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Optimization of process and operational parameters of extrusion cooking of sorghum, horse gram and defatted soy flour blends to produce protein rich ready-to-eat food snack

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Abstract
Extrusion cooking of Sorghum, Horse gram and Defatted Soy Flour blends was done to prepare snacks by using a Brabender single – screw laboratory extruder. The combined effect of moisture content (wb) of feed, blend ratio of feed, barrel temperature and screw speed of extruder on protein content of extrudate was studied. It was revealed that 15% moisture content of feed, 60:30:10 of blend ratio, 130 ^{0}C barrel temperature and 130 rpm of screw speed gave the highest protein content in the extrudate. Response surface methodology was used to develop prediction model. A central composite ratable design (CCRD) experimental approach was followed. The significance was established at $p \leq 0.05$.

Keywords: Extrusion cooking, Protein content, Sensory evaluation, Sorghum, Horse gram, Defatted soy flour

Introduction
In the recent years there has been an increasing interest in the production of extruded foods, such as snacks, pastas, breakfast cereals, baby foods, pet foods, etc. Snacks consist essentially of a cereal blend extruded with a certain amount of water. Inside the extruder the cereal mixture is heated above the starch gelatinization temperature leading to a cooked product that may be directly enrobed and flavoured, or needs further processing such as frying, roasting, etc. In fact, the chemical and physical characteristics of products strongly depend upon process variables such as extrusion temperature, screw speed and moisture content. (De Cindio *et al.*, 2002) [4]. Extrusion operational parameters such as barrel temperature, and screw speed affect the snack quality. In addition to these, processing parameters like feed moisture content, blending ratio also play important role on the quality of extrudate. Extrusion cooking has advantages, including versatility, high productivity, low operating costs, energy efficiency, and shorter cooking times (Harper, 1981) [5]. Several legumes have been treated by extrusion and good expansion was reported (Balandran *et al.*, 1998) [2]. In addition, and as a result of high temperatures, high pressures, and several shear forces reached inside the barrel, chemical reactions and molecular modifications like gelatinization of starch, denaturation of proteins, inactivation of many food enzymes, and reduction of microbial counts can occur (Harper, 1981) [5]. In cereal-based products, the degree or improper processing of starch is important for major quality aspects such as taste, digestibility, texture, appearance and puffing. Therefore, the effects of various operational and processing parameters and their interaction on quality of extrudate has to be studied and established.

Soybean (*Glysine Max* L.) is considered as an inexpensive source of high quality protein content. Soybean is rich in lysine but deficient in sulphur bearing amino acid. Horse gram (*Dolichos biflour*) is one of the lesser known beans. It is also known as Gahat, Kulath or Kulthi in India and is grown to be used as food and fodder. It is an unexploited legume of the tropics and subtropics grown mostly under dry-land agriculture. Like other legumes, it is deficient in methionine and tryptophan. The proximate composition of horse gram is 60% carbohydrate, 24% proteins, 5-6% fibres, 3.0-3.5% ash, and 1.3% fat. Sorghum (*Sorghum bicolor* L.) is the fifth most important crop in the world. Sorghum popularly known as "Jowar" is an important cereal crop and a source of nutrition for the poor.

Sorghum is a popular staple food that supplies a major portion of calories and proteins to a large segment of population. It contains approximately 65% to 75% starch, 9.5 to 10.5% protein, 1.5 to 10% fat, 1.2 to 6.6% fiber and 1.0 to 1.6% minerals. Sorghum, which contains adequate quantity of sulphur bearing amino acids, is deficient in lysine (Jambunarhan *et al.,* 1986) [7]. Incorporation of defatted soy flour to sorghum and horse gram will enhance its nutritional quality and will be useful as a means of adding value to the Horse gram pulses which are currently used as animal feed. Hence, the combination of both these sources of protein and starch can be effectively combined into snacks of high nutritive value, which is regularly consumed during teatime and breakfast. This product is expected to be good source of protein and minerals and will provide sustainable energy to school going children and pregnant ladies while serving as a popular snack.

Materials and Methods

Sorghum and Horse gram samples were procured from local market of Jabalpur. After cleaning, these were milled in a laboratory scale Hammer Mill to obtain required quantity of flour. Defatted soy flour was procured from Ruchi Soy Industry, Indore, India. The moisture content of flour of different blend ratios were measured by standard method. After getting the moisture content of blends, water was added to maintain desired moisture content in the blends, kept for conditioning for 24 hrs. In present study the laboratory - scale single - screw extruder (Model Kompakt E 19/25 D Brabender Duisburg, Germany) (length-to-dia 20:1; compression ratio 2:1 and die opening 5 mm) was used for extrusion.

Experiment design and analysis

Response surface methodology (RSM) was used in designing the experiment (Cochran and Cox, 1957). Independent variables such as moisture content, blend ratio of feed, barrel temperature and screw speed were coded as X_1, X_2, X_3 and X_4 respectively. Five levels of each of the four variables were chosen according to a central composite ratable design (CCRD). The coded and actual parameter values are presented in Table-1. The data obtained from the experiment outlined were processed in trial Design Expert 7.0.1.

The observed data were analyzed, employing multiple regression technique. The best fitting model was chosen, based on lack of fit criteria **(**Cochran and Cox, 1957). A second order polynomial of the following form was considered to fit the data:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_{11}X_{12}+\beta_{22}X_{22}+\beta_{33}X_{32}+\beta_{44}X_{42} ++\beta_{12}X_1X_2+\beta_{13}X_1X_3+\beta_{14}X_1X_4+ +\beta_{23}X_2X_3+\beta_{24}X_2X_4+ \beta_{34}X_3X_4 \quad (1)$$

Where;

Y= dependent variables;

β_0, β_1,β_2,β_3,β_4 are regression coefficients and X_1, X_2, X_3 and X_4 are coded independent variables.

Protein estimation of extrudate

The protein content in the raw and final samples were determined by using conventional micro-Kjeldhal digestion and distillation procedure as given in A.O.A.C. (1980) [1].

Results and Discussion

Effects of process parameters and operational parameters on protein content of extrudate were studied. The process parameters considered were moisture content and blend ratio of feed whereas the operational parameters were temperature and screw speed. The data obtained from the experiments (Table-2) was analyzed by using response surface methodology and second order polynomial model was fitted to the experimental data with coded values of independent variables. Sensory evaluation was conducted by a panel of judges.

Protein content of extrudate

The analysis of variance for Eq. 2 indicated non- significant lack of fit (Table-3), indicating adequate fit of data **(**Cochran and Cox, 1957) [3].

The following model was then selected

$$Y = 16.723 - 0.206 X_1 + 0.907 X_2 + 6.50 x10^{-3} X_3 + 0.012 X_4 + 9.50 x10^{-3} X_1X_2 - 6.875 x10^{-3} X_1X_3 - 0.017 X_1X_4 + 0.012 X_2X_3 + 8.75 x10^{-3} X_2X_4 +1.25 x10^{-4} X_3X_4 - 0.101 X_{1}2 - 0.127 X_{2}2 - 0.073 X_{3}2 - 0.073 X_{4}2 \quad (2)$$

Where,

Y is the protein content of extrudate, %

It is observed that protein content of extrudate increased with decreasing moisture content of feed and increased with increasing blend ratio of feed (increasing protein content and decreasing starch). Further it was observed that as barrel temperature and screw speed increased gradually, the protein content of extrudate very similar to that of untreated feed material. Similarly result was reported by Kiczorowska (2004) [8]. It may be because the change in moisture content due to high temperature and protein content remain constant at dry weight. Maximum value of protein content of extrudate observed at 15% moisture content of feed, 60:30:10 of blend ratio, 130 rpm screw speed and 130 ^{0}C barrel temperature.

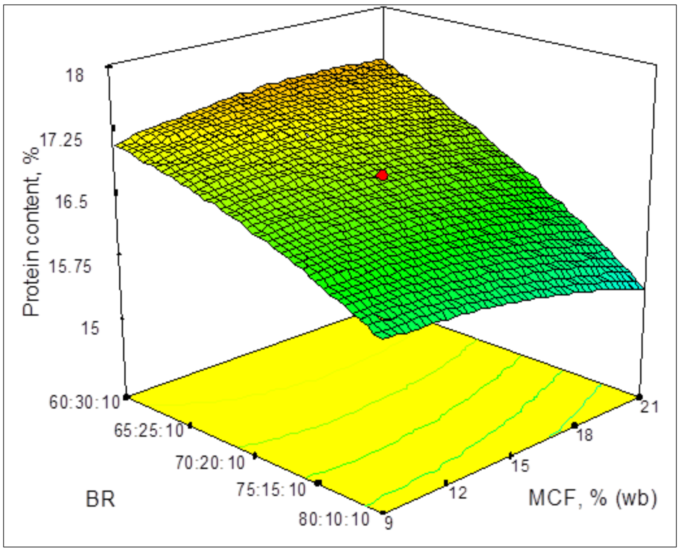

Fig 1: Effect of moisture content and blend ratio of feed on protein content of extrudate

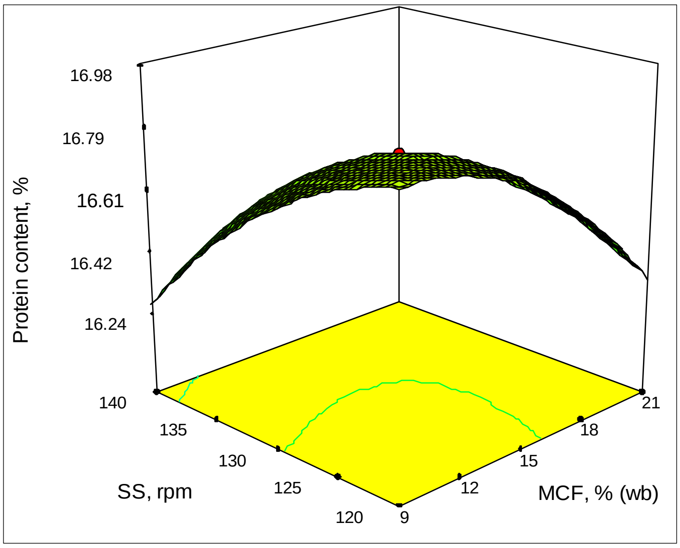

Fig 2: Effect of moisture content of feed and screw speed on protein content of extrudate

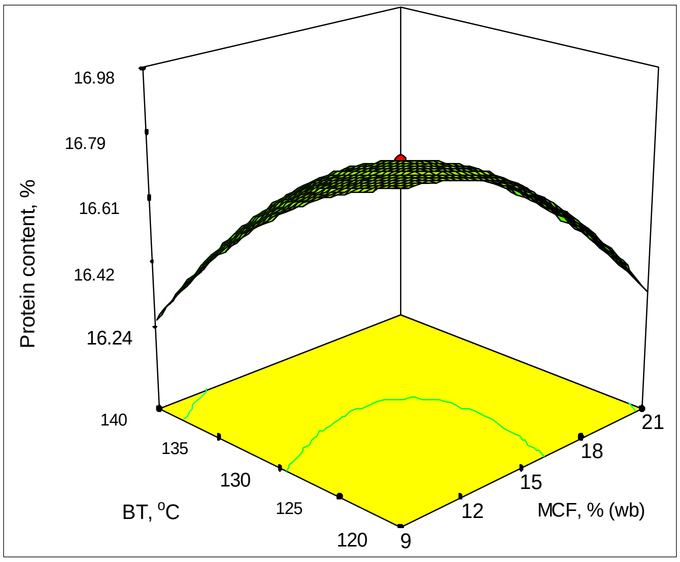

Fig 3: Effect of moisture content of feed and barrel temperature on protein content of extrudate

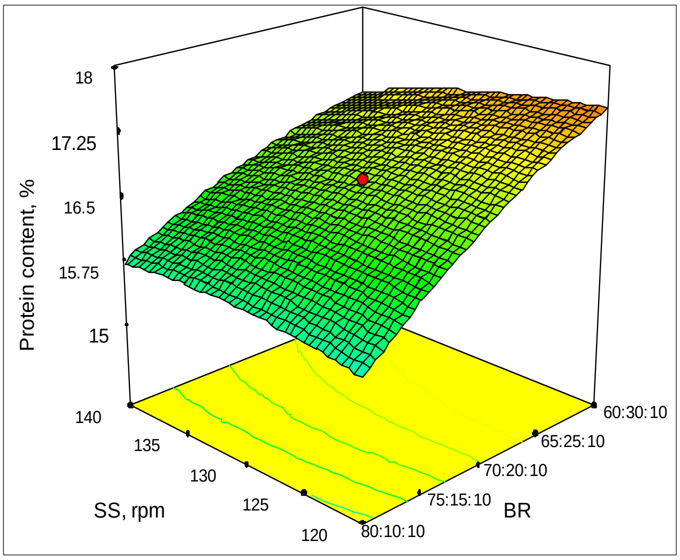

Fig 4: Effect of blend ratio and screw speed on protein content of extrudate.

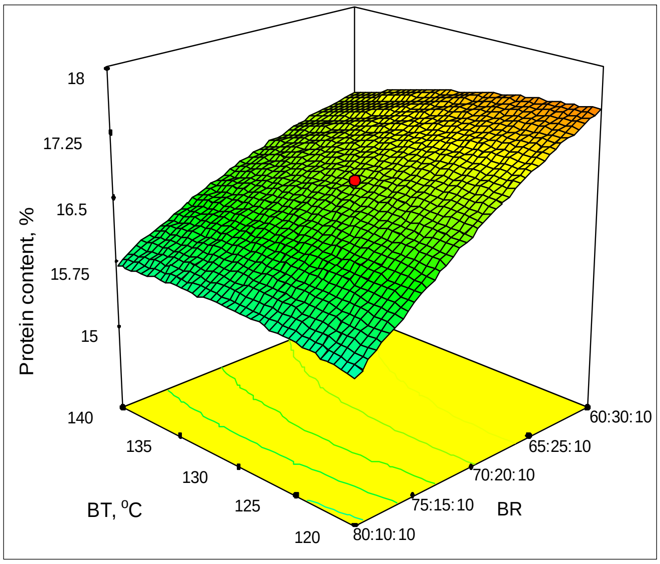

Fig 5: Effect of blend ratio and barrel temperature on protein content of extrudate.

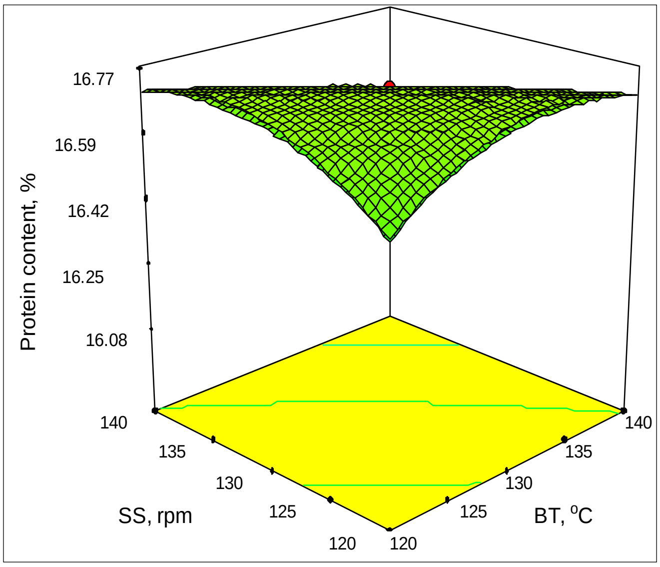

Fig 6: Effect of screw speed and barrel temperature on protein content of extrudate.

Organeoloptic Test

Sensory evaluation of extrudate were perform in ten replicates of the products. Data was quantify on Hedonic scale using simple RBD. Sensory evaluation of the best samples which have protein content were conducted by Panel of judges and compared with commercial market product. In the present investigation the interactive effect of sugar and oil had a significant effect on the overall acceptability of the extrudate. The extrudate were prepared at 15% moisture content, 80:10:10 blend ratio of feed, 130 ^{0}C barrel temperature and 130 rpm screw speed was consider to be best. The result indicates that the change in machine parameters of extrusion did not affect the overall acceptability of extrudete products. Similar results were reported by Ianoglu *et al.*, (2006) [6], Obatolu *et al.*, (2005) [9]. Based on sensory evaluation, extrusion with 4% sugar, 2% salt, 2% oil and 2% chilli powder and 1% other spices produced the most acceptable products.

Table 1: Coded and decoded parameter levels

Parameter	Code levels				
	-2	**-1**	**0**	**1**	**2**
Moisture content of feed (X_1), % (w.b.)	9	12	15	18	21
Blend ratio of feed (X_2)	80:10:10	75:15:10	70:20:10	65:25:10	60:30:10
Barrel Temperature (zone-III) (X_3), ^{o}C	120	125	130	135	140
Screw Speed (X_4), rpm	120	125	130	135	140

Table 2: Variation of observed data during the experimentation for extrusion cooking blends

Coded levels				Dependent parameters
X_1	X_2	X_3	X_4	Protein content, %
-1	-1	-1	-1	15.421
1	-1	-1	-1	14.981
-1	1	-1	-1	17.322
1	1	-1	-1	16.989
-1	-1	1	-1	15.428
1	-1	1	-1	14.988
-1	1	1	-1	17.381
1	1	1	-1	16.985
-1	-1	-1	1	15.482
1	-1	-1	1	14.982
-1	1	-1	1	17.401
1	1	-1	1	16.985
-1	-1	1	1	15.431
1	-1	1	1	14.991
-1	1	1	1	17.511
1	1	1	1	16.988
-2	0	0	0	16.978
2	0	0	0	16.241
0	-2	0	0	15.021
0	2	0	0	17.983
0	0	-2	0	16.714
0	0	2	0	16.722
0	0	0	-2	16.714
0	0	0	2	16.723
0	0	0	0	16.723
0	0	0	0	16.723
0	0	0	0	16.723
0	0	0	0	16.723
0	0	0	0	16.723
0	0	0	0	16.723

X_1= Moisture content of feed, % (WB); X_2= Blend ratio; X_3= Barrel temperature, ^{0}C; and X_4= Screw speed, rpm

Table 3: Analysis of variance for Eq.1 (R^2 =0.94)

Source	Sum of square	df	Mean square	F-Value	P-Value Prob > F	Remark
Model	21.55	14	1.54	17.13	0.0001	S
Lack of Fit	4.88	10	0.49	0.57	0.7878	NS
Error	1.35	15	0.090			
Pure Error	4.25	5	0.85			
Total	22.9	29				

S-Significant: NS- non-significant at 5% level

Conclusions

1. The protein content of extrudate varied from 14.981 to 17.983%. It was concluded that the protein content of extrudate very similar to that of untreated feed material. Maximum value of protein content of extrudate observed at 15% moisture content of feed, 60:30:10 of blend ratio, 130 rpm screw speed and 130 ^{0}C barrel temperature.
2. The extrudate were prepared at 15% moisture content, 80:10:10 blend ratio of feed, 130^{0}C barrel temperature and 130 rpm screw speed was consider to be best. Based on organoloptic evaluation, extrusion cooking with 4% sugar, 2% salt, 2% oil and 2% chilli powder and 1% other spices produced the most acceptable products. The product thus observed is as good as commercial market product.

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