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NUTRITIVE EXTRUDED PRODUCT: A BETTER OPTION FOR FASTING

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ABSTRACT

Present research work is carryout with a novel concept of preparing a nutritious extruded products for fasting. Experiment was carried out to optimize the proportions of defatted peanut flour, amaranth flour, barnyard flour and tapioca flours in the preparation of extruded products. The optimized flour proportion was 18.33% defatted peanut, 22.96% amaranth, 10% barnyard and 48.71% tapioca based on sensory parameters. Then after, experiments to optimize the process parameters, viz. feed moisture content, screw speed and die head temperature by taking the flour proportion as optimized in the experiment for optimizing the flour proportion. The effect of feed moisture content (12, 13, 15, 17, 18%), die head temperature (90, 102, 120, 138 & 150^{0}C) and screw speed (200, 220, 250, 280, 300 rpm) on different machine and physicochemical characteristic of extruded product viz. torque, mass flow rate, bulk density, expansion ratio, moisture content, water solubility index, water absorption index, hardness, crispness, calorific value, carbohydrate, protein, fat, ash and overall acceptability was studied. Response Surface Methodology (RSM) was used in designing the experiment and optimization of processing parameters. Finally, the extruded products for optimized flour proportion were prepared by keeping the feed moisture content (16%), feeder temperature (60°C), barrel temperature (100°C), die temperature (135°C) and screw speed (250 rpm) at constant level.

Key words : Extrusion cooking, Snack food, High protein.

Introduction

Extrusion cooking

Fasting is an integral part of the Indian culture and tradition and thought to be important as it nourishes both the physical and spiritual needs of the person. During fasting people would like to eat traditional product prepared from rice, sago, sweet potato, potato and fruits. Indian people are preferred khichadi, sabudana (sago) vada, sweet potato kheer, potato vada and fruit juices made traditionally at home. Amaranth, barnyard millet, tapioca pearls and peanuts are very popular food materials which are utilized in the preparation of various fast foods on the occasion of various Hindu festivals.

Peanut or groundnut (*Arachis hypogaea*), is a species in the legume or "bean" family. Groundnuts are important protein crops in India grown mostly under rain-fed conditions. They have a rich nutty flavour, sweet taste, crunchy texture and over and above a relatively longer shelf life (APEDA, 2021).Amaranth is classified as a pseudo cereal, is grown for its edible starchy seeds like cereals, but it does not belong to the family of cereals such as wheat and rice. It has one of the highest levels of protein that is also easier for the human body to absorb. It also contains an amino acid called Lysine which is missing from other cereals, making it a complete protein source. Barnyard millet (*Echinochloa* species) is an ancient millet crop grown in warm and temperate regions of the world. It is the fastest growing millet and was originated in eastern India. As every kind of millet, barnyard millet is also an appropriate food for patient's intolerant to gluten which causes celiac disease (Sudha Devi and Palanimuthu, 2020). Tapioca has tuberous roots that grow upwards from the base of the stem. These tubers make up the edible part of the tapioca plant from which tapioca starch is extracted known as cassava (Anonymous, 2021h). In India, tapioca pearls are referred to as “Sabudana” in Hindi, “Sabu” in Bengali, “Javvarisi” in Tamil, “Saggubiyyam” in Telugu and “Chavvari” in Malayalam.

Extruded snacks with multiple cereals and tubers are very famous food products consumed by peoples of all ages. No any extruded products are available in the market which can be used for the fasting purpose. Peanut, amaranth, barnyard and tapioca pearls are easily available and economical raw material source for production of extruded product. Further, all these food items contain a very important nutritional components required by our body. In view of this, the present investigation is undertaken to develop extruded snacks for fasting purpose by utilizing peanut, amaranth, barnyard and tapioca pearls as a raw material.

Materials and Methods

The defatted peanut flour and Amaranth flour available in the form of fine powder was procured from the local market of Junagadh city. The barnyard millet and tapioca pearls were obtained from market and milled into grinding machine for making the flour. The developed flour was sieved and packed in polyethylene bag for refrigerated storage. The laboratory co-rotating twin-screw extruder available in the department of processing and food engineering, Junagadh Agriculture University, Junagadh (Gujarat) was used for extrusion process in experiment.

Optimization of different flour proportion

Experiment trials conducted to optimize the proportions of different flours, *viz.* defatted peanut flour, amaranth flour, barnyard flour and tapioca flours, in the preparation of extruded products. The different proportions of these flours were to be mixed with each other as suggested by the mixture design of response surface methodology (RSM) as given in Table 1. The flours were then mixed thoroughly to prepare uniform sample for extrusion cooking. The water was added to the prepared flour sample to attain the desired moisture content. The extruded products were prepared by keeping the feed moisture content (16%), feeder temperature (60°C), barrel temperature (100°C), die temperature (135°C) and screw speed (250 rpm) at constant level. The extruded products as prepared by the different flour combinations were evaluated for their sensory parameters (Appearance, Taste, Colour, Overall Acceptability) using 9-point hedonic scale method as shown in Appendix-A. Then the optimization of the flour proportion is carried out using RSM based on the sensory score of the different extruded products. The final and optimized formulation of composite flour was selected for the further experiment to optimize the processing parameters.

Table 1 : Treatment details for optimization of flour proportion.

Treatment	Defatted peanut flour (%)	Amaranth flour (%)	Barnyard flour (%)	Tapioca pearls flour (%)	Total
1	13.53	49.33	14.90	22.24	100.00
2	10.00	39.43	10.00	40.57	100.00
3	29.05	10.00	37.19	23.76	100.00
4	24.56	24.79	25.85	24.81	100.00
5	50.00	10.00	30.00	10.00	100.00
6	10.00	10.00	30.00	50.00	100.00
7	30.00	50.00	10.00	10.00	100.00
8	24.56	24.79	25.85	24.81	100.00
9	39.00	10.00	10.00	41.00	100.00
10	25.37	14.63	50.00	10.00	100.00
11	39.00	10.00	10.00	41.00	100.00
12	25.37	14.63	50.00	10.00	100.00
13	24.56	24.79	25.85	24.81	100.00
14	10.00	10.00	50.00	30.00	100.00
15	35.54	22.65	31.82	10.00	100.00
16	50.00	30.00	10.00	10.00	100.00
17	10.00	28.50	43.34	18.17	100.00
18	24.56	24.79	25.85	24.81	100.00
19	19.45	20.55	10.00	50.00	100.00
20	10.00	47.03	32.97	10.00	100.00

Extruded product preparation

Optimized amount of amaranth, barnyard, defatted peanut and tapioca flour were mixed well. Then required amount of water was added to reach desired moisture content of composite flour in to the mixture and mixed again. After mixing it thoroughly, the mixture was sieved to get uniform sample. The lab model co-rotating twin-screw extruder was used for extrusion. The die temperature, screw speed and feed moisture content were set as per the requirement on the control panel. First, the twin-screw extruder was kept for duration of 30-40 minutes to reach the desired temperatures. The die diameter was selected at 3 mm as recommended by the manufacturer for such type product. Total 400 g composite flour was prepared for one treatment. It was fed in to feed hopper at the 14-rpm feeder speed 230 rpm cutter speed. The extruded product was coming out in approx. 20 sec after the feeding the flour. The extruded product was dried using laboratory tray drier at 60°C temperature for 15 minutes for the stabilization of moisture or to remove extra moisture from the product. Then product was packed in zip pouches and kept in a proper storage until all the experiment is completed.

Determination of product properties

Bulk density

The bulk density of dried extrudates was calculated by determining the volume of extrudates by filling a container of known volume and noting the sample mass (Anderson *et al.*, 1969).

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Weight of extrudates}}{\text{Volume of cylinder}}$$

Expansion Ratio

The ratio of diameter of extrudate and the diameter of die (3 mm) was used to express the expansion of extrudate (Fan *et al.*, 1996). The diameter of extrudate was determined as the mean of 10 random measurements made with a vernier caliper. The extrudate expansion ratio was calculated by following formula.

$$\text{Expansion ratio} = \frac{\text{Extrudate diameter}}{\text{Die diameter}}$$

Protein content

Protein content of raw flour as well as extruded product was determined by Microkjeldahl method (AOAC, 2005).

Water solubility index

The extruded puffs were milled to mean particle size of 200-250 µm. A 2.5 gram of ground water was suspended in 25 ml distilled water using glass road to break up lumps and then centrifuged by centrifuge at 3000 rpm for 15 min. The supernatant was decanted for determination of its solid content and sediment was weighed. WSI was calculated as

Water solubility Index (%)

$$= \frac{\text{Mass of dissolved solids in supernatant}}{\text{Mass of dry solids}} \times 100$$

Water Absorption Index

Water absorption Index was determined by the methodology described by the Anderson (1969). WAI is the mass of gel obtained after removal of the supernatant per unit mass of original dry solids. WSI and WAI were calculated using following formulas.

$$\text{Water Absorption Index (g/g)} = \frac{\text{Mass of sediment (g)}}{\text{Mass of dry solid (g)}}$$

Hardness of extruded product

This is the textural property of extruded product was measured using stable micro system TA-XT2 textrual analyser. Hardness value was considered as mean compression force and expressed in grams. It was determined by cylinder probe having test speed 2 mm/s, post-test speed 10 mm/s and distance 48 mm and load cell of 50 kg.

Sensory valuation of extrudates

The 9-point hedonic scale sensory method as given by Ranganna (1986) was used to examine developed extrudates. The parameters included appearance, taste, chewiness, hardness and overall acceptability (OA) and were tested with 9-point hedonic scale ranging from dislike extremely to like extremely.

Experimental design for the optimization of processing parameters

Response Surface Methodology (RSM) is used for designing the experiments (Khuri and Cornell, 1987). The effect of three independent variables, X_1(Moisture Content), X_2(Screw speed) and X_3(Die head temperature), on different response variables were evaluated by using the RSM. Central Composite Rotatable Design (CCRD) of 3 variables each at five levels with 6 centre point combinations were employed (1) to study the main effect of parameters, (2) to create models between the variables and (3) to determine the effect of these variables to optimize the selected response variables. The statistical analysis of the experimental data was carried out to observe the significance of the effect of selected process parameters on the various responses. Design Expert software 'DE-10' was used for regression and graphical analysis of the data (Anderson and Whitcomb, 2005). The optimum values of the selected process parameters were obtained by solving the regression equation and by analysing the response surface contour plots (Khuri and Cornell, 1987).

Results and Discussion

Optimization of different flour proportion

Experiment trials were conducted to optimize the proportions of different flours, *viz*. defatted peanut flour, amaranth flour, barnyard flour and tapioca flours, in the preparation of extruded products as shown in Table 2. The photographs of the extruded product as prepared by different treatments are presented in the Plate 1. The optimization of flour proportion was carried out using Response Surface Methodology on Design Expert software by giving the target as Defatted peanut flour : Maximize, Amaranth flour : In the range, Barnyard flour : In the range and Tapioca flour : In the range. The optimized flour proportion was 18.33% defatted peanut, 22.96% amaranth, 10% barnyard and 48.71% tapioca based on sensory parameters.

Optimization of processing conditions for development of extruded product suitable for fasting

Experiment trials were carried out to optimize the process parameters, *viz.* feed moisture content, screw speed and die head temperature by taking the flour proportion as optimized in the experiment as per section no. 3.1 (18.33% peanut, 22.96% amaranth, 10% barnyard and 48.71% tapioca). The photographs of the extruded product as prepared by different treatments are presented in the Plate 2. The optimization of process parameters was carried out using

Table 2 : Treatment details for the optimization of flour proportion for the proportion of extruded product.

Run	X_1	X_2	X_3	X_4	Feed M.C.	Defatted peanut (%)	Amaranth (%)	Branyard (%)	Tapioca (%)	Appearance	Taste	Colour	Overall acceptability
1	-1	-1	-1	1	16	13.53	49.33	14.90	22.24	6.54	6.58	6.25	6.75
2	0	0	-2	0	16	10.00	39.43	10.00	40.57	7.42	6.54	7.04	7.04
3	0	0	0	-2	16	29.05	10.00	37.19	23.76	5.25	5.33	5.75	5.42
4	-1	1	-1	1	16	24.56	24.79	25.85	24.81	6.08	5.92	6.04	6.25
5	0	0	0	0	16	50.00	10.00	30.00	10.00	4.33	5.33	4.88	4.75
6	-1	-1	-1	-1	16	10.00	10.00	30.00	50.00	7.38	6.58	7.29	7.08
7	0	0	0	2	16	30.00	50.00	10.00	10.00	3.75	4.46	4.13	4.13
8	1	1	-1	1	16	24.56	24.79	25.85	24.81	6.71	6.50	6.54	6.29
9	0	0	0	0	16	39.00	10.00	10.00	41.00	5.08	5.38	4.92	5.04
10	0	-2	0	0	16	25.37	14.63	50.00	10.00	6.83	6.92	6.79	7.17
11	0	0	0	0	16	39.00	10.00	10.00	41.00	4.83	5.21	5.08	4.96
12	0	2	0	0	16	25.37	14.63	50.00	10.00	6.96	7.00	6.96	7.04
13	-2	0	0	0	16	24.56	24.79	25.85	24.81	6.50	6.67	6.58	6.75
14	1	-1	-1	-1	16	10.00	10.00	50.00	30.00	7.83	7.08	7.75	7.58
15	0	0	0	0	16	35.54	22.65	31.82	10.00	4.33	4.79	4.25	4.33
16	0	0	0	0	16	50.00	30.00	10.00	10.00	3.83	3.96	3.67	3.79
17	-1	1	-1	-1	16	10.00	28.50	43.34	18.17	7.13	6.67	7.17	6.83
18	2	0	0	0	16	24.56	24.79	25.85	24.81	6.50	6.21	6.33	6.50
19	1	-1	-1	1	16	19.45	20.55	10.00	50.00	8.33	7.58	8.25	8.33
20	1	1	-1	-1	16	10.00	47.03	32.97	10.00	6.71	6.79	6.50	6.63

Plate 1 : Extruded product prepared from composite flour.

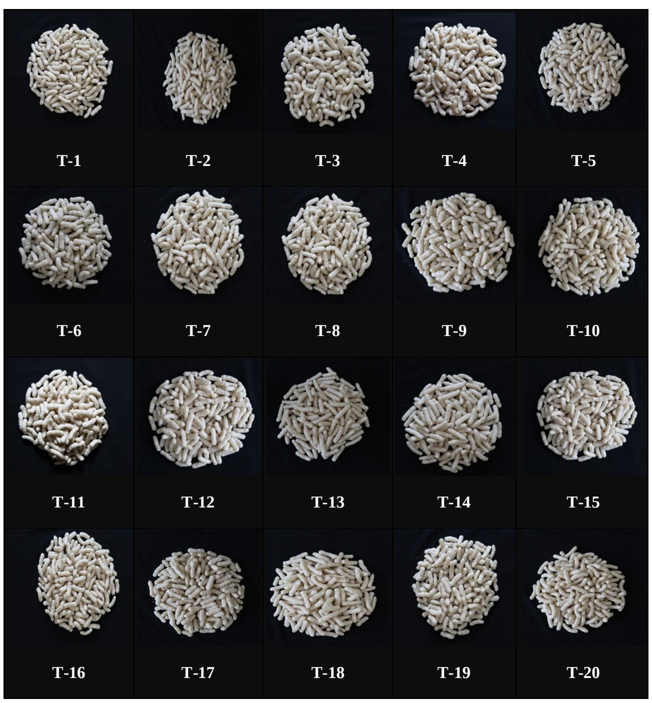

Plate 2 : Prepared extruded product at different process parameter.

Response Surface Methodology on Design Expert software by giving the target as Feed moisture content : In the range, Screw speed : In the range, Die head temperature : In the range, Expansion ratio : Maximize, Protein : Maximize, WSI : Maximize, Hardness : Minimize. The rest of the dependent parameters were not considered in the optimization and therefore the target to those parameters were given as none.

Extrudate characteristics

Bulk density

The bulk density of extruded product was ranged from 0.0492 g/cm^3 to 0.569 g/cm^3 (Table 3). It was observed from the contour map, that the bulk density was decreased with an increase in feed moisture content up to i.e. 15.15% and screw speed up to 271.57 rpm (Fig. 1a). Shruthi *et al.* (2017) reported the increasing in level of die temperature resulted in decreased in bulk density of extruded product. The calculated F-value for bulk density (17.30) was significant at $p<0.001$. At the same time, it possessed non-significant lack of fit ($p>0.05$). These values indicated that the model for bulk density was fitted and reliable. The R^2 value and Adj-R^2 value for thebulk density were 0.9396 and 0.8853, respectively.

Expansion Ratio

The expansion ratio of extruded product was ranged from 3.76 to 4.35 (Table 3). It was observed from the contour map, that the expansion ratio was increase with an increase in feed moisture content up to *i.e.*, 14.77% and screw speed up to 256.61 rpm (Fig. 1a). Gat and Ananthanarayan (2015) observed that expansion of extrudates decreased with increased in feed moisture content and increased in die temperature led to slight decreased expansion value. The calculated F-value for expansion ratio (22.81) was significant at $p<0.001$. At the same time, it possessed non-significant lack of fit ($p>0.05$). These values indicated that the model for expansion ratio was fitted and reliable. The R^2 value and Adj-R^2 value for the expansion ratio were 0.9535 and 0.9117, indicating the adequacy, good fit and high significance of the model.

Protein content

The protein content of extruded product was ranged from 15.2 % to 17.32% in Table 3. The maximum protein (17.35%) of extruded product was predicted to be obtained for the combination of highest feed moisture content (18%) and highest screw speed (300 rpm) in Fig. 1b. The protein content was increased with an increase in feed moisture content up to maximum level. The protein content was increased with a decrease in die temperature. Gojiya *et al.* (2022) observed protein content of extrudates decreases as the DHT and feed moisture content increases. This may be due to denaturation of protein at higher DHT and it may also destroy the nature of some protein molecules, thereby, ultimately reducing the PC of extrudates. The R^2 value and Adj-R^2 value for the protein were 0.8996 and 0.8093, respectively, which were higher than the 0.8, indicating the adequacy, good fit and high significance of the model.

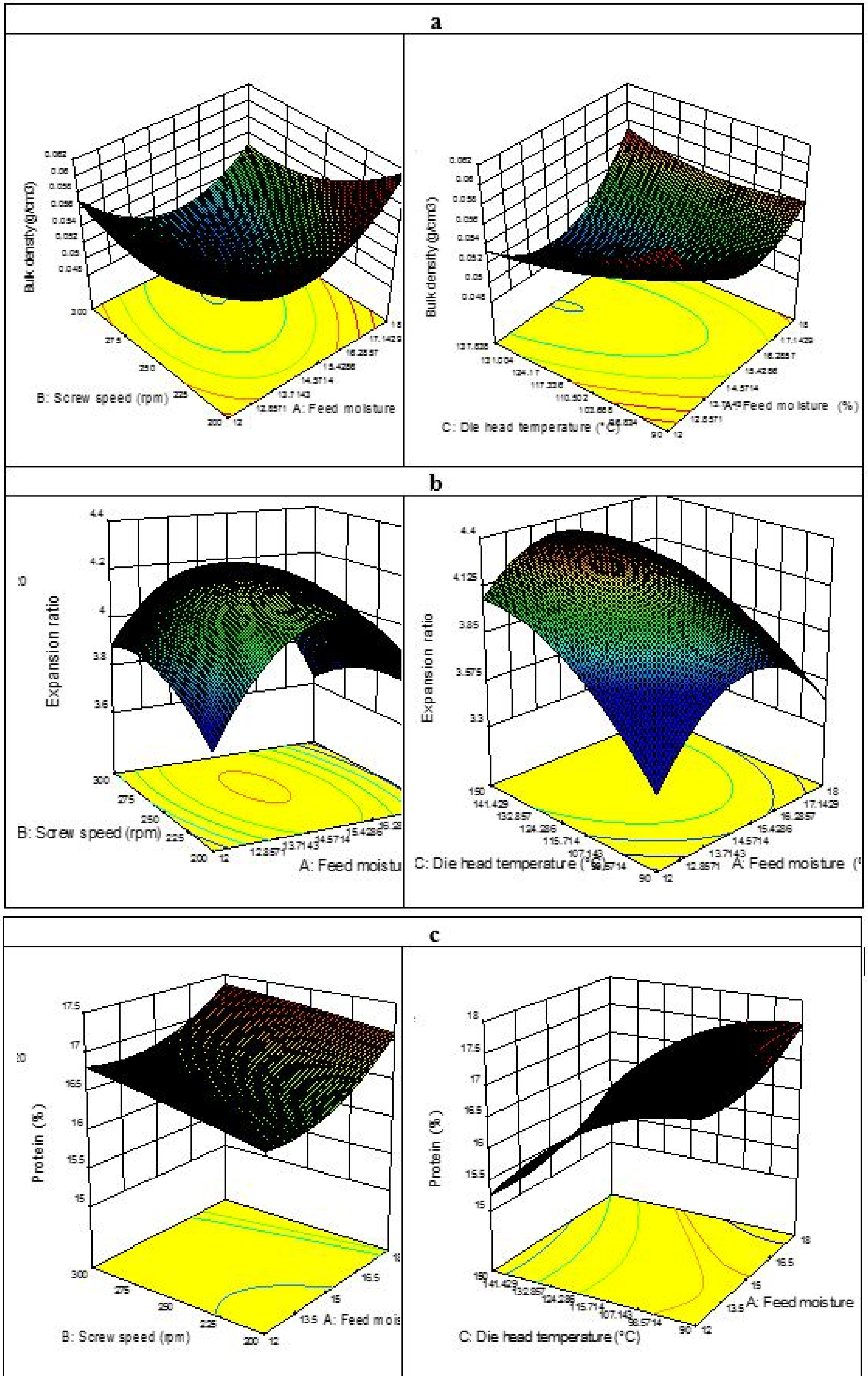

Fig. 1 continued...

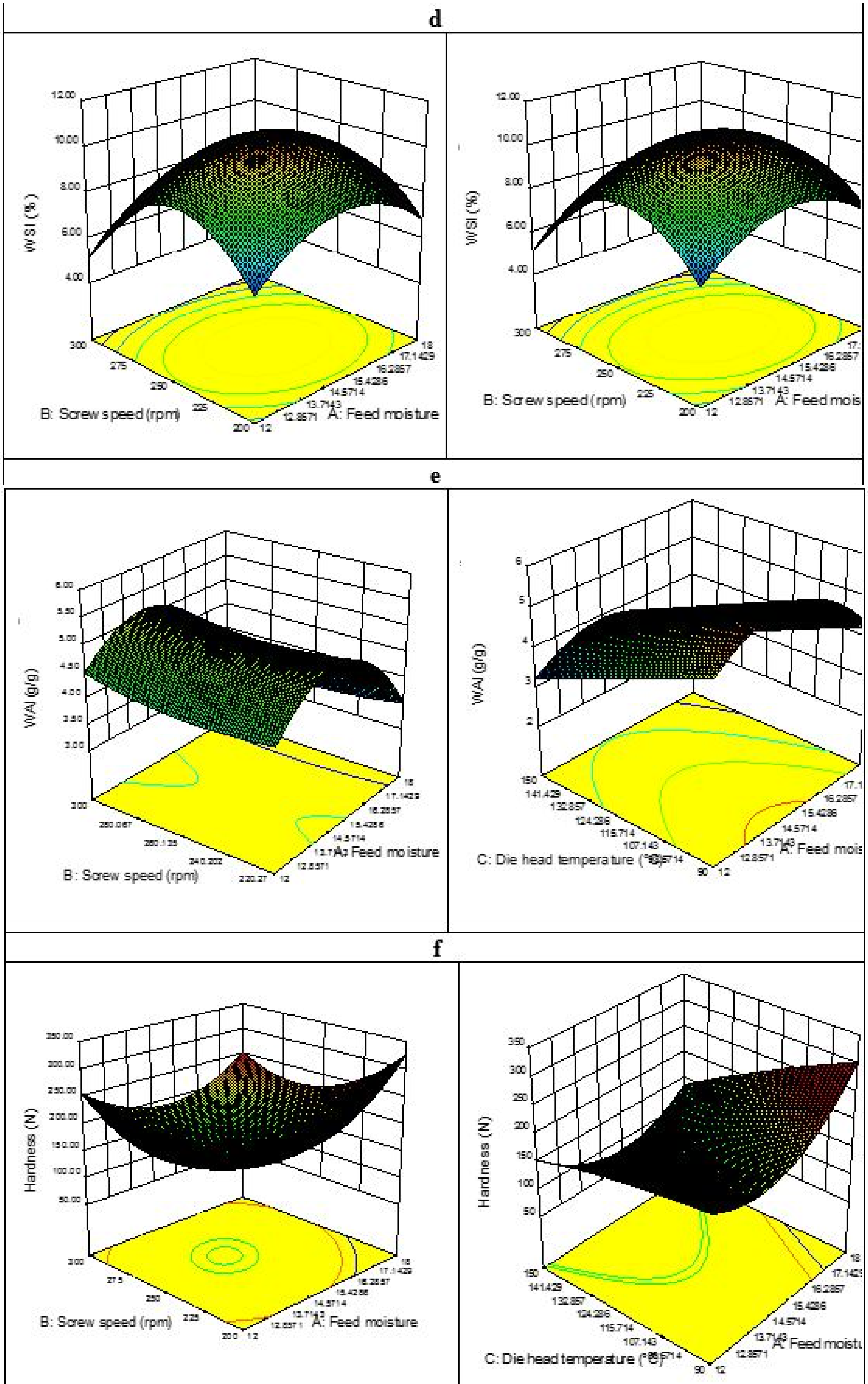

Fig. 1 continued...

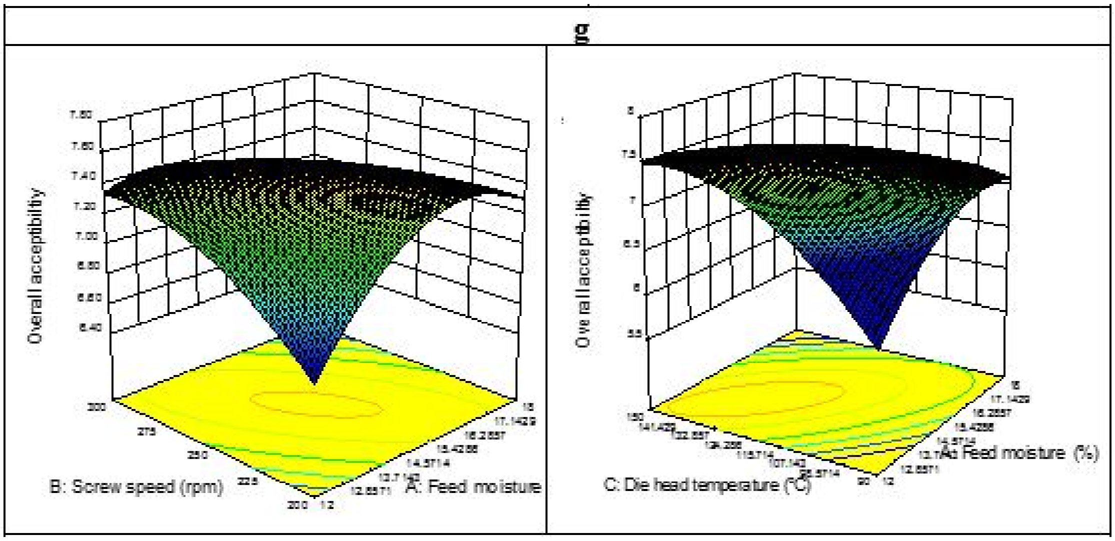

Fig. 1 : Response surface plots of interaction effects for (a) Bulk density, (b) Expansion ratio, (c) Protein, (d) WSI, (e) WAI, (f) Hardness (g) Overall acceptability.

Table 3 : Physicochemical and machine characteristics of extruded product prepared using composite flour.

Std	Run	FM (%)	Screw speed (rpm)	Die temp. (°C)	BD (g/cm³)	ER	Protein (%)	WSI (%)	WAI (g/g)	Hardness (N)	Overall acceptability
1	3	13.22	220.27	102.16	0.0568	3.86	16.88	8.63	5.07	189.56	6.7
2	20	16.78	220.27	102.16	0.0569	3.91	17.21	9.16	4.73	246.32	7.5
3	12	13.22	279.73	102.16	0.0544	3.85	16.99	7.25	5.55	184.21	7.1
4	2	16.78	279.73	102.16	0.0501	3.85	17.2	7.50	5.28	221.23	7.1
5	13	13.22	220.27	137.84	0.0521	4.15	15.86	9.21	4.52	152.32	7.5
6	15	16.78	220.27	137.84	0.0539	4.11	16.22	8.89	4.34	179.56	7.2
7	14	13.22	279.73	137.84	0.0521	4.22	16.16	9.22	3.76	161.02	7.5
8	18	16.78	279.73	137.84	0.0541	4.03	16.5	8.68	3.33	152.32	6.9
9	7	12.00	250.00	120.00	0.0549	3.91	16.49	8.61	4.51	201.32	7.2
10	8	18.00	250.00	120.00	0.0562	3.76	17.32	8.50	3.16	222.21	7
11	17	15.00	200.00	120.00	0.0553	4.08	16.41	8.70	5.18	236.52	7.3
12	6	15.00	300.00	120.00	0.0506	4.22	16.85	6.20	5.27	185.65	7.3
13	4	15.00	250.00	90.00	0.0543	3.78	17.22	7.52	5.90	216.32	6.9
14	10	15.00	250.00	150.00	0.0505	4.35	15.2	10.40	3.99	65.32	7.2
15	9	15.00	250.00	120.00	0.0510	4.27	16.45	10.32	4.80	136.45	7.5
16	5	15.00	250.00	120.00	0.0492	4.26	16.53	10.80	5.20	156.38	7.3
17	1	15.00	250.00	120.00	0.0513	4.16	16.87	9.60	4.41	142.38	7.6
18	11	15.00	250.00	120.00	0.0499	4.24	16.53	11.20	4.72	130.45	7.5
19	16	15.00	250.00	120.00	0.0508	4.19	16.52	11.19	5.05	157.14	7.7
20	19	15.00	250.00	120.00	0.0499	4.31	17.17	10.67	5.25	145.93	7.6

Water solubility Index

The water solubility index of extruded product was ranged from 6.20% to 11.20% as shown in Table 3. With this combination of feed moisture content and die temperature, the water solubility index was expected to be increased up to 10.81% (Fig. 1c). With further increase in feed moisture content and die temperature, the water solubility index was decreased. Gat and Ananthanarayan (2015) observed that water solubility index of extruded productdecreased with increase in feed moisture content. It may be observed to reduction in lateral expansion due to plasticization of melt. The calculated F-value for water solubility index (10.62) was significant at $p<0.001$. The R^2 value and Adj-R^2 value for the WSI were 0.9079 and

Table 4 : Analysis of variance table and regression coefficients for response surface quadratic model of different physical and functional characteristics of extruded product.

Source	BD	ER	Protein	WSI	WAI	Hard ness	OA
Intercept	**0.05**	**4.24**	**16.68**	**10.62**	**4.91**	**144.94**	**7.53**
Linear terms							
A(X_1)	**0.0001**	**-0.032**	**0.19***	**-0.02**	**-0.26****	**10.8**	**-0.032**
B(X_2)	**-0.0012*****	**0.011**	**0.1**	**-0.55****	**-0.043**	**-9.58**	**-0.022**
C(X_3)	**-0.0009****	**0.15*****	**-0.51*****	**0.61****	**-0.58*****	**-32.95*****	**0.088***
Inteaction							
AB(X_1X_2)	**-0.0005**	**-0.025**	**-0.017**	**-0.06**	**-0.02**	**-6.96**	**-0.14****
AC(X_1X_2)	**0.001****	**-0.035**	**0.02**	**-0.20**	**0.00**	**-9.4**	**-0.21*****
BC(X_2X_3)	**0.0017****	**0.0075****	**0.06**	**0.36**	**-0.35****	**1.49**	**-0.037**
Quadratic terms							
A^2(X_1^2)	**0.0011*****	**-0.14*****	**0.091**	**-0.65****	**-0.4*****	**22.69****	**-0.14****
B^2(X_2^2)	**0.00091****	**-0.032**	**-0.0061**	**-1.04*****	**0.096**	**22.45****	**-0.07**
C^2(X_3^2)	**0.00071****	**-0.062****	**-0.15***	**-0.51****	**-0.0030**	**-2.39**	**-0.16*****
Indicators for model fitting							
R^2	**0.9394**	**0.9535**	**0.8996**	**0.9074**	**0.9179**	**0.9287**	**0.8944**
Adj-R_2	**0.8848**	**0.9117**	**0.8093**	**0.8250**	**0.8439**	**0.8646**	**0.8004**
Pre-R_2	**0.674**	**0.7789**	**0.7059**	**0.6178**	**0.6992**	**0.5562**	**0.5745**
Adeq precision	**11.84**	**13.220**	**11.885**	**9.5380**	**12.53**	**15.71**	**9.666**
F-value	**17.22**	**22.81**	**9.96**	**10.96**	**12.42**	**14.48**	**9.46**
Lack of fit	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
C.V. %	**1.61**	**1.39**	**1.38**	**6.29**	**6.03**	**9.12**	**1.67**

A or X1 = Feed moisture content, B or X2 = Screw speed, C or X3 = Die head temperature, *** significant at p<0.001, significant at p < 0.01, significant p<0.05, NS = Non significant.

0.8250, respectively, which were higher than the 0.8, indicating the adequacy, good fit and high significance of the model.

Water absorption index

The water absorption index of extruded product was ranged from 3.16 g/g to 5.90 g/g.

It was observed from the contour map, that the water absorption index was increased with an increase in feed moisture content up to 14.41% and die temperature up to minimum level (Fig. 1d). With this combination of feed moisture content and die temperature, the water absorption index was expected to be increased up to 5.91 g/g. Alam *et al.* (2015) observed WAI decreased slightly with increasing screw speed to a certain level and then increased, whereas an increasing trend was observed with increasing die temperature.

Hardness

The hardness of extruded product was ranged from 65.32N to 246.32N (Table 3). The contour plot for hardness of extruded product as a function of feed moisture content and die temperature is presented in the Fig. 1e, which indicated the decrease in hardness as the feed moisture content was increased up to 15%. Meng *et al.* (2010) reported that the hardness of extrudates increased as the feed moisture content increased and decrease in hardness with increasing temperature at that time bulk density was observed lower value therefore low-density product naturally offers low hardness.

Overall acceptability

The overall acceptability of extruded product was ranged from 6.7% to 7.7%. It was observed from the contour map (Fig. 1f), that the overall acceptability was increased with an increase in feed moisture content up to 13.83% and die temperature up to 133 °C. With this combination of feed moisture content and die temperature, the overall acceptability was expected to be increased up to 7.57.

Optimization and validation of process variables

The optimized treatment condition was found to be, 131.73 ≅ 132°C die temperature, 255.19 ≅ 255 rpm screw speed and 14.43 ≅ 14% feed moisture content. The analysis showed that at this combination of feed moisture content, die temperature and screw speed, it would be

Table 5 : Constrains, criteria and output for numerical optimization of extruded product.

Variables				
Constraint	**Goal**	**Importance**	**Optimumvalue**	**Experimental value**
Die temperature (°C)	In the range	3	131.73	132
Screw speed (rpm)	In the range	3	255.19	255
Feed moisture content (%)	In the range	3	14.43	14

Responses					
Constraint	**Goal**	**Importance**	**Predicted value**	**Experimental value**	**Deviation (%)**
Bulk density	None	3	0.050	0.0554	10.8
Expansion ratio	Maximum	3	4.31	4.12	4.40
Protein	Maximum	3	16.24	17.68	8.86
WSI	Maximum	3	10.69	9.85	7.85
WAI	None	3	4.50	4.80	6.66
Hardness	Minimum	3	123.10	132.50	7.63
Overall acceptability	Maximize	3	7.55	7.25	3.97

possible to produce an extruded product with bulk density of 0.050 g/cm^3, expansion ratio of 4.31, protein of 16.24%, WSI of 10.69% WAI of 4.50 (g/g), hardness of 123.10 N (Table 5).

Conclusion

The results obtained from this research demonstrated that, the defatted peanut flour can be utilized effectively for development of protein enrich extrudates. The optimized flour proportion are 18.33% defatted peanut, 22.96% amaranth, 10% barnyard and 48.71% tapioca based on sensory parameters. The optimized treatment condition was found to be, 131.73 ≅ 132°C die temperature, 255.19 ≅ 255 rpm screw speed and 14.43 ≅ 14 % feed moisture content. From the study, it can be suggested for enhance the nutritional value of extruded product obtained by 132°C die temperature, 255 rpm screw speed and 14 % feed moisture content which gave the predicted values of protein 16.24%, carbohydrates 67.79%, fat 1.45% and ash 1.43%.

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