P: ISSN No. 0976-8602 RNI No.UPENG/2012/426228 VOL.-III, ISSUE-IV, October-2014
E: ISSN No. 2349 - 9443
Asian Resonance

Optimization of Process Parameter for Production of Protein Enriched Rice-Legume Based Snack Food by Extrusion Cooking

Devendra Kumar Verma
Assistant Professor,
Deptt. of Post Harvest Management,
College of Agriculture Ganjbasoda,
JNKVV, Jabalpur

Mohan Singh
Associate Professor,
Deptt. of Post Harvest Process
and Food Engineering,
College of Agricultural Engineering
JNKVV, Jabalpur

Abstract

Protein rich extruded products were prepared from different blends of defatted soy flour, rice flour and green gram flour blends using a single screw extruder and the physical properties of the extruded product were evaluated and related to process variables. A central composite rotate design (CCRD) and response surface methodology was used to evaluate the significance of independent and interaction effects of extrusion process variables on the product's various physical properties (mass flow rate, moisture content, sectional expansion index, water absorption ratio and specific length). CCRD based prediction models were developed by CCRD base optimization to relate the product responses to process variables as well as to obtain the response surface plots.

Keywords: Defatted soy flour (DSF), Rice flour (RF), Green gram flour (GF), Mass flow rate (MFR), Moisture content of extrudate (MCE), Sectional expansion index (SEI), Water absorption index (WAI), and Specific length (SL)

Introduction

Rice (Oryza sativa L.) is one of the most important foodstuffs for people in many countries, especially in the Orient (Hagenimana et. al. 2006). Extrusion processing is suitable for the production of fiber-rich foods (Lue et al. 1991). It is a continuous, high temperature-short time process, used to produce breakfast cereals, snacks, pre-cooked flours, dietetic foods from grains (Camire et al. 1990) of its importance in texturization of starchy products by extrusion cooking, expansion has been widely investigated (Della Valle et al. 1997). The extrusion of starchy foods results in gelatinization, partial or complete destruction of the crystalline structure and molecular fragmentation of starch polymers, as well as protein denaturation, and formation of complexes between starch and lipids and between protein and lipids (Colonna and Mercier, 1983; Ho and Izzo, 1992; Mercier and Feillet, 1975; Mercier et al., 1980).

As the extrusion process involves both thermal and mechanical shearing (Camire et al., 1990), it has been shown that it is possible to manufacture new food products such as cereal-based snacks, modified starches, precooked breakfast cereals (Harper, 1981), animal feeds, dietetic foods and beverages. The unique properties of rice such as its hypoallergenicity and bland taste make it a very desirable grain for new food development (Bryant et al., 2001).

Rice brokens are the byproduct of rice milling industry and rice flour prepared out of rice brokens can be used as important ingredient for many ready- to- eat breakfast cereals and snacks. Legumes are an important source of protein, minerals and vitamins for millions of people in the world, particularly in the developing countries (Singh and Singh 1992). They improve the nutritional quality of predominantly cereal-based diets of large segments of population, as cereal proteins are deficient in lysine (Deosthale 1984). The anti-nutritional compounds phytic acid, condensed tannins, polyphenols, protease inhibitors (trypsin and chymot- rypsin) and lectins present in the legumes affect the digestibility of legume protein and legume starch (Yadav and Khetrapaul 1994). Extrusion has been reported to have caused biggest effect in improving both in vitro protein digestibility and in vitro starch digestibility (Alonso 2000).The defatted soybean meals are the byproduct of solvent extraction plant and its edible use is numberless. Soybean, the first vegetable proteinaceous feed material was used for making protein rich extruded food (Harper, 1981). Extrusion cooking is capable of converting soluble globular legume protein into material having fibrous and chewy texture (Harper, 1981).

The objectives of the present work were (1) to study the effect of the extruder variables (i.e., mass flow rate, moisture content of extrudates, sectional expansion index, water absorption index and specific length) and the variables of the melt (i.e., moisture content and blend ratio) on expansion ratios of extrudates; and (2) to represent the interrelationship between the variables and expansion ratios of the extrudates with the models.

Materials and Methods

Materials

Locally grown rice and green gram was procured from the local market, defatted soy flour also procured from local market, were used as raw materials. The Rice and the legumes were ground into flour by a hammer mill, separately. The ground flour (RF and GF) was then passed through 100 mesh I.S. sieve, the underflow was collected for further research work.

Experimental Plan

Response surface methodology which involves design of experiments, selection of levels of variables in experimental runs, fitting mathematical models and finally selecting variables' levels by optimizing the response (Khuri and Cornell 1987) was employed in the study. In this study data obtained by application of response surface methodology (RSM) was used to build mathematical models to interpret the relationship between the independent and dependent variables.

The study was carried out to predict the effect of processing variables on the expansion ratios, viz. specific length (SL), sectional expansion index (SEI), longitudinal expansion index (LEI) and volumetric expansion index (VEI) of extrudates.

Table 1.
Design Details of Process/Independent and Dependent Variable Parameters Independent Variables

S.No.	Parameters	Value	Level
1.	Moisture Content in Blend (%) wb	8, 10, 12, 14, and 16	3
2.	Blend Ratio (%) RF-DSF-GF	(70:25:5, 70:20:10, 70:15:15, 70:10:20 and 70:5:25)	5
3.	Barrel Temperature ^{0}C	(140, 160, 180, 200 and 220°C)	3
4.	Screw Speed, rpm	130	1
5.	Feed Rate, (g/min)	100	1
6.	Die Diameter (mm)	5	1

Preparation of Extrudate

Rice broken, green gram dal brokens was procured from the local market of Jabalpur. Rice brokens were ground in a Hammer mill to obtain flour. Similarly the broken of moong dal were cleaned and grinded, to make samples by blending these two in appropriate proportions and defatted soy flour are added, it is directly used for present study. After determining the moisture content of each sample the calculated amount of water was added and keeping the blend samples for 24 hrs for conditioning.

The above prepared blend samples were then extruded in Single Screw Extruder. In extruder, cooking of blends took place at three different zones. When this blends came out of the extruder through die, it suddenly expanded due to sudden release of pressure. To have the desired size of extrudate, cutter was used at the end of die.

Result and Discussion

The extruded product from defatted soy flour – rice blends and green gram was prepared on Brabender single screw laboratory model. Experiments were conducted as per CCRD and RSM was applied to the experimental data using a 45days trail pack of Design Expert version (2010). The effect of variable on response was analyzed with the ANNOVA to check the significance of all the parameters. The R^2 values for all the models developed had the capability of being used to navigate the design space and to predict the responses correctly.

Mass Flow Rate (MFR) of extrudates for blend of green gram flour

The mass flow rate of the extrudates ranged from 6.63 to 12.07 g/s. MFR decreases with decrease in MC and the rate of decrease is slow at lower values of MC which goes on increasing with increase in MC also the MFR decreases with increase in proportion of DSF in feed.

The increase in MFR at higher moisture values is chiefly because at increased MC the amount of heat supplied during extrusion by shearing as well as direct heating cannot create enough vapor pressure to vaporize all the moisture by flash off as it comes out of the die and the mass of water that could not be vaporizes increases the mass of extrudates where as the decrease in MFR with decrease in proportion of DSF. The amount of green gram powder increases which have higher fibre content reduces puffing. The coefficient of determination R^2 had a value of 0.88 for the model with F-value of 4.39. This implies that the model terms had a significance level of probability less than 0.076.

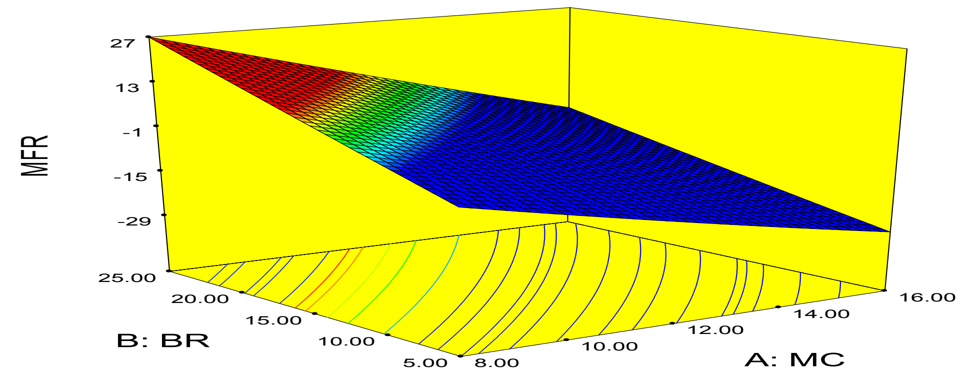

Fig. 1: Effect of moisture content and blend ratio on mass flow rate of green gram extrudates.

Where, (A), blend ratio (B), barrel temperature (C), die head temperature (D) and screw speed (E)

Moisture content (MCE) of extrudates for blends of green gram flour.

The minimum and maximum values of MCE of the extrudates 5.27 and 10.67 % wb respectively. The MCE decreases with increase in MC, whereas decrease in MCE with increase in proportion of DSF may be because DSF has more amount of gluten thus the more capacity to retain water even at high temperature. The coefficient of determination R^2 had a value of 0.755 for the model with F-value of 1.7. This implies that the model terms had a significance level of probability less than 0.1835.

The Predicted Model Developed for MCE is

MCE =

$$17.87-1.49\times A-1.83\times B-0.11\times C+0.11D+0.23\times E+0.066\times A\times B+1.906E-003$$
$$\times A\times C+3.813E-003\times A\times D+3.125E-005\times A\times E3.125E-003\times B\times C+5.512E$$
$$-003\times B\times D-3.325E-003\times B\times E+2.375E-004\times C\times D-8.438E-005\times C\times E$$
$$-9.375E-004\times D\times E-0.025A^2-2.636E-003\times B^2-2.273E-006\times C^2-$$
$$4.866E-004\times D^2+3.523E-005\times E^2$$

Where, (A), blend ratio (B), barrel temperature (C), die head temperature (D) and screw speed (E)

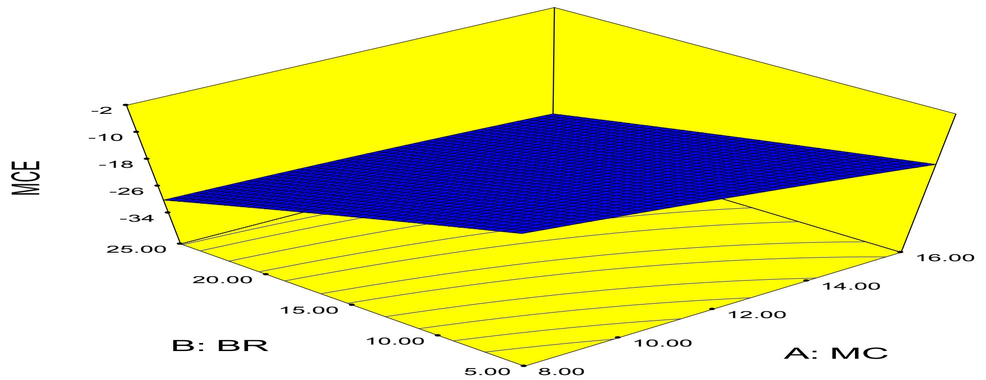

Fig. 2: Effect of Moisture Content and Blend Ratio on Moisture Content of Green Gram Extrudates.

Sectional Expansion Index (SEI) of Extrudates for Blend of Green Gram Flour.

The maximum and minimum values of SEI of the extrudates 2.13 and 1.17 respectively. The decrease in MC with increase in DHT, which is because increase the amount of moisture evaporated by flash off and capillaries are formed and more porous structure is created, which ultimately results is increased diameter of extrudates. The coefficient of determination R^2 had a value of 0.835 for the model with F-value of 2.79. This implies that the model terms had a significance level of probability less than0.042.

The Predicted Model Developed for SEI is

$$1.08 - 0.12 \times A + 0.056 \times B + 2.242E - 003 \times C - 0.024 \times D + 0.038 \times E + 1.338E - 003 \times A \times B + 1.578E - 003 \times A \times C - 3.314E - 003 \times A \times D + 1.722E - 003 \times A \times E - 1.638E - 004 \times B \times C - 9.012E - 004 \times B \times D + 8.238E - 004 \times B \times E - 1.844E - 005 \times C \times D - 5.969E - 005 \times C \times E - 4.016E - 004 \times D \times E + 0.011 \times A^2 + 7.518E - 004 \times B^2 - 3.716E - 005 \times C^2 + 3.620E - 004 \times D^2 + 3.574E - 005 \times E^2$$

Where, (A), blend ratio (B), barrel temperature (C), die head temperature (D) and screw speed (E)

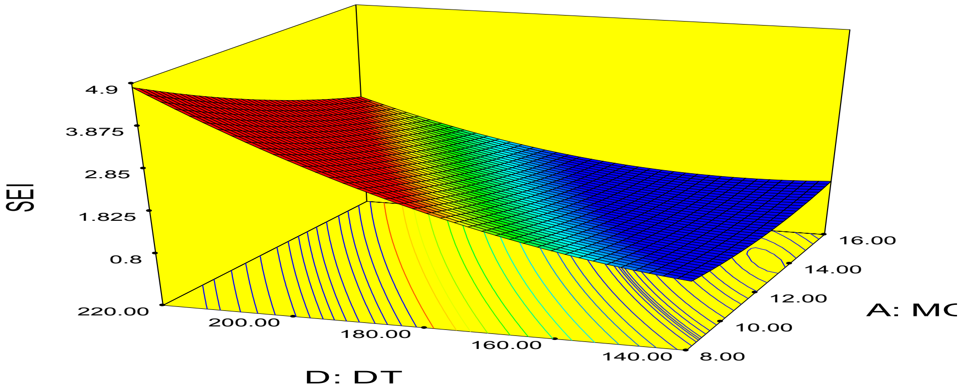

Fig. 3: Effect of Moisture Content and Die Head Temperature on Sectional Expansion Index of Green Gram Extrudates

The extrudates exhibited WAI in the range of 562 to 900. A umbrella like response surface was observed at centre point of independent variable at 12-14% moisture content of feed (w.b.) with increase in proportion of DSF, WAI increases with increase in DSF creates more porous structure and thereby creates more capillaries which increase the water absorption by the extrudates when soaked in water. The coefficient of determination R^2 had a value of 0.732 for the model with F-value of 0.084. This implies that the model terms had a significance level of probability less than 0.9.

The Predicted Model Developed for WAI is

$$WAI = -44555.23 + 1415.63 \times A + 254.01 \times B + 152.64 \times C + 190.72 \times D + 144.46 \times E - 1.87 \times A \times B - 0.12 \times A \times C - 0.23 \times A \times D + 0.23 \times A \times E - 0.13 \times B \times C + 0.047 \times B \times D + 0.39 \times B \times E + 0.055 \times C \times D - 0.047 \times C \times E - 0.098 \times D \times E - 54.12 \times A^2 - 8.97 \times B^2 - 0.55 \times C^2 - 0.51 \times D^2 - 0.56 \times E^2$$

Where, (A), blend ratio (B), barrel temperature (C), die head temperature (D) and screw speed (E)

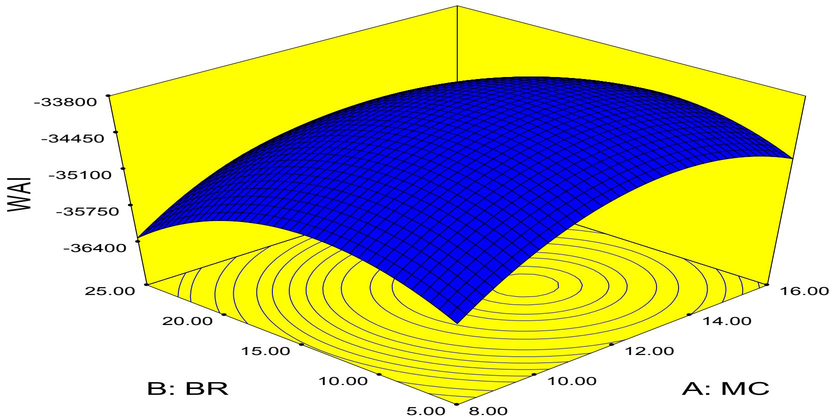

Fig. 4: Effect of Moisture Content And Blend Ratio on Water Absorption Index of Green Gram Extrudates.

Specific Length (SL) of Extrudates for blend of green gram flour

The SL of extrudates ranged from 42.34 to 73.62mm respectively, MC of feed had vital role over SL of extrudates increases with increase in MC. The coefficient of determination R^2 had a value of 0.61 for the model with F-value of 0.86. This implies that the model terms had a significance level of probability less than0.63.

The Predicted Model Developed for SL is

$$SL = -86.14+0.79\times A+4.29\times B-0.057\times C+1.47\times D-0.49\times E+0.18\times A\times B- 0.053\times A\times C-0.025\times A\times D+0.10\times A\times E-0.020\times B\times C+7.782E-003\times B\times D-0.047\times B\times E+2.405E-003\times C\times D+4.174E-003\times C\times E- 8.761E-003\times D\times E-0.064\times A^2-0.021\times B^2+2.117E-004\times C^2 -1.791E-003\times D^2+4.699E-003\times E^2$$

Where, (A), blend ratio (B), barrel temperature (C), die head temperature (D) and screw speed (E)

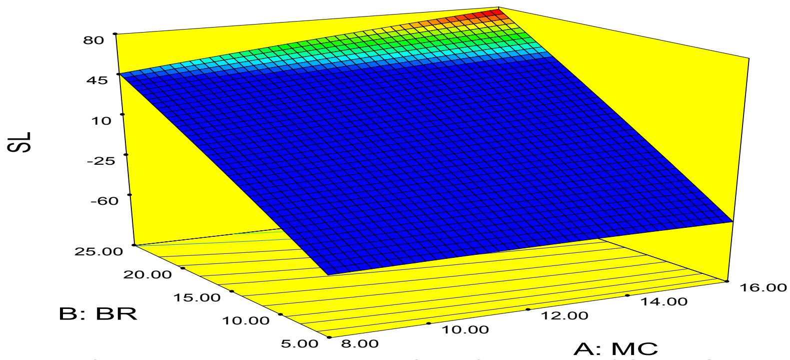

Fig. 5: Effect of Moisture Content and Blend Ratio on Specific Length of Green Gram Extrudates.

Table 2 Analysis of Variance Protein Rich Extrudates for Blend of Green Gram Flour

ANNOVA	Source	DF	SS	MSS	F	P
MFR	Regression	20	107.33	5.37	4.39	0.076
	Residual	11	13.45	1.22		
	Total	31	120.78			
MCE	Regression	20	24.86	1.24	1.7	0.1835
	Residual	11	8.04	0.73		
	Total	31	32.9			
SEI	Regression	20	2.22	0.11	2.79	0.042
	Residual	11	0.44	0.04		
	Total	31	2.66			
WAI	Regression	20	5.33E+06	2.66E+05	0.084	1
	Residual	11	3.50E+07	3.18E+06		
	Total	31	4.03E+07			
SL	Regression	20	1629.43	81.47	0.86	0.63
	Residual	11	1041.34	94.67		
	Total	31	2670.77			

Where, ANOVA: Analysis of Variance, DF: Degree of freedom, SS: Sum of square, P-value: Probability value

Conclusion

Addition of higher ratio of DSF in rice gave the higher resistance which the snack offers on first bite to the consumer. The maximum and minimum values shown for mass flow rate for blend of green gram flour were 0.63 and 12.07 g/s with a mean of 6.35 g/s. The moisture content of extrudates for blend of green gram flour attained maximum and minimum values of 5.27 and 10.67 respectively with a mean value of 7.97% (w.b.). The maximum and minimum values shown for sectional expansion index for blend of green gram flour were 1.17 times and 2.13 times with a mean of 1.65 times. The water absorption index for blend of green gram flour achieved a maximum value of 900% and a minimum value of 562.5% and its mean value was 731.25%.

References

1. ALONSO, R. 2000. Effects of extrusion and traditional processing methods on anti nutrients and in-vitro digestibility of protein and starch in faba and kidney beans. Food Chem. 68(2), 159-165.
2. Anderson, R. A. (1982). Water absorption and solubility and amylograph characteristics of roll-cooked small grain products. Cereal Chemistry, 59(4), 265–269.
3. Bryant, R.J., Kadan, R.S., Champagne, T.E., Vinyard, B.T., Boykin, D., 2001. Functional and digestive characteristics of extruded rice flour. Cereal Chemistry 78, 131–137.
4. Camire, M.E., Camire, A., Krumhar, K., 1990. Chemical and nutritional changes in foods during extrusion. Food Science Nutrition 29, 35–57.

5. Colonna,P., and Mercier, C., 1983. Macromolecular modifications of manioc starch components by extrusion-cooking with and without lipids. Carbohydrate Polymers 3, 87–108.
6. Della Valle, G., Vergnes, B., Colona, P. and Patria, A.1997. Relation between rheological properties of molten starches and their expansion behaviour in extrusion. J. Food Eng. 31(3), 277-295.
7. Deosthale,Y.G.1984. Food processing and nutritive value of legumes. In Pulse Production Constraints and Opportunities.Proceedings of Symposium on Increasing Pulse Production in India (H.C. Srivastava, S. Bhaskaran, M.V. Rao, eds.) pp. 377-388, Oxford and IBH Publishing Co., New Delhi.
8. Hagenimana, A., Ding, X., & Fang, T. (2006). Evaluation of rice flour modified by extrusion cooking. Journal of Cereal Science, 43, 38–46.
9. Harper J M 1981. Starch-based extended foods : In : Extrusion of foods. Vol II. CRC Press Inc. Florida 83-87.
10. Harper, J. M. (1978). Extrusion processing of food. Food Technology, 32(7), 67–72.
11. Harper, J.M., 1981. Food extrusion, in: Extrusion of Foods. CRC Press, Boca Raton, FL, pp.1–6.
12. Ho, C.T., Izzo, M.T., 1992. Lipid protein and lipid–carbohydrate interaction during extrusion. In: Kokini, J.L., Ho, C.T., Karwe, M.V. (Eds.), Food Extrusion Science and Technology. Marcel Dekker, New York, NY, pp. 415–426.
13. Jha SK, Prasad S 2003. Studies on extrusion cooking of rice and mung blend with salt and sugar J. Food Science Technology 40 (3) : 257-261.
14. Lue, S., Hsieh, F. and Huff, H.E. 1991. Extrusion cooking of cornmeal and sugar beet fiber: Effect on expansion properties, starch gelatinization, and dietary fiber content. Cereal Chem. 68, 227.
15. Mercier, C., and Feillet, P., 1975. Modification of carbohydrate components by extrusion-cooking of cereal products. Cereal Chemistry 52, 283–297.
16. Mercier, C., Charbonniere, R., Grebaut, J., De la Gueriviere, J.F., 1980. Formation of amylose lipid complexes by twin-screw extrusion cooking of manioc starch. Cereal Chemistry 57, 4–9.
17. Singh Daya S, Garg SK, Singh Mohan, Goyal Neeraj 2006. Effect of major processing parameters on the quality of extrudates made out of soy-kodo blends. J Food Sci.Technology 43 (4) : 434-437.
18. Singh, U. and Singh, B. 1992. Tropical grain legumes as important human foods. Econ. Bot. 46, 310-321.
19. Yadav, S. and Khetrapaul, N. 1994. Indigenous legumefermentation: Effect of some anti nutrients and in vitro digestibility ofstarchand protein. Food Chem. 50(4), 403-406.