



Extrusion Characteristic of Bengal Gram Brokens and Maize Flour Blends for Preparation of Extruded Snack Food

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ABSTRACT

Extruded products from Bengal gram (*Cicer arietinum* L.) brokens and maize (*Zea mays* L.) flour blends were prepared on a BTPL-LAB Twin Screw Extruder. The effect of extrusion cooking parameters (mainly moisture content in blend, and barrel temperature) and blend ratio on quality of extruded products were determined. The properties of product were evaluated on the basis of mass flow rate (MFR), specific length of extrudates (SL), sectional expansion index (SEI), longitudinal expansion index (LEI) and water absorption index (WAI). Protein content of extrudates was also measured to analyze and evaluate the nutritional value of product. The best quality extrudates were obtained at 80°C barrel temperature, 10% moisture content of feed, 20% blending ratio followed by 10% moisture content, 85°C barrel temperature and 25% blending ratio. Also this processing approach enables the value addition of Bengal gram brokens and maize flour for preparation of extruded snack food.

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INTRODUCTION

Pulses are inseparable part of Indian diet especially for vegetarian and are the major source of protein, when blended with cereals in certain proportion they provides with good protein diet to the consumer. Combination of cereal and pulse provide protein at cheaper cost and suitable for highly populated country like India. The amino acid profile of a cereal-pulses combination is better than that of cereals alone. Also, large amount of pulses in pulse milling industries waste due to non utilization of that part of pulses which are equally rich in protein as compared to whole pulses. More-over, high protein by-product of industry offer scope for their use as supplement, but all these require heat processing to make them suitable for human consumption.

Extrusion has become an important processing technique in an increasing variety of food processes. Extrusion cooking application today cover a wide range of food products based on starches, cereals, protein and sugars (Smith and

Singh, 1996). Extrusion cooking is a high temperature short time cooking process which could be used for processing of starchy as well as proteinaceous materials. The extrusion characteristics of legume-cereal blend have been studied for several raw materials like soybean, fababean, corn, potato and sorghum. Harper (1981) reported the optimal incorporation of full fat soy flour or defatted soy flour in snacks to increase protein quality. Fapojuwo et al. (1987) studied effect of extrusion cooking on invitro protein digestibility of sorghum. Extrusion improves digestibility from 45.8% to 74.6% and 43.9% to 68.2% for two varieties. Respective temperature was key extrusion variable that influenced digestibility. Chinaswami and Hanna (1988) optimized the extrusion cooking condition for maximum expansion of corn starch. Normal corn starch was extruded in single screw extruder at various barrel temperatures, screw speeds, feed rate and moisture content. Maximum expansion ratio of 16:1 was obtained when 14.5% moisture content starch was fed at the rate of 60g/min with a screw speed of 150 rpm and barrel temperature of 140°C.

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Likimani et al (1990) studied the extrusion cooking of a maize-soybean (70:30) mix in a single screw extruder for examining the starch hydrolysis. The result indicated that extent of starch hydrolysis increased with increasing barrel temperature and feed moisture content and decreased with increasing screw speed. Ilo et al (1996) studied extrusion cooking characteristics of maize grits with respect to feed rate (47 to 60 kg/h), product temperature (150 to 160°C), moisture content (13 to 17 g/100g wb.) and measured expansion ratio and bulk density. Product properties were found to be most dependent on the feed moisture content. Increasing moisture content decreased expansion ratio and giving products with high bulk density. Singh et al (1996) studied a comparison of the effect of process variables like temperature and moisture content on the extrusion behaviour of wheat starch, whole wheat meal and oat flour. Wheat starch and meal behaved broadly similarly but differed from oats in water solubility index (WSI) and water absorption index (WAI) in their response to moisture content and temperature. The experiments were conducted to study the effect of extrusion cooking parameters (mainly moisture content in blend, and barrel temperature) and blend ratio on quality of extruded product made out of Bengal gram brokens and Maize flour.

MATERIALS AND METHODS

Bengal gram (*Cicer arietinum* L.) brokens and Maize (*Zea mays* L.) flour blends was used for the preparation of protein rich extruded product. In the preparation of this product, moisture content in blend were 10%, 15% and 20% and Bengal gram brokens to Maize blend ratio (BR) were 10:90, 15:85, 20:80, 25:75, 30:70, with temperature levels of 80°C, 85°C, 90°C, 95°C and 100°C were taken for each set of moisture content and blend ratio. Overall effects of independent variables on mass flow rate, specific length, sectional expansion index (SEI), longitudinal expansion index (LEI), water absorption index, and protein content of extrudates were measured. The methods used for calculating different depended variables are shown in table 1.

Extrusion Cooking

The prepared blend samples were then extruded in BTPL-LAB Twin Screw Extruder. Extrusion cooking of blends took place under control temperature i.e. 80°C, 85°C, 90°C, 95°C and

100°C. This blend came out of extruder through die. As soon as the extrudates comes out from die, it get puffed and expanded due to sudden release of pressure and moisture content together. To have the desired size of extrudates, cutter was used at the end of die.

The effects of variable on responses were analyzed with the full factorial ANOVA to check the significance of parameter. Efforts were made to prepare mathematical models representing interaction between different properties with barrel temperature, moisture content and blend ratio by using Design expert software.

RESULTS AND DISCUSSION

Physical properties of extrudates were calculated with different per centage of Bengal gram brokens in blend at different temperature (80°C, 85°C, 90°C, 95°C and 100°C) and moisture content (10%, 15% and 20%) and found operating condition for maximum and minimum value of physical properties (Table 2). The second order mathematical model was developed for each physical parameter (Eq.1 to 7) and effects of independent variables on each parameter were analyzed by response graph. (Figure 1 to 6)

Specific Length of Extrudates (SL)

Maximum value of specific length (6.58 mm/g) was obtained at 10% moisture content (MC), 95°C barrel temperature (BT) and 15% blending ratio (BR) and specific length was minimum (3.55 mm/g) at 10% MC, 90°C BT, and 30% BR. The multiple regression analysis of the mass flow rate versus feed moisture content (MC), blend ratio (BR), and barrel temperature (BT) yielded following polynomial model (Eq. 1) :

$$SL = 3.82 - 0.35 MC - 0.081 BR - 0.26 BT - 0.0031 MC*BR + 0.40 MC*BT + 0.007 BR*BT - 0.0067 MC^2 + 0.21 BR^2 + 0.16 BT^2 \quad (\text{Eq. 1})$$

The value of R² was 68.87% which showed that model was adequate at 1% level of significance with F-value 2.46. It was found that specific length was highly affected by moisture content and temperature and it increased with decrease in these levels. (Fig.1)

Mass Flow Rate (MFR)

The mass flow rate of extrudates were measured and found maximum (12.48 g/sec) at 15% moisture content (MC), 95°C barrel temperature (BT) and 10% blending ratio (BR) and was

minimum (5.37g/sec) at 20% MC, 80°C BT, 25% BR. The multiple regression analysis of the mass flow rate versus feed moisture content (MC), blend ratio (BR), and barrel temperature (BT) yielded following polynomial model (Eq. 2):

$$MFR = 9.59 + 0.56 MC + 0.56 BR + 0.43 BT - 0.38 MC \cdot BR - 0.75 MC \cdot BT + 0.45 BR \cdot BT - 0.55 MC^2 - 0.79 BR^2 - 0.097 BT^2 \quad (\text{Eq. 2})$$

feed moisture content (MC), blend ratio (BR), and barrel temperature (BT) yielded following polynomial model (Eq. 3):

$$SEI = 7.61 - 1.57 MC + 0.011 BR + 0.11 BT - 0.20 MC \cdot BR + 0.22 MC \cdot BT - 0.40 BR \cdot BT - 0.88 MC^2 + 0.0051 BR^2 + 0.31 BT^2 \quad (\text{Eq. 3})$$

The second order mathematical model was fitted for SEI and found the value of R² as 82.42% and F

Table 1 : Calculation of different dependent variables

S. No.	Parameters	Method/Formula Used
1.	Specific Length (SL)	$SI = \frac{\text{Length of specimen}}{\text{Mass specimen}}$
2.	Mass Flow Rate (MFR)	$MFR = \frac{\text{Wt. of sample collected}}{\text{Time taken to collect sample}}$
3.	Sectional Expansion Index (SEI)	$\left\{ SEI = \frac{\text{Diameter of Extrudates}^2}{\text{Diameter of Die}} \right\}$
4.	Longitudinal Expansion Index (LEI)	$LEI = \frac{D_d}{D_e} \times \frac{1}{SEI} \left\{ \frac{1 - M_d}{1 - M_e} \right\}$ D _d = density of melt, D _e = Density of extrudate, M _d = Moisture content of of extrudate (wb)
5.	Volumetric Expansion Index (VEI)	$VEI = \frac{D_d}{D_e} \times \left\{ \frac{1 - M_d}{1 - M_e} \right\}$
6.	Water absorption index (WAI)	$MFR = \frac{W_2 - W_1}{W_1} \times 100$ W ₁ = wt. of grind extrudates sample W ₂ = wt. of grind extrudates sample after keeping in water
7.	Protein content	Micro-Kjeldhai Method

The coefficient of determination was 81.40% which suggested that model could account 81.40% data. So the second order model was adequate for describing the mass flow rate of extrudates. All the independent variables gave positive effect on the mass flow rate and combination of barrel temperature and blend ratio with low moisture content increased the mass flow rate (Fig.2).

Sectional Expansion Index (SEI)

It was found that SEI was highly correlated with moisture contents and blend ratio but not much affected by temperature. SEI increased as the level of independent variable decreased. The multiple regression analysis of the mass flow rate versus

value of 5.21 at 1% level of significance. Model equation showed that moisture content gave negative effect on sectional expansion index. It is also observed that high value of barrel temperature can minimize the negative effect of moisture content on sectional expansion index (Fig. 3). Similar result of extrudates from lentil was also reported by Banerjee (2003).

Longitudinal Expansion Index (LEI)

LEI was maximum (1.97) at 10% MC, 95°C BT and 30% BR and minimum (0.65) at 20% MC, 80°C BT and 15% BR. It followed more or less inverse trend as that of SEI and VEI. The multiple regression analysis of the mass flow rate versus feed

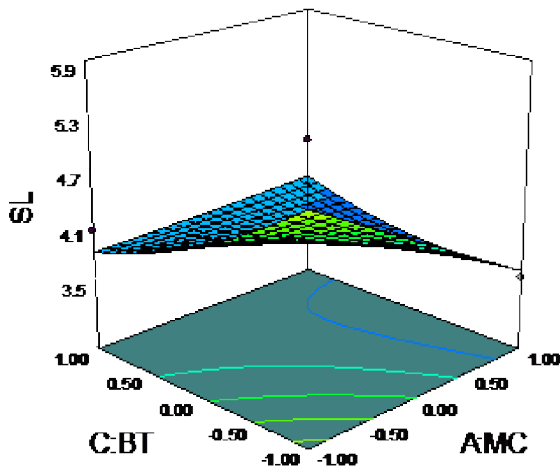


Fig.1 Response surface graph of feed moisture content and barrel temperature on specific length of extrudates

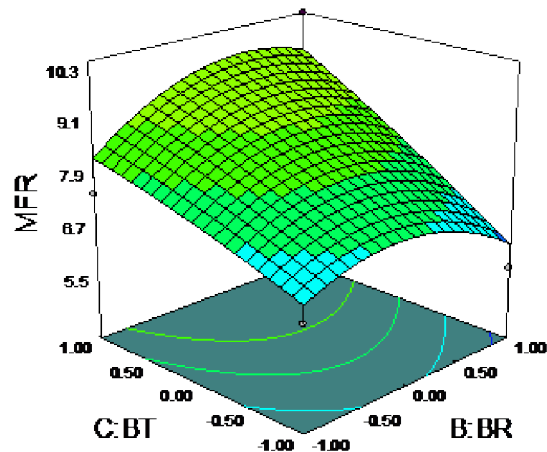


Fig.2 Response surface graph of blend ratio and barrel temperature on mass flow rate of extrudates

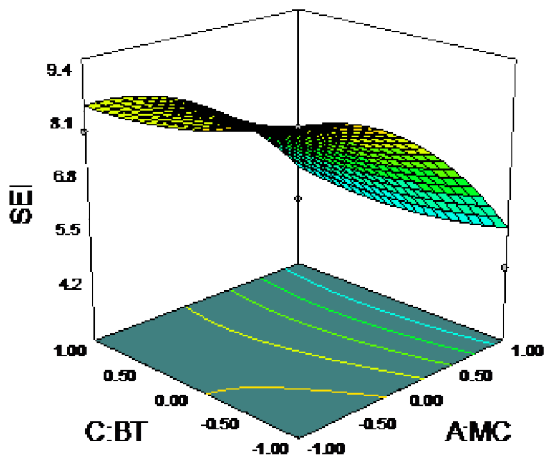


Fig.3 Response surface graph of moisture content and barrel temperature on sectional expansion index of extrudates

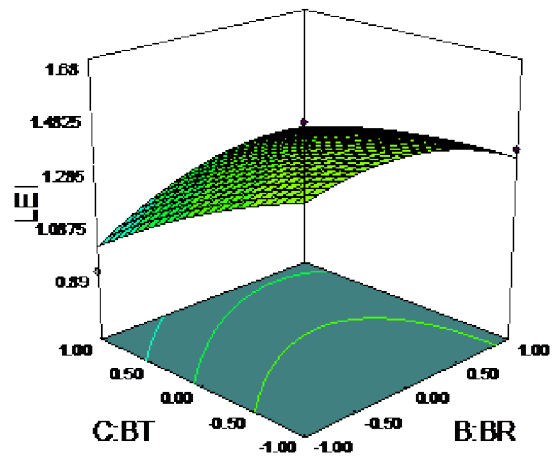


Fig.4 Response surface graph of blending ratio and barrel temperature on longitudinal expansion index of extrudates

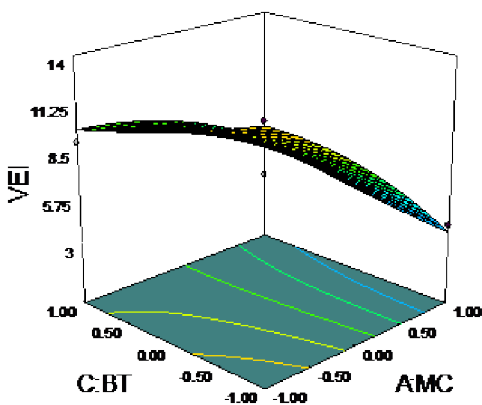


Fig.5 Response surface graph of feed moisture content and barrel temperature on volumetric expansion index of extrudates

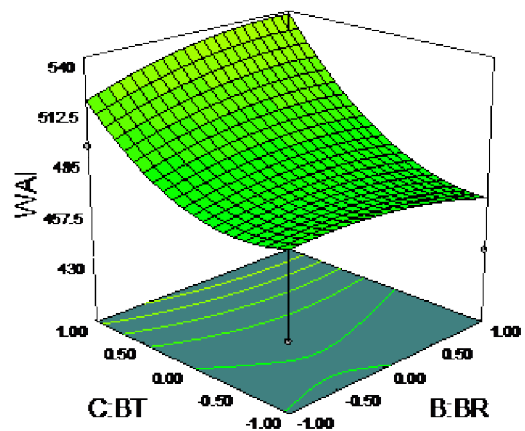


Fig.6 Response surface graph of blend ratio and barrel temperature on water absorption index of extrudates

Table 2: Operating conditions at maximum and minimum value of different physical parameter

S.No.	Parameter	Condition for Max. value	Maximum value	Condition for min	Minimum value
1.	Mass Flow Rate (MFR) (g/sec)	BT : 95°C MC : 15% BR : 10%	12.48	BT : 80°C MC : 20 % BR : 25 %	5.37
2.	Specific Length (mm/g)	BT : 95°C MC : 15% BR : 10%	6.58	BT : 80°C MC : 15 % BR : 10%	3.55
3.	Sectional Expansion Index (SEI)	BT : 80°C MC : 10% BR : 20%	10.36	BT : 90°C MC : 20% BR : 20%	4.12
4.	Logitudinal Expansion (LEI)	BT : 95°C MC : 10% BR : 30%	1.97	BT : 80°C MC : 20% BR : 15%	0.65
5.	Volumetric Expansion Index	BT : 85°C MC : 10% BR : 15%	14.07	BT : 80°C MC : 20% BR : 20%	2.72
6.	Water Absorption Index	BT : 100°C MC : 10% BR : 10%	691.2	BT : 90°C MC : 20% BR : 10%	350

moisture content (MC), blend ratio (BR), and barrel temperature (BT) yielded following polynomial model (Eq. 4) :

$$LEI = 1.25 - 0.14 MC - 0.029 BR - 0.061 BT - 0.057 MC*BR - 0.078 MC*BT + 0.080 BR*BT - 0.028 MC^2 - 0.087 BR^2 - 0.036 BT^2 \quad (Eq. 4)$$

The full second order mathematical model showed the value of R² as 74.47% at 1% level of significance. It was observed that all the independent variables gave negative effect on longitudinal expansion index, while the combination of blending ratio with barrel temperature gave positive effect on LEI. In combination of blending ratio and barrel temperature, barrel temperature is more effective than blending ratio (Fig.4).

Volumetric Expansion Index (VEI)

The highest value of VEI (14.07) obtained at 10% MC, 85°C BT and 15% BR followed by 10% MC, 95°C BT, and 20% BR and was minimum (2.72) at 20% MC, 80°C BT and 20% BR. Multiple-regression analysis of the VEI versus feed moisture content (MC), blend ratio (BR), and barrel temperature (BT) yielded following polynomial model (Eq. 5) :

$$VEI = 9.46 - 2.78 MC - 0.22 BR - 0.24 BT - 0.61 MC*BR + 1.42 MC*BT - 0.10 BR*BT - 0.85 MC^2 - 0.46 BR^2 + 0.23 BT^2 \quad (Eq. 5)$$

The value of R² was 84.47% which showed that model was adequate at 1% level of significance with F-value 6.04. Combination of moisture content with barrel temperature gave positive effect on volumetric expansion index that is similar in case of SEI. (Fig.5)

Water Absorption Index (WAI)

It was maximum (691.2) at 10% MC, 100°C BT and 10% BR and was minimum (350.0) at 20% MC, 90°C BT and 10% BR. This result showed that WAI is directly proportional to average diameter of extrudates. The multiple regression analysis of the mass flow rate versus feed moisture content (MC), blend ratio (BR), and barrel temperature (BT) yielded following polynomial model (Eq. 6) :

$$WAI = 461.66 - 38.46 MC - 3.02 BR + 25.09 BT - 5.03 MC*BR - 3.43 MC*BT + 8.55 BR*BT - 14.22 MC^2 - 5.82 BR^2 + 19.21 BT^2 \quad (Eq. 6)$$

The second order mathematical model was fitted for WAI and found the value of R² as 54.14 and F value of 1.31 at 1% level of significance. Individual effect on barrel temperature and

combination of barrel temperature with blending ratio depicted positive effect on value of WAI. Higher value of barrel temperature was desired to increase water absorption index. (Fig. 6)

Protein Content of Extrudates

High protein snack food (15.76%) was reported at 20% blend with 10% MC and at low temperature of 80°C. The moisture levels showed remarkable effect on quality of protein in extrudates at all other combination of independent variables. The protein content decreased with increase in moisture content, which means denaturation of protein, was more in higher moisture per centage of blend. Similar result was also reported by Liceti et al (1995).

CONCLUSION

There is remarkable effect of moisture content of raw material, barrel temperature and per centage of bengal gram brokens in the blend on physical properties, texture characteristics and protein content of extrudates. It was concluded that best quality of extrudates were obtained at 80°C barrel temperature, 10% moisture content of feed, 20% blending ratio followed by 10% moisture content., 85°C barrel temperature and 25% blending ratio.

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