FINAL REPORT

Title of the Project: Development of health promoting extruded RTE breakfast cereals incorporating *choukua* rice and *bhimkol* banana of Assam along with carambola pomace

Sanction No: 11/MFPI/R&D/2009

Submitted to:

Director
Ministry of Food Processing Industries
New Delhi

Submitted by:
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FINAL REPORT

1. Title of the Project: "**Development of health promoting extruded RTE breakfast cereals incorporating *choukua* rice and *bhimkol* banana of Assam along with carambola pomace**"

2. Institute / College / University / Organization:

Department of Food Engineering and Technology

School of Engineering, Tezpur University, Tezpur – 784028, Assam.

3. Duration of the project: 05.04.2011 to 05.04.2013

4. Objectives of the Project:

- To standardize the processing conditions of extruded RTE health food
- To conduct acceptability studies of the product
- To study physicochemical and rheological properties of the extrudates
- To analyse the nutritional quality of the product
- To estimate the health promoting properties of the extrudates
- To study the shelf life of the extruded products

5. Financial assistance released by MFPI:

S. No.	Particulars	Grant Sanctioned (₹)	Amount Sanctioned	Expenditure (₹)		Balance (₹)
			Grand Total (₹)	2011-12	2012-13	
1	Equipments	30,36,036 /-	23,11,639 /-	11,72,714/-	8,17,644/-	3,21,281/-
2	SRF [@14000/-]	3,36,000 /-	2,55,830/-	1,58,666/-	1,46,000/-	(-)48,836/-
3	Consumables	6,00,000 /-	4,56,840 /-	1,42,478/-	1,74,973/-	1,39,389/-/-
4	Travel	60,000 /-	45,684 /-	NIL	1,090/-	44,594/-
Grand Total		40,32,036 /-	30,69,993 /-	14,73,858/-	11,39,707/-	4,56,428/-

6. Equipments purchased for the Project:

Name of the equipment Expenditure	
i	Single screw extruder
ii	Automatic fiber estimation system
iii	Water Bath
iv	Nitrogen flushing and sealing machine:
v	Electronic weighing scale 10 kg
vi	Recirculation Type Tray drier
vii	Analytical Balance

viii	Humidity chamber
ix	Ribbon Blender

7. Methodology/ Procedure applied/ adopted:

Preparation of composite flour

The rice used in the study is low amylose rice called *chokua* and is referred to as *chokua* rice here after. Seeded banana (*Musa balbisiana*, ABB, locally called as *bhimkol*) is hereafter referred to as banana. *Chokua* rice and banana and carambola were procured from local market. Rice was cleaned to remove foreign matter. Rice grains were ground in the hammer mill (ALFA Instruments, Delhi) to pass through 1mm sieve to get fine flour. Seeded banana was sliced into pieces and dried in a tray drier (Labotech, India) at 55 °C for 10 h followed by grinding in the hammer mill (ALFA, Instruments, India). The juice from carambola fruits was squeezed out and the pomace obtained was dried in the tray drier at 55 °C for 18 h followed by grinding in the hammer mill. The *chokua* rice, banana and carambola pomace flours were blended in definite ratios and conditioned with water for 24 h to achieve feed moisture level between 9g/100g and 21g/100g (wb).

Extrusion cooking conditions

Extrusion cooking was performed in a single screw extruder (G. L. Extrusion Systems Pvt. Ltd., India), driven by a 5 HP Induction motor. The feed and cutter were controlled with 1HP AC motor, separately. The composite flour was fed into the extruder with a pre-calibrated feeding screw and temperature was controlled by means of water circulation system. Steady state condition was assumed to have been reached when there were no visible drifts in product temperature. Extrudate was allowed to pass through 2 mm circular die and cut with a constant cutter speed (600 rpm). Extrudates were collected, cooled to room temperature under natural convection conditions and stored in low density polyethylene (LDPE) bags for further analysis.

Experimental design and statistical analysis

Response Surface Methodology (RSM) was applied to the experimental data using the package, Design expert version 7.1.1, (STATE-EASE Inc, Minneapolis, USA. Trial version). The same software was used for generation of response surface plots, superimposition of counter plots and optimization of process variables (Altan et al. 2008a; Yagci & Gogus, 2008; Ding et al. 2005; Dhingra & Paul 2005). The results are reported as mean of three replicates. A four variable (five level of each variable) central composite design was employed (Montgomery, 2001; Yagci & Gogus, 2008). The parameters and their levels were chosen based on literature available on rice based extrudates (Yagci & Gogus, 2008; Ding et al. 2005; Upadhyaya, 2008). The ingredients used for the dietary fiber rich extrudates were: *chokua* rice flour, banana powder, carambola pomace. The independent variables included screw speed (SS), barrel temperature (BT), feed moisture content (FMC) and blend ratio (BR). Response variables were expansion index (EI), sectional expansion index (SEI), hardness (HRD), puncture force (PF), breaking strength (BS), bulk density (BD), and colour (hunter Lab) values. The five levels of the process variables were coded as -2, -1, 0, 1, 2 (Montgomery, 2001) and the design in coded (x) form are given in Table 1.

Physicochemical Analysis

Expansion Index

Expansion of extrudate was measured in terms of diameter, at three points on each piece, of the extruded product to the die diameter by using a vernier caliper (Ding et al. 2005, 2006) to measure the average thickness of the extrudates. Measurements were taken on ten randomly selected pieces of extrudates.

Expansion Index (EI) = Diameter of extrudate / Diameter of Die ----------------------------- (1)

Sectional Expansion Index (SEI) = (Diameter of extrudate)^2 / (Diameter of Die)^2 --------------- (2)

Bulk Density

Bulk density (BD) of extrudates was determined following glass bead displacement method using a 100 ml graduated cylinder. The cylinder was tapped soundly 20 times. The weight of each sample was weighed with an electronic balance. The bulk density (g/cm^3) was calculated by dividing the weight of the extrudates by the volume displaced. Ten measurements were taken for each treatment (Bhatnagar & Hanna, 1995).

Textural measurement

Texture evaluation of the extrudates was performed with texture analyzer (TA-HD-plus, Stable Micro Systems,UK). Hardness (HRD), Puncture force (PF) were determined by using P-75 and P-5 as the maximum force offered by the extrudates during 40g/100g compression. Breaking strength (BS) of extrudates was determined as the peak breaking force offered by extrudates during three point cutter test, respectively (Onwulata et al. 2001).

Breaking Strength (N/mm^2) = Peak breaking force / Cross sectional area ------------------- (3)

Color

The color of the raw materials and ground extrudates were measured using the color measurement spectrophotometer (Hunter Lab, Ultra-scan VIS) as lightness (L), redness (a) and yellowness (b). Extrudates were cooled and dried at room temperature (35°C) for 1h, then milled to pass through a 0.21 mm screen for color analysis. For each sample, four measurements were taken and averaged. The total color change (ΔE) was calculated as

$$\Delta E = \sqrt{(L - Lo)^2 + (b - bo)^2 + (a - ao)^2} \qquad \text{------------------- (4)}$$

Rheological Properties

Pasting properties of extrudate powders were determined using a Rapid Visco Analyser (RVA) model 2-D (Newport Scientific Instrument) with Thermocline software (3.0 version) by ICC Standard Method No. 162 (1995). Briefly, sample suspension was prepared by placing 3.5g extrudate powder, in an aluminum canister containing 25g distilled water. A programmed heating and cooling cycle was used. Each sample was stirred at 960 rpm for 10 s while heating at 50°C, and then constant shear rate (160 rpm) was maintained for the rest of the process. Sample was held at 50°C for 1 min. Then the samples were heated from 50°C to 95°C within 3 min 42 s and held at 95°C for 2 min 30 s. Subsequently samples were cooled down from 95 °C to 50°C within 3 min 48 s and then held at 50°C for 2 min. A RVA plot of viscosity (cp) versus time (s) was used to determine peak viscosity (PV) and final viscosity (FV).

Water absorption index (WAI) and water solubility index (WSI)

WAI and WSI were determined following the procedure of Anderson et al. (1969). Flour (2.5 g) was suspended in 30ml of distilled water in a tared 60ml centrifuge tube. The slurry was stirred with a glass rod for 1min at room temperature and centrifuged at 3000 x g for 10 min. The supernatant was poured carefully into a tared evaporating dish. WAI was calculated from the weight of the remaining gel and expressed as g gel/ 100 g (dry sample). WSI, expressed as g solids/ 100g original solids, was calculated from the weight of dry solids recovered by evaporating the supernatant overnight at 110°C.

XRD

The X- ray diffraction patterns of starch samples were obtained on a X-ray diffractometer (Miniflex,Rigaku Corporation, Japan). Patterns were recorded from a diffraction angle (2^θ) of 5-35 θ angle at a scan speed of 2 θ/min.

Nutritional evaluation

Energy value was estimated in a bomb calorimeter (model LECO AC-350, LECO Corp.) and protein content was determined by Micro Kjeldhal method. Moisture, fat, crude fiber and ash were determined by standard methods (AOAC 2000). Carbohydrate was determined by difference. Dietary fiber content was determined by AOAC enzymatic – gravimetric method of Proxy et al. (1998). Magnesium and potassium content were determined using flam-mode in an Atomic Absorption Spectrophotometer (model 3600, Thermofisher).

Storage Study

The low amylose rice extrudates incorporated with seeded banana and carambola pomace were packed in N_2 – filled laminates and storage study was done for a period of 6 months at different conditions viz. (a) humidity chamber 39°C & 70% RH and (b) room temperature respectively(22° to 35 °C & 66% to 85% RH).

8. Results and output of the R&D

Part – A: Optimisation of processing parameters and quality of extruded *choukua* rice and *bhimkol* banana

1.Effect of extrusion cooking on Sectional Expansion Index (SEI) of extrudates

The regression equation relating the response function expansion, measured as sectional expansion index and independent variable, was represented in terms of coded variable as given below.

$$SEI = + 12.74 -0.032\, x_1 -1.49\, x_2 +1.18\, x_3 + +0.10\, x_1^2 - 0.53 x_2^2 -0.021\, x_3^2 -0.24\, x_1.x_2 -0.065\, x_1.x_3 +0.35\, x_2.x_3$$

ANOVA for the model of SEI as fitted shows significance ($P < 0.05$) and the lack of fit is non-significant ($P > 0.05$). The response surface regression model on SEI yielded excellent fits with coefficient of determination ($R^2 = 0.9451$) for *bhimkal* incorporated rice extrudates. Temperature has a significant positive linear effect ($p < 0.01$) whereas its non-significant quadratic effect ($p > 0.05$) was negative. Feed moisture has significant negative linear and quadratic effect on SEI of *bhimkal* incorporated rice extrudates. SEI of *bhimkal* incorporated rice extrudates varied between 9.181 to 15.415 based on the level of extrusion variables. The response surface (Fig 1) shows that temperature and feed moisture content had a dominant effect on SEI whereas level of *bhimkal* incorporation seems to have a minimum effect. Altan (2008b) also reported significant effect of barrel temperature on SEI of barley flour extrudates. According to Chinnaswamy and Hanna (1998) expansion of corn starch extrudates increased as the barrel temperature increased from 110 to 140 °C and declined with further increase in temperature. SEI increases rapidly with the increase in BT which may be due to higher degree of superheating of water in the extruder encountering bubble formation and expansion of the melt (Ding et al. 2006). The increase in FMC resulted decrease in expansion which may occur due to reduction of elasticity of dough through plasticization of melt (Ding *et al.*, 2005 & 2006). The increase in FMC reduces the friction between the feed material, screw and barrel and also has a negative effect on the starch gelatinization and consequently reduces product expansion (Liu *et al.*, 2000).

2. Effect of extrusion cooking on Bulk Density (BD) of extrudates

Bulk density of *bhimkal* incorporated rice extrudates ranged from 0.129 to 0.268. SEI is not sufficient enough for expansion by itself under the extrusion condition. Bulk density expressed as gcm^{-3} is another measure of expansion besides SEI. Acceptable coefficient of determination (R^2=0.877) was obtained for significant model ($P < 0.05$) with non-significant lack of fit ($P > 0.05$) variations.

$$BD = +0.18 - 4.940\text{ E-003 } x_1 + 0.022\, x_2 - 0.028\, x_3 + 2.147\text{ E-003 } x_1^2 + 9.572\text{ E-003 } x_2^2 + 8.758\text{ E-003 } x_3^2 - 2.800\text{ E-003 } x_1.x_2 + 9.550\text{ E-003 } x_1.x_3 - 9.350\text{ E-003 } x_2.x_3$$

It was perceived from Fig 2 that with the increase in barrel temperature bulk density decreased which may be attributed to higher expansion but at higher temperatures its quadratic effect dominates. Suksomboon *et al.* (2011) reported similar effect of barrel temperature on the BD of extrudates developed from Hom Nil rice. Altan *et al.* (2008a) described that the degree of superheating of water in the extruder would increase along with rise in BT, also leading to higher expansion and hence shows lower bulk density. At comparatively higher temperatures melt viscosity get reduced hence bubble walls become too thin to contain the vapor pressure, resulting in more bubble fracture, thus increasing rate of collapse and overall expansion deduced, which is sufficient enough to favor the quadratic effect on BD (Fletcher et al 1985). The higher BD values were obtained at lower temperatures as shown in Fig. 3. Increased feed moisture may reduce the elasticity of the dough through plasticization of the melt, resulting in reduced SME and therefore reduced gelatinization, decreasing expansion and accompanied by increase in bulk density of the extrudates (Ding *et al.*, 2006).

3. Effect of extrusion cooking on Breaking Strength (BS) of extrudates

The following regression equation was developed in terms of coded variable for breaking strength as textural attribute of extrudates.

$BS = + 0.88 + 0.036\ x_1 + 0.25\ x_2 - 0.20\ x_3 - 0.011\ x_1^2 + 0.066 x_2^2 + 8.416E\text{-}003\ x_3^2 - 0.017\ x_1.x_2 + 0.025\ x_1.x_3 - 0.11\ x_2.x_3$

BS of extrudates ranged from 0.549 to 1.508 with an average of 0.934 respectively. ANOVA for the model of BS as fitted shows significance ($P < 0.05$) and the lack of fit is non- significant ($P > 0.05$). The response surface regression model on SEI yielded excellent fits with coefficient of determination ($R^2 = 0.96$) for *bhimkal* incorporated rice extrudates. BT and FMC were found to have the most significant effect. Liu *et al.* (2000) reported that increase in feed moisture reduced expansion and provided a dense product that required the higher force to break the sample. BS was found to have lower values for extrudates at higher barrel temperature as shown in Fig. 3. Suksomboon et al. (2011) reported lower hardness values for extrudates developed from Hom Nil rice at higher barrel temperature. A decrease in BS of the extruded product was observed with increase in BT. Sacchetti (2005) reported direct correlation between hardness and density of extruded cereal blend. An increase in processing temperature will cause drop in melt viscosity favoring bubble growth, signifying better expansion and lower density to have softer extrudates.

4. Effect of extrusion cooking on Rheological Properties of extrudates

Multiple regression equations for peak viscosity and final viscosity as a funtion of feed moisture (X_1), barrel temperature (X_2) and *bhimkal* flour (X_3) of *chokua* rice extrudates are given as follows.

$PV = + 677.46 + 40.72\ x_1 + 77.61\ x_2 - 85.36\ x_3 - 19.41\ x_1^2 + 35.22\ x_2^2 + 24.08 x_3^2 + 7.13\ x_1.x_2 + 31.38\ x_1.x_3 - 41.63\ x_2.x_3$

$FV = +122.20 + 2.78\ x_1 + 10.86\ x_2 - 2.75\ x_3 - 1.71\ x_1^2 + 3.24\ x_2^2 + 0.59\ x_3^2 + 0.63\ x_1.x_2 - 3.12\ x_1.x_3 - 0.88\ x_2.x_3$

ANOVA results for quadratic models of viscosity parameters are given in Table 2. Acceptable coefficient of determination values ($R^2 = 0.8175$ and 0.8759) were obtained for significant models such as peak viscosity with significant ($P < 0.05$) and final viscosity with non-significant lack-of-fit ($P > 0.05$) variations. Ding *et al.* (2005) reported decrease in melt viscosity and reduced viscosity effect which favored better expansion. It was observed from Fig. 5 that PV and FV gradually decreased with increase in BT (Guha *et al.*, 1998; Balasubramanian *et al.*, 2012). The decrease in PV and FV may be explained by the fact that due to extrusion cooking water penetrates into the granules and weakens the hydrogen bonds in starch segments and reflects a degradative RVA profile (Balasubramanian *et al.,* 2012a). Increase in PV was observed with higher FMC which may be due to gelatinization, since during heating the rate of thinning declines which could be ascribed to the counter effect of swelling of partially gelatinized material (Schweizer et al. 1986). Moraru and Kokini (2003) also reported that extrusion temperature plays the major role in changing the rheological properties of the extruded melts, which in turn affect the expansion volume.

5. Effect of extrusion cooking on Hunter L, a, b values of extrudates

Multiple regression equations for Hunter L color value and total color difference (ΔE) as a function of *bhimkal* flour (X_1), feed moisture (X_2) and barrel temperature (X_3) of *chokua* rice extrudates are given below.

$$\text{Hunter } L = +55.48 - 2.36\, x_1 + 1.87\, x_2 - 0.87\, x_3 - 0.91\, x_1^2 + 0.42\, x_2^2 + 0.29\, x_3^2 + 1.23\, x_1.x_2 - 0.13\, x_1.x_3 - 0.50\, x_2.x_3$$

$$\text{Hunter } \Delta E = +10.84 - 2.25\, x_1 + 1.73\, x_2 - 0.89\, x_3 - 0.85\, x_1^2 + 0.50\, x_2^2 + 0.25\, x_3^2 + 1.19\, x_1.x_2 - 0.21\, x_1.x_3 - 0.42\, x_2.x_3$$

The significance of Hunter *L* and ΔE is given in Table 3 and lack of fit ($P < 0.05$) found to be significant for both. The coefficient of determination (R^2) for the Hunter *L* color parameter and ΔE were 0.7612 and 0.7626 respectively. The choosen processing condition did not influence significantly ($P > 0.05$) either Hunter *a* or *b* color value, thus detailed analyses of the two color values are not further explained in this study. The effect of independent variables on Hunter *L* value is shown in Fig 6. Increase in processing temperature results in decrease in Hunter *L*, *a*, *b* value, due to Millard browning of sugar present in *bhimkal* powder. Ilo and Berghofer (1999) also reported similar decrease in Hunter *L* value due to rise in extrusion cooking temperature of maize grits. The expansion gets reduced at high feed moisture and results in higher Hunter *L*, *a*, *b*. However, incorporation of *bhimkal* powder showed significant positive linear effect ($p < 0.05$).

6. Multiple response optimizing

In order to optimize processing condition for extrusion cooking of *chokua* rice blend by numerical optimization, which finds a point that maximizes the desirability function, equal importance of 3 was given to all the 3 parameters. However, based on their relative contribution to quality of final product the importance given to different responses was 4,4,3,3, 3 and 3 for SEI, BD, BS, PV, FV, Hunter L and ΔE values respectively. The optimal combination for BP, FMC and BT, was 100 g/kg, 10% and140 °C (Table 4), which corresponds to run-17. The overall desirability (Fig. 8), which ranges from zero outside of the limits to one at the goal, was 0.872.

7. Physicochemical and Nutritional characteristics of optimized extruded flour

The single-screw extruder was operated at the optimum combination of process variables, ie SS = 350 rpm, BT=140°C, FMC=10 % and BP=100 g/kg, for the production of extrudates from chokua rice. Extrudates were cooled and dried at room temperature (50°C) for 1h, then milled to pass through a 65-US mesh (0.21 mm) screen, packed in plastic bags and stored at 4°C. This flour was recognized as optimized extruded flour. The WAI and WSI values were found to be 4481.60 g/kg and 444.32 g/kg respectively. Extrudates were found to have better nutrition profile (Table 5) and considerable amount of Mg (13.25 mg) and K (21.7 mg) respectively.

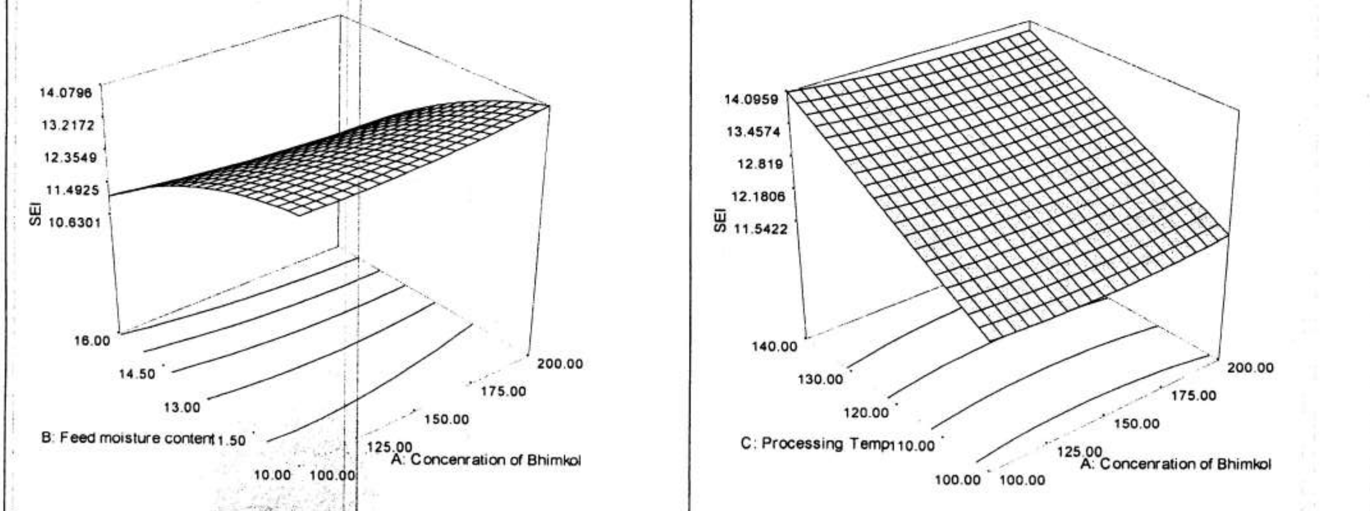

Fig. 1. Effect of the *bhimkal* powder concentration and (a) the feed moisture content and (b) barrel temperature on the expansion (SEI) of the extrudates

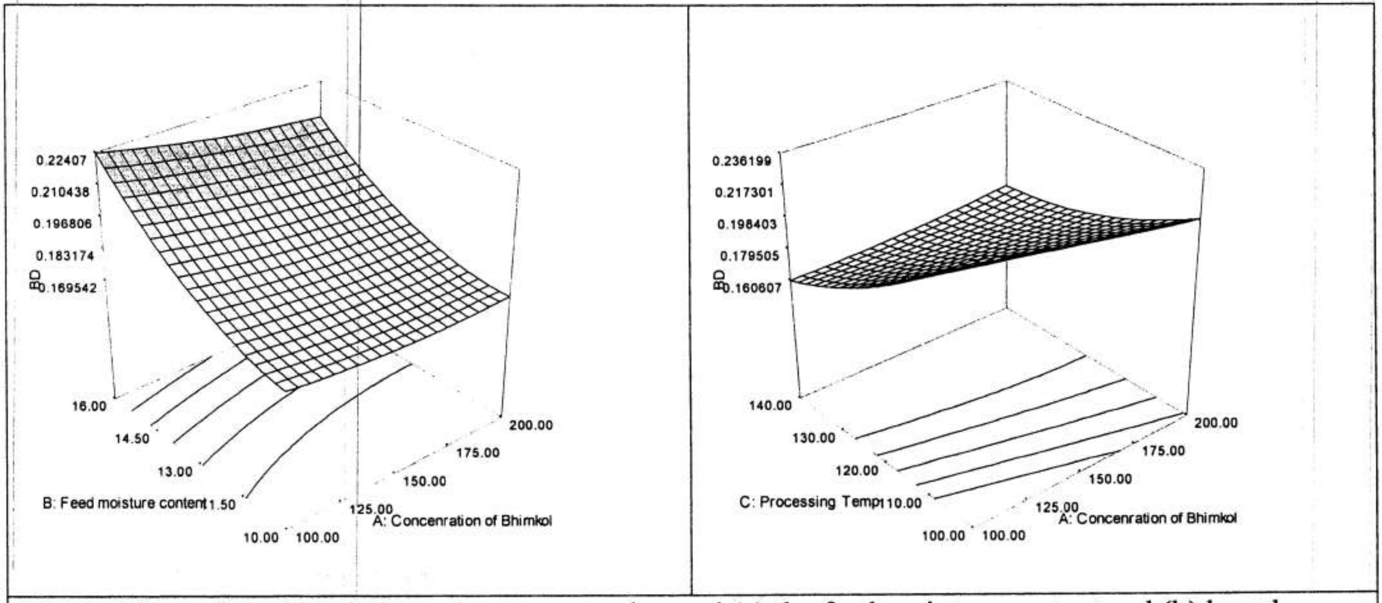

Fig. 2. Effect of the *bhimkal* powder concentration and (a) the feed moisture content and (b) barrel temperature on bulk density (BD) of the extrudates

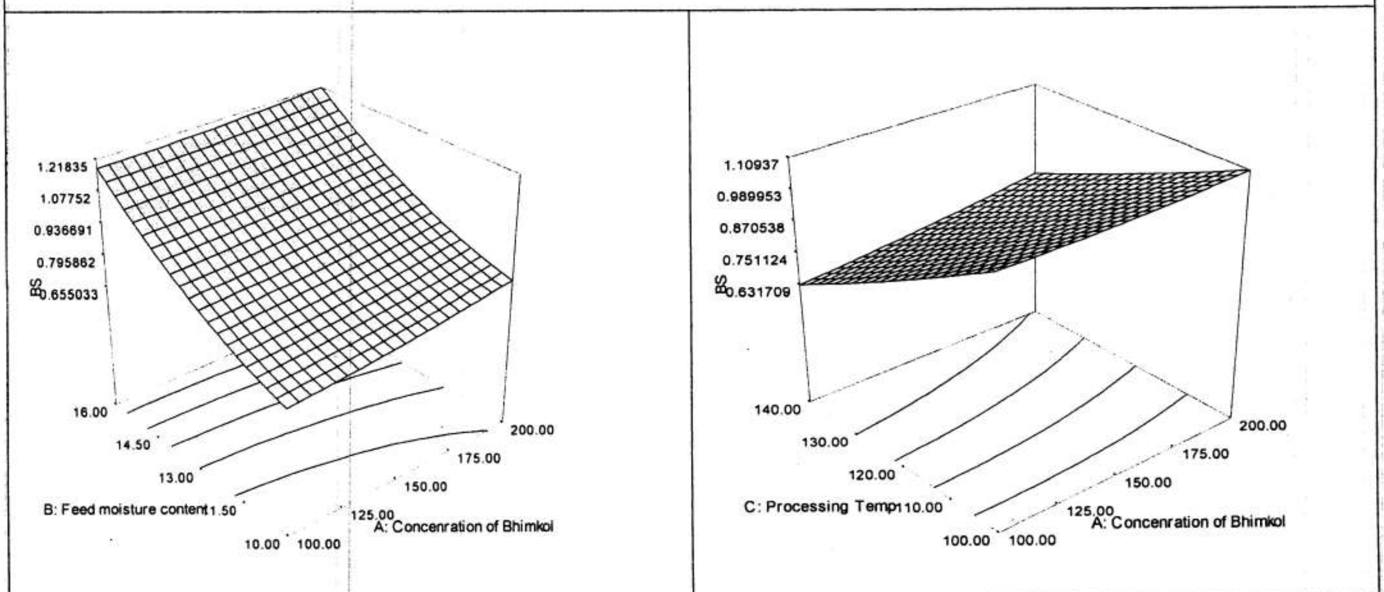

Fig. 3. Effect of the *bhimkal* powder concentration and (a) the feed moisture content and (b) barrel temperature on the breaking strength (BS) of the extrudates

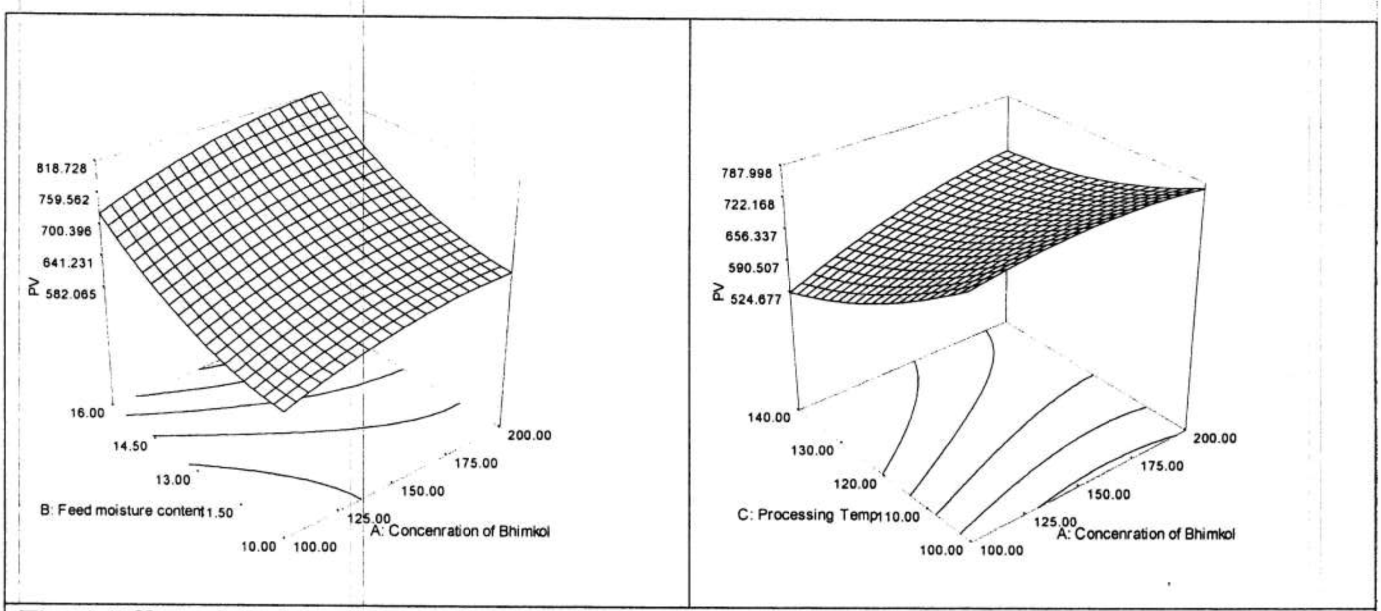

Fig. 4. Effect of the *bhimkal* powder concentration and (a) the feed moisture content and (b) barrel temperature on the peak viscosity (PV) of the extrudates

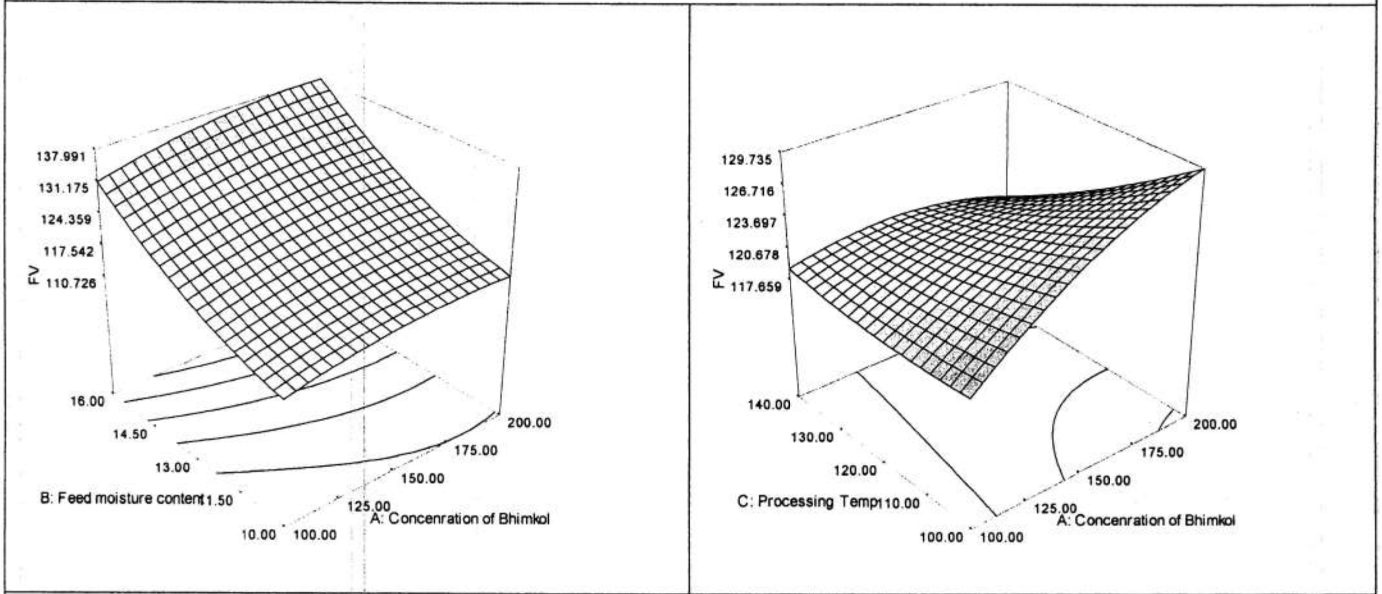

Fig. 5. Effect of the *bhimkal* powder concentration and (a) the feed moisture content and (b) barrel temperature on the final viscosity (FV) of the extrudates

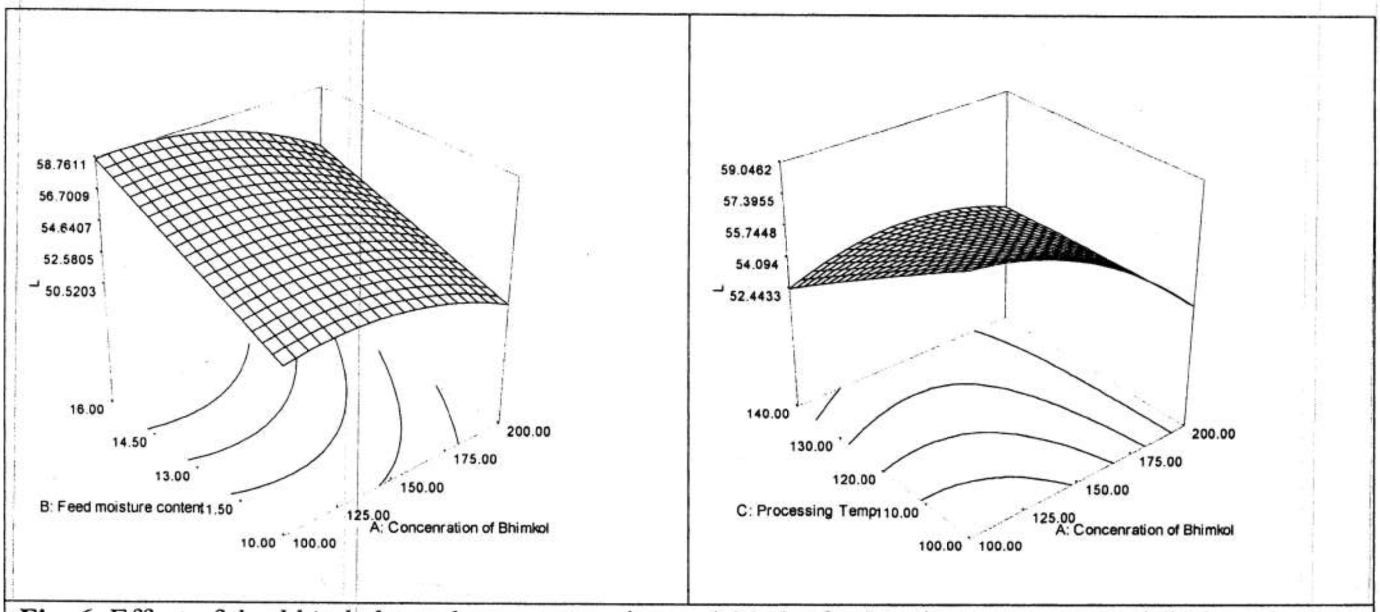

Fig. 6. Effect of the *bhimkal* powder concentration and (a) the feed moisture content and (b) barrel temperature on the Hunter (L) of the extrudates

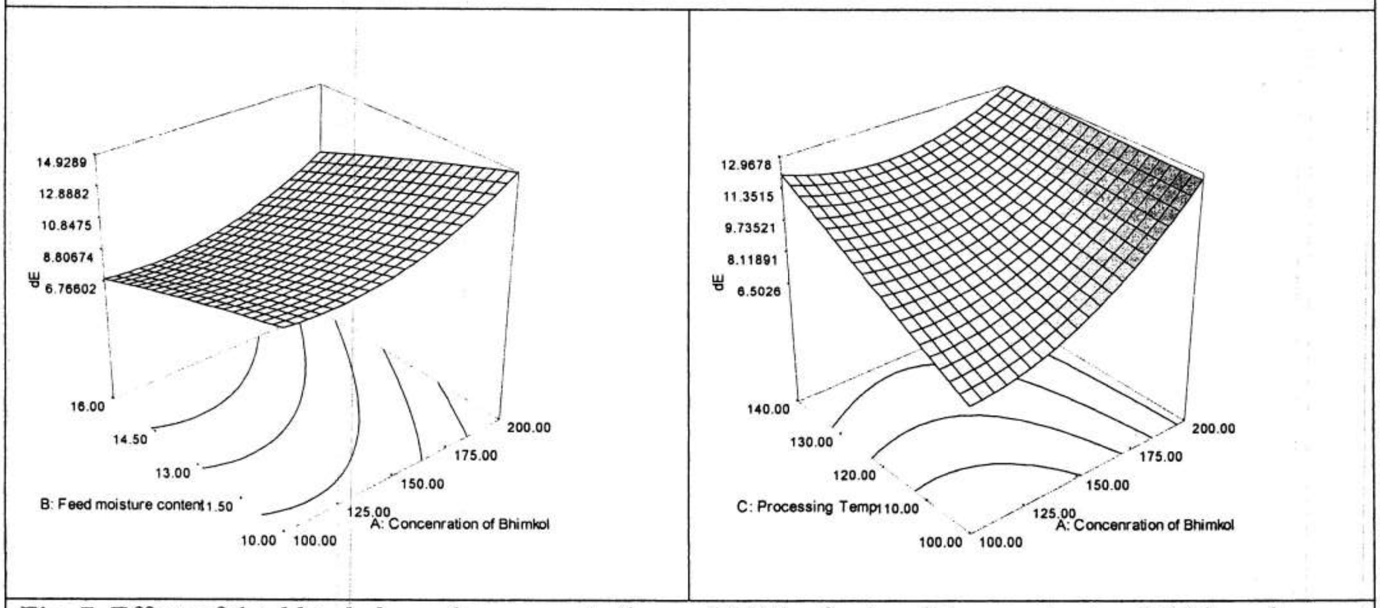

Fig. 7. Effect of the *bhimkal* powder concentration and (a) the feed moisture content and (b) barrel temperature on the Hunter (ΔE) of the extrudates

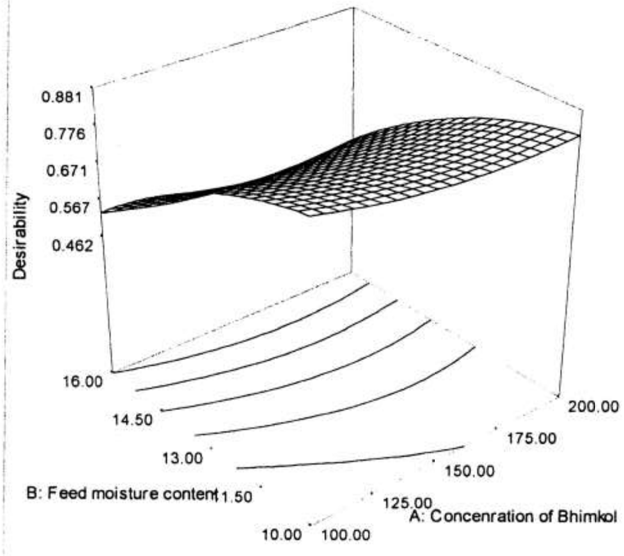

Fig. 8. Desirability function response surface for *bhimkal* incorporated *chokua* rice extrudates at 140 °C and 350 rpm.

Table 1: Experimental design for extrusion experiment with coded and actual variable levels

Run	Coded			Un coded		
	x_1[a]	x_2[b]	x_3[c]	X_1[a]	X_2[b]	X_3[c]
1	1	-1	1	200	10	140
2	0	0	0	150	13	120
3	0	-1.68	0	150	8	120
4	1.68	0	0	234	13	120
5	0	0	1.68	150	13	154
6	0	0	0	150	13	120
7	0	0	0	150	13	120
8	-1	-1	-1	100	10	100
9	1	1	-1	200	16	100
10	1	1	1	200	16	140
11	0	1.68	0	150	18	120
12	-1	1	1	100	16	140
13	-1	1		100	16	100
14	1	-1	-1	200	10	100
15	0	0	0	150	13	120
16	-1.68	0	0	66	13	120
17	-1	-1	1	100	10	140
18	0	0	0	150	13	120
19	0	0	-1.68	150	13	86
20	0	0	0	150	13	120

[a] x_1 and X_1, concentration of *bhimkal* power {g kg^{-1}}

[b] x_2 and X_2, feed moistur content {%}

[c] x_3 and X_3, extrusion temperature (C)

Table 2: Analysis of variance results for fitted models of product properties

Response	Source	df	Sum of square	Mean squares	F- value	P- value
SEI	Regression	9	53.94	5.99	19.11	<0.0001**
	Lack of Fit	5	*2.26*	*0.45*	*2.58*	*0.1608*
	Pure error	5	*0.88*	*0.18*		
	Residual	10	3.14	0.31		
	Total	19	57.07			
BD	Regression	9	0.022	2.397×10^{-3}	7.92	0.0017**
	Lack of Fit	5	2.275×10^{-3}	4.551×10^{-4}	3.03	0.1244
	Pure error	5	7.503×10^{-4}	1.501×10^{-4}		
	Residual	10	3.026×10^{-3}	3.026×10^{-4}		
	Total	19	0.025			
BS	Regression	9	1.58	0.18	26.86	<0.0001**
	Lack of Fit	5	*0.044*	*8.741E-003*	*2.03*	*0.2273*
	Pure error	5	*0.021*	*4.299E-003*		
	Residual	10	0.065	6.520E-003		
	Total	19	1.64			
PV	Regression	9	2.596×10^{5}	28845.34	4.98	0.0097**
	Lack of Fit	5	*49006.81*	*9801.36*	*5.48*	*0.0427*
	Pure error	5	*8943.33*	*1788.67*		
	Residual	10	57950.14	5795.01		
	Total	19	3.176×10^{5}			
FV	Regression	9	2120.18	235.58	7.84	0.0017**
	Lack of Fit	5	*223.53*	*44.71*	*2.91*	*0.1331*
	Pure error	5	*76.83*	*15.37*		
	Residual	10	300.37	30.04		
	Total	19	2420.55			
L	Regression	9	221.87	24.65	3.78	0.0251*
	Lack of Fit	5	20.77	4.15	0.47	0.7888
	Pure error	5	44.52	8.90		
	Residual	10	65.29	6.53		
	Total	19				
ΔE	Regression	9	218.39	24.27	3.34	0.0369*
	Lack of Fit	5	27.43	5.49	0.61	0.7016
	Pure error	5	45.20	9.04		
	Residual	10	72.63	7.26		
	Total	19				

* Significant at P< 0.05; ** Significant at P< 0.01; df: degree of freedom.

Table 3: Optimized parameters in the response optimizer

Response	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
SEI	**Maximum**	9.181	15.416	1	1	4
BD	**Maximum**	0.129	0.268	1	1	4
BS	**Minimum**	0.549	1.589	1	1	3
PV	**Minimum**	460	978	1	1	3
FV	**Minimum**	110	152	1	1	3
L	**Minimum**	46.47	61.39	1	1	3
ΔE	**Minimum**	3.698	16.555	1	1	3

Table 4: Optimized solution obtained using the response optimizer

Optimal solution			**Predicted responses**						
X_1 (g/kg)	**X_2 (%)**	**X_3 (°C)**	**SEI**	**BD, g/cm^3**	**BS, N/ mm^2**	**PV**	FV	**L**	**ΔE**
100	10	140	14.541	0.15467	0.54662	531.05	112.556	48.632	5.28907

Table 5: Nutrition profile of *bhimkal* Incorporated *chokua* extrudates

Sl. No	Nutritional Information Per 100g	Values
1	Energy, Kcal	398.50 ± 4.2
2	Moisture, %	7.02 ± 0.2
3	Protein, g	8.12 ± 0.19
4	Fat, g	0.62 ± 0.007
6	Crude Fiber, g	1.79 ± 0.05
7	Ash, g	1.08 ± 0.02
8	Carbohydrate, g	81.44 ± 2.13
9	Mg, mg	13.25 ± 0.02
10	K, mg	21.7 ± 0.05

Part –B: Optimisation of processing parameters and quality of extruded *choukua* rice, *bhimkol* banana and carambola pomace

Table 1 gives the response variables (EI, SEI, HRD, PF, BS, BD, Hunter -L and Hunter -ΔE) of extrudates along with independent variables of screw speed (SS), barrel temperature (BT), feed moisture (FMC) and blend ratio (BR). A complete second order model was tested for its adequacy to decide the variation of responses with independent variables. To aid visualization of variation in responses with respect to processing variables, series of three dimensional response surface (Fig. 1 to 5) were drawn using design expert software (State-ease 7.1.1).

$$y = b_o + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + b_{11} x_1^2 + b_{22} x_2^2 + b_{33} x_3^2 + b_{44} x_4^2 + b_1b_2 x_1 x_2 + b_1b_3 x_1 x_3 + b_1b_4 x_1 x_4 + b_2b_3 x_2 x_3 + b_2b_4 x_2 x_4 + b_3b_4 x_3 x_4 + \varepsilon \text{ ---------- (5)}$$

1. *Effect of extrusion cooking on expansion of extrudates*

Multiple regression equations for Expansion Index (EI) and Sectional Expansion Index (SEI) as a function of screw speed (X_1), barrel temperature (X_2), feed moisture (X_3) and blend ratio (X_4) of *chokua* rice extrudates are given below.

$$EI = + 3.30 + 0.22 x_1 - 0.23 x_3 - 0.18 x_1x_3 \text{ ---------- (6)}$$

$$SEI = + 10.97 + 1.46 x_1 - 1.57 x_3 - 1.17 x_1x_3 \text{ ---------- (7)}$$

Expansion index (EI) and Sectional Expansion Index (SEI) of extrudates ranged between 2.55 to 4.15 and 6.49 to 17.25 respectively. The coefficient of x_3 was negative but those of x_1, x_2 and x_4 were positive. Therefore, increase in FMC may reduce expansion whereas increase in screw speed, barrel temperature and blend ratio may increase the expansion. Since coefficients of x_2^2 and x_4^2 are negative, a maximum expansion will occur in the range of BT and BR selected for study. On the other hand x_1^2 and x_3^2 are positive, a minimum expansion will occur in the selected range of SS and FMC. The coefficients of the model and other statistics are given in Table 2. The model F-value of 2.86 and 2.81 implies model was significant ($p < 0.05$) for both EI and SEI. The coefficient of determination (R^2) for EI and SEI were 0.7143 and 0.7109, respectively. Analysis of variance of Eq.6 showed that F-value for linear terms of SS and FMC were 11.16 and 12.40 and p-values 0.0041 and 0.0028 ($p<0.05$), signifying that x_1 and x_3 were significant terms. F and p value for interacting terms x_1x_3 were 0.18 and 0.0374 ($p < 0.05$), signifying that interacting term is also significant. F-value for square terms of SS, BT, FMC and BR were found to be non significant.

It may be observed from Fig. 1 that the expansion increases with the increase in BT and SS, which may be due to higher shear resulting in higher expansion (Ding et al. 2006). Ding et al. (2006) also reported rapid increase in lateral expansion with the increase in barrel temperature which may be due to higher degree of superheating of water in the extruder encountering bubble formation. The increase in FMC and BR reduces the friction between the feed material, screw and barrel and also has a negative effect on the starch gelatinization and consequently reduces product expansion (Liu et al. 2000). Tang & Ding (1994) also reported reduced expansion ration due to increase in fibre content in feed. According to Lue et al. (1991) the presence of fiber ruptured the cell walls and prevented the gas bubbles from expanding to their maximum potential. The increase in FMC caused decrease in expansion which may occur due to reduction of elasticity of dough through plasticization of melt (Ding et al., 2005, 2006). Altan (2008b) also reported significant effect of barrel temperature on SEI of barley flour extrudates. According to Chinnaswamy & Hanna (1998), expansion of corn starch extrudates increased as the barrel temperature increased from 110 to 140 °C and declined with further increase in temperature.

2. Effect of extrusion cooking on bulk density of extrudates

The regression equation relating the response function expansion measured as bulk density (BD) and independent variable is represented in terms of coded variable as given below.

$BD = + 0.23 - 0.022\, x_1 + 0.022\, x_3 - 0.015\, x_1x_2 + 0.016\, x_1x_3$ ------------------------------------ (8)

Bulk density of extrudates ranged from 0.160 to 0.302 g/cm^3. The maximum bulk density at coded point (0, 0, 2, 0) was about 2 times more than the minimum expansion at coded point (0,0,-2,0). The model F-value of 2.65 implies model is significant ($p < 0.05$). R^2 and adjusted R^2 value of the model are 0.699 and 0.4357 respectively. The coefficient of x_3 is positive but those of x_1, x_2 and x_4 are negative and the average is 0.23. Therefore increase in feed moisture content may increase bulk density whereas increase in screw speed and barrel temperature may reduce bulk density. Since coefficients of x_1^2, x_2^2 and x_3^2 are positive; a minimum BD will occur in the range of SS, BT and FMC selected for study. In contrast coefficients of x_4^2 is negative so we could expect a maximum BD in the range of BR selected for study. ANOVA of Eq. 8 showed that F-value for linear terms of SS and FMC were 10.47 and 10.64 and p-values 0.0052 and 0.0049 ($p<0.01$), showed that x_1 and x_3 are significant terms. F-value for square terms of SS, BT, FMC and BR were found to be non significant. F value for interacting terms x_1x_2 and x_1x_3 were 3.19 and 3.79 and p values 0.0932 and 0.0692 ($p < 0.1$), signifying that interacting term is also significant.

It was perceived from Fig. 2 that with the increase in barrel temperature BD decreased which may be attributed to higher expansion (Ding et al. 2006). Suksomboon et al. (2011) reported similar effect of barrel temperature on the BD of extrudates developed from Hom Nil rice. Altan et al. (2008a) described that the degree of superheating of water in the extruder would increase along with rise in BT, also leading to higher expansion with resultant lower bulk density. The increase in BD due to higher FMC may be because of reduction in elasticity of dough and lower expansion (Ding et al. 2006). At comparatively higher temperatures melt viscosity get reduced hence bubble walls become too thin to contain the vapor pressure, resulting in more bubble fracture, thus increasing rate of collapse and overall expansion decreased, which is sufficient enough to favor the quadratic effect on BD (Fletcher et al. 1985).

3. *Effect of extrusion cooking on Textural propertiers of extrudates*

The regression equation for hardness (HRD), puncture force (PF) and breaking strength (BS) as textural attributes were determined in terms of coded variables as follows:

$HRD = + 38.57 - 5.7\,x_2 + 1.79\,x_3 + 2.87\,x_3^2$ ---------------------------(9)

$PF = + 26.40 - 1.59\,x_1 - 3.64\,x_2 + 1.89\,x_3 + 1.99\,x_3^2 + 1.76\,x_1x_2$ ---------------------------(10)

$BS = + 0.79 - 0.15x_1 - 0.20\,x_2 + 0.18\,x_3 - 0.097x_4 + 0.093x_2^2 + 0.081x_3^2 + 0.12\,x_1x_3$ --------(11)

Acceptable coefficients of determination values ($R^2 = 0.832$, $R^2 = 0.869$ and $R^2 = 0.7912$) were obtained for significant models of HRD, PF and BS with non-significant lack of fit variations. The coefficients of x_3 is positve and those of x_1, x_2 and x_4 negative,thus increase in FMC may increase hardness whereas SS and, BT and BR may reduce the extent of hardness. Analysis of variance of Eq. 9 showed that F-value for linear terms of BT and FMC were 40.18 and 4.75 and p-values 0.0001 ($p<0.01$) and 0.0466 ($p<0.05$), showed that x_2 and x_3 are significant terms. F-value and p value for square terms of FMC 14.6 and 0.0015, found to be significant ($p<0.01$). ANOVA of Eq . 10 showed that that x_1, x_2 and x_3 are the significant terms. F-value for linear terms of SS, BT and FMC were 9.75, 51.37 and 13.79 with p-values 0.006 ($p<0.05$), 0.0001 ($p<0.001$), and 0.0019 ($p<0.05$) respectively. F and p value for interacting terms

x_1x_2 were 7.95 and 0.0123($p < 0.05$), signifying that interacting term is also significant. Similarly Analysis of variance of Eq. 11 had showed that x_1, x_2 x_3 and x_4 all are significant terms.

In Fig. 3a it can be observed that with the increase in FMC hardness increased which may be due to reduced expansion. Ding et al. (2006) also reported increase in hardness with increase in SS due to lower melt density. . It is evident from Fig. 3(c-f) that PF and BS decrease with increase in SS and BT. BT and FMC were found to have the most significant effect. Similarly Altan et al. (2008) also reported decrease in PF with increase in BT. Liu et al. (2000) reported that increase in FMC reduced expansion and provided a dense product that required higher force to break the sample. Sacchetti (2005) reported direct correlation between hardness and density of extruded cereal blend, better expansion results in more friable product that requires less force / energy to break. Suksomboon et al. (2011) reported lower hardness values for extrudates developed from Hom Nil rice at higher barrel temperature. An increase in processing temperature will cause drop in melt viscosity favoring bubble growth, signifying better expansion and lower density to have softer extrudates (Yulini et al. 2006).

4. *Effect of extrusion cooking on Hunter L, a, b values of extrudates*

Multiple regression equations for Hunter *L* value and total color difference (ΔE) as a function of screw speed (X_1), barrel temperature (X_2), feed moisture (X_3) and blend ratio (X_4) of *chokua* rice extrudates are given below.

$$\text{Hunter } L = +47.79 + 1.08x_1 - 0.71x_2 + 0.46x_3 + 0.62x_4 - 0.50x_4^2 + 0.77x_1.x_3 \text{ ---------- } (12)$$

$$\text{Hunter } \Delta E = +12.62 - 1.11x_1 + 0.71x_2 - 0.45x_3 - 0.75x_4 + 0.51x_4^2 - 0.7x_1.x_3 \text{ ------------ } (13)$$

The significance of Hunter *L* and ΔE is given in Table 2 and lack of fit ($P < 0.05$) was found to be significant for both. The choosen processing condition did not influence significantly ($P > 0.05$) either Hunter *a* or *b* color value, thus detailed analyses of the two color values are not further explained in this study. The coefficient of determination (R^2) for the Hunter *L*- value and ΔE were 0.7943 and 0.7963 respectively. In Eq. 12 it has been observed that the coefficients of x_2 is negative and those of x_1, x_3 and x_4 are positve, thus increase in BT may decrease Hunter *L*- value whereas SS, FMC and BR may increase Hunter *L*- value. On the contrary from Eq. 13 it could be observed that the coefficients of x_2 is positve and those of x_1, x_3 and x_4 are negative, thus increase in BT may increase total color difference whereas SS, FMC and BR may reduce Hunter ΔE - value. The analysis of variance of Eq. 12 and Eq. 13 has shown that F- value for all the liner terms of SS, BT, FMC and BR are significant (Table 2). The effect of independent variables on Hunter *L* value is shown in Fig. 4(a-b). Increase in processing temperature results in decrease in Hunter *L*, *a*, *b* value, due to Maillard browning of sugar present in *bhimkol* powder. The expansion gets reduced at high feed moisture and resuled in higher Hunter *L*, *a*, *b* values. Ilo and Berghofer (1999) also reported similar decrease in Hunter *L* value due to rise in extrusion cooking temperature of maize grits. Increase in processing temperature results increased rate of browning reactions, which increased the total color difference, ΔE (Fig. 4). Increase in BR and SS resulted in slight increase in total color difference; ΔE varied from 9.532 to 15.722.

5. .Multiple response optimizing

In order to optimize processing condition for extrusion cooking of *chokua* rice blend by numerical optimization, which finds a point that maximizes the desirability function, equal importance of 3, was given to all the 4 parameters and the entire 8 responses (Table 3). The optimal combination for SS, BT, FMC and BR was 350 rpm, 120 °C, 12g/100g and 65:25:10 (Table 4), which corresponds to run-15. The overall desirability, which ranges from zero outside of the limits to one at the goal, was 0.789 (Fig. 5).

6. Physicochemical and nutritional characteristics of optimized extruded flour

Extrudates produced in the optimal condition (run-15) were cooled and dried at room temperature (35°C) for 1h, then milled to pass through a 0.21 mm screen, packed in plastic bags and stored at 4°C. Physicochemical and nutritional properties of the *chokua* rice blend (*chokua* rice flour, banana flour and carambola pomace) compared to *chokua* rice flour alone is shown in Table 5. The *chokua* rice blend and *chokua* rice flour has higher PV and comparatively lower FV which could be attributed to the higher BT and SS at the optimized condition (Guha and Bhattacharya 1998). In the optimized condition *chokua* rice blend is found to have better physicochemical properties as well as nutritive value (WAI of 481.79 g/100g; WSI of 44.13 g/100g; energy value of 405.5Kcal/100g; protein content of 8.92 g/100g; crude fiber content of 2.12g/100g and dietary fiber content of 21.35g/100g). Above all due to incorporation of seeded banana powder *chokua* rice blend has showed considerable amounts of minerals like Mg and K respectively (Table 5).

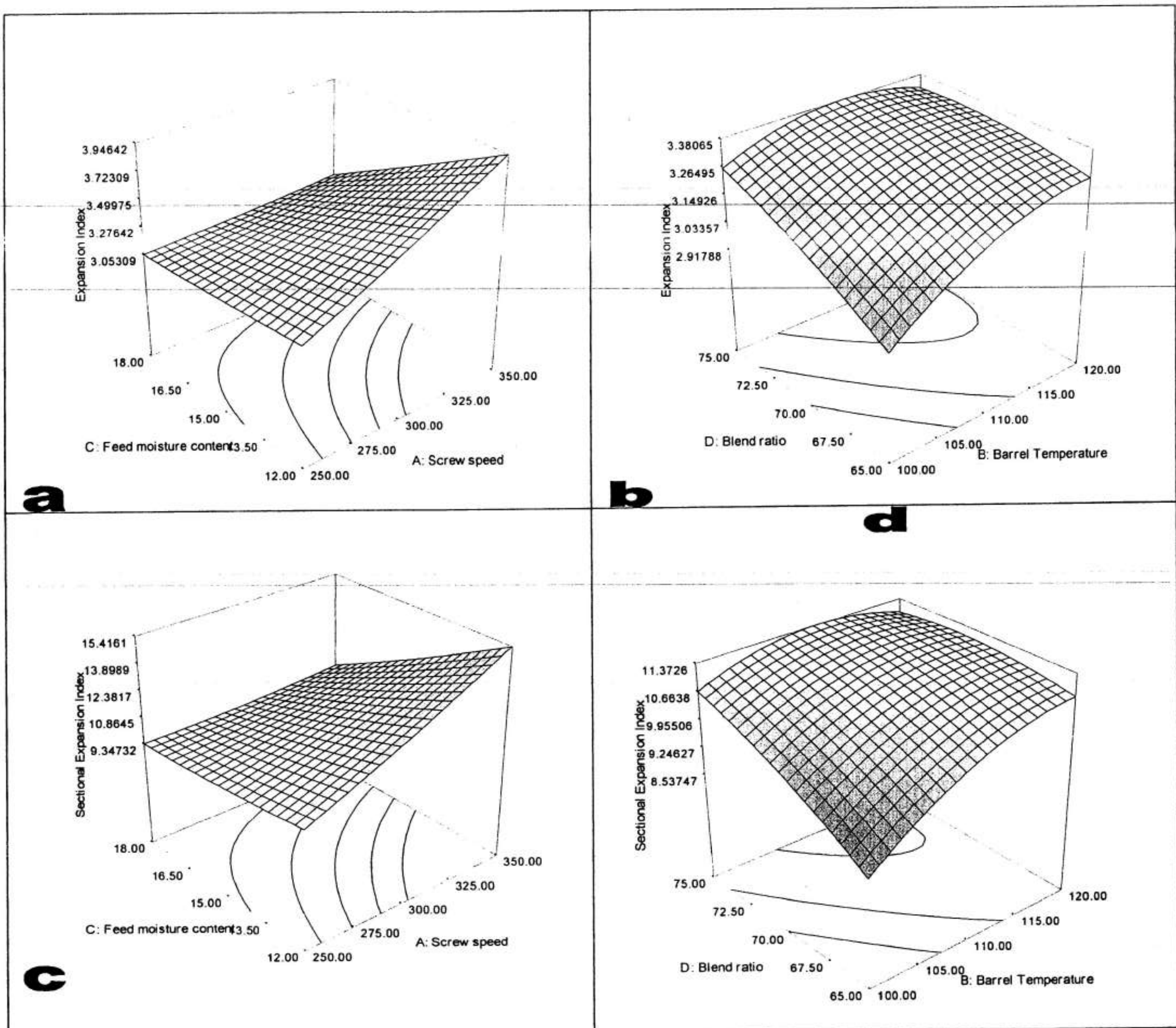

Fig. 1. Effect of processing variables on EI (a-b) and SEI (c-d) of the extruded products

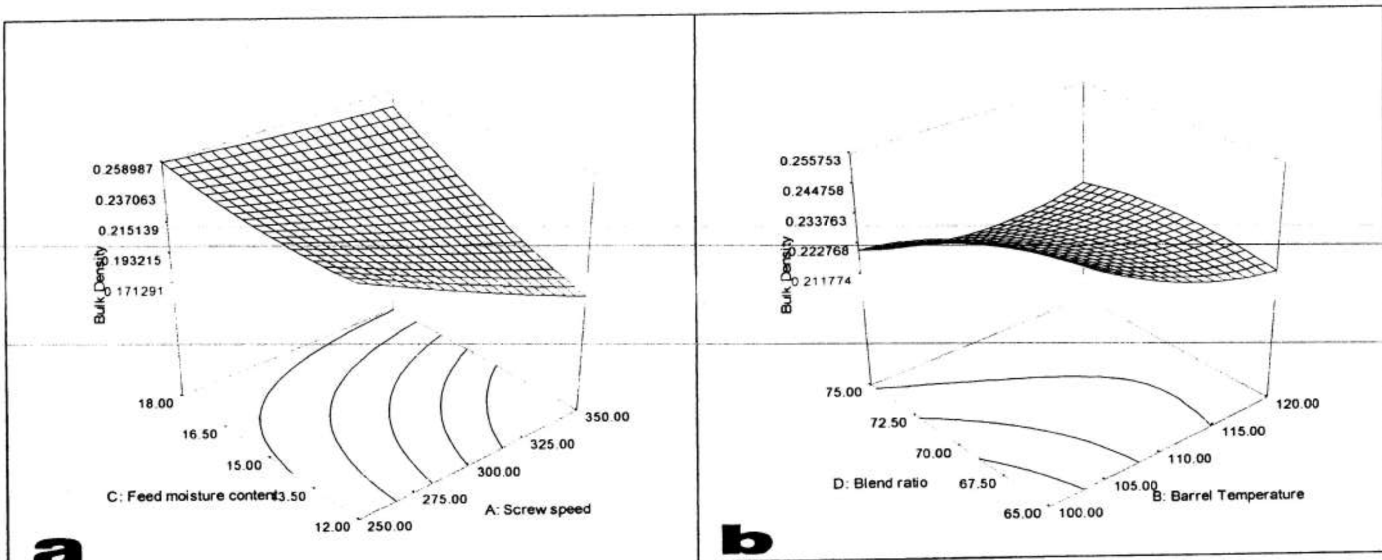

Fig. 2. Effect of processing variables on BD (a-b) of the extruded products

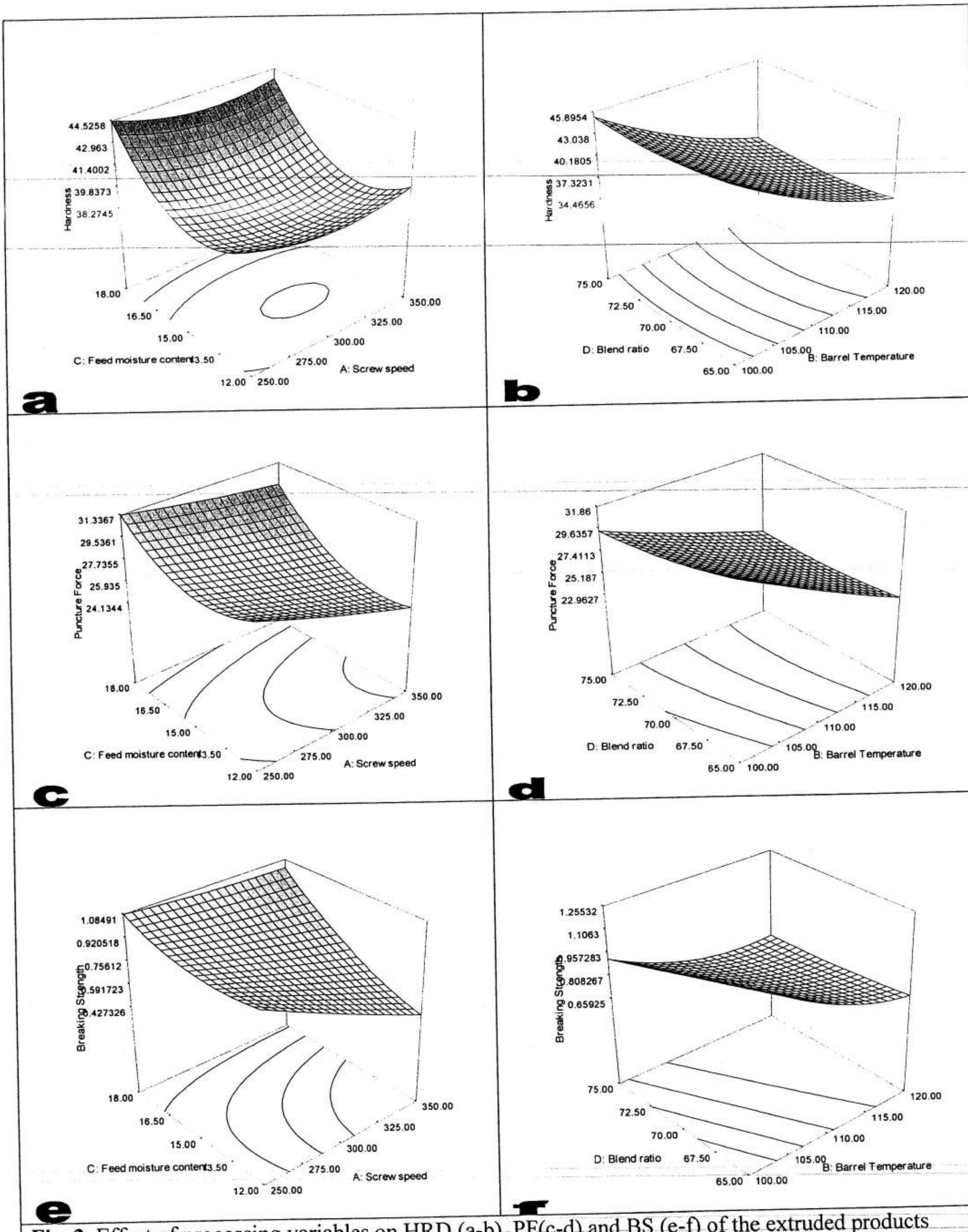

Fig. 3. Effect of processing variables on HRD (a-b), PF(c-d) and BS (e-f) of the extruded products

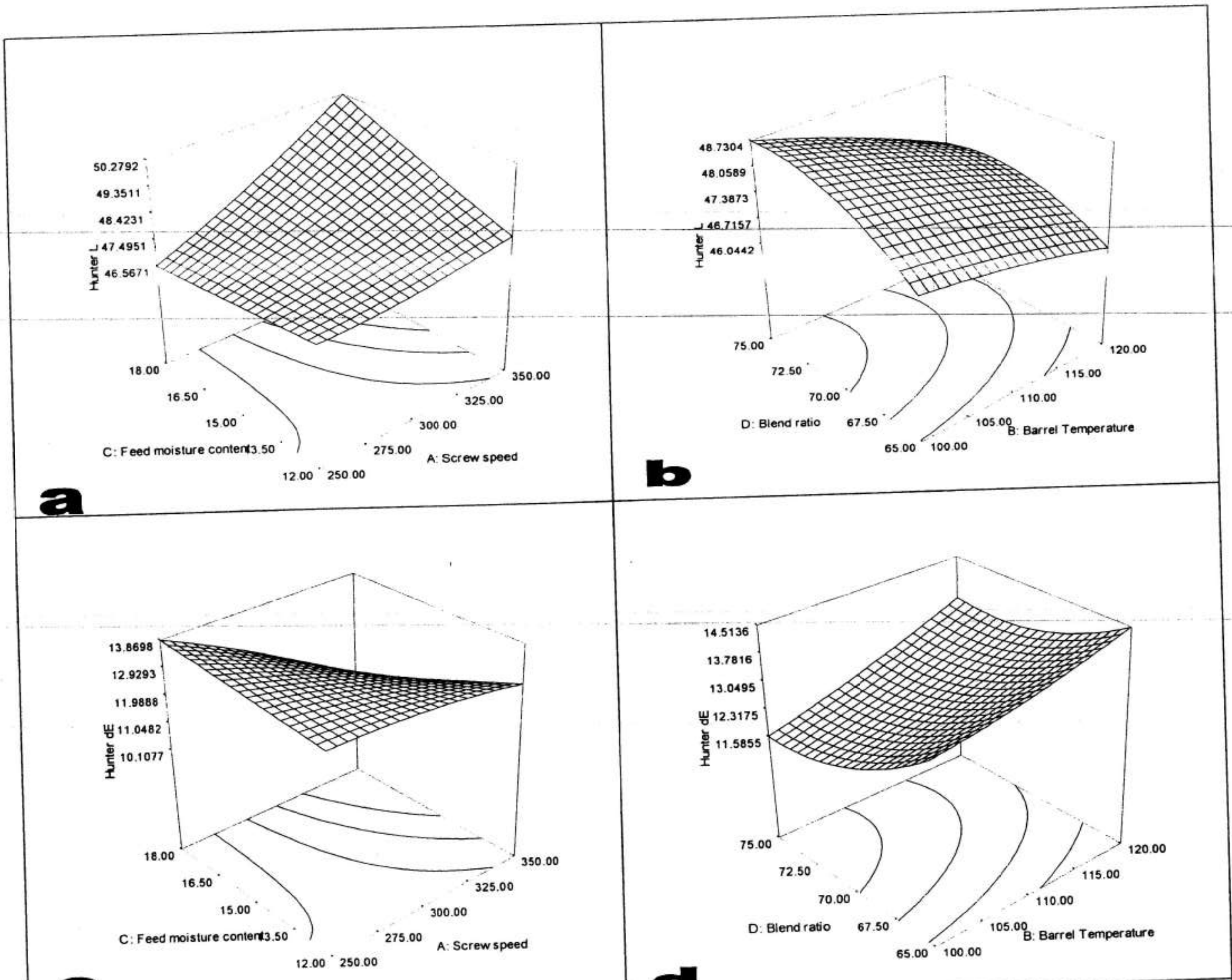

Fig. 4. Effect of processing variables on on Hunter L- value (a-b) and Hunter ΔE (c-d) of the extruded products

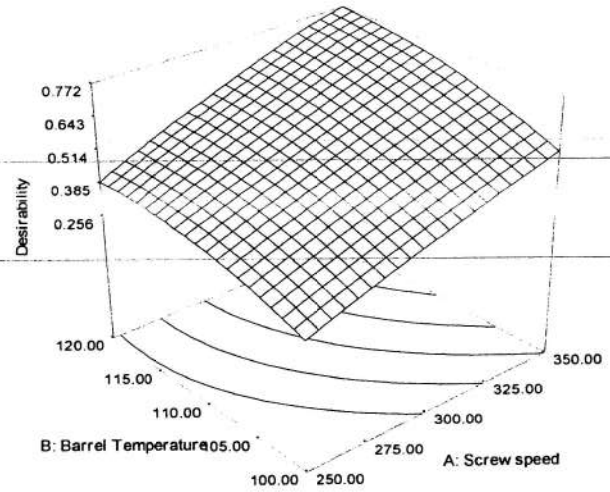

Fig. 5. Desirability function response surface for *chokua* rice extrudates at FMC of 12% and blend ration of 65:25:10.

Table 1 Experimental design for extrusion with coded and actual levels of the variables

Run	X_1	X_2	X_3	X_4	SS	BT	FMC	Blend Ratio
1	0	0	-2	0	300	110	9	70:20:10
2	0	0	0	0	300	110	15	70:20:10
3	-1	-1	-1	1	250	100	12	65:25:10
4	-1	-1	1	-1	250	100	18	75:15:10
5	0	0	0	2	300	110	15	60:30:10
6	0	0	0	0	300	110	15	70:20:10
7	-1	-1	1	1	250	100	18	65:25:10
8	0	0	0	-2	300	110	15	80:10:10
9	2	0	0	0	400	110	15	70:20:10
10	0	0	2	0	300	110	21	70:20:10
11	0	0	0	0	300	110	15	70:20:10
12	-1	1	1	-1	250	120	18	75:15:10
13	0	0	0	0	300	110	15	70:20:10
14	1	-1	0	0	350	100	12	75:15:10
15	1	1	-1	1	350	120	12	65:25:10
16	0	2	0	0	300	130	15	70:20:10
17	0	-2	0	0	300	90	15	70:20:10
18	1	-1	-1	1	350	100	12	65:25:10
19	-2	0	0	0	200	110	15	70:20:10
20	0	0	0	0	300	110	15	70:20:10
21	-1	1	1	1	250	120	18	65:25:10
22	0	0	0	0	300	110	15	70:20:10
23	1	1	1	1	350	120	18	65:25:10
24	1	1	-1	-1	350	120	12	75:15:10
25	1	-1	1	-1	350	100	18	75:15:10
26	1	-1	1	1	350	100	18	65:25:10
27	-1	-1	-1	-1	250	100	12	75:15:10
28	1	1	1	-1	350	120	18	75:15:10

29	-1	1	-1	-1	250	120	12	75:15:10
30	-1	1	-1	1	250	120	12	65:25:10
31	0	0	0	0	300	110	15	70:20:10

Table 2 Coefficients of variables in the predictive model for response variables (coded units)

Variables	EI	SEI	BD	HRD	PF	BS	Hunter value	
							L	ΔE
x_1	0.22**	1.46**	- 0.022**	- 0.29	- 1.59**	- 0.15**	1.08***	- 1.11***
x_2	0.10	0.65	- 0.011	- 5.70***	- 3.64***	- 0.20***	- 0.71**	0.71**
x_3	- 0.23**	- 1.57**	0.022**	1.79**	1.89**	0.18**	0.46*	- 0.45*
x_4	0.10	0.59	$- 8.8 \times 10^{-3}$	- 0.25	- 0.57	- 0.097*	0.62**	- 0.75**
x_1^2	9.79×10^{-3}	0.12	1.36×10^{-3}	0.93	0.13	0.011	0.17	- 0.17
x_2^2	- 0.08	- 0.51	6.76×10^{-3}	1.11	0.21	0.093**	0.11	0.11
x_3^2	5.21×10^{-3}	0.12	4.81×10^{-3}	2.87**	1.99***	0.081	5.31×10^{-3}	$- 7.19 \times 10^{-3}$
x_4^2	0.026	- 0.20	$- 4.27 \times 10^{-3}$	0.74	0.42	0.015	- 0.50**	0.51**
$x_1 x_2$	0.11	0.72	- 0.015*	0.23	1.76**	$- 2.16 \times 10^{-3}$	0.14	- 0.16
$x_1 x_3$	- 0.18**	- 1.17**	0.016*	- 0.071	0.67	0.12*	0.77**	- 0.7**
$x_1 x_4$	- 0.086	- 0.56	8.52×10^{-3}	1.03	0.70	0.076	0.12	$- 4.93 \times 10^{-3}$
$x_2 x_3$	0.021	0.10	$- 1.23 \times 10^{-3}$	- 0.37	0.055	- 0.015	- 0.46	0.48
$x_2 x_4$	- 0.071	- 0.48	8.62×10^{-3}	0.024	0.63	0.069	- 0.20	0.18
$x_3 x_4$	0.017	0.12	$- 4.01 \times 10^{-3}$	0.19	0.050	$- 1.1 \times 10^{-3}$	- 0.19	0.18
Model (F-value)	2.86	2.81	2.65	4.49	7.58	4.33	4.41	4.47
R^2	0.714	0.711	0.69	0.797	0.869	0.7912	0.794	0.796
Adj R^2	0.464	0.458	0.436	0.619	0.755	0.609	0.614	0.618
Adeq Precision	6.523	6.548	6.625	7.516	11.091	8.335	8.844	9.049
Lack of Fit	2.15	2.15	3.78	1.18	0.59	2.33	1.18	1.19

x_1 screw speed (rpm), x_2 extrusion temperature (°C), x_3 feed moisture content (%), x_4 blend ratio

* Significant at $p < 0.1$

** Significant at $p < 0.05$

*** Significant at $p < 0.001$

Table 3 Optimized parameters in the response optimizer

Response	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
EI	Maximum	2.55	4.15	1	1	3
SEI	Maximum	6.49	17.25	1	1	3
HRD	Minimum	32.66	58.64	1	1	3
PF	Minimum	18.20	41.01	1	1	3
BS	Minimum	0.42	1.86	1	1	3
BD	Minimum	0.16	0.32	1	1	3
Hunter *L*-value	Minimum	44.5	50.85	1	1	3
Hunter ΔE-value	Minimum	9.53	15.72	1	1	3

Table 4: Optimized solution obtained using the response optimizer

Optimal solution				Predicted responses							
x_1 (rpm)	x_2 (°C)	x_3 (g / 100 g)	x_4	EI	SEI	HRD (N)	PF (N)	BS, (N/mm^2)	BD, (g/cm^3)	Hunter value *L*	Hunter value ΔE
350	120	12	65:25:10	4.08	16.36	36.02	22.45	0.32	0.148	47.26	13.08

Table 5 Physicochemical properties and nutritional profile of extruded products

Properties	Extrudate: Blend*	Extrudate: Low amylose rice
WAI, g/100g	481.79± 9.19	497.07 ± 7.76
WSI, g/100g	44.13± 1.41	42.62 ± 3.14
Peak Viscosity, cp	703.00±7.07	298.50 ± 6.36
Final Viscosity, cp	124.50.± 2.12	269.00 ± 1.41
Energy, Kcal/100g	405.50 ± 2.12	390.25 ± 3.54
Moisture, g/100g	7.08 ± 0.03	7.35 ± 0.035
Protein, g/100g	8.92 ± 0.0.2	7.15± 0.24
Fat, g/100g	0.67 ± 0.014	0.52 ± 0.002
Crude Fiber, g/100g	2.12 ± 0.04	0.67 ± 0.004
Dietary Fiber, g/100g	21.35 ± 0.17	3.6 ± 0.24
Ash, g/100g	1.125 ± 0.028	0.43 ± 0.01
Carbohydrate, g/100g	80.08 ± 0.015	83.86 ± 0.018
Mg, mg /100g	14.54 ± 0.17	10.62 ± 0.18
K, mg /100g	29.24 ± 0.3	17.41 ± 0.21

*Blend of low amylose rice: seeded banana: carambola pomace at 65:25:10

Part –C: Storage study of the extruded *choukua* rice, *bhimkol* banana and carambola pomace

Moisture content of the extrudates was found to be in the range of 7.35% – 7.90% during 1st four months of storage study (Fig-1). After six months of storage extrudates were found to have higher moisture content for both types of storage conditions. The increase in moisture content was dependent on relative humidity and temperature of storage.

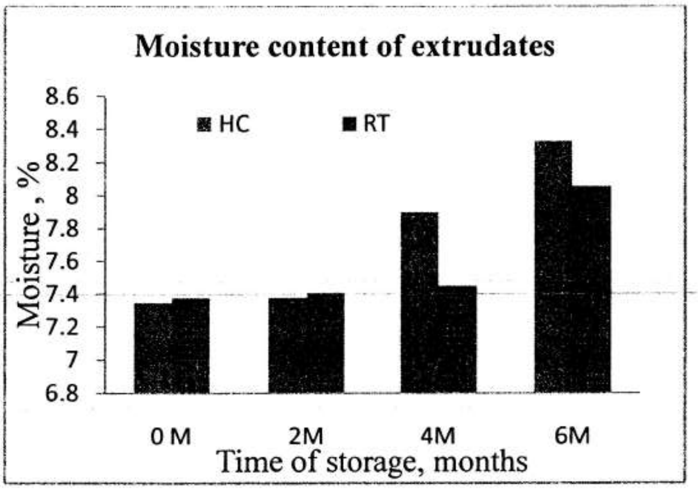

Fig. 1: Moisture content of extrudates during 6 months storage.

After six months of storage extrudates showed lower hardness values (Fig. 1). Extrudates showed a gradual decrease in hardness values when stored at 39°C & 70% RH while at room temperature it retained hardness up to 4 months.

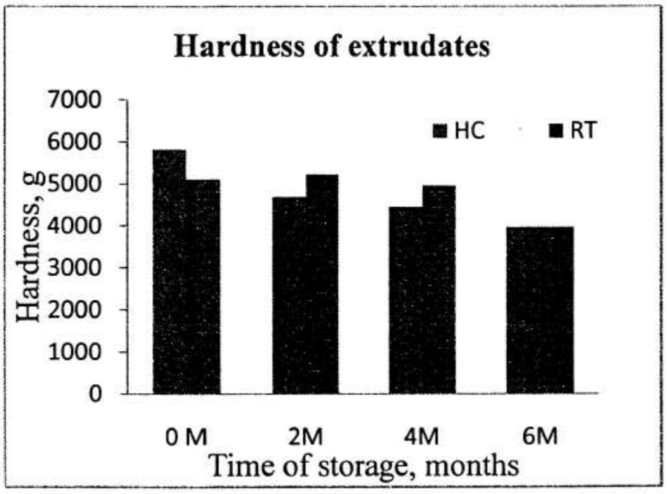

Fig. 2: Hardness of extrudates during 6 months storage.

Viscosity profile of the extrudates was found to be moderate for all except those stored up to 6 months ; higher "peak viscosity" may be due to higher rate of break-down of the starch granules. Sensory analysis of the extrudates had shown that extrudates retained taste and mouth feel up to 6 months. Overall all acceptability was recorded in the range 6.5 – 7.4 respectively.

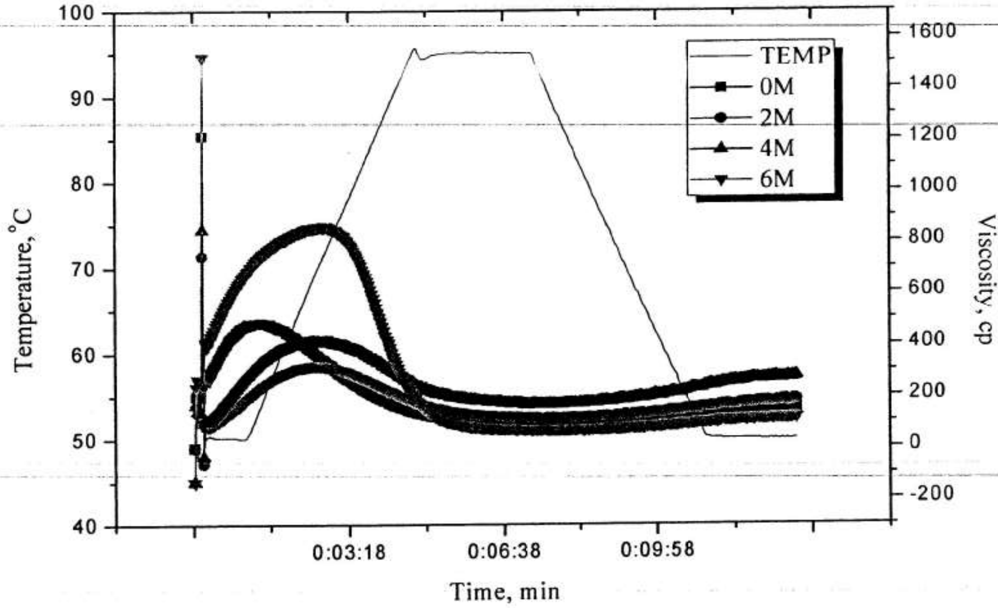

Fig. 2: Pasting properties of extrudates during 6 months storage.

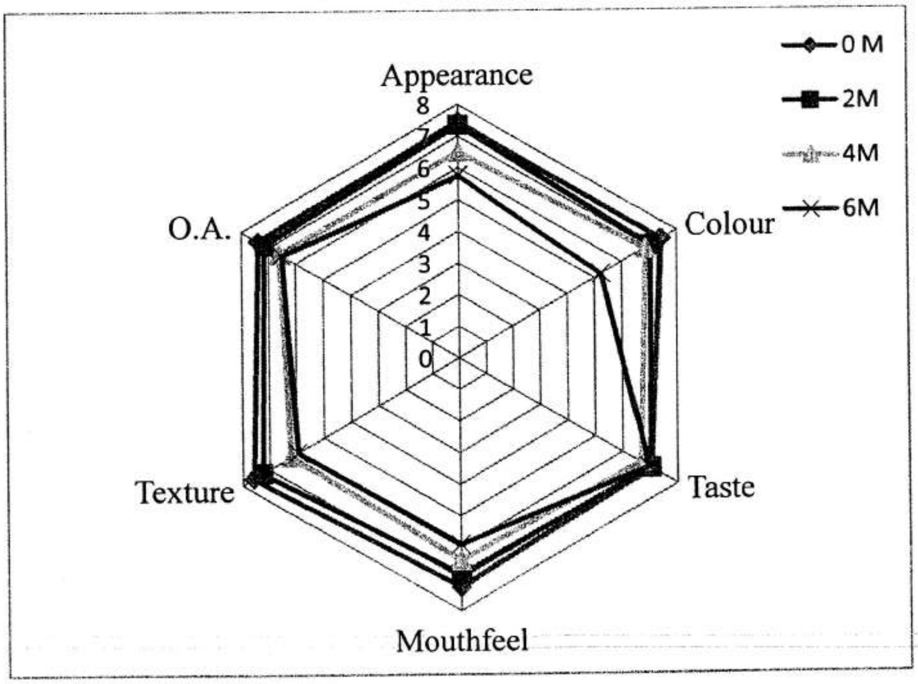

Fig. 3: Sensory score for the extrudates during 6 months storage.

9. Patent required: N/A

10. Commercialization of the R&D:

11. Expertise developed: N/A

12. Research Publication papers published:

1. The effect of extrusion conditions on physicochemical properties of *chokua* rice extrudate incorporated with *bhimkol* (*Musa balbisiana*, ABB)

[IFRJ - submitted]

2. Response surface optimization of process parameters for extrusion cooking of low amylose rice flour blended with banana (*(Musa balbisiana*, ABB) and carambola pomace.

[Food and Bioproducts Processing- submitted]

13. Any seminar/workshop conducted: Not yet.

14. Further research required (if any):

The scaling up of this technology with different combination of low-amylose rice incorporated with *bhimkol* and by-products of different fruits could be utilized in development of health foods.

Charu Lata Mahanta 4/9/2013
Principal Investigator
Dept. of Food Engg. & Tech.
Tezpur University
Tezpur -784 028, Assam

Title of the Project: "Development of health promoting extruded RTE breakfast cereals incorporating *choukua* rice and *bhimkol* banana of Assam along with carambola pomace"

Ref: File No. 11/MFPI/R&D/2009

Principal Investigator: Prof. Charu Lata Mahanta

Statement of Expenditure (Final):

S. No.	Particulars	Grant Sanctioned (₹)	Amount Sanctioned			Expenditure (₹)		Balance (₹)
			1st Installment (₹)	2nd Installment (₹)	Grand Total (₹)	2011-12	2012-13	
1	Equipments	30,36,036 /-	15,18,018 /-	7,93,621 /-	23,11,639 /-	11,72,714/-	8,17,644/-	3,21,281/-
2	SRF [@14000/-]	3,36,000 /-	1,68,000 /-	87,830 /-	2,55,830/-	1,58,666/-	1,46,000/-	(-)48,836/-
3	Consumables	6,00,000 /-	3,00,000 /-	1,56,840 /-	4,56,840 /-	1,42,478/-	1,74,973/-	1,39,389/-/-
4	Travel	60,000 /-	30,000 /-	15,684 /-	45,684 /-	NIL	1,090/-	44,594/-
Grand Total		40,32,036 /-	20, 16,018 /-	10,53,975 /-	30,69,993 /-	14,73,858/-	11,39,707/-	4,56,428/-

Charu Lata Mahanta
Name and signature of Principal Investigator

Date: 1/8/2013

8/8/13
Signature of Competent financial authority (with seal)

OSD Finance
Tezpur University

Date

Title of the Project: "Development of health promoting extruded RTE breakfast cereals incorporating *choukua* rice and *bhimkol* banana of Assam along with carambola pomace"

Ref: File No. 11/MFPI/R&D/2009

Principal Investigator: Prof. Charu Lata Mahanta

Statement of Expenditure (Final):

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Charu Lata Mahanta

Name and signature of Principal Investigator

Date: 1/8/2013

8/8/13

Signature of Competent financial authority (with seal)

OSD Finance
Tezpur University

Date

GFR 19 – A

(See Rule 212 (1))

Utilization Certificate

Sl.	Letter No. & Date	Amount
1.	**11/MFPI/R&D/2009, dtd. 29-10-2010**	**20, 16,018 /- (50%)**
2.	**11/MFPI/R&D/2009, dtd. 22/3/2012**	**Rs. 10,53,975/- (40%)**

Certified that out of **Rs. 30,69,9935/-**of Grants- in-aid sanctioned during the years 2011 in favour of Registrar, Tezpur University, Napaam-784028, Assam under this Ministry letter No. **11/MFPI/R&D/2009, dtd. 22/3/2012** given in the margin, a sum of **Rs. 27,37,940/-** has been utilized for the purpose of purchasing equipment, glassware, chemicals, raw materials for which it was sanctioned and that the balance of Rs. **3,32,053/-** remaining unutilized at the end of the year has been surrendered to Government will be adjusted towards the grants - in-aid payable during the next year 2013.

1. Certified that I have satisfied myself that the conditions on which the grants- in-aid was sanctioned have been duly fulfilled/are being fulfilled and that I have exercised that following check s to see that the money was actually utilized for the purpose for which it was sanctioned.

Kinds of check s exercised.

1. Accounts audited by qualified Chartered Accountant appointed by this University as Internal Auditor
2. All the equipment, glassware, chemicals, raw materials, etc., purchased from the grant are entered in the stock book.

Charu lata Mahanta 01/07/2013

Signature of Principal Investigator with date

Signature of Registrar/ Accounts Officer

Signature of Head of the Institute

GFR 19 – A
(See Rule 212 (1))
Utilization Certificate

Sl.	Letter No. & Date	Amount
1.	**11/MFPI/R&D/2009, dtd. 29-10-2010**	**20, 16,018 /- (50%)**
2.	**11/MFPI/R&D/2009, dtd. 22/3/2012**	**Rs. 10,53,975/- (40%)**

Certified that out of **Rs. 30,69,9935/-**of Grants- in-aid sanctioned during the years 2011 in favour of Registrar, Tezpur University, Napaam-784028, Assam under this Ministry letter No. **11/MFPI/R&D/2009, dtd. 22/3/2012** given in the margin, a sum of **Rs. 27,37,940/-** has been utilized for the purpose of purchasing equipment, glassware, chemicals, raw materials for which it was sanctioned and that the balance of Rs. **3,32,053/-** remaining unutilized at the end of the year has been surrendered to Government will be adjusted towards the grants - in-aid payable during the next year 2013.

1. Certified that I have satisfied myself that the conditions on which the grants- in-aid was sanctioned have been duly fulfilled/are being fulfilled and that I have exercised that following check s to see that the money was actually utilized for the purpose for which it was sanctioned.

Kinds of check s exercised.

1. Accounts audited by qualified Chartered Accountant appointed by this University as Internal Auditor
2. All the equipment, glassware, chemicals, raw materials, etc., purchased from the grant are entered in the stock book.

Charu Lata Mahanta
01/07/2013
Signature of Principal Investigator with date

Signature of Registrar/ Accounts Officer

Signature of Head of the Institute

GFR 19 – A

(See Rule 212 (1))

Utilization Certificate (consolidated)

Sl.	Letter No. & Date	Amount
1.	**11/MFPI/R&D/2009, dtd. 29-10-2010**	**Rs. 20, 16,018 /- (50%)**
2.	**11/MFPI/R&D/2009, dtd. 22/3/2012**	**Rs. 10,53,975/- (40%)**

Certified that out of **Rs. 30,69,993/-**of Grants- in-aid sanctioned during the years 2010-2011 and 2011-2012 in favour of Registrar, Tezpur University, Napaam-784028, Assam under this Ministry letter No. **11/MFPI/R&D/2009, dtd. 29/10/2010 and 11/MFPI/R&D/2009, dtd. 22/3/2012** given in the margin, a sum of **Rs. 28,63,473/-** has been utilized for the purpose of purchasing equipment, glassware, chemicals, raw materials for which it was sanctioned and that the balance of Rs **2,06,520/-** remaining unutilized at the end of the year has been surrendered to Government will be adjusted towards the grants - in-aid for third installment.

1. Certified that I have satisfied myself that the conditions on which the grants- in-aid was sanctioned have been duly fulfilled/are being fulfilled and that I have exercised that following check s to see that the money was actually utilized for the purpose for which it was sanctioned.

Kinds of check s exercised.

1. Accounts audited by qualified Chartered Accountant appointed by this University as Internal Auditor
2. All the equipment, glassware, chemicals, raw materials, etc., purchased from the grant are entered in the stock book.

Charu Lata Mahanta 28/4/2014
Signature of Principal Investigator with date

31/12/24
Signature of Registrar/ Accounts Officer
Finance Officer
Tezpur University

Signature of Head of the Institute
Registrar
Tezpur University

Charu Lata Mahanta

Statement of Expenditure

S. No.	Particulars	Grant Sanctioned (₹)	Amount Sanctioned			Expenditure (₹)				Balance (₹)
			1st Installment (₹)	2nd Installment (₹)	Grand Total (₹)	2011-12	2012-13	2013-14	1-4-2014 to 30-6-2014	
1	Equipments	30,36,036 /-	15,18,018 /-	7,93,621 /-	23,11,639 /-	11,72,714/-	8,17,644/-	1,07,375/-	NIL	2,13,906/-
2	SRF	3,36,000 /-	1,68,000 /-	87,830 /-	2,55,830/-	1,58,666/-	1,46,000/-	NIL	NIL	(-)48,836/-
3	Consumables	6,00,000 /-	3,00,000 /-	1,56,840 /-	4,56,840 /-	1,42,478/-	1,74,973/-	1,39,358/-	NIL	31/-
4	Travel	60,000 /-	30,000 /-	15,684 /-	45,684 /-	NIL	1,090/-	3,175/-	NIL	41,419/-
Grand Total		40,32,036 /-	20, 16,018 /-	10,53,975 /-	30,69,993 /-	14,73,858/-	11,39,707/-	2,49,908/-	NIL	2,06,520/-

Unspent balance: Rs.2,06,520/-

Amount to be refunded: Rs. 2,06,520/-

Chorun Lata Mahanta
Name and Signature of Principal Investigator

Date: 28/11/2014

Signature of Competent financial/ audit authority with seal
31/12/14
Finance Officer
Tezpur University

Date:

Chorun Lata Mahanta