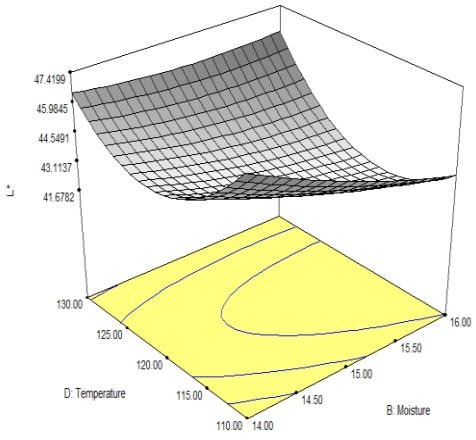


Fig.4 Effect of temperature: screw speed on colour (a*) value

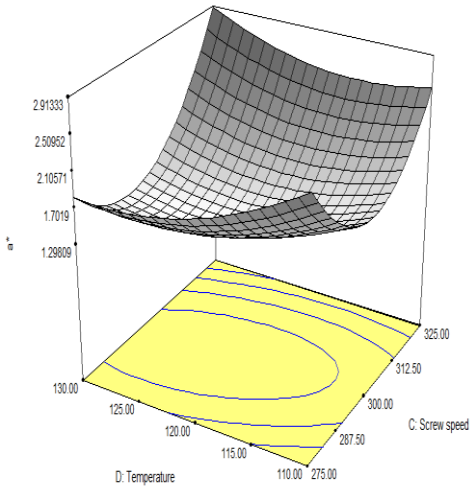
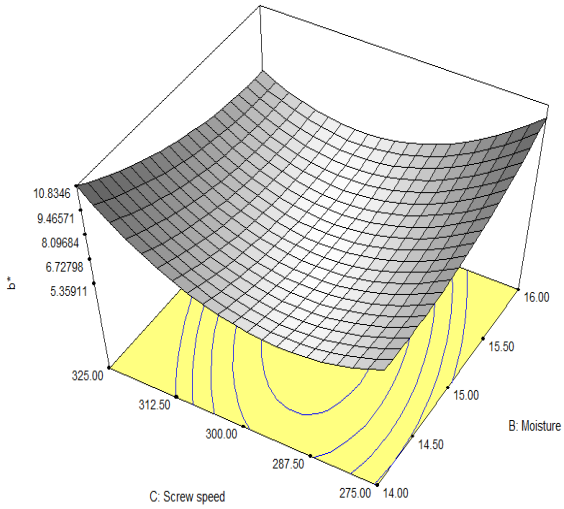


Fig.5 Effect of screw speed: feed moisture on colour (b*) value



The increase in a* value of extrudates with respective to feed composition may be due to reduction of corn flour for Maillard reaction and destruction of heat sensitive pigments. F-value for the interaction term $x_3.x_4$ is 2.59 which P value is 0.1283.The coefficient of the interaction term is positive so a* value will show concave shaped variation with the change in value of variables. From the Fig.4 we can observe that a* value increases as screw speed and temperature increases

Effect of process variables on product color (b* value)

Color (b*) is the important physical characteristics of extrudate products and directly related to the acceptability of food products. Color (b*) of germinated buckwheat flour and corn extrudate varied between 4.22 to 16.88. The maximum value for b* is 100 indicating blueness. Therefore increase in b* value indicates a increase in blueness. Tables 6 and Table 7 shows the

coefficient of the model and other statistical attributes of Color (b* value).

The Model F-value of 9.59 implies model is significant. In this case x_1^2, x_2^2, x_3^2 x_4^2 *and* $x_2.x_3$ are significant model terms at (P<0.05). R^2 0.8995, Adj R^2 0.8057 and Adeq precision is 9.524.

$b^* = 5.37-0.34.x_1 -0.20.x_2 +0.13.x_3 -0.53.x_4 +1.62.x_1^2 +0.91x_2^2 +2.68.x_3^2 +1.97.x_4^2 +0.000.x_1.x_2 -0.16.x_1.x_3 +0.59.x_1.x_4 -1.54\ x2.x3 +0.33.x_2.x_4 +0.29.x_3.x_4$ (3)

Where, x_1, x_2, x_3, *and* x_4 are the coded values of Feed composition, moisture content %, screw speed rpm and temperature ^{0}C respectively.

From equation (3), it is evident that the coefficient of x_1, x_2 are negative, therefore as feed moisture decreases b* value increases. Increase screw speed will also increase b*value. Coefficient of x_1 and x_4 is negative indicating that as of the barrel temperature and feed composition of buckwheat increases b* value of product decreases.

F-value for interaction term of moisture content and barrel screw speed(x_2x_3) is 14.21 which is significant (P <0.0019), since coefficient of x_2x_3 is negative, it will show convex shaped variation with the change in value of variables shown in Fig 5 we can observe that b* value decreases as screw speed and feed moisture decreases.

From the present study the following conclusion were drawn:

Significant effect was observed on the product response by varying in corn flour level, moisture content, temperature and screw speed. Higher corn flour proportion in feed composition showed higher L value of color.

L* value varied between 40.68 to 58.74, a* value ranged from 0.73 to 6.89 and b* value varied from 4.22 to 16.88 of extruded product.

Numerical optimization resulted in following optimized value of process variable, corn flour: germinated buckwheat flour (34.52:65.48), moisture content 14%, barrel temperature 129.69°C, screw speed 275 rpm, as optimum variables to produce acceptable extrudates.

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