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Optimization of Physical Parameters for Cereals-Pulses Combination Based Extrudates Using Sequential Response Surface Methodology

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Plant proteins in the form of flour, grits etc. are not in the palatable form as such due to lack of meat like texture, flavour and appearance. Thus the present need exists to prepare a palatable inexpensive vegetable based high protein foods. The extrusion cooking process converts the protein in its amorphous defatted flour form to fibrous structures. An extruded snack from Bengal gram brokens-sorghum blends was prepared by using Wenger X-5 extruder. The properties of the extrudates were studied at three different moisture levels (15, 20 and 25% w.b.) and three levels of barrel temperature (80, 90 and 100°C) with 5 levels of blending ratio of Bengal gram brokens-sorghum blends (10, 15, 20, 25 and 30%). All the physical parameters were optimized to have the best quality extrudates by RSM. The best quality extruded snack was obtained at 80°C barrel temperature, 15% moisture content of feed and 10% blending ratio followed by 15% moisture content of feed and 10% blending ratio at 100°C barrel temperature. Texture analysis of the optimized extrudate was also done for crispiness test and hardness test to have an idea of the resistance that the snack may offer on first bite to the consumer. The maximum value of crispness and minimum hardness was obtained at 15% moisture content, 100°C temperature.

Keywords: Response surface methodology (RSM), Extrusion, Specific length, Sectional expansion index, Mass flow rate

Introduction

Extrusion cooking process is high temperature short time (HTST) process in which moistened starchy and/or proteinous food material by a combination of heat, pressure and mechanical shear get cooked. The process is achieved by screw and barrel mechanism. An extruder is a thermodynamic unit where material is conveyed and pressed by a screw inside a barrel, due to which there is high temperature rise inside the barrel. High temperature of operation and presence of moisture promotes gelatinization of starch component. The expanded food product is shaped by the opening of the die. The expanded and cooked material discharged from the die of extruder is cut into desired length. Extruded products in a wide variety of shape like, ring, stars, curls or ball can be formed. The transformations of product during extrusion are irreversible.

Pulses are the inseparable part of Indian diet especially for the vegetarian masses. Where the cereal constitutes the major portion of diet, pulses are major sources for providing the bulk of body building proteins.
In spite of the importance of pulses in our daily diet, its annual production figures for the country have not increased since 1953. It has been fluctuating between 10 to 15 million tons with area of production ranging between 22-24 million hectares.

Bengal gram (*Cicer arietinum* L.) is one of the major pulse crops of India, which yield well under un-irrigated condition and on cloddy land. Presently the main utilization of *Bengal* Gram is in the form of '*Dal*' or '*Besan*'.

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Sorghum is good source of starch and when mixed with pulses, provides amino acids that are lacking in pulses (Patil *et al*., 1990). Therefore, the protein quality of cereals-pulses combination is thus betters then that of cereals alone (Harper *et al.*, 1981).

The snacks constitute an important part of our daily nutrient and calories intake. Extrusion cooking is capable of converting soluble globular legume protein into material having fibrous and chewy texture. When material is conveyed and pressed by a screw inside a barrel, there is high temperature rise inside the barrel. High temperature of operation in presence of water promotes gelatinization of starch components and stretching of expandable components.

The study was conducted with the objective to study the effect of blending ratios of *Bengal* gram brokens and sorghum blends on product quality at different process parameters like barrel temperature and moisture content of blends.

All the experiments were conducted by following Response Surface Methodology (RSM) (Myres, 1976). The main advantage of RSM is that it requires less number of experimental runs to provide sufficient information for statistically acceptable results. It is faster and less expensive method as compared to the full factorial experimental approach (Cochran and Cox, 1957).

Materials and Methods

In the extrusion of snacks and other food products, proper control of the extrusion process is of vital importance to the quality of the final product. In cereal-based products, the degree of starch processing is all-important for major quality

aspects. However, the effect of various processing parameters and their interaction on extrudates quality for Bengal gram broken and Sorghum were studied.

Extrusion processing parameters like feed moisture content, blending ratio, and temperature play important role in extrudates quality. Combine effect of various processing parameters in relation to product quality have not been investigated and standardization so far. Therefore, a systematic and integrated study considering the effect of various processing parameters need to be carried out, in order to develop integrated extruded quality models which can then be used to optimize these parameters for best quality of ready-to-eat snack food product. The Bengal gram broken and Sorghum was taken as a raw material for the present study and procured from local market of Jabalpur.

Experimental design

Independent variables	**Levels**	**Values**
1. Moisture content of blend	3	15, 20 and 25%
2. Blend ratio (Bengal gram broken: Sorghum)	5	10:90, 15:85, 20:80, 25:75 and 30: 70
3. Barrel temperature	3	80, 90 and 100º C

Dependent Variable

1. Specific Length (SL)
2. Sectional Expansion Index (SEI)
3. Mass Flow Rate (MFR)

Response surface methodology (RSM)- This is a combination of mathematical and statistical techniques that are useful for the modeling and analysis of problems, in which response of interest is influenced by several variables and objective is to optimize the response. Actually in the response surface plotting the values of the dependent variables for any two values of independent variables can be determined from the plot.

$$Y = a_0 + \sum_{i=1}^{n=3} a_i X_i + \sum_{i=1}^{n=3} \sum_{\substack{j=1 \\ i \le j}}^{n=3} a_j \; X_i X_j$$

Regression models were developed for the design of experiments, establishing the relation between the extrudate characteristics and the independent variables. The optimization of the variables for the development of the best quality product was done by Response Surface Methodology (RSM). Second order polynomial of the following form can be assumed to approximate the true functions.

Where, Y is Product responses for xi and xj independent variables in coded form (i.e. –2, -1, 0, 1 and 2) with a_0, ai and aij constant and coefficients respectively.

Optimization of process parameters- The optimization of process parameter was carried out by using multiple response concept (Khuri and Cornell, 1987) and data analysis was done by using software, Design-Expert 7.0.0. Optimum values of responses for the value of variables are shown in Table 1. Best fit regression equations were also determined. Response surface graphs and contour plots were drawn to see the effect of independent variables on the responses.

Table 1. Optimum values of responses for the value of variables

Temperature	Blend ratio	Moisture content	Responses
0.029554	-0.25689	-2.44251	Sp. Length = 7.77783
-1.94702	-0.08908	-1.48157	SEI = 6.71534
-0.32881	0.215855	-2.40811	MFR = 2.47398

Results and Discussion

The extruded product of *Bengal* gram broken and sorghum blend was prepared and the properties of the extrudates were studied with development of mathematical models, which were representing interaction between different properties with moisture level, temperature and blend ratio.

The mathematical model for the estimated value of specific length were fitted in full second order model and found the value of coefficient of determination R^2 as 90.4. This value of R^2 showed the model viability more than 80 percent with f-value as 36.70, which is greater than f-table value i.e. 4.61, means model was highly significant at 1% level of significance.

SL = 4.96 - 0.288 T - 0.032 BR - 0.468 MC + 0.063 T*T - 0.105 BR*BR + 0.271 MC*MC - 0.088 T*BR + 0.086 BR*MC - 0.116 T*MC -(1)

SEI = 4.69 - 0.438 T - 0.241 BR - 0.410 MC + 0.0419 T*T - 0.045 BR*BR - 0.030 MC*MC - 0.075 T*BR - 0.033 BR*MC + 0.164 T*MC -(2)

MFR = 5.72+ 0.283T + 0.160 BR + 1.13 MC - 0.048 T*T + 0.001 BR*BR-0.074 MC*MC+0.009T*BR+0.122BR*MC + 0.046 T*MC -(3)

The contour plots were generated by using software, Design-Expert 7.0.0 for Specific length, Sectional Expansion Index and Mass flow rate, respectively. It can be observed from Figure 1 that the Specific length of extrudates varied from 6.9–7.9, 4.6–6.1, 4.3-5.6 and from Figure 2 the range for SEI varied from 4.2-6.2, 3.9-5.5 and 4.6-6.4. Similarly, from Figure 3 showed the value for Mass flow rate varied from 2.96-2.12, 7-4.2 and 6.8-4.2. Similar trends of observation were found by Patil *et al*., (2000). Therefore, it could be concluded that the responses were found maximum. The multiple regression analysis showed the quadratic portion of the models was highly significant.

After complete evaluation and analysis of all the attributes for physical parameters like moisture content, mass flow rate and specific length of extrudates, and textural properties like crispness and hardness, it was concluded that best quality products were obtained at 10% feed moisture content, 10:90 blend ratio, 100°C temperature.

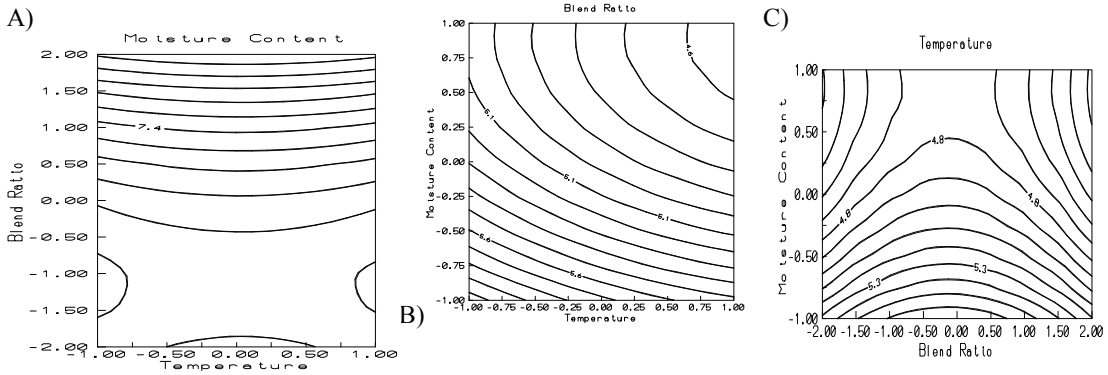

Figure 1. Contour plots for the Specific Length

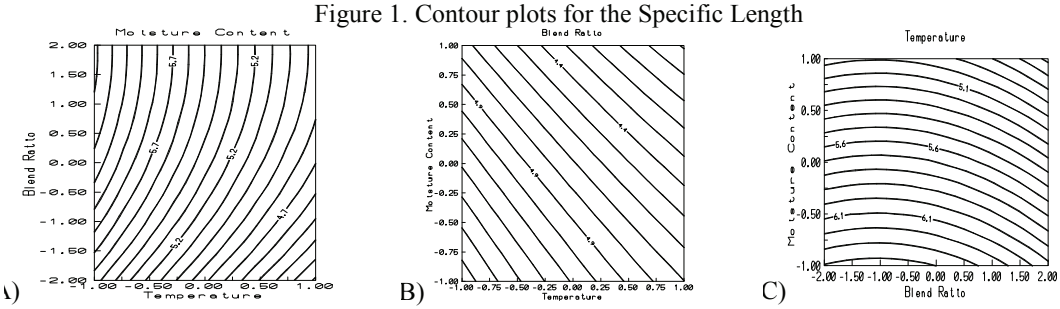

Figure 2. Contour plots for the Sectional Expansion Index

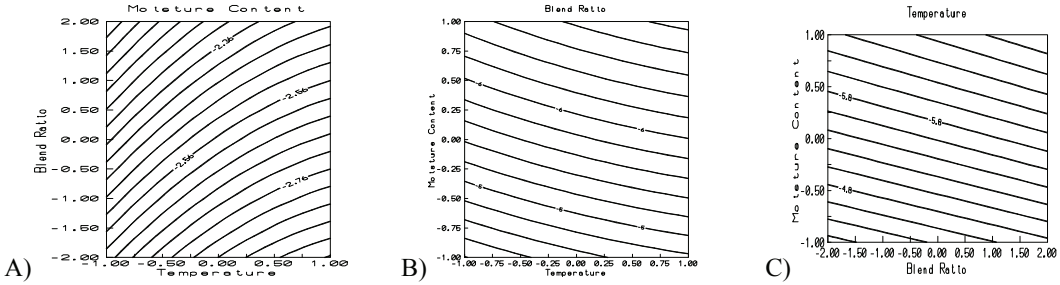

Figure 3. Contour plots for the Mass flow rate

Conclusion

The best quality extruded snack was obtained at 100^{0}C barrel temperature, 15% moisture content of feed and 10:90 blending ratio followed by 15% moisture content of feed and 15:85 blending ratio at 100^{o}C barrel temperature. Texture analysis of the optimized extrudate was also done for crispiness test and hardness test to have an idea of the resistance that the snack may offer on first bite to the consumer.

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