Plant Archives Vol. 19 No. 2, 2019 pp. 2405-2410 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

EVALUATION OF TEXTURAL PROPERTIES OF CORN BASED EXTRUDED PRODUCTS

Shruthi V.H*, Sharanagouda Hiregoudar and Udaykumar Nidoni

Department of Processing and Food Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur, Karnataka, India.

Abstract

A nutri-rich extruded product was made by using corn (variety: Hema: NAH-1137; Popcorn: Sugar baby), pigeonpea brokens and rice bran using twin screw extruder. The process was performed at different temperature levels (110, 120 and 130°C), feed composition (92:4:4, 94:3:3 and 96:2:2) and feed moisture (15, 17.5 and 20%) and at constant screw speed (350 rpm). The objectives of this study were to determine the possibility of application of agro-waste products such as pigeonpea brokens and rice bran for the production of snack food products and comparison of textural properties of extruded product prepared with two corn varieties *i.e.*, Hema (NAH-1137) and Popcorn (Sugar baby). Response surface methodology and Box-Behnken experimental design was used to evaluate the significance of independent and interaction effects of the process variables. The independent variables had significant (p d $\leq$ 0.05) effects on textural properties of corn extrudates. The optimized condition was found to be 127.66°C temperature, 18.96% feed moisture and 92:4:4 feed composition at constant screw speed of 350 rpm for Hema variety and 130°C temperature, 20% feed moisture and 92:4:4 feed composition at constant screw speed of 350 rpm for popcorn variety.

Key words : Twin screw extruder, Temperature, Feed Moisture, Feed Composition, Textural properties.

Introduction

Cereals and starch-based products provide a large proportion of energy to all the humans. Besides, providing energy, starch also contributes to the texture as well as the structure of the food that we consume. The textural and the functional properties of the final product depends upon the gelatinization, molecular degradation and/or reassociation of the raw material (Guha and Ali, 2006). The technology of extrusion cooking is no exception. The extrusion technology is growing day by day because of its versatility and economical production. It produces variety of food products with attractive texture, size and shape (Smith and Singh, 1996; Sharma *et al.,* 2015).

Extruded foods are composed mainly of cereals, starches, and/or vegetable proteins. The major role of these ingredients is to give structure, texture, mouth feel, bulk, and many other characteristics desired for specific finished products (Anton and Luciano, 2007). Consumer acceptance of extruded foods is mainly due to the convenience, value, attractive appearance and texture found to be particular for these foods, especially when it concerns to snack products (Harper, 1981). The extruded product usually puffs and changes texture as it is extruded because of the reduction of forces and release of moisture and heat.

Corn has become an attractive ingredient in the extrusion industry due to its attractive yellow colour and great expansion characteristic, which is one of the important parameters in the production of a cereal-based extruded snack food in terms of the functional properties of the final product (Tahnoven *et al.,* 1998). Rice is a popular, nonallergic, gluten free source of carbohydrate, vitamins, and minerals with little fat. With an annual production of over 120 million tonnes of paddy, rice is the largest crop produced and consumed in India. Rice bran can also be used in extrusion cooking to produce nutritional extruded product (Liu *et al.,* 2011). Due to the high antioxidant activity and abundance in raw materials, polysaccharides extracted from rice bran can be developed as a new dietary supplement and functional food to replace some rare medicinal plants (Zha *et al.,*

***Author for correspondence :** E-mail : shruthihgowda@gmail.com

2009).

Cereal grains being of lower protein content (apart from lysine), have a poor biological value due to their limiting amount of essential amino acid content. They are usually fortified with lysine or pulse protein to produce nutritious snack foods to attain the protein requirement. Therefore, pigeonpea brokens are also acceptable for incorporation in extruded product (Sobota and Rzedzicki, 2009).

Mixing different ingredients to make a puffed snack product using the extrusion is difficult. Consequently, the potential to use two main food processing by-products, Rice bran and pigeonpea brokens as sources of protein and dietary fiber in corn-based snack food was investigated in this study. The effects of the extrusion variables including feed moisture content, feed composition and barrel temperature of the extruder on textural properties of the extruded snacks were investigated by using response surface methodology.

Materials and Methods

Raw materials

The raw material such as corn (variety: Hema (NAH-1137) and Popcorn (Sugar baby)) and pigeonpea brokens (variety: TS3R) were procured from Seed Unit, University of Agricultural Sciences, Raichur and rice bran of fresh unparboiled sona masoori (variety: BPT 5204) from M/S. Laxmi Venkateshwara Industry, Raichur (Karnataka). All raw materials were cleaned and ground separately in grinder and passed through 0.88 mm sieve.

The composite flour were prepared by mixing corn, pigeonpea brokens and rice bran with calculated amount of water and the flour were allowed to equilibrate for 15 min (Table 1). The blended samples were conditioned to achieve required moisture content per cent (w.b.) by spraying with a calculated amount of water and mixing uniformly. The samples were kept in container and stored at 4°C for 12 h (Deshpande and Poshadri, 2011). The flow chart for the preparation of corn based extruded product is given in Fig. 1.

Extrusion Process

The experiments were performed using a co-rotating twin-screw extruder. The main drive was provided with 7.5 hp motor (400 V, 3 phase, 50 cycles). The output shaft of worm reduction gear was provided with a torque limiter coupling. The screw configuration used was a standard design for processing cereals and flour-based product. The ratio of barrel length to diameter ratio (L/D) was 8:1 and 3 mm diameter die was selected. The barrel zone temperatures were kept constant at 60°C throughout the experiments. The speed of cutter was fixed at 150 rpm for all experiments. Extrudates were cut with a sharp knife, at the exit end of the die and left to cool at room temperature for about 20 min.

Table 1: Proportion of composite flour.

Sl. No.	Raw material	A	B	C
1	Corn (Hema/Popcorn), %	92.00	94.00	96.00
2	Pigeonpea brokens, %	4.00	3.00	2.00
3	Rice bran, %	4.00	3.00	2.00

Textural properties

Textural Analyzer (Stable Micro Systems, TA.XT Plus/TA.HD Plus, New Delhi) was used for measuring textural properties of extruded product. The experiments were carried out by different tests that generated as plot of force (kg) vs. time (s), from which texture values for extruded product were obtained. Three replications of each combination were taken for analysis. During the testing, the samples were held manually against the base plate and the different tests were conducted according to TA settings. The textural properties such as hardness and fracturability were measured by using penetration test (Stable Micro Systems). A 2 mm cylindrical probe was used for the measurement of hardness of the extruded products.

Penetration test by using cylindrical probe

The penetration test is defined as one in which the depth of penetration (or the time required to reach a certain depth) is measured under a constant load. In the penetration test, the 2 mm cylinder probe was made to penetrate into the test sample and the force necessary to achieve a certain penetration depth or the depth of penetration in a specified time, under defined conditions, was measured and used as an index of firmness.

Statistical Design

Box-Behnken design of Response surface methodology was employed for optimization of process parameters (Montgomery 2001). The experiments were designed using Design Expert Software, Version 7.7.0 (State-Ease, Minneapolis, MN). The same software was used for statistical analysis of experimental data. The detail of experimental design is shown in table 2.

Results and Discussion

Textural properties of extruded product

It was observed from TPA that, as the temperature increased, the force required for penetration and compression decreased. A typical TPA from which the textural properties of developed extruded product, like hardness, fracturability, work of shear and stickiness were

Table 2: Experimental design as per Box-Behnken for coded and un-coded variable levels.

Run	Coded levels			Uncoded levels		
	X_1	X_2	X_3	X_1 Temperature (°C)	X_2 Feed moisture (%)	X_3 Feed composition (%)
1	0	-1	1	120	15.0	96:2:2
2	0	0	0	120	17.5	94:3:3
3	0	1	1	120	20.0	96:2:2
4	0	0	0	120	17.5	94:3:3
5	0	-1	-1	120	15.0	92:4:4
6	-1	-1	0	110	15.0	94:3:3
7	1	1	0	130	20.0	94:3:3
8	0	0	0	120	17.5	94:3:3
9	0	0	0	120	17.5	94:3:3
10	-1	0	-1	110	17.5	92:4:4
11	1	0	-1	130	17.5	92:4:4
12	-1	1	0	110	20.0	94:3:3
13	-1	0	1	110	17.5	96:2:2
14	0	0	0	120	17.5	94:3:3
15	0	1	-1	120	20.0	92:4:4
16	1	-1	0	130	15.0	94:3:3
17	0	0	0	120	17.5	94:3:3
18	1	0	1	130	17.5	96:2:2

recorded. The average values and its range of the textural properties of all the treatments obtained from the TPA are presented in table 3. The texture profile analysis (TPA) graphs for optimized extruded product prepared by using both varieties are shown in Fig. 2 and 3.

Hardness (g)

The hardness of expanded extrudate is a perception of the human being and is associated with the expansion and cell structure of the product. Hardness of the extrudate varied from 990.80 to 1387.20 g for corn based extrudates (Hema: NAH-1137). The minimum hardness (990.80 g) was observed for treatment $T_3M_2F_1$ *i.e.,* 130°C temperature, 17.5 per cent feed moisture and 92:4:4 feed composition whereas, maximum hardness (1387.20 g) was observed for treatment $T_1M_2F_1$ *i.e.,* 110°C temperature, 17.5 per cent feed moisture and 92:4:4 feed composition as given in table 3.

Hardness of the extrudate varied from 518.10 to 1277.53 g for corn based extrudates (Popcorn: Sugar baby). The minimum hardness (518.10 g) was observed for treatment $T_3M_2F_1$ *i.e.,* 130°C temperature, 17.5 per cent feed moisture and 92:4:4 feed composition whereas, maximum hardness (1277.53 g) was observed for treatment $T_1M_2F_1$ *i.e.,* 110°C temperature, 17.5 per cent feed moisture and 92:4:4 feed composition as given in table 3.

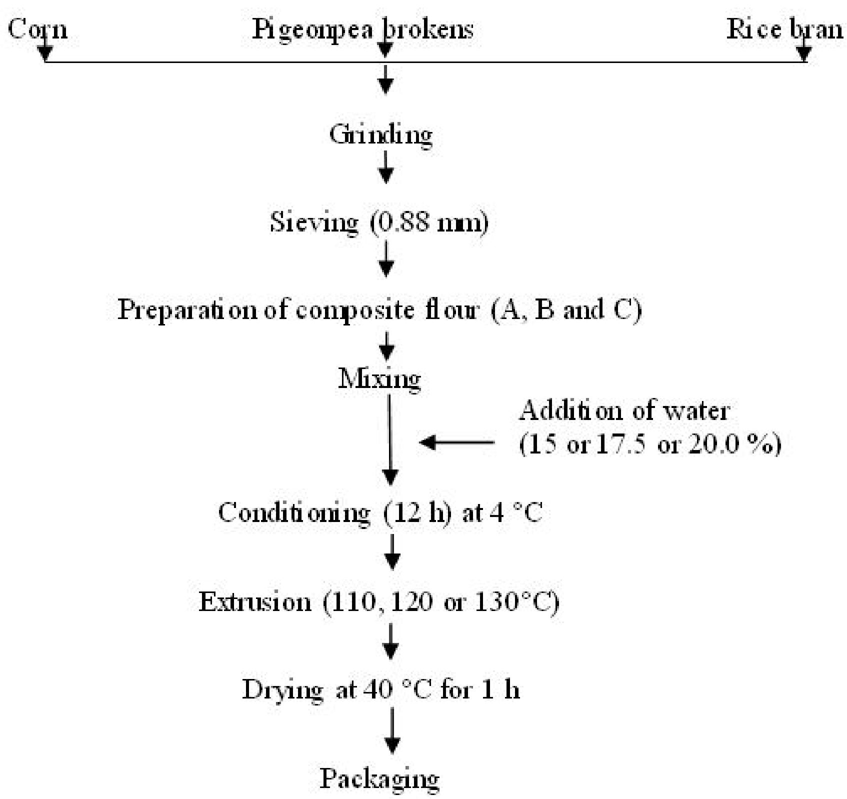

Fig. 1 Process flow chart for preparation of corn based extruded product.

Feed moisture and temperature were found to have the most significant effect on extrudate hardness. Increase in temperature results in decrease in hardness and also decrease in feed moisture results in increase in hardness. An increase in temperature increased the degree of superheating of water in the extruder, encouraging bubble formation and also decreased melt viscosity, leading to reduced density and hardness of extrudate (Mercier and Feillet, 1975). It was noted that progressive increase in temperature resulted in pore formation of air cells and the surface appeared flaky and porous and hence decreased hardness (Bhattacharya and Choudhary, 1994). Therefore, a crispy texture was obtained with increasing temperature due to decrease in hardness. Similar behaviour was observed by Chaiyakul *et al.,* (2009) for high-protein, glutinous rice-based snack. Increase in pigeonpea and

Table 3: Textural properties of corn based extruded product.

Treatments	Corn (Hema: NAH-1137)			Corn (Popcorn: Sugar baby)		
	Hardness (g)	Fracturability (g)	Stickiness (g)	Hardness (g)	Fracturability (g)	Stickiness (g)
$T_2M_1F_3$	1066.97	161.21	30.37	920.80	203.97	23.87
$T_2M_2F_2$	1094.67	183.45	31.57	937.13	206.30	25.53
$T_2M_3F_3$	1038.30	146.48	28.17	860.10	200.10	23.76
$T_2M_2F_2$	1094.69	184.21	31.54	937.14	206.31	25.55
$T_2M_1F_1$	1178.98	209.78	39.5	992.30	224.40	30.11
$T_1M_1F_2$	1348.60	264.14	47.97	1264.70	295.07	40.96
$T_3M_3F_2$	990.80	105.36	25.23	822.23	158.90	20.90
$T_2M_2F_2$	1094.64	182.65	31.54	937.13	206.30	25.49
$T_2M_2F_2$	1094.71	183.74	31.57	937.12	206.22	25.57
$T_1M_2F_1$	1387.20	242.95	50.18	1277.53	291.77	35.87
$T_3M_2F_1$	987.45	101.90	26.53	518.10	137.47	23.73
$T_1M_3F_2$	1260.43	221.04	45.1	1263.73	284.60	43.71
$T_1M_2F_3$	1204.83	218.14	43.9	1161.37	236.83	34.41
$T_2M_2F_2$	1094.66	184.11	31.53	937.13	206.12	25.53
$T_2M_3F_1$	1174.45	197.24	37.47	940.67	218.03	28.80
$T_3M_1F_2$	1096.78	126.89	22.4	607.30	175.87	20.47
$T_2M_2F_2$	1094.68	184.21	31.58	937.13	206.33	25.56
$T_3M_2F_3$	1086.89	135.87	20.00	524.60	180.33	19.20
Mean	1132.76	179.63	33.66	932.01	213.94	27.22
Std. Dev	20.93	3.57	0.92	50.24	9.16	1.23
C.V.(%)	1.85	1.99	2.74	5.39	4.28	4.52
Adj. R^2	0.9634	0.9935	0.9886	0.9499	0.9545	0.9735
R^2	0.9828	0.9969	0.9946	0.9764	0.9786	0.9875
Adeq. Precision	25.10	61.65	45.24	20.48	22.18	30.02
'F' value	50.70	290.52	164.87	36.82	40.65	70.29
Lack of fit	1.979E+006	90.01	3251.71	3.211E+008	33179.40	1236.21
$p < 0.01$	S	S	S	S	S	S

T : Temperature, °C (T_1-110 °C, T_2-120 °C, T_3-130 °C);
M : Feed moisture (w.b.), % (M_1-15 %, M_2-17.5 %, M_3-20 %);
F : Feed composition, % (F_1-92:4:4, F_2-94:3:3, F_3-96:2:2)
S : Significant

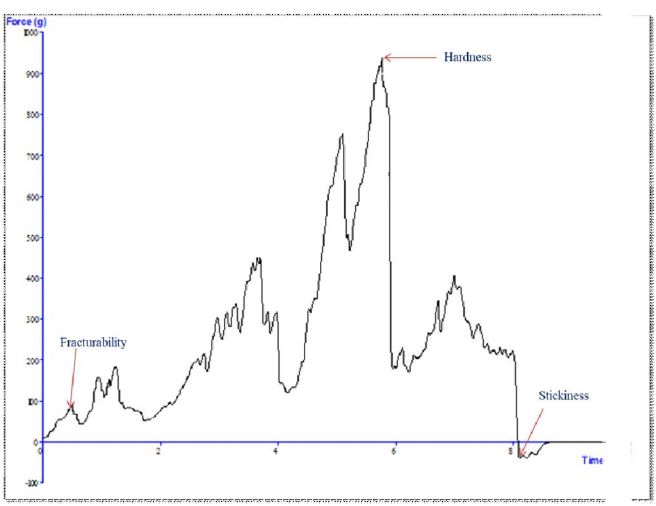

Fig. 2: Texture profile analysis (TPA) graph for optimized corn (Hema: NAH-1137) based extruded product.

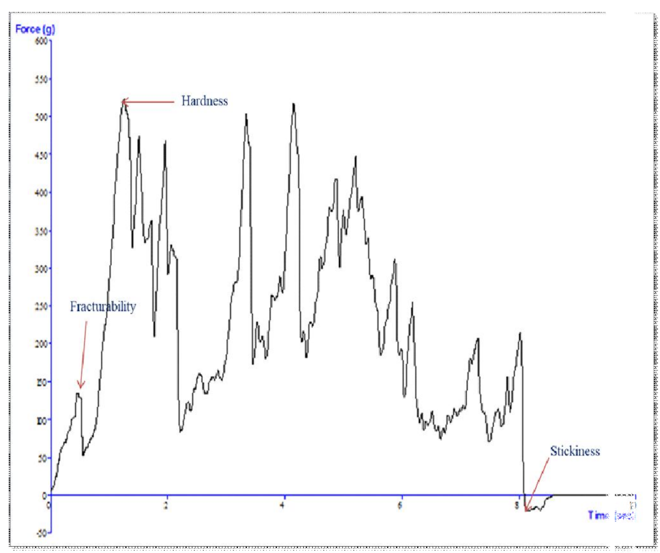

Fig. 3: Texture profile analysis (TPA) graph for optimized corn (Popcorn: Sugar baby) based extruded product.

rice bran content in the feed material and decreasing corn content resulted in increased hardness of the extrudate. It also agrees with the work of Areas (1992) in a sense that addition of protein to starch-rich flours produces the usual "protein-type" extrudates that are harder and less expanded.

Fracturability (g)

Fracturability of the extrudate varied from 101.90 to 264.14g for corn based extrudates (Hema: NAH-1137). Results show that minimum fracturability (101.91 g) was observed for treatment $T_3M_2F_1$ *i.e.,* 130°C temperature, 17.5 per cent feed moisture and 92:4:4 feed composition whereas, maximum fracturability (264.14 g) was observed for treatment $T_1M_1F_2$ *i.e.,* 110°C temperature, 15 per cent feed moisture and 94:3:3 feed composition as seen from table 3.

Fracturability of the extrudate varied from 137.47 to 295.07g for corn based extrudates (Popcorn: Sugar baby). Results show that the minimum fracturability (137.47 g) was observed for treatment $T_3M_2F_1$ *i.e.,* 130 °C temperature, 17.5 per cent feed moisture and 92:4:4 feed composition whereas, maximum fracturability (295.07 g) was observed for treatment $T_1M_1F_2$ *i.e.,* 110 °C temperature, 15 per cent feed moisture and 94:3:3 feed composition as given in table 3.

Feed moisture was found to have the most significant effect on the fracturability of the extrudate. Increase in feed moisture content significantly decreased the fracturability of corn based extrudate. Temperature had significant effect on fracturability of the developed extruded product. However, increasing temperature decreases the fracturability of the extrudate. Similar results were obtained by Ding *et al.,* (2005) for rice-based expanded snacks. Increasing pigeonpea and rice bran content in the feed material and decreasing corn content resulted in increased fracturability of the extrudate. The study reported similarity with the work of Areas (1992) which explained as protein was added to starch rich flours, harder and less expanded products were obtained which results in "protein-type" extrudates with more value of fracturability.

Stickiness (g)

The negative value of force required in gram, to breakdown the sample, means higher the stickiness of the sample (Li *et al.,* 2005). Stickiness of corn based extrudates (Hema: NAH-1137) varied from 20.00 and 50.18 g whereas, mean value of stickiness was 33.66 g. The minimum stickiness (20.00g) was observed for treatment $T_3M_2F_3$ *i.e.,* 130°C temperature, 17.5 per cent feed moisture and 96:2:2 feed composition whereas, maximum stickiness (50.18 g) was observed for treatment $T_1M_2F_1$ *i.e.,* 110°C temperature, 17.5 per cent feed moisture and 92:4:4 feed composition as seen from in table 3.

Stickiness of corn based extrudates (Popcorn: Sugar baby) varied from 19.20 and 43.70 g whereas, the mean value of stickiness was 27.22 g. The minimum stickiness (19.20 g) was observed for treatment $T_3M_2F_3$ *i.e.*, 130°C temperature, 17.5 per cent feed moisture and 96:2:2 feed composition whereas, maximum stickiness (43.70 g) was observed for treatment $T_1M_3F_2$ *i.e.*,110°C temperature, 20 per cent feed moisture and 94:3:3 feed composition as seen in table 3.

The stickiness of the extruded product is largely dependent on the temperature and feed moisture content. The stickiness of extruded product increased as the temperature decreased. At lower temperature there is higher retention of moisture, causing more stickiness in the product. The stickiness of the extrudates decreased as the feed moisture decreases. Increasing addition of pigeonpea brokens and rice bran to the feed blend resulted in extrudate became stickier. The extrusion processing would have induced chemical changes on increased addition of pigeonpea flour in the feed blends which results in stickier product.

Optimization of Extrusion Process Parameters

A numerical multi-response optimization technique was applied (Park *et al.,* 1993) to determine the optimum combination for the production of extrudate. The assumptions were made to develop a product which would have maximum score in sensory acceptability so as to get market acceptability.

Under these criteria, the uncoded optimum operating conditions for development of corn based (Hema: NAH-1137) extrudates were 127.66°C of temperature, 18.96 per cent of feed moisture and 92:4:4 feed composition at constant screw speed of 350 rpm. The responses predicted by the Design-Expert 7.7.0 software for these optimum process conditions were resulted as follows with desirability 0.746. The optimum operating conditions for development of corn based (Popcorn: Sugar baby) extrudates were 130°C temperature, 20 per cent feed moisture and 92:4:4 feed composition at constant screw speed of 350 rpm. The responses predicted by the Design-Expert 7.7.0 software for these optimum process conditions were resulted as follows with desirability 0.698.

Conclusion

The texture refers to the structure and arrangement of particles in a substance. It can be regarded as a manifestation of the rheological properties of a food. It encompasses all properties of foods which are perceived by kinaesthetic and tactile senses of mouth. It affects processing and handling, influences food habits, affects shelf-life and consumer acceptance of foods. The texture of food is a challenging area for food characteristics and quality parameters affecting the food preference. An attempt was made to use possibility of application of agro-waste products such as pigeonpea brokens and rice bran for the production of extruded snack food products and comparison of textural properties of extruded product prepared with two corn varieties *i.e.*, Hema (NAH-1137) and Popcorn (Sugar baby). The developed extruded products prepared using both the corn varieties had acceptable textural properties. Hema variety had good textural properties in comparison with popcorn variety.

References

Anton, A.A. and F.B. Luciano (2007). Instrumental texture evaluation of extruded snack foods: a review. *CYTA-J. Food*, **5(4):** 245-251.

Areas, J.A.G. (1992). Extrusion of food proteins. *Crit. Rev. Food Sci*., **32:** 365-392.

Bhattacharya, S. and G.S. Choudhury (1994). Twin screw extrusion of rice flour: effect of extruder length to diameter ratio and barrel temperature on extrusion parameters and product characteristics. *J. Food Proc. Pres.*, **18:** 389-406.

Chaiyakul, S., K. Jangchud, A. Jangchud, P. Wuttijumnong and P. Winger (2009). Effect of extrusion conditions on physical and chemical properties of high protein glutinous rice-based snack. *LWT-Food Sci. Technol.,* **42:** 781-787.

Deshpande, H.W. and A. Poshadri (2011). Physical and sensory characteristics of extruded snacks prepared from foxtail millet based composite flours. *Int. Food Res. J*., **18:** 751-756.

Ding, Q., P. Ainsworth, T. Gregory and M. Hayley (2005). The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based expanded snacks. *J. Food Engg*., **66:** 283-289.

Guha, M. and S.Z. Ali (2006). Extrusion cooking of rice: Effect of amylase content and barrel temperature on product profile. *J. Food Process. Preserv*., **30:** 706-716.

Harper, J.M. (1981). Extrusion of Foods, Vol. 1, CRC Press, Inc. Boca Raton, FL.

Li, S., H.Q. Zhang, Z. Tony and F. Hsieh (2005). Textural modification of soya bean/corn extrudates as affected by moisture content, screw speed and soya bean concentration. *Int. J. Food Sci. Technol*., **40:** 731-741.

Liu, C., Y. Zhang, J. Wan, L.W. Wang and N. Zuo (2011). Preparation, physicochemical and texture properties of texturized rice produce by improved extrusion cooking technology. *J. Cereal Sci.*, **54:** 473-480.

Mercier, C. and P. Feillet (1975). Modification of carbohydrate component by extrusion cooking of cereal product. *Cereal Chem.,* **52:** 283-297.

Montgomery, D.C. (2001). Design and Analysis of Experiments. Wiley, New York, 416-419.

Park, J., K.S. Rhee, B.K. Kim and K.C. Rhee (1993). Single-screw extrusion of defatted soy flour, corn starch and raw beef blends. *J. Food Sci.*, **58(1):** 124-132.

Smith, A.C. and N. Singh (1996). New applications of extrusion technology. *Indian Food Ind*., **15:** 14-23.

Sharma, R., R. Kumar and D.C. Saxena (2015). Textural and Microstructural Properties of Extruded Snack Prepared from Rice Flour, Corn Flour and Deoiled Rice Bran by Twin Screw Extrusion. *Int. J. Comp. Appl*., **975:** 8887.

Sobota, A. and Z. Rzedzicki (2009). Effect of extrusion process of corn semolina and pea hulls blends on chemical composition and selected physical properties of extruded products. *Int. Agro. Phys.*, **23:** 67-79.

Tahnoven, R., A. Hietanen, T. Sankelo, V.M. Kortaniemi, P. Laakso and H. Kallio (1998). Snack Foods. *Lebensm. Unters. For*., **206:** 360-363.

Zha, X.Q., J.H. Wang, X.F. Yang, H. Liang and L.L. Zhao (2009). Antioxidant properties of polysaccharide fractions with different molecular mass extracted with hot-water from rice bran. *Carbohyd. Polym.,* **78:** 570-575.