International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(4): 730-737

Received: 15-05-2018
Accepted: 16-06-2018

SK Khot
M Tech, PhD Scholar, Deptt. of Processing and Food Engg, CTAE, MPUAT, Udaipur Rajasthan, India

SM Chavan
PhD Scholar, Deptt. of Processing and Food Engg., CTAE, MPUAT, Udaipur, Rajasthan, India

NK Jain
Professor and Head, Department. of Dairy and Food Tech., CDFST, MPUAT, Udaipur, Rajasthan, India

N Wadhawan
Professor, Deptt. of Dairy and Food Tech., CDFST, MPUAT, Udaipur, Rajasthan, India

Correspondence
SK Khot
M Tech, PhD Scholar, Deptt. Of Processing and Food Engg, CTAE, MPUAT, Udaipur Rajasthan, India

Standardisation of extrusion process parameters for quality protein maize based nutri-rich extruded product

SK Khot, SM Chavan, NK Jain and N Wadhawan

Abstract
Maize (*Zea mays* L.) is cultivated globally being one of the most important cereal crop. From the nutritional and clinical point of view it is recommended as a safe food. The research was carried out to optimize the extrusion variables for maize based nutri rich extruded product. The primary ingredients used for the experiment were 45 percent of quality protein maize (QPM) (Pratap, HQPM-1), 28 percent of pearl millet (Avika Bajra Chari, AVKB-19) and 20 percent of moringa leaf powder (MLP). The extruded product was prepared by varying feed moisture content (12, 14 and 16%), screw speed (200, 300 and 400 rpm) and die temperature (120, 150 and 180 °C). The extruded product was evaluated for physico-chemical and quality parameters. The best optimum condition or treatment was found to be $M_1R_1T_2$ i.e. 12 percent of feed moisture, 200 rpm of screw speed and 150 °C of die temperature given the best product with proximate composition was observed as 5.63 percent of moisture, 4.86 percent of ash, 7.54 percent of fat, 12.93 percent of protein, 65.86 percent of carbohydrates and 7.37 percent of dietary fiber wiAth an overall acceptability of 7.92.

Keywords: Moringa leaf powder, optimization, proximate composition, QPM

1. Introduction

Maize is cultivated on nearly 178 million hectare globally in about 160 countries and contributes approx. 50 per-cent (1,170 million MT) to the global grain production, it is the fastest growing cereal crop of India and is recommended as a safe food for celiac patients. QPM (Quality Protein Maize), specialty maize with increased levels of the essential amino acids lysine and tryptophan (Paes & Bicudo, 1995), has been produced in developing countries as a strategy to improve protein quality of maize-based products and help reduce protein-energy malnutrition. Pearl millet (Pennisetum glaucum) is the most widely grown type of millet, a course cereal grain, has the highest content of macronutrients such as carbohydrates, protein, fats etc. and micronutrients such as iron, zinc, magnesium, phosphorous, folic acid and riboflavin, significantly rich in resistant starch, soluble and insoluble dietary fibres among the wheat flour and other cereal whole grains (Antony *et al*., 1996; Ragaee *et al.,* 2006) [2, 14]. Moringa (Moringa oleifera) is an important food source in some parts of the world. Non-starchy vegetables are the richest sources of dietary fibre (Agostoni *et al.,* 1995) [1] and are according to Saldanha (1995) [17] employed in the treatment of diseases such as obesity, diabetes and gastrointestinal disorders. Extrusion cooking technology plays a central role in the modern cereal-based food industry especially for the production of snack and breakfast products from maize, wheat, rice and oats. The results of extrusion are gelatinization of starch, denaturation of proteins, inactivation of enzymes and anti-nutritional factors, reduction of microbial counts, and improvement in digestibility and biological value of proteins (Riaz, 2007). The commercially available snack foods have carbohydrates (54-56 percent), protein (5-7 percent) and fiber (3-5 percent). Therefore, the present investigation was undertaken to develop maize based a quality nutri-rich extruded product, which is higher in their nutritive values.

2. Materials and methods

Studies were made to improve the protein and fiber content through the incorporation of pearl millet and moringa leaf powder in the extruded product prepared by using QPM as a base material.

2.1 Development of extruded product

In the present investigation the whole Quality Protein Maize flour (45%), pearl millet flour (28%) and Moringa leaf powder (20%) were taken to make flour and passed through 300 µm sieve as the primary ingredient, whereas Chilli, salt, maggie masala (spices), baking powder, benzoic acid etc. were the secondary raw material used in this study for the addition of taste and flavour in the preparation of extruded product. Extrusion trials were performed using a co-rotating SYSLG-IV Double-Screw Lab Extruder machine (Jinan Saibainuo Machinery Co. Ltd, China). The main drive was provided with 5.5 kW motor (440 V, 3 phase, 50 Hz). The first three barrel zone temperatures were kept constant at 40 °C, 70 °C, 100 °C and fourth barrel temperature or die temperature varied according to the experimental design. The speed of cutter was fixed 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. The cylindrical extrudates were dried at 40 °C for about 2 hr to obtain dry extrudates (Bhattacharya, 1997) [4].

2.2 Optimization of process parameters

For Extrusion cooking, Box-Behnken design of Response Surface Methodology (Montgomery, 2001) [10] was used to design the experiments for three variables with three levels of each [feed moisture content (12 percent, 14 percent, 16 percent), screw speed (200 rpm, 300 rpm, 400 rpm), die temperature (120 °C, 150 °C, 180 °C)] and six responses (moisture content, ash, oil, protein, carbohydrate, dietary fiber). RSM was applied to the experimental data using the package, design-expert version 10.0.3 software (Stat-Ease Inc, Minneapolis, USA). The independent variables considered were feed moisture content (*A*), screw speed (*B*) and die temperature (*C*). The three levels of the process variables were coded as -1, 0, +1. To examine the combined effect of the three independent variables on rotatable design $2^3 = 8$ plus 3 centre points and (2 × 3 = 6) star points leading to a total of 17 experiments were performed. The second order polynomial coefficient for each term of the equation was determined through multiple regression analysis using design expert. Experimental data were fitted to the selected models and regression coefficients obtained. Statistical significance of the terms in the regression equation was examined by analysis of variance (ANOVA) for each response.

2.3 Proximate composition

Moisture content of developed extruded product was measured by hot air oven method.

$$\text{Moisture (\%)} = \frac{\text{(Initial weight of product-weight of dry product)}}{\text{Initial weight of extruded product}} \times 100 \quad (2.1)$$

For determination of ash content, 2 g of ground extruded product sample was placed in silica dish and kept in muffle furnace [Meta Instruments, Mumbai] at 550 °C until grey colored ash is occurred to a constant weight. The ash content of extruded product was then calculated by,

$$\text{Total Ash(\%)} = \frac{\text{Weight of Ash}}{\text{Weight of Sample}} \times 100 \quad (2.2)$$

Oil content was determined using Soxlet apparatus [SOCS PLUS SCS 06 AS DLS.] as per method given by AOAC, 2012.

$$\text{Oil content (\%)} = \frac{\text{(Weight of flask+oil)-(weight of flask)}}{\text{Weight of product taken}} \times 100 \quad (2.3)$$

The protein assay was performed by using Folin-Lowry method (Lowry *et al.*, 1951).

$$\text{Protein (\%)} = \frac{\text{Graph factor} \times \text{Optical density} \times \text{Total volume of buffer (ml)}}{\text{Volume taken from extract (ml)} \times \text{weight of sample (gm)}} \times 100 \quad (2.4)$$

Carbohydrate was determined by using Phenol sulphuric acid method (Sadasivam and Manikam, 1991).

$$\text{Total carbohydrates(\%)} = \frac{\text{Graph factor} \times \text{Optical density} \times \text{Total volume} \times 10^{-6} \times 100}{\text{Aliquot taken}} \quad (2.5)$$

Crude fiber of extruded product was determined by Mynard, (1970) method.

$$\text{Crude fiber(\%)} = \frac{\text{Loss in wt. on ignition } (W_2\text{-}W_1) - (W_3\text{-}W_2)}{\text{wt. of the sample}} \times 100 \quad (2.6)$$

3. Results and discussions

The values of various responses at different experimental combinations for coded variables are given in Table 3.1. A wide variation in all the responses was observed for different experimental combinations i.e. 5.45 to 7.49% for product moisture content, 3.94 to 6.48% for total ash content, 4.25 to 9.75% for oil content, 7.56 to 12.93% for protein, 65.71 to 70.98% for carbohydrates and 1.42 to 7.37% for crude fiber. Maximum consumer acceptance (7.92) was recorded for the sample developed at best treatment $M_1R_1T_2$ *i.e.* experimental condition of 12% of feed moisture content, 200 rpm of screw speed, and 150 °C of die temperature. The data was analyzed using multiple regression technique. A linear model and a second order model with and without interaction terms for each response were tested for their adequacies and R2 values were calculated. A second order polynomial equation was fitted to the data for all the responses and the results are given in Table 3.2.

$$Y_k = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \sum_{i=1}^{n} \beta_{ii} X_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} X_i X_j \beta_{ij}$$

Where, β_i, β_{ii}, β_{ij} are constant coefficient and Xi, Xj are coded independent variables.

All models were tested for their adequacy using ANOVA technique. F-values for the lack of fit were found non-significant ($p \leq 0.05$) for each responses thereby confirming the validity of the models. The sign and magnitude of coefficients indicate the effect of process variable on the response. Negative sign of the coefficient shows decrease while positive sign indicates increase in the response with the increase in variable level. Significant interaction suggests that the level of one of the interactive variable can be increased while the other decreased for constant value of the response (Montgomery, 2001) [10].

3.1 Moisture content

The minimum moisture retention (5.45 percent) was observed for treatment $M_1R_2T_1$ *i.e.* 12 percent feed moisture, 300 screw rpm and 120 °C temperature whereas, maximum moisture retention (7.49 percent) was observed for treatment $M_3R_2T_1$ *i.e.* 16 percent feed moisture, 300 screw rpm and 120 °C temperature (Table 1). Quadratic model fitted to the experimental results of moisture content (Table 2) which shows that Model F-value of 1409.11 implies that the model is significant ($p<0.001$) whereas, lack-of-Fit F-value 0.012 was not significant. The fit of model was also expressed by the coefficient of determination R^2, which was found to be 0.9994, indicating that 99.94 percent of the variability of the response could be explained by the model. The adjusted R^2 was 0.9987 and adequate precision was 140.779 showed an adequate signal.

The model was selected for representing the variation of lateral expansion ratio and for further analysis.

Product moisture content = $6.51 + 0.48\times A - 0.23\times B - 0.12\times C - 0.44\times AB - 0.59\times AC\ 0.29\times BC - 0.10\times A^2 - 0.091\times B^2 + 6.50\times 10^{-3}\times C^2$ Where, A, B and C are the coded values of the feed moisture content (percent), screw speed (rpm) and die temperature (°C) respectively

Table 1 indicated that linear terms of all process variables have significant effect at 0.1 percent level of significance ($p<0.001$). Further quadratic term of temperature (C^2) was not significant and screw speed (B^2) and feed moisture (A^2) had significant effect ($p<0.001$). The moisture content decreases as there is increase in temperature, it may be because more moisture has been utilized during cooking process (Fig. 1). The screw speed has significant effect on the moisture content, the decrease in moisture content as the screw speed increases (Fig. 2). Similar results were found to be (Lo *et al.,* 1998) [7]. Higher screw speeds also cause a reduction in the die pressure due to the reduction of viscosity which indicated less resistance for the starchy meal traveling through the extruder (Shah, 2003) [18].

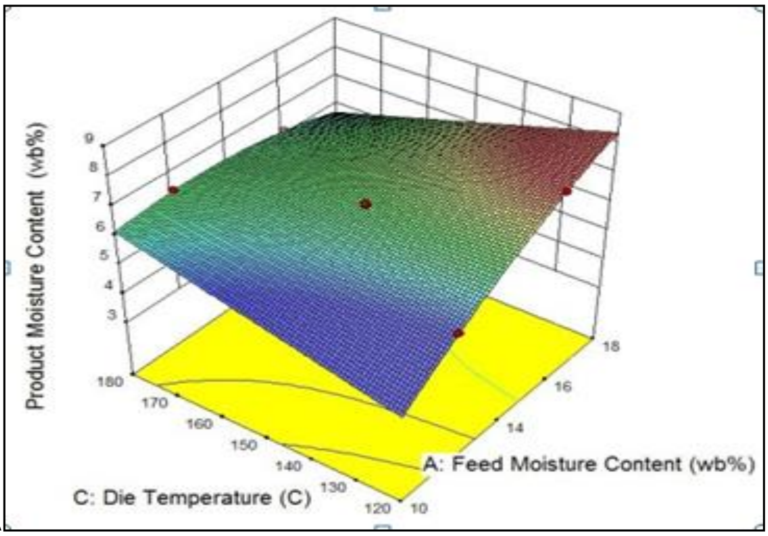

Fig 1: Response surface plot for product moisture content as a function of feed moisture content and die temperature at a center value of screw speed

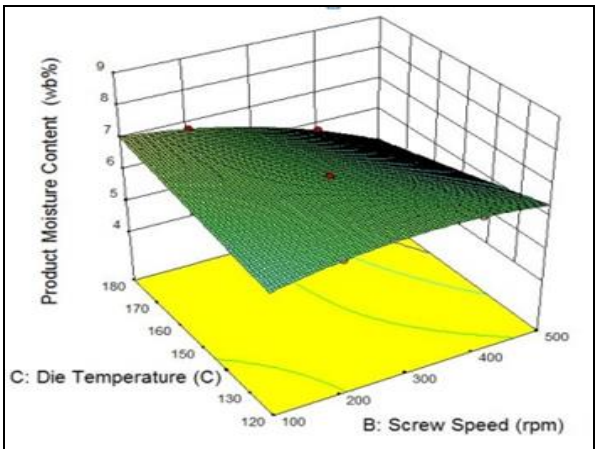

Fig 2: Response surface plot for product moisture

3.2 Ash content

The minimum ash content (3.94 percent) was observed for treatment $M_3R_3T_2$ *i.e.* 16 percent feed moisture, 400 screw rpm and 150 °C temperature whereas, maximum ash content (6.48%) was observed for treatment $M_1R_3T_2$ *i.e.*12 percent feed moisture, 400 screw rpm and 150 °C temperature given in Table 3.13. Regression model fitted to experimental results of ash content (Table 2) which shows that model F-value of 52.13 was significant ($p<0.001$), whereas lack-of-fit F-value of 0.37 was not significant. The lack of fit of model was also Expressed by the coefficient of determination R^2, which was 0.9853, indicating that 98.53 percent of the variability of the response could be explained by the model (Table 3). The results shows that the process parameters changes from minimum to maximum level, there is 32.79 percent decrease in ash content of extrudate (Table 1). The magnitude of p-value in the Table 3 indicates that linear terms of screw speed and feed moisture have significant effect on ash content of extrudate at 0.1 percent level of significance ($p<0.001$). Further, the temperature have not significant effect on ash content of extrudate. The other terms are significant at 0.1 percent level of significance ($p<0.001$). The quadratic model (Eq.) obtained for moisture retention in terms of coded levels of the variables is as follows:

Ash content = $5.45 - 0.49\times A + 0.076\times B + 0.022\times C - 0.74\times AB + 0.12\times AC + 0.52\times BC - 0.13\times A^2 - 0.19\times B^2 - 0.33\times C^2$

Where, A, B and C are the coded values of the feed moisture content (percent), screw speed (rpm) and die temperature (°C) respectively.

The results show that ash content of the extrudate increases as the temperature increases (Fig. 3). Ash content increases as the screw speed increases this may be due to higher screw speed, there is less residence time for feed. The screw speed decreases the residence time increases and ash content increases. The ash content also decreases as the feed moisture increases (Fig. 4).

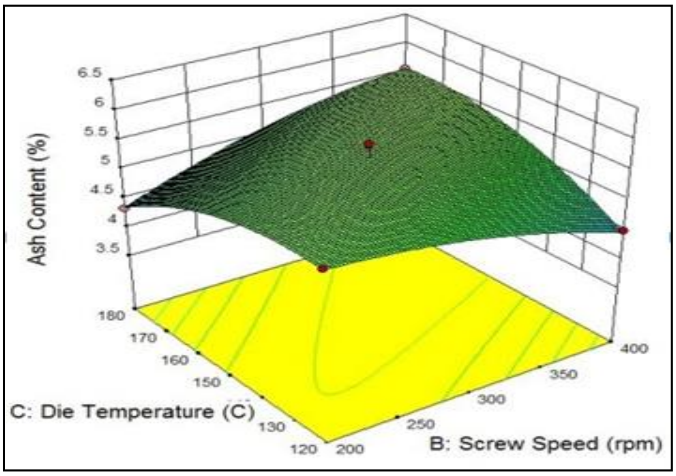

Fig 3: Response surface plot for ash content as a function of feed moisture content and die temperature at a center value of screw speed

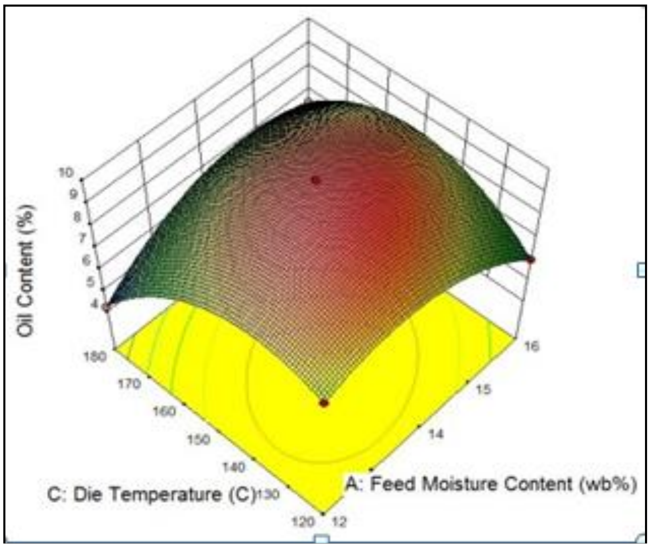

Fig 4: Response surface plot for ash content as a function of screw speed and die temperature at a center value of feed moisture content

3.3 Oil content

The minimum oil content (4.25 percent) was observed for treatment $M_1R_2T_3$ *i.e.* 12 percent feed moisture, 300 screw rpm and 180 °C temperature whereas, maximum oil content (9.75%) was observed for treatment $M_2R_2T_2$ *i.e.*14 percent feed moisture, 300 screw rpm and 150 °C temperature given in Table 1. Regression model fitted to experimental results of oil content (Table 3.2) which shows that model F-value of 12510.19 was significant ($p<0.001$), whereas lack-of-fit F-value of 0.33 was not significant. The lack of fit of model was also expressed by the coefficient of determination R^2, which was 1.000, indicating that 100 percent of the variability of the response could be explained by the model. The adjusted R^2 value was 0.9999 and adequate precision was 506.815, which is greater than 4 and hence this model may be used to navigate the design space (Table 3). The magnitude of p-value in the Table 2 indicates that linear terms of screw speed, die temperature and feed moisture have significant effect on oil content of extrudate at 0.1 percent level of significance ($p<0.001$). Further, the interaction terms of temperature and screw speed also having significant effect on oil content of extrudate at 0.1 percent level of significance.

The quadratic model (Eq. 3) obtained for moisture retention in terms of coded levels of the variables is as follows:

$$\text{Oil content} = 9.73 + 0.062\times A - 0.47\times B - 0.81\times C - 0.062\times AB + 1.06\times AC + 0.98\times BC - 1.48\times A^2 - 1.06\times B^2 - 2.06\times C^2$$

Where, A, B and C are the coded values of the feed moisture content (percent), screw speed (rpm) and die temperature (°C) respectively.

The oil content of the extruded product was decreased with increase in screw speed. As the screw speed increases there is less shearing action, hence retention of oil increases. The feed moisture has significant effect on the oil content of the extrudates (Fig. 5). As the feed moisture increases the retention of the oil content in the extrudate is increased. Similar results were obtained by (Vasanthan *et al*., 2002). The oil content in the extrudates decreases as the temperature increases (Fig. 3.6). This is because the burning of oil take place during the extrusion process and high temperature burns the oil available in product.

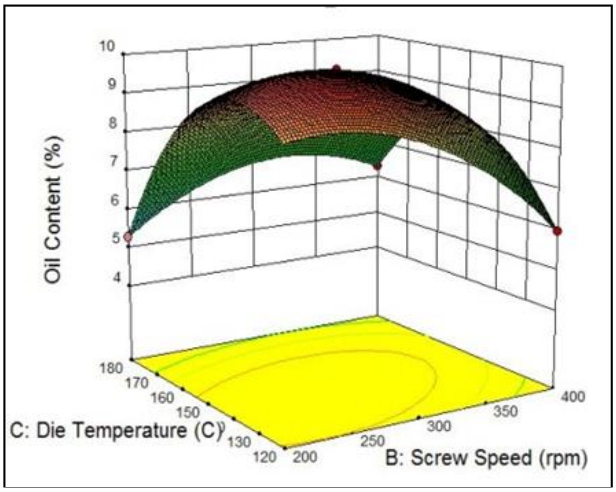

Fig 5: Response surface plot for oil content as a function of feed moisture content and die temperature at a center value of screw speed

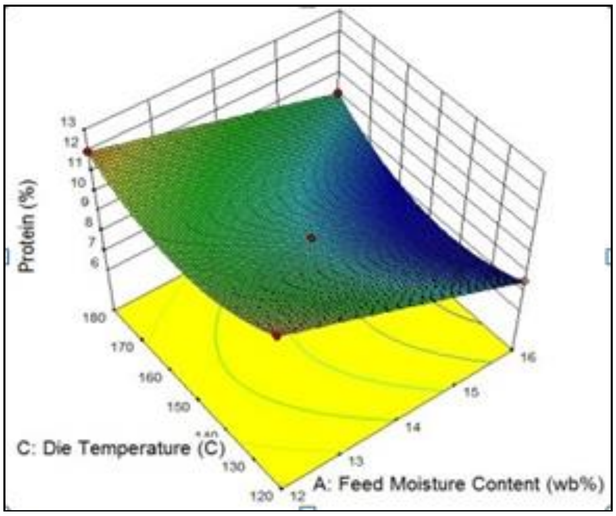

Fig 6: Response surface plot for oil content as a function of screw speed and die temperature at a center value of feed moisture content

3.4 Protein content

It was observed that the minimum protein content (7.56 percent) was observed for treatment $M_3R_2T_1$ *i.e.* 16 percent feed moisture, 300 screw rpm and 120 °C temperature whereas, maximum protein content (12.93 percent) was observed for $M_1R_1T_2$ *i.e.* 12 percent feed moisture, 200 screw rpm and 150 °C temperature given in Table 1. Regression model fitted to experimental results of protein content (Table 2) which shows that model F-value of 29891.36 was significant ($p<0.0001$), whereas lack-of-fit F-value of 0.071 was not significant. The adjusted R^2 value was 0.9999 and adequate precision 506.815, which is greater than 4 and hence this model may be used to navigate the design space. (Eq.) was selected for representing the variation of protein value and for further analysis.

$$\text{Protein content} = 8.71 + 1.88\times A + 0.10\times B - 0.33\times C + 0.94\times AB + 0.43\times AC - 0.80\times BC - 0.030\times A^2 + 1.53\times B^2 + 1.52\times C^2$$

Where, A, B and C are the coded values of the feed moisture content (percent), screw speed (rpm) and die temperature (°C) respectively.

The feed moisture has significant effect on the protein content of the extrudates. As the feed moisture content increased the retention of the protein content in the extrudate is increased, Gui *et al.*, (2012) [6] reported that the higher feed moisture content leading to lower degrees of protein denaturation and as the die temperature increased the protein content decreased (Fig. 7). The decrease in the protein content could be as a result of denaturation of the protein due to high thermal energy in which the feed was subjected to during extrusion cooking. The thermo-mechanical action during extrusion brings about gelatinization of starch, denaturation of protein and inactivation of enzymes, microbes and anti-nutritional factors (Bhattacharya and Prakash, 1994) [5]. The protein content of the product increases as there is increase in screw speed. As the screw speed increases there is less shearing action hence retention of protein increases (Fig. 8).

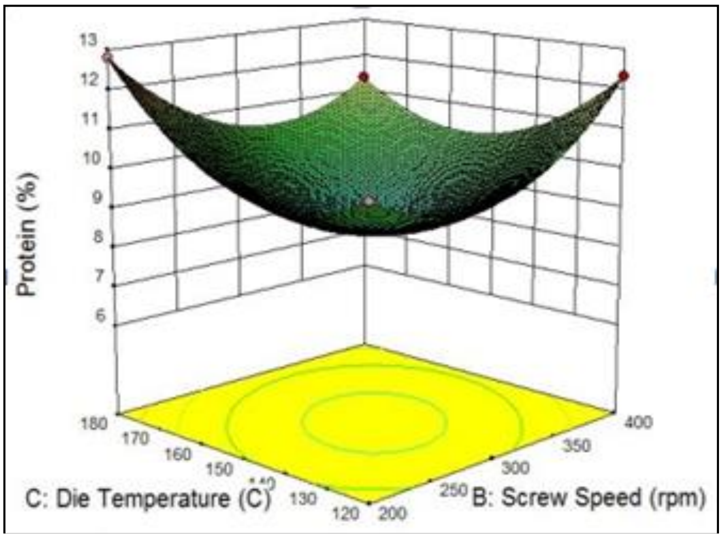

Fig 7: Response surface plot for protein content as a function of feed moisture content and die temperature at a center value of screw speed

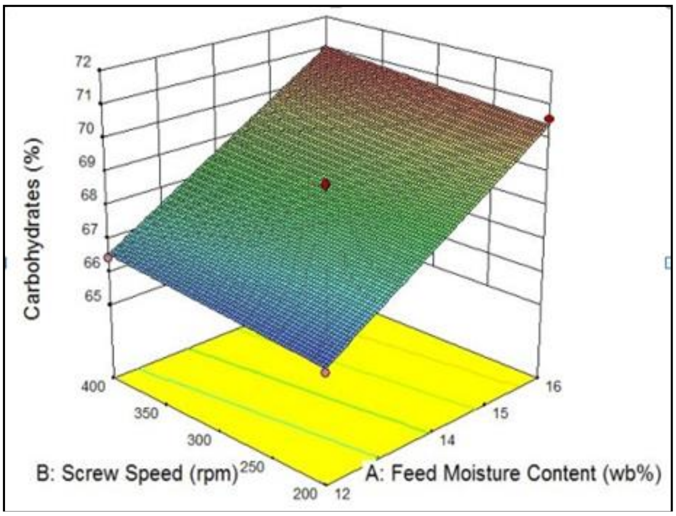

Fig 8: Response surface plot for protein content as a function of screw speed and die temperature at a center value of feed moisture content

3.5 Carbohydrates

Carbohydrates are the important characteristic while assessing the quality and nutritional status of the extruded product. The minimum carbohydrates content (65.71 percent) was observed for $M_1R_2T_1$ *i.e.*12 percent feed moisture, 300 screw rpm and 120 °C temperature whereas, maximum carbohydrates content (70.98%) was observed for treatment $M_3R_2T_3$ *i.e.*16 percent feed moisture, 300 screw rpm and 180 °C temperature given in Table 1. Regression model fitted to experimental results of carbohydrate content (Table 2) showed that model F-value of 137.57 was significant ($p<0.001$) indicates there is only 0.01 percent chances that the model F-value could occur large. The lack of fit F-value of 1.45 implies that it is not significant relative to the pure error. The fit of model was also expressed by the coefficient of determination R^2, which was 0.9695, indicating that 96.95 percent of the variability of the response could be explained by the model (Table 3). Linear terms of feed moisture, screw rpm and temperature have significant effect on carbohydrate content of extrudate at 0.1 percent level of significance ($p < 0.001$).

The linear model (Eq) for carbohydrate content in terms of coded levels of the variables was as follows:

$$\text{Carbohydrates} = 68.50 + 2.23\times A + 0.29\times B + 0.77\times C$$

Where, A, B and C are the coded values of the feed moisture content (percent), screw speed (rpm) and die temperature (°C) respectively.

The total carbohydrates content increases as the screw speed increases, the higher screw speed the residence time is less. The feed moisture also has significant effect on the total carbohydrate content (Fig 9). The total carbohydrate increases as there is increase in feed moisture and die temperature. (Omohimi *et al.*, 2013) [11] reported that the carbohydrates content increases with both barrel temperature and screw speed.

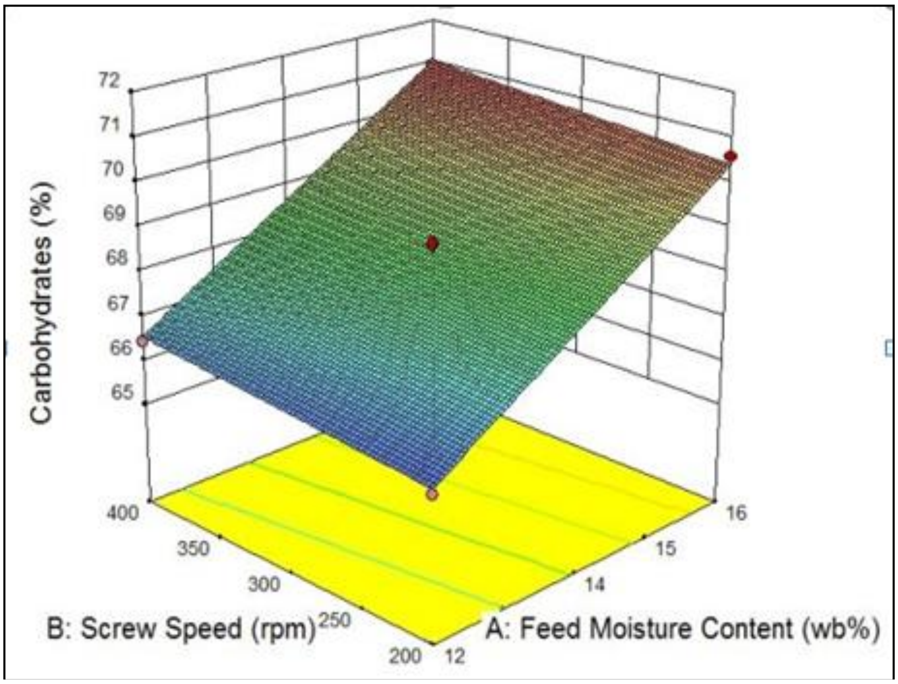

Fig 9: Response surface plot for carbohydrates content as a function of feed moisture content and screw speed at a center value of die temperature

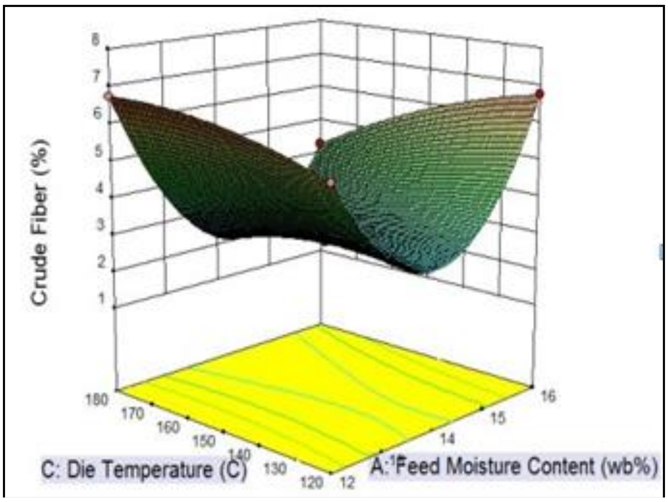

Fig 10: Response surface plot for crude fiber content as a function of feed moisture content and die temperature at a center value of screw speed

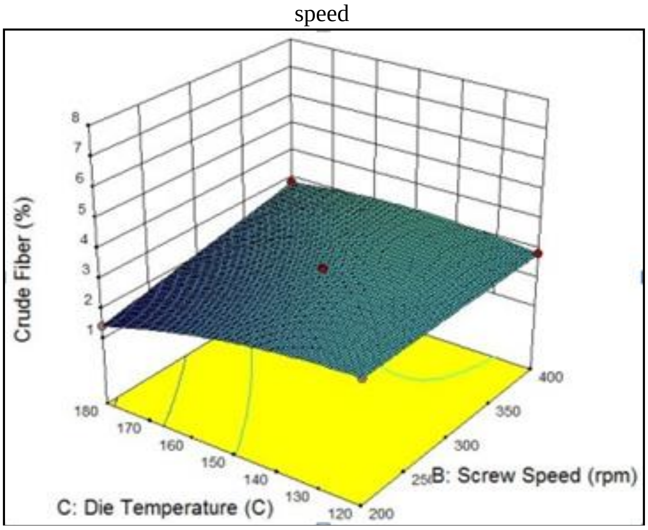

Fig 11: Response surface plot for crude fiber content as a function of screw speed and die temperature at a center value of feed moisture content

3.6 Crude fiber

The treatment $M_2R_1T_3$ *i.e.* 14 percent feed moisture, 200 screw rpm and 180 °C temperature shows minimum dietary fiber content (1.42 percent) whereas, the treatment $M_1R_1T_2$ *i.e.* 12 percent feed moisture, 200 screw rpm and 150 °C temperature shows maximum dietary fiber content (7.37%). The average value of dietary fiber content for all treatment was given in Table 1. Regression model fitted to experimental results of dietary fiber content (Table 2) showed that model F-value of 15814.41 was significant ($p < 0.001$). Lack of fit F value of 0.36 implies that it was not significant. There is 0.10 percent chance that a model F-value could occur large. The fit of model was also expressed by the coefficient of determination R^2, which was 1.00, indicating that 100 percent of the variability of the response could be explained by the model (Table 3). linear and interaction terms of feed moisture content, screw rpm and die temperature have significant effect on dietary fiber content of extrudate at 0.1 percent level of significance ($p < 0.001$). Further, the interaction terms of screw rpm, temperature and feed moisture having significant effect on dietary fiber content of the extrudate ($p < 0.001$). Quadratic terms of screw speed having not significant effect on diatery fiber ($p > 0.1$).

The quadratic model (Eq) for dietary fiber in terms of coded levels of the variables was as follows:

$$\text{Dietary fiber} = 2.82 - 0.36\times A + 0.35\times B - 0.36\times C + 1.17\times AB - 0.87\times AC + 0.36\times BC + 3.36\times A^2 - 0.015\times B^2 - 0.32\times C^2$$

Where, A, B and C are the coded values of the feed moisture content (percent), screw speed (rpm) and die temperature (°C) respectively.

The feed moisture has significant effect on the dietary fiber content of the extrudates (Fig. 10). As the feed moisture increased the retention of the dietary fiber content in the extrudate is slightly decreased. Dietary fiber content also decreased when temperatures increased die. Similar result was also found by Rabe, (1999). The dietary fiber content of the product increased as there was increase in screw speed. As the screw speed increases there is less shearing action, hence retention of dietary fiber increases (Fig. 11).

Table 1: Nutritional properties of extruded product

Std	Run	Treatments	Moisture Contet (%)	Ash Content (%)	Oil Content (%)	Protein (%)	Carbo-hydrates (%)	Crude Fiber (%)
1	1	$M_1R_1T_2$	5.63	4.86	7.54	12.93	65.86	7.37
6	2	$M_3R_2T_1$	7.60	4.39	6.00	7.56	70.35	6.74
4	3	$M_3R_3T_2$	6.13	3.94	6.71	9.37	70.91	7.32
3	4	$M_1R_3T_2$	6.05	6.48	6.71	11.24	66.45	5.71
14	5	$M_2R_2T_2$	6.48	5.38	9.72	8.69	68.40	2.84
8	6	$M_3R_2T_3$	6.18	4.72	6.50	9.07	70.98	4.28
12	7	$M_2R_3T_3$	5.79	5.55	6.33	11.38	69.85	2.85
2	8	$M_3R_1T_2$	7.46	5.27	7.79	7.29	70.61	4.28
10	9	$M_2R_3T_1$	6.61	4.49	5.98	12.33	68.10	2.85
16	10	$M_2R_2T_2$	6.55	5.40	9.75	8.70	68.68	2.81
11	11	$M_2R_1T_3$	6.82	4.34	5.28	12.78	69.49	1.42
9	12	$M_2R_1T_1$	6.49	5.38	8.87	10.52	67.02	2.85
17	13	$M_2R_2T_2$	6.50	5.41	9.69	8.74	68.45	2.79
15	14	$M_2R_2T_2$	6.52	5.69	9.72	8.71	67.96	2.83
5	15	$M_1R_2T_1$	5.48	5.52	8.00	12.17	65.71	5.71
13	16	$M_2R_2T_2$	6.51	5.39	9.75	8.71	68.65	2.85
7	17	$M_1R_2T_3$	6.40	5.35	4.25	11.98	67.00	6.74

Table 2: Analysis of variance for nutritional properties of extruded product

	Sum of Squares			F- value			
	A	B	C	A	B	C	Model
Product Moisture	1.81	0.41	0.12	1409.1***	4695.6***	1071.4***	1409.11***
Ash content	1.89	0.04	0.004	14704***	3.63*	0.32(ns)	52.13***
Oil content	0.03	1.76	5.27	69.55***	3912.4***	1171.6***	12510.1***
Protein	28.2	0.08	0.86	1.3×10^5***	379.66***	4103.2***	29891.36***
Carbohydrates	39.7	0.68	4.71	363.40	6.21	43.09	137.57
Crude Fiber	1.06	0.99	1.02	2515.99	2346.04	2430.27	15814.41

*Significant at $P < 0.1$, **Significant at $P < 0.05$, ***Significant at $P < 0.001$, df: degrees of freedom ns: not significant

Table 3: ANOVA results of equation for nutritional properties of extruded product

	R^2	Adequate Precision	Lack of fit		
			Df	F	Prob>F
Product Moisture	0.9994	140.779	3	0.012	0.9978 (ns)
Ash content	0.9853	28.175	3	0.37	0.7773 (ns)
Oil content	1.0000	506.815	3	0.33	0.8049 (ns)
Protein	1.0000	506.815	3	0.071	0.9722 (ns)
Carbohydrates	0.9665	37.359	9	1.45	0.3821 (ns)
Crude Fiber	1.0000	377.031	3	0.36	0.7867 (ns)

4. Conclusions

The experiment was conducted to determine the optimized process condition for the preparation of extruded product. The twin screw extruder operational parameters like screw speed and die temperature were varied to optimize the operating conditions for extruded products. Based on quality characteristics and sensory scores, the best formulation for each of the extruded product was selected. The optimum condition or the best treatment was found to be $M_1R_1T_2$ *i.e.* 12 percent feed moisture, 200 screw rpm and 150 °C temperature. Proximate composition of the developed quality protein maize based nutri rich product at optimized operating condition was observed as 5.63 percent of moisture, 4.86 percent of ash, 7.54 percent of fat, 12.93 percent of protein, 65.86 percent of carbohydrates and 7.37 percent of dietary fiber.

5. References

1. Agostoni C, Riva R, Giovannini M. Dietary Fiber in Weaning Foods of Young Children. Pediatrics. 1995; 96:1000-1005.
2. Antony U, Sripriya G, Chandra TS. Effect of fermentation on the primary nutrients in finger millet (*Eleusine coracana*). Journal of Agriculture and Food Chemistry. 1996; 44:2616-2618.
3. AOAC. Official Methods of Analysis. Association of Official Analytical Chemists, 19th Edition. VA, United States, 2012.
4. Bhattacharya S. Twin-screw extrusion of rice-green gram blend: extrusion and extrudate characteristics. Journal of Food Engineering. 1997; 32:83-99.
5. Bhattacharya S, Prakash M. Extrusion of blends of rice and chick pea flours: A response surface analysis. Journal of Food Engineering. 1994; 21:315-330.
6. Gui Y, Gil SK, Ryu GH. Effects of Extrusion Conditions on the Physicochemical Properties of Extruded Red Ginseng. Preventive Nutrition and Food Science. 2012; 17:203-209.
7. Lo TE, Moreira RG, Castell-Perez ME. Effects of operating conditions on melt rheological characteristics during twin-screw food extrusion. ASAE. 1998; 41:1721-1738.
8. Lowry DN, Ronegrough WJ. Journal of biochemistry. 1951; 193:265-275.
9. Maynard AJ. Methods in Food Analysis. Academic Press, New York, 1970, 176.

10. Montgomery DC. Design and Analysis of Experiments, Wiley, New York, 2001, 416-419.
11. Omohimi CI, Sobukola OP, Sanni LO. Effect of process parameters on the proximate composition, functional and sensory properties. World Academy of Science, Engineering and Technology. 2013; 76:124-129.
12. Paes MCD, Bicudo MH. Nutritional perspectives of quality protein maize. In: International Symposium on Quality Protein Maize, Sete Lagoas. Quality protein maize: 1964-1994 - proceedings. Purdue University, 1994, 65-78.
13. Rabe, E. Effect of processing on dietary fiber in foods. In: Cho, S., Prosky, L. and Deher, M.L. (Eds.), Complex carbohydrates in foods, Marcel Dekker, New York, USA, 1999, 395-409.
14. Ragaee S, Abdel-Aal EM, Noaman M. Antioxidant activity and nutrient composition of selected cereals for food use. Food Chemistry. 2006; 98:32-38.
15. Riaz MN. Extruders and Expanders in Pet Food, Aquatic and Livestock Feeds. Agrimedia GmbH, Germany, 2007.
16. Sadasivam S, Manickam A. Biochemical methods. 2nd Edition, New age International Private Ltd. Publishers, Coimbatore, India, 1996.
17. Saldanha LG. Fibre in the diet of U. S. Children: results of national surveys. Pediatrics. 1995; 96:994-996.
18. Shah A. The Effect of Extrusion Conditions on Aggregation of Peanut Proteins. M. Sc. thesis submitted to The University of Georgia, Athens, Georgia, 2003.
19. Vasanthan T, Gaosong J, Yeung J, Li J. Dietary fiber profile of barley flour as affected by extrusion cooking. Food Chemistry. 2002; 77:35-40.