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Optimization of extrusion process for the production of ready-to-eat extruded snacks based on maize, wheat and rice blends– A response surface methodology approach

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In the present study, process for preparation of extruded snacks from high quality protein maize, wheat and rice using twin screw extruder was standardized using response surface methodology (RSM). A five-level-three-factor central composite rotatable design (CCRD) was employed for optimizing the mixed flour grain formulation with feed rate (11-19 kg/hr) moisture (10-18 %) and feed composition (maize:wheat:rice) *viz*., 100:0:0, 80:10:10, 60:20:20, 40:30:30 and 20:40:40 as independent variables. 20 different experimental combinations given by RSM design were used to investigate the effect of independent variables on product response variables *viz*., bulk density (BD), expansion ratio, sectional expansion index (SEI), texture and overall acceptability of the developed extruded snacks. Significant regression models were generated, that explained the effects of different percentages of maize (20-100%), wheat (0-40%) and rice (0-40%) on all response variables of extrudates. The co-efficients of determination, R^2, of response variables were higher than 0.73 except, hardness. Results showed that product responses of extrudates were significantly affected by changes in maize, wheat and rice flour level, moisture content and feed rate. Increase in moisture, feed rate and wheat flour level resulted in higher bulk density and texture and lower expansion ratio, sectional expansion index (SEI) and overall acceptability. Mixed grain RTE snacks containing feed composition 80:10:10 (maize: wheat: rice) extruded at moisture content 12 per cent and feed rate 13 kg/hr were found most acceptable. Thus, maize, rice and wheat can be blended in an appropriate level and can be further utilized to prepare value added snacks by supplementation with sources having nutraceutical characteristics.

Key Words : : HQPM maize, Rice, Wheat, Response surface methodology, Ready-to-eat (RTE) extruded snack

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INTRODUCTION

Manufacturing of extruded products has great scope in the food processing sector (Frame, 1994; Fellows, 2000; Guy, 2001) as these products are convenient to use and covers variety of food products. With the changing socio-economic factors *i.e.* changing lifestyle, urbanization, women working outside, large choice of variety, quality and higher spending behaviour the demand for convenience foods is increasing steadily such as ready-to-eat, ready-to-cook, and convenient mixes by the consumers. These products have dramatically

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transformed the cereal industry, the key being quality offered to consumers at competitive prices. These are produced by extrusion cooking which is an emerging technology in which material is subjected to high-temperature for short-time (HTST) inside the extruder. It is a process, which combines several unit operations including mixing, cooking, kneading, shearing, shaping and developing products. The process has many advantages as the HTST conditions in extrusion processing have minor effects on natural colours and flavours of foods while inactivating undesirable enzymes, lowering anti-nutritional factors and sterilizing the product (Fellows, 2000; Guy, 2001). It provides high product quality than the other traditional food processes because it has good control over the process parameters (Kaur *et al*., 2007).

The present study was aimed to optimize the production of expanded extruded snack based on high quality protein maize, wheat and broken rice. Maize has high carbohydrate content, but very low levels of tryptophan and lysine content. Maize hybrids (quality protein maize, QPM) in which lysine and tryptophan amino acid levels are twice that of normal corn (Sproule *et al*., 1988; Vargas, 1990) has been used in the present study. Extrusion cooking of QPM maize in combination with nutritionally complementary cereal grains such as wheat and rice is of even greater interest, because it can be used to produce nutritionally balanced products in the well-accepted form of a puffed extrudate. The effectiveness of response surface methodology (RSM) in optimization of several ingredients, formulations, processing and handling conditions in snack food has been documented by different researchers (Altan *et al*., 2008). Response surface methodology is one of the attractive statistical mathematical method, which analyzes quantitative data in an experimental design to determine and at the same time solves multi-variate equations necessary for optimization of processes and products. The main advantage of RSM is that it reduces number of experimental runs, which are required to provide appropriate information for statistically acceptable results.

Thus, present study was carried in order to standardize the process for preparation of extruded snacks from maize, wheat and rice using response surface methodology and to study the influence of extrusion independent variables on physical and sensory properties of extruded mixed grain product.

METHODOLOGY

The study was carried out in the Centre of Food Science and Technology, CCS Haryana Agricultural University, Hisar in 2012.

Raw material :

Maize variety HQPM-I was procured from the Regional Research station, Uchani, Karnal, wheat variety WH-147 was procured from the Department of Plant Breeding, CCSHAU, Hisar and broken rice were procured from local market, Hisar.

Method of preparation :

Maize, wheat and broken rice grains were cleaned for extraneous matter and flour was prepared by milling the clean grains in Brabander Quardamat Junior Mill.

Optimizing extrusion process for expanded mixed grain product :

The maize, wheat and rice flours were mixed as per

Plate 1 : Twin screw extruder BTPL model used for preparation of RTE extruded snacks during investigation

the experimental runs. The moisture content of the blend was determined (AOAC, 1995). Processing conditions such as feed rate, feed moisture and feed composition were maintained at 10-18 per cent, 11-19 kg/hr and maize (100-20%), wheat (0-40%) and rice (0-40%), respectively during development of extrudates using BTPL lab model twin screw extruder where material was heated to 100-150ºC temperature for 10-20 sec. and finally forced to the nozzle (Plate 1). 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. These were packed in suitable packaging material for further study.

Experimental design and statistical analysis :

RSM generated twenty experimental runs having eight axial, six factorial and six central points. These were designed by the statistical software package according to the input given by the user under second order central composite rotatable design with three independent variables and five response levels of each variable. The independent variables considered were feed composition (A), feed rate (B) and feed moisture content (C). The independent variables and variation levels are shown (Table A) :

The levels of each variable were established according to research literature data and preliminary trials. The outline of experimental design with the actual level is depicted in Table B. Dependent variables were Bulk Density (BD), Expansion Ratio (ER), Sectional Expansion Ratio (SEI) and Hardness as product responses. Response surface methodology was applied for experimental data, a statistical package of design-expert version 8.01 (Stat-Ease Inc., Minneapolis, MN, USA) for generation of response surface plots and for statistical analysis of experimental data. The results were

Table A : Independent variables and variation levels

Process variables	Code	Variables level codes				
		-1.682	-1	0	1	1.682
Feed composition (%)	A	100:0:0	80:10:10	60:20:20	40:30:30	20:40:40
Feed rate (kg/hr)	B	11	13	15	17	19
Feed moisture (%)	C	10	12	14	16	18

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

Run No.	Coded levels A	B	C	Actual levels Moisture content [C] (%)	Feed rate [B] (kg/hr)	Feed composition [A] (Maize: Wheat: Rice)
1	1	-1	-1	12	13	40:30:30
2	-1	-1	1	12	13	80:10:10
3	1	1	-1	12	17	40:30:30
4	-1	1	-1	12	17	80:10:10
5	1	-1	1	16	13	40:30:30
6	-1	-1	1	16	13	80:10:10
7	1	1	1	16	17	40:30:30
8	-1	1	1	16	17	80:10:10
9	1.682	0	0	14	15	20:40:40
10	-1.682	0	0	14	15	100:00:00
11	0	-1.682	0	14	11	60:20:20
12	0	1.682	0	14	19	60:20:20
13	0	0	-1.682	10	15	60:20:20
14	0	0	1.682	18	15	60:20:20
15	0	0	0	14	15	60:20:20
16	0	0	0	14	15	60:20:20
17	0	0	0	14	15	60:20:20
18	0	0	0	14	15	60:20:20
19	0	0	0	14	15	60:20:20
20	0	0	0	14	15	60:20:20

evaluated by multiple linear regression method, which explains the effects of variables in the models derived. Experimental data were fitted to the selected/appropriate models and regression co-efficients were then obtained. Software generates analysis of variance (ANOVA) tables for each of the response functions which were used to determine the individual and interaction effect of each variable by applying significance at 5 per cent level. To each of these variables (Y) full-term second-order polynomial response surface models were fitted according to the following equation;

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 + £$$

where b_0, b_1, b_2… b_{23} are the estimated regression coefficients, b_0 refers to the constant term, linear and quadratic effects are represented by b_1, b_2, b_3 and b_{11}, b_{22}, b_{33}; respectively. b_{12}, b_{13}, b_{23} represents the interaction effects, ε is the random error, whereas X_1, X_2, X_3 are the independent coded variables of feed rate, feed rate and feed composition, respectively. The statistically non-significant linear and interaction terms persisted in the model when the corresponding quadratic effects were statistically significant. Besides the significant terms (at 5% level), statistically non-significant terms were also included in the final models. The results were derived from the mean of three replicates. All RSM generated models adequately explain the variation of responses with high R^2 values and non-significant lack of fit. If the response model gives significant lack of fit, it will judge the respective model as bad and the user has to perform the particular response values again so as to make the model good by achieving non-significant lack of fit.

Quality evaluation of RTE-snacks :

Bulk density:

The bulk density was determined according to the method of Pan *et al.* (1998) by volumetric method. 100 pieces of extrudates (about 2 cm in length) were placed in a 500 ml graduated measuring cylinder. The bottom of the cylinder was tapped gently on a laboratory bench until there was no further reduction in sample volume. The volume and weight was recorded and bulk density was calculated by dividing weight of sample to volume

Bulk density=Weight of sample/ volume of sample

Expansion ratio:

The cross-sectional diameter of extrudates and that of die opening of the extruder were determined using vernier caliper. The expansion ratio was calculated as follows

Expansion ratio= De/ Dd.

where, De = cross-sectional diameter of extrudate and Dd = diameter of die *i.e.* 3mm

Sectional Expansion Index (SEI):

It was determined by the method given by Martinez *et al.* (1988). SEI was calculated by dividing the cross sectional areas of the ready-to-eat extruded snack (De) by the cross sectional areas of the extruder die opening (Dd) and expressed as:

$$SEI = (De/ Dd)^2$$

Texture:

Texture of ready to extruded snacks was assessed using TAXT plus Texture analyzer in triplicates using 35 mm cylinder probe (CP/35) with 5 kg load cell. The force required to break the ready-to-eat extruded snacks was considered as hardness of snacks.

Sensory evaluation:

Extrudates were given auxiliary treatment with spice mixture. Extrudates were evaluated for colour and appearance, aroma, texture, taste using 9- point Hedonic scale by a panel of ten semi-trained judges. Average of the scores for all the sensory characteristics was expressed as overall acceptability score.

Proximate composition of selected cereals and optimized RTE snack :

The moisture, fat, ash, fibre, carbohydrates and protein content of HQPM maize, wheat, rice flour and optimized snack were determined (AOAC, 1995).

OBSERVATIONS AND ASSESSMENT

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Standardization of process and composition :

Physical and sensory characteristics of ready to eat extruded snacks :

For preparation of extruded snacks, a suitable Central Rotatable Composite Design (CRCD) was used. Data regarding physical and overall acceptability of ready to eat extruded snacks prepared using different feed compositions containing corn, wheat and rice, feed rate and moisture level has been presented in Table 1.

Effect on process variables :

Influence of three independent variables on five product response variables *viz*., bulk density, expansion ratio, sectional expansion index, hardness and overall acceptability have been assessed.

Effect on bulk density :

Bulk density is one of the important expansion indices. Density is a measure of how much expansion has occurred because of extrusion. Bulk density ranged from 0.057 to 0.12 g/cc. Minimum bulk density was observed with formulation containing 100 per cent corn extruded at 14 per cent moisture content and 15 kg/hr feed rate and maximum value was observed for formulation containing 60 per cent corn, 20 per cent rice and 20 per cent wheat extruded at 18 per cent moisture content with 15 kg/hr feed rate. The quadratic model obtained from software assessed regression analysis for bulk density (BD) in terms of coded level of the variables, was developed as follows in terms of final equation:

$$\text{Bulk Density} = \pm 0.52905 - 2.99432E\text{-}004\ A - 2.61080E\text{-}003\ B \pm .067653\ C \pm 5.93750E\text{-}005\ AB\ 4.06250E\text{-}00\ AC - 2.18750E\text{-}00\ 4B\ 6.81818E\text{-}007\ A^2 \pm 1.50568E\text{-}004 B^2 \pm 2.74432E\text{-}003 C^2 \quad (1)$$

The analysis of variance (ANOVA) for bulk density of quadratic model Eq. (1) is given in (Table 2). Regression model fitted to experimental result of bulk density showed the model F-value of 8.03 implies the model is significant and P- value for lack of fit as 0.1441 ($P>0.05$) which implies the lack of fit was non-significant *i.e.* we want the model to be fit and good. The fit of model was also assessed by co-efficient of determination R^2, which was found to be 0.87. Regression analysis showed that bulk density was significantly affected by linear ($P<0.05$) effect of feed rate, while also significantly affected by linear ($P<0.01$) effect of moisture but feed composition was not significant ($P>0.05$). Further, quadratic effect of moisture content (C^2) has significant effect on bulk density. Considering all the above criteria, the model can be fitted for further analysis. Regression analyses indicated that bulk density increased with increase in moisture and feed rate (Fig. 1). The results are in agreement with Ryu and Walker (1995) who reported that bulk density of wheat flour extrudates was affected by moisture content and processing temperature.

Table 1 : Experimental design with physical and sensory properties of the extruded mixed grain RTE

Sr. No.	Feed composition* A	Feed rate B	Feed moisture C	Bulk density (g/cc)	Expansion ratio	SEI (mm)	Hardness (kg)	Overall acceptability
1.	40:30:30	13	12	0.065	2.99	8.94	2.53	7.5
2.	80:10:10	13	12	0.067	3.01	9.06	4.18	8.2
3.	40:30:30	17	12	0.081	2.99	8.94	3.56	7.6
4.	80:10:10	17	12	0.087	3.00	9.00	4.56	7.7
5.	40:30:30	13	16	0.088	2.87	8.23	5.59	7.6
6.	80:10:10	13	16	0.078	2.88	8.29	6.98	7.5
7.	40:30:30	17	16	0.095	2.65	7.02	7.61	7.22
8.	80:10:10	17	16	0.1	2.32	5.38	7.66	7.8
9.	20:40:40	15	14	0.068	2.78	7.72	4.56	7.2
10.	100:00:00	15	14	0.057	2.8	7.84	4.66	8.1
11.	60:20:20	11	14	0.063	3.09	9.54	4.71	7.9
12.	60:20:20	19	14	0.069	2.76	7.61	3.92	7.7
13.	60:20:20	15	10	0.095	2.96	8.76	5.70	7.4
14.	60:20:20	15	18	0.12	2.22	4.92	7.01	6.9
15.	60:20:20	15	14	0.07	2.73	7.45	4.65	7.9
16.	60:20:20	15	14	0.074	2.71	7.34	3.41	7.8
17.	60:20:20	15	14	0.068	2.78	7.72	4.98	7.9
18.	60:20:20	15	14	0.058	3.27	10.69	5.15	7.8
19.	60:20:20	15	14	0.062	3.00	9.00	4.56	7.9
20.	60:20:20	15	14	0.065	2.95	8.70	5.98	7.7

*Maize: wheat: rice

Kokini *et al.* (1992) reported that increase in feed moisture content at the same extrusion temperature reduced the degree of starch conversion and increased the bulk density values (Thymi *et al.*, 2005). At low water level, significant change in the molecular structure of the starch takes place due to structural breakdown of the starch granules (Van Lengerich, 1990). Also, Ding *et al.* (2006) studied that it is possible that an increase in feed rate may be likely to increase the viscosity of the mix in the extruder, giving a denser, rigid and harder extruded product.

Effect on expansion ratio :

Expansion is an important physical aspect for the extruded snacks that greatly influences consumer acceptability. Crispness is one of the important quality criteria of extruded snacks, which is directly linked to their expansion (Chinnaswamy and Hanna, 1988). Major role in expansion process is of starch which is the main component of cereal (Kokini *et al.*, 1992). In the present study, Expansion ratio ranged from 2.22 to 3.27. Formulation containing 60 per cent maize, 20 per cent rice and 20 per cent wheat extruded at 18 per cent moisture content and 15 kg/hr feed rate showed minimum expansion ratio whereas the same formulation when extruded at 14 per cent moisture content with same feed rate; maximum value was observed.

The quadratic model obtained from regression analysis for Expansion ratio in term of coded level of the variables was developed as follows in terms of final equation:

Expansion ratio = -5.62506 ± 0.038710A ± 0.29838B ± 0.87199C-1.09375E-003AB-1.09375E-003AC-0.024063BC-6.47727E-005A²±1.96023E-003B² -0.018977C² (2)

The significance of coefficient of fitted quadratic model was evaluated by using F-value and P- value. The analysis of variance (ANOVA) for Expansion ratio of

Table 2 : ANOVA analysis for product responses showing significance of co-efficient estimate (only p value)

Parameters	Estimated p-value				
	Bulk density (Quadratic model)	Expansion ratio (Quadratic model)	SEI (Quadratic model)	Hardness (Linear model equation)	O.A (Quadratic model)
Intercept (b_0)	0.0016	0.7056*	0.0441	0.0184	0.0028
Feed rate (b_1)	0.0347	0.0478	0.0577*	0.5795*	0.2029*
Feed moisture (b_2)	0.0055	0.0016	0.0029	0.0030	0.0155
Food composition (b_3)	0.5601*	0.0044	0.7599*	0.3521*	0.0008
Feed rate x Feed Moisture (b_{12})	0.7599*	0.1212*	0.1566*	-	0.4995*
Feed Rate x Food composition (b_{13})	0.4140*	0.4592*	0.5229*	-	0.8644*
Feed Moisture x Food comp (b_{23})	0.5727*	0.4592*	0.5218	-	0.4995*
Feed rate x feed rate b_1^2	0.7096*	0.8117*	0.8318*	-	0.8689*
Feed moisture x feed moisture b_2^2	<0.0001	0.0394	0.0618*	-	0.0004
Food Composition x feed composition C_3^2	0.8675*	0.4378*	0.4160*	-	0.2118*
Lack of Fit**	0.1441*	0.975*	0.9916*	0.2126*	0.0275*
R^2	0.87	0.77	0.73	0.46	0.86

*non-significant at P=0.05 level
**Lack of fit is non-significant (p>0.05). Hence, all the models are fit

Table 3 : Solutions generated for standardization by RSM

Solutions	Feed comp	Feed rate	Feed moisture	Bulk density	Expansion ratio	SEI	Hardness	OA*	
1	80	13	12	0.0617158	3.06071	9.30238	4.41242	8.0772	Selected
2	79	13	12	0.0615984	3.06041	9.30225	4.4213	8.07464	
3	77	13	12	0.0622002	3.05779	9.29595	4.36491	8.05329	
4	73	13	13	0.0610887	3.05516	9.28677	4.47847	8.04063	
5	68	13	13	0.0612904	3.04766	9.25481	4.48696	8.00103	
6	62	13	12	0.0633864	3.03198	9.18128	4.23241	7.93525	
7	80	14	12	0.0664359	3.0269	9.11785	4.43437	8.03151	

*OA- Overall Acceptability

quadratic model Eq. (2) is given in (Table 2). Regression model fitted to experimental result of Expansion ratio showed the model F-value of 3.77 implies the model is significant and P-value for lack of fit as 0.975 (P>0.05) which implies the lack of fit was non-significant *i.e.* we required the model to be fit. The fit of model was also indicated by the coefficient of determination R^2, which was found to be 0.772. Considering all the above criteria, the model can be fitted for further analysis. Regression analyses indicated that Expansion ratio decreased with increase in moisture content and feed rate (Fig.2). Similar results were obtained by Anuonye *et al.* (2010) who processed soybean-based expanded snacks, reported that expansion ratio decreases as moisture content and soybean percentage increases. The expansion ratio of starch is mainly influenced by its degree of gelatinization (Chinnaswamy and Bhattacharya, 1983), which may be further affected by temperature, feed rate and moisture content of the feed material (Chang and El-Dash, 2003).

Effect on SEI :

SEI ranged from 4.92 to 10.69 mm. The quadratic model obtained from regression analysis for Sectional expansion index in term of coded level of the variables was developed as follows in terms of final equation:

$$\textbf{SEI=-35.74529}\pm\textbf{0.20347A}\pm\textbf{1.55096B}\pm\textbf{ 4.5336C-5.49281E-003AB-5.50781E-003AC-0.12707BC-3.97114E-004A}^2\pm\textbf{0.010204B}^2\textbf{-0.098411C}^2 \quad (3)$$

The significance of co-efficient of fitted quadratic model was evaluated by using F-value and P- value. The analysis of variance (ANOVA) for sectional expansion index of quadratic model Eq. (3) is given in (Table 2). Regression model fitted to experimental result of Sectional expansion index showed the model F-value of 3.15 implies the model is significant and P- value for lack of fit as 0.997 (P>0.05) which implies the lack of fit was non-significant *i.e.* we want the model to be fit. The fit of model was also expressed by the co-efficient of determination R^2, which was found to be 0.73. The model can be fitted for further analysis by considering all the above criteria. Regression analyses indicated that sectional expansion index decreased with increase in moisture content (Fig. 3). Launay and Lisch (1983) proposed that the longitudinal and sectional (diametral) expansion of corn extrudate were dependent on the melt viscosity and elasticity, respectively. They described their findings by stating that increased water content gives lower melt viscosity and increased longitudinal expansion while decrease in Sectional (diametral) expansion would be observed if the melt elasticity would be lowered due to softening of the amlylopectin molecular structure. This result is also in agreement with the works of other researchers (Ilo *et al.*, 1999; Dogan and Karwe, 2003).

Effect on hardness :

The hardness is the peak force required for a probe to break the extrudate. The higher the value of maximum peak force required, higher be the hardness of the extrudate sample. Hardness ranged from 2.53 to 7.66 kg. Minimum hardness was observed with formulation containing 40 per cent corn, 30 per cent rice and 30 per cent wheat at 12 per cent moisture content and 13 kg/hr feed rate whereas, maximum hardness was observed with formulation containing 80 per cent maize, 10 per cent rice and 10 per cent wheat extruded at 16 per cent moisture content with 17 kg/hr feed rate. In the present study, extrudates resulting from dough with higher moisture contents were harder after cooling as compared with extrudates developed from lower moistures dough as these are characterized by porous, expanded and sponge like structures. The reason is lower vapor pressure during extrusion which results in a lower flashing of moisture during exit from the die and finally reduced expansion ratio and harder product.

The linear model obtains from regression analysis for hardness in term of coded level of the variables was developed as follows in terms of final equation.

$$\textbf{Hardness= -3.72398}\pm\textbf{0.013415A}\pm\textbf{0.079184B}\pm\textbf{ 0.48817C} \quad (4)$$

The significance of coefficient of fitted linear model was evaluated by using F-value and P- value. The analysis

Table 4 : Proximate composition (% on dry weight basis)

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Crude fibre	Carbohydrate[a] (%)	Energy*(kcal/100g)
Maize	10.8 ± 0.05	10.52 ± 0.25	4.43 ± 0.13	1.51 ± 0.04	2.37 ±0.006	81.16 ± 0.26	350.7
Wheat	11.9 ± 0.05	12.4 ± 0.27	2.2 ± 0.15	1.5 ± 0.05	1.6 ± 0.08	82.24 ± 0.23	350.8
Rice	12.9 ± 0.05	7.8 ± 0.25	0.72 ± 0.03	0.49 ±0.01	0.36 ± 0.009	90.63 ± 0.21	400.2
Optimized RTE snack	4.08±0.07	10.4±0.1	3.8±0.07	1.3±0.04	2.2±0.03	80.2±0.03	404.0

*= calculated by factorial method, S.D.± mean of three replicates
a= calculated by difference method

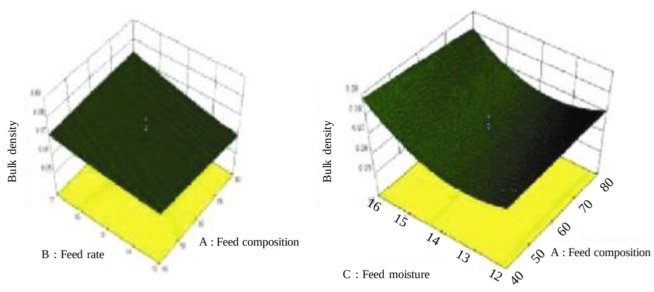

Fig. 1 : Effect of feed rate, feed moisture and feed composition on bulk density

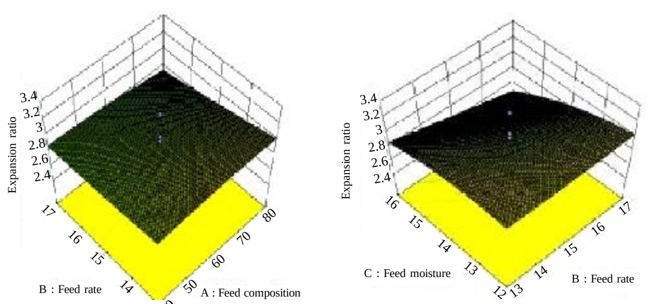

Fig. 2 : Effect of feed rate, feed moisture and feed composition on Expansion ratio

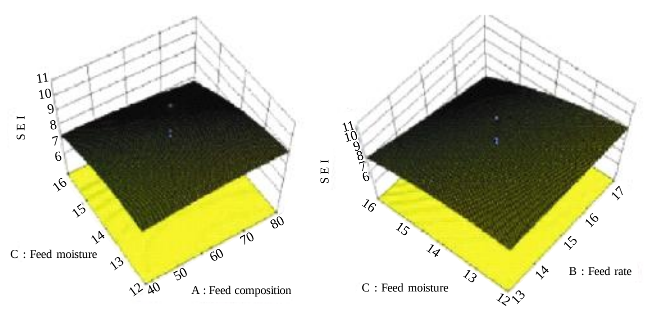

Fig. 3 : Effect of feed rate, feed moisture and feed composition on Sectional Expansion

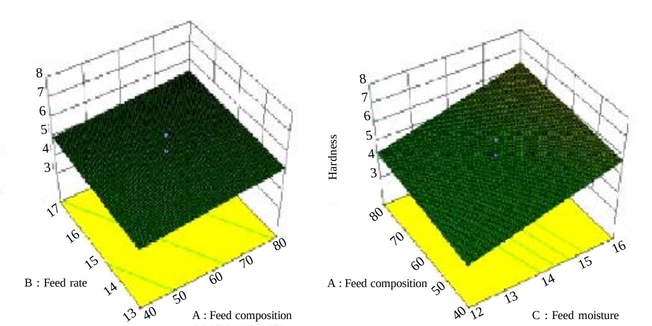

Fig. 4 : Effect of feed rate, feed moisture and feed composition on Hardness

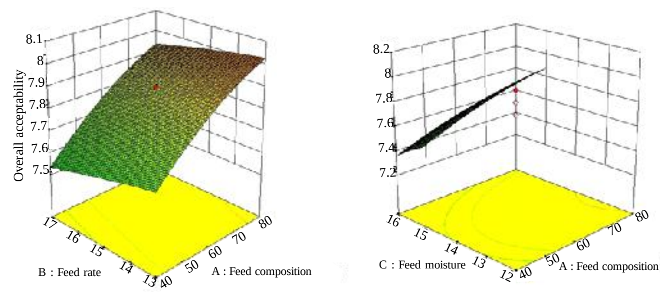

Fig. 5 : Effect of feed rate, feed moisture and feed composition on overall acceptability

of variance (ANOVA) for hardness of linear model Eq. (4) is given in (Table 2). Regression model fitted to experimental result of hardness showed the P- value for lack of fit as 0.2126 which implies the lack of fit was non-significant *i.e.* we required the model to be fit. Co-efficient of determination R^2 was found to be 0.46. Considering all the above criteria, the model can be fitted for further analysis. Regression analysis indicated that hardness increased with increase in moisture content (Fig 4). Altan *et al.* (2008) also recorded similar results and concluded that texture of extrudates increased as the feed moisture content increased based on study of barley tomato extrudates.

Effect on overall acceptability :

Sensory evaluation indicates the acceptability of the product. 9-point Hedonic scale was used to find the different aspect of sensory evaluation. It sharply increased at optimal condition later it gradually decreased. It decreased with increase in proportion of wheat flour in the formulation and increase in moisture content.

The quadratic model obtained from regression analysis for overall acceptability in term of coded level of the variables was developed as follows in terms of final equation as follows:

$$\mathbf{O.A=1.05841 \pm 0.032761A - 0.14159B \pm 1.0293C \pm 2.50000E\text{-}004AB\text{-}1.00000E\ 003AC \pm 0.010000BC\text{-}1.07386E\ 004A^2\ \text{-}1.36364EB^2\text{-}003\text{-}0.041989C^2} \quad (5)$$

The significance of co-efficient of fitted quadratic model was evaluated by using F-value and P- value. The analysis of variance (ANOVA) for overall acceptability of quadratic model Eq. (5) is given in (Table 2). Regression model fitted to experimental result of overall acceptability showed the P- value for lack of fit as 0.0275 which implies the lack of fit was non-significant. The fit of model was also expressed by the co-efficient of determination R^2 which was found to be 0.8619. Regression analyses indicated that overall acceptability sharply increased at optimal condition later gradually decreases (Fig. 5).

Optimum conditions for standardization :

The optimum condition for the development of extruded ready to eat snack prepared with maize, wheat and rice was determined using the following criteria by Response Surface Methodology (RSM) software dxt trial 8.01 version in which product should get the maximum score in sensory characteristics, maximum expansion and sectional expansion index, minimum bulk density and hardness. Based on these conditions, solutions generated by RSM software has been presented in Table 3. Formulation containing 80 per cent maize, 10 per cent wheat, 10 per cent rice at 12 per cent moisture and 13 kg/hr feed rate was selected for standardization.

Proximate composition :

The data regarding proximate composition has been presented in Table 4. Analysis showed that well puffed and nutritive extruded products could be produced by combination of maize, wheat and rice blends as compared to traditional extruded products.

Conclusion :

Our work demonstrated that well expanded extrudates can be prepared from the combination of cereals, *viz*., maize, wheat and rice. In this study, system parameters and product responses were found to be most dependent on feed moisture and feed rate whereas increase in moisture, feed rates and wheat percentage level resulted in high bulk density and texture and low expansion ratio, sectional expansion index and overall acceptability of the ready-to-eat extruded snacks. In the optimization/standardization process, extrudates with formulation of 80 per cent corn, 10 per cent wheat and 10 per cent rice levels extruded at 12 per cent moisture content and 13 kg/hr feed rate had higher preference levels for parameters of colour and appearance, texture, taste, aroma and overall acceptability. It has well expanded properties and hence, was selected for standardization (Plate 2).

Plate 2 : Optimized mixed grain extruded product with feed composition of maize, wheat and rice in 80:10:10 extruded at 12 per cent moisture content and 13kg/hr feed rate

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