IJFANS
International Journal of Food And Nutritional Sciences

Volume 4, Issue 5, Oct-Dec 2015, www.ijfans.com e-ISSN: 2320-7876

INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

IMPACT FACTOR ~ 1.021

Official Journal of IIFANS

IJFANS International Journal of Food And Nutritional Sciences

INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

e-ISSN 2320 –7876 *www.ijfans.com*
Vol.4, Iss.5, Oct-Dec, 2015

Research Paper ***Open Access***

EFFECT OF FEED AND MACHINE PARAMETERS ON PHYSICAL PROPERTIES OF EXTRUDATE DURING EXTRUSION COOKING OF PEARL MILLET, SORGHUM AND SOYBEAN FLOUR BLENDS

Yatin, M.K.Garg, Vijay K Singh* and D.K.Sharma
Department of Processing and Food Engineering, COAE&T, CCSHAU, Hisar

*Corresponding mail: vijurss@gmail.com

Received on: 6th November, 2015 **Accepted on: 18th December, 2015**

ABSTRACT

Extrusion cooking of Pearl millet (*Pennisetum americanum*), Sorghum *(Sorghum bicolor)* and Soybean *(Glycine max)* flour blends was done to prepare snacks by using lab model twin screw extruder. The combined effect of operational parameters of extrusion cocking process *i.e.* feed rate (11, 13, 15, 17 and 19 kg/hr), moisture content of feed (10, 12, 14, 16 and 18 %) and feed composition of Pearl millet: Sorghum: Soybean (40:40:20, 55:30:15, 70:20:10, 85:10:05, and 100:0:0) on physical properties *i.e* bulk density, specific length and sectional expansion index of extrudate were observed. After complete evaluation and analysis of all physical properties, it was found that the bulk density of extrudate increased with increase in moisture content of feed while decreased with increasing proportion of soybean in feed composition. The bulk density of extrudates ranged from 0.062 to 0.139 g/cc. Specific length increased with increase feed moisture and feed rate and it ranged from 62.33 to 120.45 mm/g. Sectional expansion index decreased as the percentage of soybean increased in the composites, it may be due to the higher starch content of pearl millet, sorghum and higher protein content of soybean. The sectional expansion ratio of extrudates varied from 4.92 to 15.52 %.

Keywords: Extrusion, feed rate, temperature, bulk density, specific length

INTRODUCTION

Health and nutrition is the most demanding and challenging field in this era and would continue to be in the future as well. Maintaining and increasing the nutritional quality of food during food processing is always a potentially important area for research. Deterioration of nutritional quality, owing to high temperature, is a challenging problem in most traditional cooking methods (Singh, *et al* 2007). Extrusion cooking is a well-established industrial technology with a number of food processing applications, since in addition to usual benefits of heat processing, extrusion has the possibility of changing the functional properties of food. The advantages of this cooking process are based mainly on the fact that it is an HTST process, which minimizes the degradation of food nutrients by heat while improving digestibility by gelatinising starch, denaturing protein and deactivating undesirable compounds, such as enzymes, antinutritional factors (Alonso, *et al* 2000; Shimelis, and Rakshit, 2007). Moreover, extrusion cooking of starchy materials has become a very common technique to obtain a wide range of products such as snacks, breakfast cereals etc (Bouzaza, *et al* 1996). Extrusion cooking is preferable to other food-processing techniques as it is a continuous process with high productivity and significant nutrient retention, owing to the high temperature and short time required (Guy, 2001). Extrusion cooking had a positive effect on total and soluble dietary fibre (Rashid, *et al*. 2015).

Pearl millet (*Pennisetum americanum*) is quite comparable to other cereal food grain with regards to protein, fat, and mineral content (Gopalan *et al*., 1989). Pearl millet grains are as good as wheat and rice and better than jowar, maize and ragi in its capacity to supply calories on equal weight basis because of its higher level of lipids (Rooney, 1978). Like other cereal, protein quality of Pearl millet is low as its digestibility range from 53 to 68 per cent (Mahajan and Chauhan, 1987). It also has better mineral profile because of higher level of calcium but owing to certain inherent factors, the availability of these mineral to human system is low (Kumar and Kapoor, 1984).

Sorghum *(Sorghum bicolor)* finds use as a cereal base for low dietary bulk and calorie dense weaning foods, supplementary foods, health foods and also as amylase rich foods (Malleshi and Desikachar, 1982; Gopaldas, *et al*., 1986). This results in improving status of sorghum among cereal in economic upliftment of millets producers and will contribute for the health of the population. Among various bakery products, biscuits account for over 70 per cent of total production in India (Srivastava, and Rao, 1993). Good keeping quality makes biscuit attractive for protein fortification and other nutrional improvement. Noodles and

Macaroni are the food products that have received the fancy of India consumer in the recent years. Conveniences and aggressive advertising have led to the increase in consumption of these products.

Soybean *(Glycine max)* is often used to improve the protein quality of cereal blends, due to its high levels of protein (40%) and fat (20%). It is particularly high in lysine (Harper, 1980) which is deficient in most cereals. Soybean is considered as the cheapest source of high quality protein, oil content, rich in Lysine but deficient in sulphur bearing amino acids. While Sorghum, which contains adequate quantity of sulphur bearing amino acids, is deficient of lysine. Hence, the combination of both these source of protein and starch can be effectively combined into snack of high nutritive value, which is regularly consumed during tea time or for breakfast.

The extrusion characteristics of legume-cereal blends have been studied for several raw materials like soybean, favabean, corn, potato, and sorghum etc. Harper, *et al* (1981) reported the optimal incorporation of full fat soy flour or defatted soy flour in snack to increase protein quality. Patil, *et.al* (1990) studied the dry extrusion cooking for the production of snacks with full fat soy rice blends and soy sorghum blends at 30:70 ratios.

In the present study, pearl millet (*Pennisetum americanum*), sorghum *(Sorghum bicolor)* and Soybean (*Glycine max)* flour were used to develop an extruded snack which is protein rich, has good textural properties due incorporation of sorghum and pearl millet. The main objective of this study is to develop a nutritionally rich snack at an affordable price and was to examine the effect of extrusion condition (feed rate, feed moisture content and blending ration) on physical properties of extrudate.

MATERIALS AND METHODS

The pearl millet and sorghum and soybean were procured from Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar. The sorghum and pearl millet was cleaned for extraneous matter, immature and wrinkled seeds. The grains were conditioned to obtain 15% moisture and milled in Brabander Quardamat Junior Mill. Soy bean flour was prepared as per the method described by Khetarpaul *et al*, (2004). The moisture content of the of different blend rations were measured by hot air oven method. After gating the moisture the moisture content of blend, water was added to maintain desired moisture content levels in the blends i.e 10,12,14,16 and 18, kept for conditioning for 24 h as per the method described by Basediya, *et al.* (2013) as follows:

$$W_w = W_d \left\{ \frac{(M_2 - M_1)}{(1 - M_1)(1 - M_2)} \right\}$$

Where,

W_w = Weight of water to be added

W_d = Bone dry weight of raw flour

M_1= Initial moisture content of flour, % wb in decimal

M_2= Desired moisture content of flour, % wb in decimal

PREPARATION OF (READY TO EAT) EXTRUDED SNACKS

The extrudates were prepared using BTPL lab model twin screw extruder. Pearl millet-sorghum flour and soy flour were mixed in different proportion and moisture contents were maintained at different levels. The mixture was kept for 20 minutes at ambient temperature and remixed before extrusion. The extrudates were prepared using extruder where material was heated to 100-150^{o}C temperature for 10-20 sec and finally forced to the nozzle. The pressure at die nozzle varied from 20-40 atmospheres. The extrudates were cuts into pieces by the rotating cutter fixed at the nozzle and extrudates were collected in a trough.

EXPERIMENTAL DESIGN AND DATA ANALYSIS

Response surface methodology (RSM) was used in designing the experiment (Cochran and Cox, 1957). The central composite rotatable design (CCRD) for the three independent variables was performed. The independent variables considered were feed rate (A), feed moisture (B) and feed composition (C). The independent variables and variation levels are shown in Table1.

The levels of each variable were established according to literature data and preliminary trials. The outline of experimental design with the actual level is presented in Table 2. Dependent variables were bulk density (BD), specific length (SL) and sectional expansion index (SEI) of the product responses. Response surface methodology was applied for experimental data, a statistical package of design-expert version 8.01 (Trial version for 45 days) for generation of response surface plots and for statistical analysis of experimental data was used. The results were analyzed by a multiple linear regression method which describes the effects of variables in the models derived. Experimental data were fitted to the selected models and regression coefficients obtained. The analysis of variance (ANOVA) tables were generated for each of the response functions. The individual effect of each variable and also the effects of interaction term in coded levels of variables were determined.

Total no. of experiments = $2^{\text{No of variables}}$ + 2× No of variables+ Central points

Total no of experiments for three variables = $2^3 + 2\times3 + 6 = 20$

Five different levels for each experiment in coded form are as follows:

$-\alpha, -1, 0, +1, +\alpha$

Where,

$\alpha = 2^{\text{no of variables}/4} = 2^{3/4} = 1.682$

ANALYSIS OF EXTRUDATE

Physical properties *i.e* bulk density (BD), specific length (SL) and sectional expansion index (SEI) of extrudate were calculated as per the standard method (Anderson, *et al.* 1969; Moreyra and Peleg, 1981).

Table 1 Process variables used in the central composite design for three independent variables

Process variables	Code	Variables level codes				
		-1.682	**-1**	**0**	**1**	**1.682**
Feed rate (kg/hr)	A	11	13	15	17	19
Moisture content (%)	B	10	12	14	16	18
Feed composition*	C	40:40:20	55:30:15	70:20:10	85:10:05	100:0:0

*Feed composition-Pearl millet: Sorghum: Soybean

Table 2: Response surface experimental design in terms of coded levels and actual levels

Run	Coded values			Actual values		
	A	B	C	Feed rate (kg/hr)	Moisture content (%)	Feed composition (Pearl millet: Sorghum: Soybean)
1	-1	-1	-1	13	12	55:30:15
2	1	-1	-1	17	12	55:30:15
3	-1	1	-1	13	16	55:30:15
4	1	1	-1	17	16	55:30:15
5	-1	-1	1	13	12	85:10:5
6	1	-1	1	17	12	85:10:5
7	-1	1	1	13	16	85:10:5
8	1	1	1	17	16	85:10:5
9	-1.682	0	0	11	14	70:20:10
10	1.682	0	0	19	14	70:20:10
11	0	-1.682	0	15	10	70:20:10
12	0	1.682	0	15	18	70:20:10
13	0	0	-1.682	15	14	40:20:20
14	0	0	1.682	15	14	100:0:0
15	0	0	0	15	14	70:20:10
16	0	0	0	15	14	70:20:10
17	0	0	0	15	14	70:20:10
18	0	0	0	15	14	70:20:10
19	0	0	0	15	14	70:20:10
20	0	0	0	15	14	70:20:10

RESULTS AND DISCUSSION

In extrusion cooking process various operating condition like moisture content, feed rate and feed composition etc., influence the preparation of extrudate in a complex fashion and effect are listed in Table 3.

BULK DENSITY

The quadratic model obtained from regression analysis for bulk density (BD) in terms of coded level of the variables was developed as follows.

$$\text{Bulk density} = 0.669 - 6.479A + 0.043B - 0.00573C - 7.455^{-018}AB + 0.0000222AC + 0.000188BC + 0.000145A^2 + 0.00114B^2 + 0.0000120\,C^2$$

Regression model fitted to experimental result of bulk density showed the P- value for lack of fit as 0.0564 which implies the lack of fit was non significant. The value of R^2 was found to be 0.87. Regression analysis showed that bulk density was significantly affected by linear ($P < 0.001$) effect of feed composition, while also significant affected by linear ($P < 0.01$) effect of moisture.

Fig.1A-B shows that the bulk density of extrudate increased with increase in moisture content of feed while decreased with increasing proportion of soybean in feed composition. Similar findings were observed on the optimization and end use charactertics of extrudate millet fortified with soybean blends extrudates by Filli, *et al.* (2010). The highly dependence of bulk density and expansion on feed moisture would reflect its influence on elasticity characteristics of the starch- based material. The bulk density of extrudates ranged from 0.062 to 0.139 g/cc.

SPECIFIC LENGTH (SL)

Specific length (mm/g) of extruded product measures the axial expansion of the extrudate and related to the expansion volume. The linear model obtained from regression analysis for specific length in term of coded level of the variables was developed as follows.

$$SL = 36.23226 + 6.05906\,A - 0.65406\,B - 0.34552\,C$$

The significance of coefficient of fitted linear model was evaluated by using F-value and P- value. Regression model fitted to experimental result of specific length showed the P- value for lack of fit as 0.2590 which implies the lack of fit was non significant. The value of R^2 was found to be 0.58. Regression analysis showed that specific length was significantly affected by linear ($P < 0.001$) effect of feed moisture, while was also significant affected by linear ($P < 0.01$) effect of feed rate.

Fig. 2 illustrate that specific length increased with increase feed moisture and feed rate. Singh *et al.* (2006) who processed bengalgram broken and sorghum in extruder reported that SL increases with decreases moisture followed by temperature. The specific length of extrudates ranged from 62.33 to 120.45 mm/g.

Table 3 Effect of extrusion condition on process and product response

Run	Feed rate (kg/hr)	Feed moisture (%)	Feed composition*	Bulk density (g/cc)	SL** (mm/g)	SEI*** (%)
1	13	12	55:30:15	0.104	79.37	7.56
2	17	12	55:30:15	0.102	92.71	10.56
3	13	16	55:30:15	0.109	85.23	7.23
4	17	16	55:30:15	0.111	98.67	8.17
5	13	12	85:10:5	0.081	68.82	7.61
6	17	12	85:10:5	0.083	92.52	12.53
7	13	16	85:10:5	0.104	62.54	7.34
8	17	16	85:10:5	0.102	89.71	10.82
9	11	14	70:20:10	0.095	62.33	5.06
10	19	14	70:20:10	0.087	120.45	15.52
11	15	10	70:20:10	0.099	105.48	9.36
12	15	18	70:20:10	0.115	98.65	4.92
13	15	14	40:20:20	0.139	105.23	5.38
14	15	14	100:0:0	0.062	100.55	11.22
15	15	14	70:20:10	0.099	95.37	10.36
16	15	14	70:20:10	0.089	98.25	8.94
17	15	14	70:20:10	0.088	115.82	9.98
18	15	14	70:20:10	0.094	94.56	9.54
19	15	14	70:20:10	0.090	90.77	9.73
20	15	14	70:20:10	0.087	99.65	8.70

* Pearl millet: Sorghum: Soybean, **SL= Specific length, ***SEI=Sectional expansion

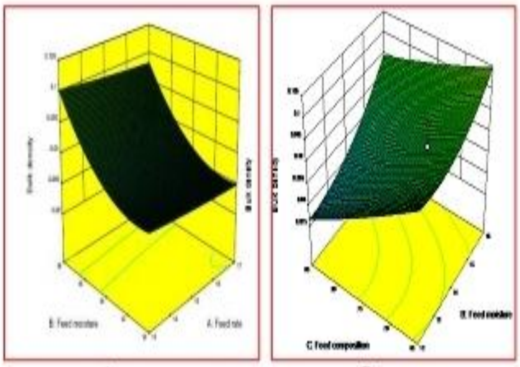

Fig. 1 The effect of feed rate, feed moisture and feed composition on bulk density

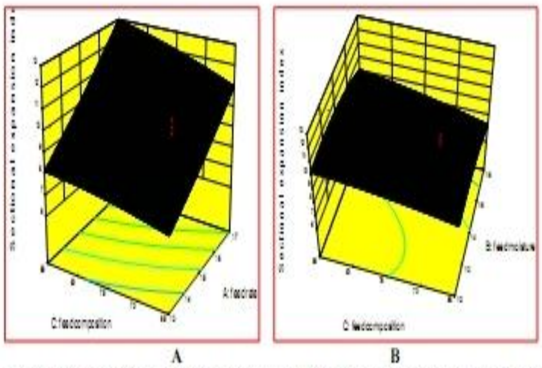

Fig 3 The effect of feed rate, feed Moisture and feed composition on Sectional expansion index

SPECIFIC LENGTH (SL)

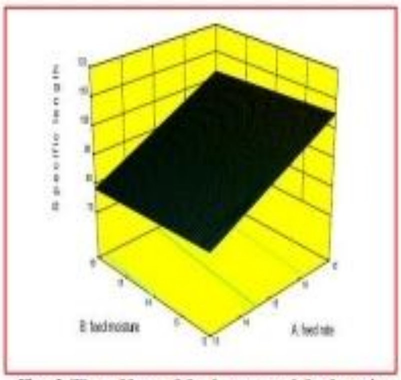

Fig. 2 The effect of feed rate and feed moisture on specific length

SECTIONAL EXPANSION INDEX (SEI)

The amount of expansion in food depends on the difference between the vapour pressure of water and atmospheric pressure, as well as the ability of the existing product to sustain expansion. The quadratic model obtained from regression analysis for sectional expansion index in term of coded level of the variables was developed as follows.

$$SEI = -35.103 + 0.501A + 4.943B + 0.0357C - 0.109AB + 0.0128\ AC + 9852.181BC + 0.0379\ A^2 - 0.158\ B^2 - 0.000482C^2$$

Regression model fitted to experimental result of SEI showed the P- value for lack of fit as 0.0688 which implies the lack of fit was non significant. The value of R^2

was found to be 0.92. Regression analysis showed that sectional expansion ratio was significantly affected by linear ($P<0.001$) effect of feed rate. The sectional expansion ratio of extrudates ranged from 4.92 to 15.52 %.

It can be observed from Fig. 3A-B, SEI decreased as the percentage of soybean increased in the composites, it may be due to the higher starch content of pearl millet, sorghum and higher protein content of soybean. Several researchers were demonstrated that the expansion ratio of extruded cereals depends on the degree of starch gelatinization (Case, *et al*, 1992; Chinnaswamy & Hanna, 1988). However, increasing level of soybean flour resulted in decrease in SEI of extrudates, it may be because of attributed to dilution effect of soybean on starch.

CONCLUSION

In this study the effect of operational parameters of extrusion cocking process *i.e.* feed rate (11, 13, 15, 17 and 19 kg/hr), moisture content of feed (10, 12, 14, 16 and 18 %) and feed composition like Pearl millet: Sorghum: Soybean (40:40:20, 55:30:15, 70:20:10, 85:10:05, and 100:0:0) on physical properties *i.e* bulk density (BD), specific length (SL) and sectional expansion index (SEI) of extrudate were observed. Bulk density of extrudate increased with increase in moisture content of feed while decreased with increasing proportion of soybean in feed composition. The bulk density of extrudates ranged from 0.062 to 0.139 g/cc. Specific length increased with increase feed moisture and feed rate and it ranged from 62.33 to 120.45 mm/g. Sectional expansion index decreased as the percentage of soybean increased in the composites, it may be due to the higher starch content of pearl millet, sorghum and higher protein content of soybean. The sectional expansion ratio of extrudates varied from 4.92 to 15.52 %.

REFERENCES

- Alonso R, Aguirre A and Marzo F. Effects of extrusion and traditional processing methods on antinutrients and in vitro digestibility of protein and starch in faba and kidney beans. *Food Chemistry*, 2000; 68: 159-165.
- Anderson R A, Conway H F, Pfeifer V F, Griffin E L. Gelatinization of corn grits by roll and extrusion cooking. Cereal Sci Today. 1969; 14(4–7):11–12.
- Basediya A L, Pandey S, Shrivastava S P, Khan K A and Nema A.. Effect of process and machine parameters on physical properties of extrudate during extrusion cooking of sorghum, horse gram and defatted soy flour blends. J Food Sci Technol. 2013; 50(1):44–52
- Bouzaza D, Arhaliass A and Bouvier J M. Die design and dough expansion in low moisture extrusion cooking process. *Journal of Food Engineering*. 1996; 29: 139-52.
- Case S E, Hanna M A and Scwartz S J. Effect of starch gelatinization on physical properties of extruded wheat and corn based products. *Cereal Chem*istry. 1992; 69: 401-404.
- Chavan J K and Kadam S . Nutritional improvement of Cereals fermentation. *Crit. Rev. Food Sci. Nutr*. 1989b; 28(5): 349-400.
- Chinnaswamy R and Hanna M A. Optimum extrusion-cooking conditions for maximum expansion of corn starch. *Journal of Food Science*. 1988; 53 (3): 834-836.
- Cochran WG and Cox G M. A text book of experimental designs. John Wiley & Sons. Inc, 1957; pp 335–375.
- Filli K B, Nkama I , Abubakar U M and Jideani VA. Influence of extrusion variables on some functional properties of extruded millet-soybean for the manufacture of „fura": A Nigerian traditional food. *African Journal of Food Science*. 2010; 4: 342- 352.
- Gopaldas T, Mehta P, Patil A, Gandhi H. Studies on reduction in viscosity of thick rice gruels with small quantities of an amylase-rich cereal malt. *UNU Food and Nutrition Bulletin*. 1986; 8(4): 42-47.
- Guy. Extrusion cooking: Technologies and Application. pp. 3-5 Cambridge: Woodhead Publishing Ltd. 2001.
- Harper J M. Extrusion processing of nutritious foods. Taipei, ROC: International Symposium on Recent Advances in Food Science and Technology. 1981.
- Horvath E and Czukor B. Effect of extrusion temperature and initial moisture content on the protein solubility and distribution in full fat soybean. *Acta Alimentaria*. 1993; 22: 151-167.
- Kumar V and Kapoor A C. Trace mineral composition of different varieties of cereal and pulses. *Indian Journal. Nutr. Diet*. 1984; 21:137.
- Mahajan S and Chauhan B M. Phytic acid and extractable phosphorus of pearl millet as affected by natural lactic acid fermentation. *Journal Science and Food Agricultural*. 1987; 41: 381-386.
- Malleshi N G and Desikachar H S R Formulation of a weaning food with low hot-paste viscosity based on malted ragi (*Eleusine coracana*) and green gram (*Phaseolus radiatus*). *Journal of Food Science and Technology*. 1982; 19(5): 193-197.
- Moreyra R, Peleg M. Effect of equilibrium water activity on the bulk properties of selected food powders. J Food Sci. 1981;46(6):1918–1922
- Patil R T, Singh D S and Tribelhorn R E. Effect of processing condition cooking of soy rice blend with a dry extrusion cooker. *Journal of Food Science and Technology*.1990; 276: 376-378.
- Rashid S, Allah R, Faqir M. A, Waqas A and Muhammad S. Effects of extrusion cooking on the

dietary fibre content and Water Solubility Index of wheat bran extrudates. International Journal of Food Science & Technology. 2015; Vol. 50, Issue 7, pages 1533–1537.

- Rooney L W. Sorghum and pearl millet lipids. *Cereal Chemistry*. 1978; 55: 584-590.
- Shimelis E A and Rakshit S K. Effect of processing on antinutrients and in vitro digestibility of kidney bean (*Phaseolus vulgaris* L.) varieties grown in East Africa. *Food Chemistry*. 2007; 103: 161-72.
- Singh B, Sekhon K S and Singh N. Effects of moisture, temperature and level of pea grits on extrusion behaviour and product characteristics of rice. *Food Chemistry*. 2007; 100: 198-202.
- Singh D S, Garg S K, Singh M and Goyal. Bengal gram broken and sorghum blend by using wenger X-5 extruder. *Journal Food Science and Technology*. 2006; 43(3): 301- 304.
- Srivastava A K and Rao H P Studies on Low-Fat Soft Dough Biscuits. *Journal Food Science & Technology*.1993; 30 (1): 21-24.