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FULL-LENGTH RESEARCH ARTICLE

Development of Groundnut Meal Incorporated Rice–Corn Flour Based Extruded Snack-Food

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Abstract Response surface methodology based at three levels and four factors central composite rotatable design was employed to develop groundnut meal (GM) incorporated extruded snack-food using twin screw extruder. The effect of GM incorporation (15–25%), moisture content of extruder feed (14–18%), screw speed (300–330 rpm) and barrel temperature (110–130 °C) on responses like expansion ratio (ER), breaking strength (BS), water solubility index (WSI) and overall acceptability (OAA) score of extrudates. A second-order polynomial model was used to study and explain the relationships between the responses and independent variables. GM content was found to be the most significant variable as it affected negatively ER and OAA ($p < 0.01$) while positively BS ($p < 0.01$) and WSI ($p < 0.1$). Moisture content significantly affected negatively on ER ($p < 0.05$), WSI ($p < 0.01$), OAA ($p < 0.05$) and positively on BS ($p < 0.01$). Screw speed significantly affected negatively ER ($p < 0.05$), OAA ($p < 0.01$) and positively BS ($p < 0.05$). Barrel temperature did not affect significantly on the responses within experimental levels. By employing graphical superimposition GM content of 20%, moisture content of 15%, screw speed of 309 rpm and barrel temperature of 130 °C were optimized. Extruded snack-food at optimized variables showed higher protein and fiber content as compared with control.

Keywords Extrusion · Expansion ratio · Breaking strength · Water solubility index · Overall acceptability score · Response surface methodology

Introduction

Globally, China ranks first in groundnut production (42% of total production) followed by India (12%) and USA (8%). Groundnut accounts for about 25 percent of total oilseed production in India [11]. In India, 80% of groundnut is utilized for the production of groundnut oil. India produces 1.25 million metric tonnes of groundnut oil [10].

Groundnut oil industry produces a considerable amount of groundnut meal (GM) as a by-product. GM production was 5.78 million metric tonnes during 2000–2010 [34]. GM, the by-product of oil industry, contains protein (45–60%), carbohydrate (22–30%), crude fiber (3.8–7.5%) and minerals (4–6%) [7]. The oil content of GM may vary depending on the extraction method. Though GM contains good amount of proteins, it is being primarily utilized for animal feeding or manure. Exploring the possibilities of incorporation of GM into food products seems to be promising and can act as an excellent vehicle for enriching food products with desirable nutrients. However, GM may not be fit for human consumption because of the unhygienic conditions prevailing in small scale industries [21]. This depicts the need for improvement in good manufacturing practices (GMP) during oil extraction and pretreatment of GM before incorporation into food products. GM incorporation into different cereal composite flours, snack, infant, breakfast cereals, bakery foods and weaning food products was reported [5, 30]. They reported that GM can

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be easily blended and enhanced the nutritive value of food product. Processed food products like nutritious flour, protein isolate, weaning food, infant food and multipurpose supplement from edible groundnut meal were reported by Central Food Technological Research Institute. Moreover, GM incorporated fiber-rich pasta, laddu (Indian sweet), chutney powder, biscuits, fryums and cold extruded products were reported [3, 21].

Hot food extrusion combines unit operations like mixing, shearing, cooking, puffing and shaping drying. It is an energy-efficient rapid continuous process. This process is used to manufacture varieties of starchy foods including snacks, ready to eat (RTE) cereals, confectioneries and extruded crispbreads. Moreover, functional snack food can be manufactured by blending of different active ingredients in extrusion [14]. Packaged food snacks market is Rs. 150 billion in India. The organized sector is accounting for half of the market volume. It is growing at a rate of 15–20% [22]. Globally, extruded food products have imparted commercially successful varieties in the convenient RTE snack foods and still, market is growing. Extruded snacks are enjoyed by all age groups due to its crispy texture and tongue licking flavors [4]. The response surface methodology (RSM) is a mathematical and statistical technique used for standardization of responses with less number of experiments. Modeling of food extrusion by RSM was reported by various authors [2, 15, 20, 24]. However, the literature on GM incorporated extruded snack-food product and its characteristics are scanty. To develop value-added extruded snack-food by using GM (low-value by-product of oil mill) was the purpose of the present investigation.

Materials and Methods

Materials

Cereal flours like rice flour (M/s Shree Bhagwati Flour and Foods Pvt. Ltd., Ahmedabad, Gujarat, India), corn flour (M/s Bluebird Food Products Pvt. Ltd., Mumbai, Maharashtra, India), iodized salt (M/s Tata Chemicals Ltd., Mithapur, Gujarat, India) and black pepper powder (M/s Everest Spices, Mumbai, Maharashtra, India) were purchased from local market. GM was obtained by hygienic processing of groundnut at Billeshwar Oil Mill, Kodinar, Gujarat (India). It was ground in mixer for 2 min. Microwave roasting of GM was carried out by using microwave (MW) power of 80% and time 150 s in microwave oven (M/s Kenstar, Model OM-34 ECR). Roasted GM was ground in mixer for 2 min and passed through 40 mesh screen (0.420 mm opening). Obtained GM flour was packed in polyethylene bag ($80\mu \pm 7.8$) and stored at refrigerated temperature till further use. Particle size of rice flour and corn flour were 265µ and 291μ, respectively, estimated by sieve analysis. Proximate composition of GM (Moisture, wb 7.02%; ash 5.13%; fiber 6.70%; fat 7.09%; protein 50.95%), rice flour (Moisture 10.58%; ash 0.86%; fiber 0.18%; fat 1.23% and protein 5.88%) and corn flour (Moisture 9.48%; ash 1.02%; fiber 1.35%; fat 2.09% and protein 8.15%) was carried out by AOAC standard methods [1].

Preparation of Extruder Feed

Extruder feed of control sample was prepared by blending 720 g rice flour and 240 g corn flour (Rice flour: Corn Flour = 3:1), 16 g black pepper, 24 g iodized salt (Total feed 1 kg). Preliminary trials were conducted to decide the level of GM incorporation. GM was incorporated with the replacement of rice in rice–corn flour composite (3:1). Experimental feed samples were prepared by mixing rice flour (540–612 g) and GM (108–180 g—15–25% of rice flour basis). Corn flour, black pepper and iodized salt quantity were kept constant. The desirable moisture content in each extruder feed was achieved by addition of water. Each feed sample was mixed in ribbon blender and then sieved to ensure uniform feed mass. The experimental and control samples prepared were packed in polyethylene bags. Packed samples were stored at 40 °C for 24 h to enhance uniform moisture distribution (conditioning). During preliminary trials, it was observed that GM level more than 25% produced unacceptable extruded product with low expansion ratio (ER) and high breaking strength (BS).

Extrusion

An intermeshed and corotating high shear twin screw extruder from Basic Technology Private Limited, Kolkata, India was used in this investigation. Specifications of the extruder are as follows: Motor 7.5 HP, Voltage 400 V, 350 mm screw length, 30 mm diameter of each screw, 20 mm constant pitch and 3.5 mm flight of screw. Feeder screw rpm 35, extruder barrel first zone (feeding zone) temperature of 60 °C and 4 mm diameter extruder die were kept constant during the study. The extruder was run for 5 min until attains constant outlet temperature and torque during each experimental extruder run. Extruded products were collected on stainless steel tray and packaged in low density polyethylene (LDPE)—aluminum laminates.

Experimental Design

Experimental designs, statistical analysis and regression model were generated by adopting response surface methodology (RSM) in Design Expert Software (Statease

Inc.) Version 8. Preliminary trials were conducted to decide the level of independent variables, i.e., GM incorporation level (15–25%), moisture content of extruder feed (14–18%, wet basis), screw speed (300–330 rpm) and barrel temperature (110–130 °C). The central composite rotatable design (CCRD) with quadratic model was used. Selected parameter had 3 levels at −1, 0 and +1. A total of 30 different combinations divided into three blocks including six replicates of the center point each signed the coded value (0) were undertaken. The rotability of the design was assured by assigning α-values outside the parameter range. The experimental design in the coded (x) and actual (X) levels of parameters is shown in Table 1. Expansion ratio (ER), breaking strength (BS), water solubility index (WSI) and overall acceptability (OAA) were selected as responses function (y). Average of three determinations reported as response values. The adequacy of the model was tested using coefficient of determination R^2 values, nonsignificant lack of fit and model F-value. The following second-degree polynomial equation was related to the coded variables values (xi, i = 1, 2, 3 and 4).

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{14}x_1x_4 + b_{23}x_2x_3 + b_{24}x_2x_4 + b_{34}x_3x_4 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 + b_{44}x_4^2 \quad (1)$$

where y = response variable, b_0 = coefficient of the polynomial (constant term), b_1, b_2, b_3 and b_4 = linear effects of parameters, b_{12}, b_{13}, b_{14}, b_{23}, b_{24} and b_{34} = interaction

Table 1 Central composite rotatable design with actual values employed and experimental results for response variables

Run no.	Independent variables				Responses			
	GM (%)	Moisture (%)	Screw speed (rpm)	Barrel temperature (°C)	ER	BS (N)	WSI	OAA
1	25 (+1)	18 (+1)	300 (−1)	110 (−1)	2.76	22.13	0.150	4
2	25 (+1)	14 (−1)	300 (−1)	130 (+1)	2.61	13.92	0.220	5
3	15 (−1)	14 (−1)	330 (+1)	130 (+1)	3.10	24.32	0.135	5
4	20 (0)	16 (0)	315 (0)	140 (+α)	2.73	12.94	0.220	6
5	20 (0)	16 (0)	315 (0)	100 (−α)	2.71	15.78	0.275	5
6	15 (−1)	14(−1)	300 (−1)	130 (+1)	2.92	16.18	0.140	5
7	15 (−1)	18 (+1)	330 (+1)	110 (−1)	2.77	29.02	0.100	4
8	10 (−α)	16 (0)	315 (0)	120 (0)	3.10	25.39	0.080	5
9	20 (0)	12 (−α)	315 (0)	120 (0)	2.81	27.94	0.215	5
10	15 (−1)	14 (−1)	300 (−1)	110 (−1)	2.88	20.00	0.215	4
11	25 (+1)	18 (+1)	300 (−1)	130 (+1)	2.78	28.83	0.115	3
12	15 (−1)	18 (+1)	330 (+1)	130 (+1)	2.76	12.55	0.180	4
13	25 (+1)	18 (+1)	330 (+1)	130 (+1)	2.42	13.33	0.170	2
14	20 (0)	16 (0)	315 (0)	120 (0)	2.89	26.37	0.130	5
15	30 (+α)	16 (0)	315 (0)	120 (0)	2.33	15.49	0.155	2
16	20 (0)	16 (0)	315 (0)	120 (0)	3.23	16.57	0.135	6
17	20 (0)	16 (0)	315 (0)	120 (0)	2.92	24.41	0.139	6
18	15 (−1)	18 (+1)	300 (−1)	110 (−1)	2.84	23.34	0.170	5
19	20 (0)	16 (0)	285 (−α)	120 (0)	2.97	14.22	0.115	5
20	25 (+1)	14 (−1)	300 (−1)	110 (−1)	2.58	33.24	0.225	3
21	15 (−1)	14 (−1)	330 (+1)	110 (−1)	2.98	34.22	0.180	4
22	25 (+1)	14 (−1)	330 (+1)	130 (+1)	2.46	16.47	0.260	3
23	20 (0)	16 (0)	315 (0)	120 (0)	2.80	15.59	0.105	5
24	20 (0)	20 (+α)	315 (0)	120 (0)	2.48	24.02	0.125	3
25	25 (+1)	18 (+1)	330 (+1)	110 (−1)	2.40	18.83	0.105	2
26	20 (0)	16 (0)	315 (0)	120 (0)	2.82	21.38	0.125	6
27	20 (0)	16 (0)	315 (0)	120 (0)	2.88	22.13	0.225	5
28	20 (0)	16 (0)	345 (+α)	120 (0)	2.72	13.92	0.125	3
29	25 (+1)	14 (−1)	330 (+1)	110 (−1)	2.79	24.32	0.235	3
30	15 (−1)	18 (+1)	300 (−1)	130 (+1)	3.00	12.94	0.190	4

Table 2 Regression coefficient result analysis

Particulars	ER	BS	WSI	OAA
Intercept	2.923	15.360	0.143	5.500
GM (b1)	− 0.166*	2.223*	0.013***	− 0.667*
Moisture (b2)	− 0.052**	4.045*	− 0.025*	− 0.333**
Screw RPM (b3)	− 0.050**	2.018**	− 0.002	− 0.417*
Temperature (b4)	0.004	− 0.719	− 0.003	0.167
b12	0.027	0.452	− 0.023**	− 0.125
b13	− 0.039	0.491	0.011	− 0.250
b14	− 0.036	1.470	0.004	0.000
b23	− 0.086*	− 0.160	− 0.005	− 0.125
b24	0.021	0.183	0.014***	− 0.375
b34	− 0.028	− 0.785	0.014	0.000
b11	− 0.048**	1.568**	− 0.005	− 0.583*
b22	− 0.066*	2.474*	0.008	− 0.458*
b33	− 0.016	1.285**	− 0.004	− 0.458*
b44	− 0.047**	1.218**	0.028*	− 0.083
SD	0.11	0.37	0.032	0.570
Mean	2.78	2.06	0.170	4.230
F value lack of fit	0.25	2.17	0.35	1.14
R^2	0.863	0.832	0.810	0.886
Model (*F* value)	6.78	5.74	4.57	8.37

*Significant at 0.01 level, **significant at 0.05 level, ***significant at 0.1 level

effects of parameters, b_{11}, b_{22} b_{33} and b_{44} = quadratic effects of parameters.

Extrudate Product Characteristics

Expansion Ratio (ER)

The ratio of diameter of extrudate to the diameter of extruder die was determined as ER of extrudate. The cylindrical extrudate diameter was determined by using vernier caliper (M/s Mitutoyo, Tokyo, Japan). Ten samples were analyzed, and the average values of ten determinations were reported for each experimental run [20].

Breaking Strength (BS)

It was determined in Newton (N) force by Texture analyzer (M/s Lloyd Instruments Ltd., Model TA Plus Hampshire UK) under set parameters of probe speed of 2 mm/s, trigger force of 0.1 N, load cell of 100 N and probe penetration limit of 15 mm in snap test setup. Extrudate samples were placed on the center of testing platform and Warner–Bratzler cutting blade was employed as test probe. Mean of ten random determinations was reported as BS (N) [16].

Water Solubility Index (WSI)

Extrudate sample of each experimental run was ground, and 500 µm mesh size was used to sieve. Grounded extrudates (0.5 g) were dispersed in 10 ml of distilled water taken in pre-weighed centrifuge tube. Each sample centrifuge tube was hold for 30 min. To prepare uniform suspension, lump formation was avoided by allowing intermittent shaking at 5 min. interval. These tubes were centrifuged at 1800× *g* for 15 min. followed by decanting of supernatant in a pre-weighed aluminum container and dried at 105 °C to constant mass [13, 32]. WSI is determined by using the following Eq. 2.

$$\mathrm{WSI} = \frac{\text{Weight of dry solids in supernatant}}{\text{Dry weight of extrudate}} \times 100 \quad (2)$$

Overall Acceptability Score (OAA)

Each experimental run extrudate sample was evaluated for OAA score by ten semi-trained panel members on 7-point hedonic scale (1-Dislike extremely to 7-Like extremely) [23]. Average age of semi-trained panel members was 32 years. Mean value of ten judges' score for each experimental sample was reported.

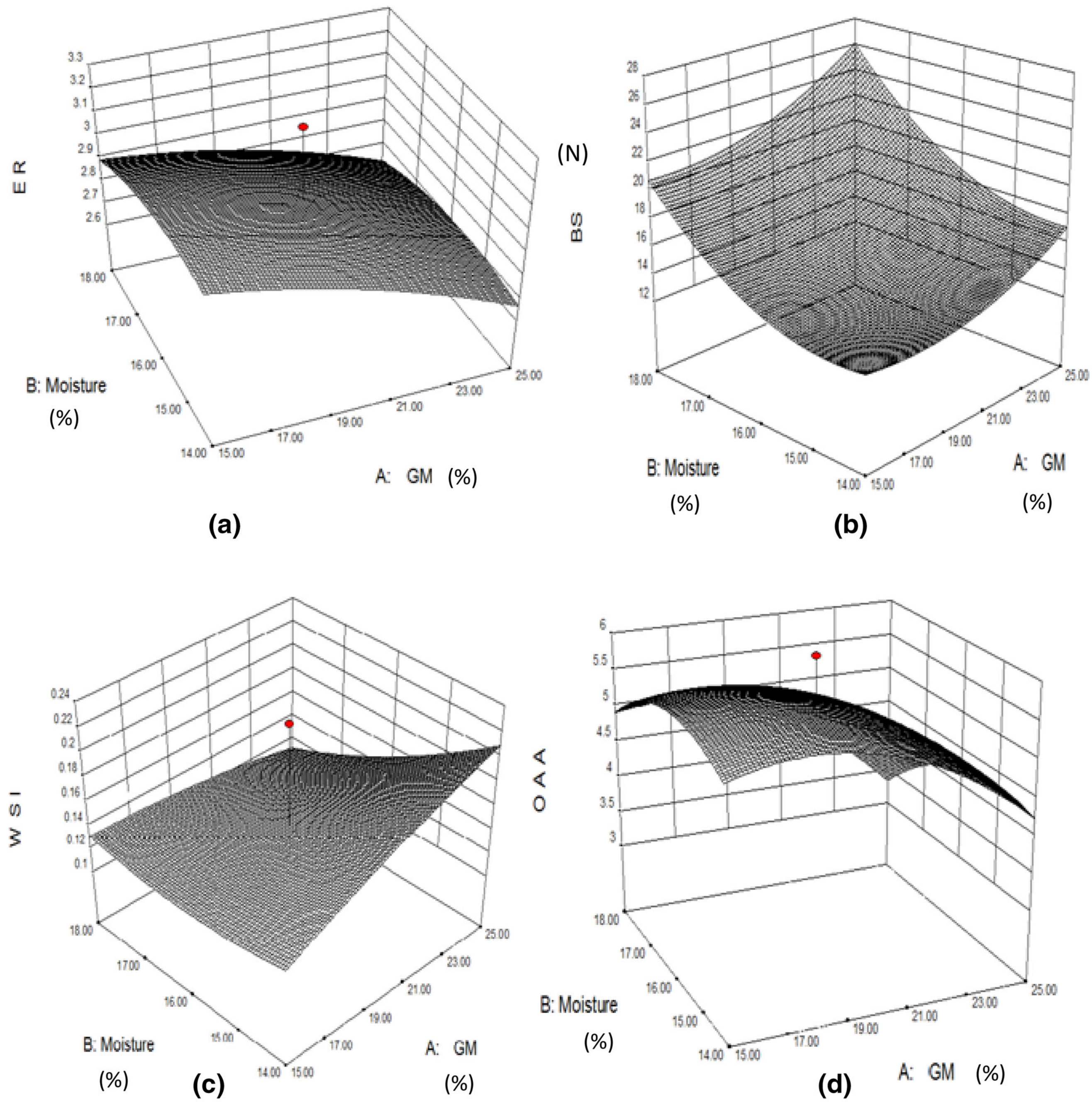

Fig. 1 Response surface plots: **a** ER, **b** BS, **c** WSI and **d** OAA as function of GM level and feed moisture content at screw speed 315 RPM and Barrel Temperature 120 °C

Results and Discussion

Model Fitting

Table 1 explains selected parameters (independent variables) effect on product responses ER, BS, WSI and OAA. Second-order model was assessed against selected parameters. Lack of fit values was examined and found non significance lack of fit in all responses. The calculated R^2 for each response was higher than 0.80 (Table 2). So, adequacy was obtained [12]. Therefore, the prediction at any values of the parameters within experimental range can be appropriately done through proposed models.

Effect of Independent Variables on Expansion Ratio

A lighter and crispier extruded product is generally having higher expansion ratio (ER), which is desirable in extruded

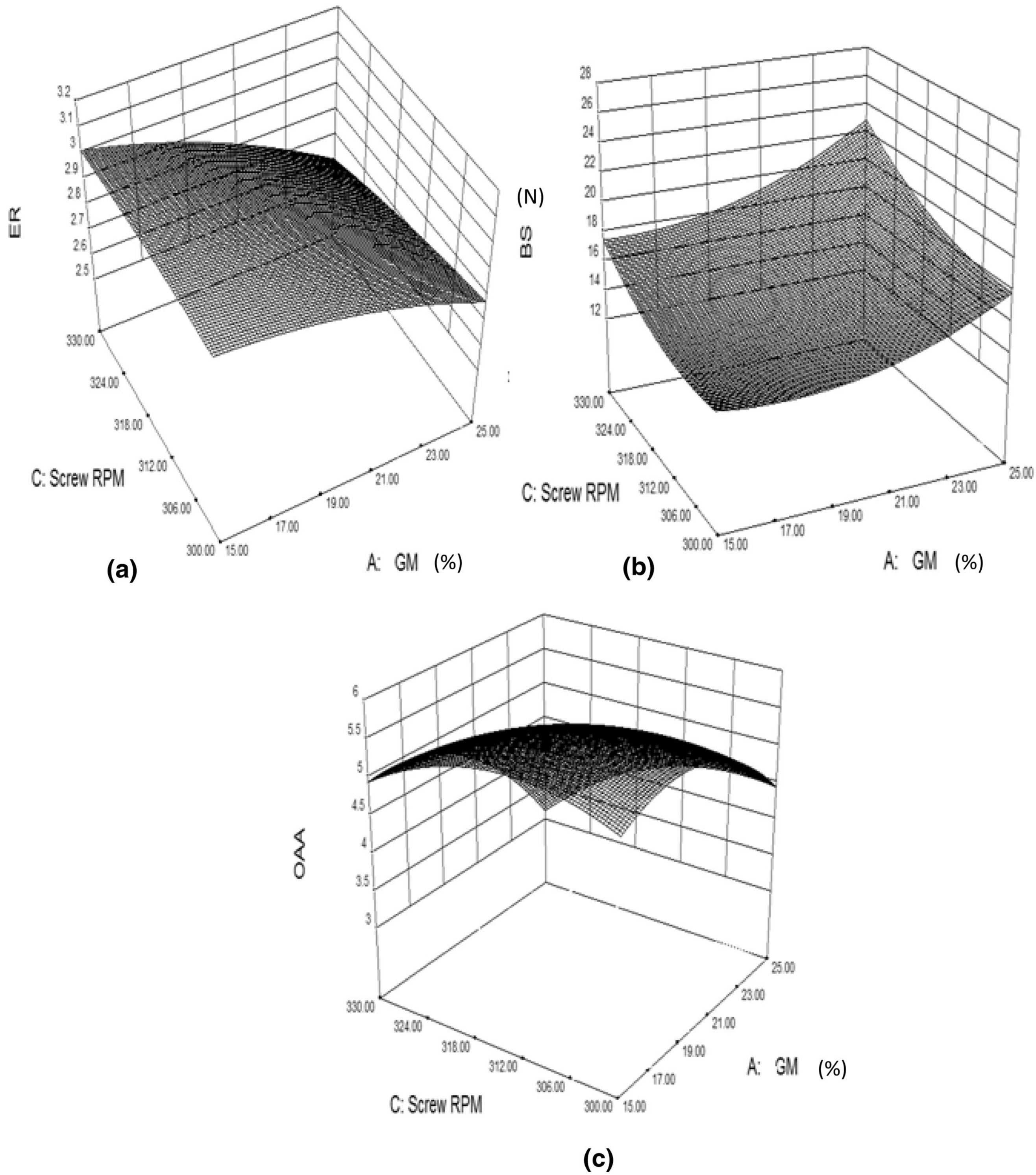

Fig. 2 Response surface plots: **a** ER, **b** BS, **c** OAA as function of GM level and screw speed (RPM) at feed moisture content 16% and Barrel Temperature 120 °C

snack-foods. Extrudate ER varied from 2.33 to 3.23 (Table 1). Observed results are well comparable with cereal and pulse-based extrudate results [18, 25], revealing that desired ER can be achieved for GM incorporated extrudate snacks. The variations of 86.3% were observed in developed ER regression models (Table 2). ER was mainly influenced by GM content as its linear effect at $p < 0.01$, and quadratic effect at $p < 0.05$ were negatively significant. Moisture content and screw speed interaction effect ($\beta = -0.086$), moisture content quadratic effect ($\beta = -0.066$) were found to be negatively significant ($p < 0.01$) (Table 2). After GM level, moisture content observed as second parameter affecting on ER as its quadratic effect ($p < 0.01$) and linear effect ($p < 0.05$) were significant. Moreover, ER was negatively related with quadratic effect of barrel temperature at $p < 0.05$.

Response surface plot of ER (Fig. 1a) depicts that as the GM level increased, ER decreased substantially. GM being protein and fiber source affected majorly starch gelatinization during extrusion in the barrel. The formation of bubbles when cooked melts exit the die defines extrudate ER [6]. Increase in content of protein and fiber content in composite feed decreased starch content and consequently decreased ER. Moreover, the protein does not expand well compared with the starch. More protein of composite feed resulted in a lower melt viscosity inside the barrel and which is attributed for reduced ER [19]. Fiber absorbs more water and ruptured bubble structures in cooked melt. Insoluble fibers decrease the elastic properties. These binds with bubble structure and ruptures formed bubble cell wall. Moreover, fibers have high hydrophilic characteristics; therefore, they absorb more water in formulation [15, 29]. Water adheres more tightly to non-polysaccharides bind water compared with starch. This adherence inhibits water vapor to escape out at the die and thus reduces the ER. Similar results of decreased ER after incorporation of defatted soy flour [26], defatted flaxseed meal [13] and almond flour [15] were reported.

Increase in moisture content of extruder composite feed (14–18%), decrease in ER was observed (Fig. 1a). However, ER also depends upon the composition of extruder feed. Decreased ER at higher moisture levels is due to decrease in extruder melt temperature [17], which consequently leads to lower swelling and volume. Moreover, negative impact of moisture levels could attribute to amylopectin structure change, reducing the elasticity of melt [8, 28], reducing shear force per unit weight of extrudate [27] and the melt temperature reduced through lowering friction between dough and screw barrel and negatively affected starch gelatinization [33]. Similar results for fish protein and fish oil incorporated extruded products at higher moisture levels were reported [27]. Similar trend was observed for sorghum extrudates after increasing moisture content (13–18%). However, further increase prevented extrudate expansion [9].

Screw speed was negatively related to ER (Table 2). Extruder barrel temperature did not significantly affect ER. However, quadratic effect of barrel temperature significantly affected ER ($p < 0.05$). Higher the shear rate due to higher screw speed increased the potential for mechanical damage to starch molecules. These damaged starch molecules were low in compactness than undamaged and gelatinized starch. Moreover, higher screw speed imparted less residence time in extruder barrel. Ultimately, these molecules expanded low giving extrudate with less ER (Fig. 2a). Similar results for partially defatted hazelnut flour and fruit waste fiber incorporated extruded product were reported [32].

Effect of Independent Variables on Breaking Strength

Breaking strength (BS), indicative of expanded product texture, varied between 12.55 and 34.22 N (Table 1). The variations of 83.2% could be explained by developed regression models to envisage BS (Table 2). Significant linear effect ($p < 0.01$) and quadratic effect ($p < 0.05$) of GM depicted positive correlation with BS (Table 2). BS was also influenced significantly by moisture content of extruder feed due to significant linear and quadratic effect ($p < 0.01$) (Table 2). After moisture content and GM level, it is positively correlated with linear and quadratic effect of screw speed ($p < 0.05$). Figure 1b revealed that as GM level increased, BS of the product increased. This might be due to the decrease in total starch content of extruder feed as GM increased since GM being rich in protein and fiber. This reduced expansion and porosity of product. Higher compactness in extrudates with thick cell walls and small size air cells were resulted from increased GM. Therefore, higher BS values were observed. Similar results were reported for rice flour amaranth blends [16] and defatted flaxseed meal incorporated extrudates [13]. BS was positively related with increased moisture content. At higher moisture content and higher GM level, the highest BS value was observed. As earlier discussed in ER section, higher moisture content reduced melt elasticity and temperature. Extrusion cooking was not sufficient to vaporize the higher moisture leading to the retention of moisture content [2]. This imparted negative impact on starch gelatinization resulted in more compact extrudates. A less expanded extrudate product would take more force to shear and consequently higher BS values obtained. Similar results flaxseed meal incorporated corn extrudates [31]. Increased moisture content in flaxseed meal corn flour blend resulted harder extrudates. BS increased with increase in the screw speed (Fig. 2b). Higher screw speed decreases the retention time of extruder feed-in extruder barrel. Moreover, increased screw speed imparted higher shear rate which damages starch molecules. Both these facts resulted for less expanded product with thick cell walls and small air cells. Chickpea flour-based extruded snack imparted same trend [18].

Effect of Independent Variables on Water Solubility Index

The amount of soluble polysaccharide unconfined from the starch component extrusion is measured by WSI [8, 32]. WSI values varied in the range of 0.080–0.275 (Table 1). Regression analysis (Table 2) revealed that WSI was positively correlated with linear effect of GM content ($p < 0.10$) and negatively correlated with linear effect of moisture content ($p < 0.01$). Also, the interaction effect between GM level and moisture content found to be negatively correlated ($p < 0.05$) and the interaction effect between moisture content and barrel temperature found to be positively correlated ($p < 0.10$). Moreover, WSI was positively correlated with quadratic effect of barrel temperature ($p < 0.01$). R^2 value of 0.81 was observed in multiple regression models for forecasting WSI (Table 2). Increased GM content increased WSI values (Fig. 1c). As mentioned earlier, GM being rich in fiber, disturbed the continuous structure of melt in the extruder barrel hindering the elastic deformation during extrusion [13]. As the moisture content increased, WSI decreased. This might be attributed to the protective effect of water on starch molecule. Water did not allow separating out low molecular weight compounds from the melt. Moreover, higher moisture would not have allowed degrading the starch even the desired degree of gelatinization did not achieve (earlier discussed in ER section). No significant changes in WSI values were observed with increase in screw speed (Table 2). However, being significant quadratic effect of temperature on WSI values, at either side of temperature (maximum and minimum), higher WSI values were observed. In combination with screw speed (at lower temperature and lower screw speed), higher WSI values was observed. This might be due to higher residence time of feed to temperature in extruder barrel.

Effect of Independent Variables on Overall Acceptability

Consumer acceptability is evaluated through sensory evaluation by OAA scores. In Table 1, data related to effects of selected parameters on OAA was presented. OAA was negatively related to the linear effect of GM incorporation level and screw speed at 0.01% significance level and moisture content at 0.1% significance level from extruded product regression analysis (Table 2). It was also observed that it is negatively related to the quadratic effect of GM level, moisture content and screw rpm ($p < 0.01$). R^2 value of 0.88 was observed (Table 2). It is evident from Fig. 1d that as the GM content and moisture content increased, OAA decreased. This is attributed to decreased ER (mentioned in section of ER) and increased in BS (discussed in section of BS). Moreover, increase in screw speed yielded low OAA (Fig. 2c). Lower ER and higher increased BS value imparted low porous (more compact structure) and more hard product which was not relished by panel member. Consequently, the extrudate scored lower OAA.

Optimization

The optimization of independent variables was carried out by response surface graphical superimposition in Design Expert Version 8. Dependent variables criteria of maximum ER and OAA, minimum BS and in range values of WSI were employed. An independent variable, GM content

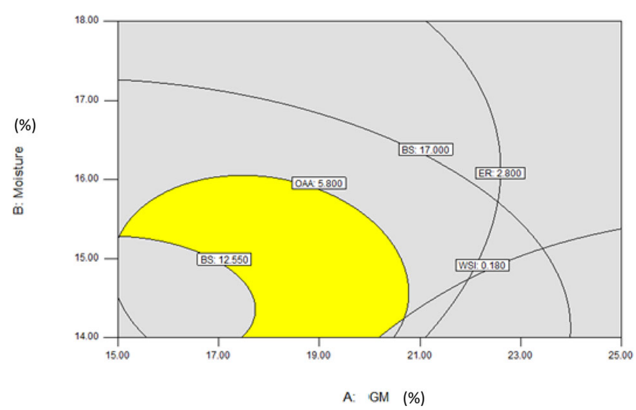

Fig. 3 Superimposed contour plots for ER, BS, WSI and OAA as function of feed moisture (%) and GM incorporation level (%)

Table 3 Proximate composition and responses comparison between control and optimized GM incorporated extruded snack-food

Parameter	Control sample**	GM incorporated sample
Moisture (wb), (%)	5.68 ± 0.31^a	7.24 ± 0.39^b
Ash, %	1.63 ± 0.21^a	3.58 ± 0.31^b
Fat, %	0.68 ± 0.17^a	1.92 ± 0.45^b
Protein (%N × 6.25), %	7.53 ± 0.52^a	13.88 ± 0.73^b
Crude fiber, %	0.63 ± 0.27^a	1.71 ± 0.19^b
*Carbohydrate, %	84.48	73.38
Expansion ratio	3.34 ± 0.07^a	2.92 ± 0.055^b
Breaking strength (N)	11.33 ± 0.45^a	14.24 ± 0.18^b
Water solubility index	0.062 ± 0.005^a	0.168 ± 0.006^b
Overall acceptability	6.21 ± 0.24^a	5.98 ± 0.18^a

Mean values followed by the different superscript alphabet in a row are significantly different at $p < 0.05$

*Carbohydrate content was estimated by difference method (inclusive of fiber)

**Control sample processed at optimized parameters without GM

Reported values are the average of three determinations criteria was set to 20% because the optimized product should contain possible maximum GM without hampering extrudate product acceptability. Other independent variables (selected parameters) were set as in range values. It was assumed that ER of 2.85–3.1, BS from 12.55 to 17, WSI from 0.09 to 0.18 and OAA score from 5.85 to 6 were acceptable. Constraints were selected so that all dependent variables to get best suitable province with the same independent variable level. Depending on the best desirability rating ($\approx$ 0.90), 308.94 screw speed (rpm) and 129.93 °C barrel temperature was selected. Suitable province was found out by the superimposing contour graph for all the responses using independent variables level that confirmed limits of acceptable quality for each parameter as shown in Fig. 2. Superimposing the individual contour plots for the response variables resulted in the province identification (dark shaded area) which confirms all limits as shown in Fig. 2.

The predicted values of ER, BS, WSI and OAA were 2.88, 13.84 N, 0.17 and 5.90, respectively, at superimposition can be obtained at the combination of independent variables GM content, moisture content, screw speed and barrel temperature of 20%, 14.76%, 308.94 and 129.93 °C, respectively. Keeping in view of practical conditions, moisture content of 14.76%, screw speed of 308.92 rpm and barrel temperature of 129.93 °C were rounded off to 15%, 309 rpm and 130 °C, respectively (Fig. 3).

Hence, the product was prepared by employing the optimized conditions. The prepared optimized GM incorporated extruded product was compared with control extruded product for the proximate analysis and responses (Table 3). Proximate analysis clearly depicted that GM incorporated product showed higher protein content (13.88%) and fiber content (1.71%) as compared to control without affecting overall acceptability.

Conclusion

The by-product of groundnut oil industry, GM, being rich in functional nutrients like protein and fiber, explored for the development of hot extruded snack-food. Present investigation establishes that the acceptable and value-added extruded snack-food can be prepared by incorporation of GM content up to 20%. GM content was found to be the most important variable to affect the characteristics of extruded product characteristics followed by moisture content of feed and screw speed of extruder. Enhancement in the protein and fiber content is confirmed by analysis of optimized product and control. GM shows effective promising protein and fiber-rich food ingredient potential for product formulation. Moreover, it has potential to tackle protein-energy malnutrition in underdeveloped and developing countries.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. AOAC (2000) Official methods of analysis, 17th edn. Association of Official Analytical Chemist, Washington DC
2. Asare E, Safa-Dedeh S, Afoakwa EO, Sakyi-Dawson E, Simpson BA (2012) Extrusion cooking of rice-groundnut-cowpea mixtures—effects of extruder characteristics on nutritive value and physico-functional properties of extrudates using response surface methodology. J Food Process Preserv 36:465–476
3. Badwaik LS, Prasad K, Seth D (2014) Optimization of ingredient levels for the development of peanut based fiber rich pasta. J Food Sci Technol 51:2713–2719. https://doi.org/10.1007/s13197-012-0779-8
4. Brennan MA, Derbyshire E, Tiwari BK, Brennan CS (2013) Ready to eat snack products: the role of extrusion technology in developing consumer acceptable and nutritious snacks. Int J Food Sci Technol 48:893–902
5. Chavan JK, Shinde VS, Kadam SS (1991) Utilization of expeller pressed partially defatted peanut cake meal in the preparation of bakery products. Plant Foods Hum Nutr 41:253–259
6. De Pilli T, Carbone BF, Derossi A, Fiore AG, Severini C (2008) Effects of operating conditions on oil loss and structure of almond snacks. Int J Food Sci Technol 43:430–439
7. Desai BB, Kotecha PM, Salunkhe DK (1999) Composition and nutritional quality in introduction science and technology of groundnut: biology, production, processing and utilization. Naya Prakash Publications, New Delhi, pp 185–199
8. Ding QB, Ainsworth P, Tucker G, Marson H (2005) The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice based expanded snacks. J Food Eng 66:283–289
9. Falcone RG, Phillips RD (1988) Effects of feed composition, feed moisture and barrel temperature on physical and rheological properties of snack-like products prepared from cowpea and sorghum flour by extrusion. J Food Sci 53:1464–1469
10. FAOSTAT (2017) Food and agricultural organization of the United Nation. http://www.fao.org/faostat/en/#data/QC
11. FAS USDA (2017) Foreign agricultural services. United States Department of Agriculture Commodity Intelligence Report. https://ipad.fas.usda.gov/highlights/2017/01/India/index.htm
12. Gan HE, Karim R, Muhammad SKS, Bakar JA, Hashim DM, Rahman RA (2007) Optimization of the basic formulation of a traditional baked cassava cake using response surface methodology. Lebensm Wiss Technol 40:611–618
13. Ganorkar PM, Patel JM, Shah V, Rangrej VV (2016) Defatted flaxseed meal incorporated corn-rice flour blend based extruded product by response surface methodology. J Food Sci Technol 53:1867–1877. https://doi.org/10.1007/s13197-015-2134-3
14. Guy R (2001) Extrusion cooking: technologies and application. Wood Head Publishing Ltd, Cambridge

15. Hashemi N, Mortazavi SA, Milani E, Yazdi FT (2017) Microstructural and textural properties of puffed snack prepared from partially defatted almond powder and corn flour. J Food Process Preserv 2017(00):e13210. https://doi.org/10.1111/jfpp.13210
16. Ilo S, Liu Y, Berghofer E (1999) Extrusion cooking of rice flour and amaranth blends. Lebensm Wiss Technol 32:79–88
17. Liu Y, Hsieh F, Heymann H, Huff HE (2000) Effect of process conditions on the physical and sensory properties of extruded oat-corn puff. J Food Sci 65:1253–1259
18. Meng X, Threinen D, Hansen M, Driedger D (2010) Effects of extrusion conditions on system parameters and physical properties of chickpea flour-based snack. Food Res Int 43:650–658
19. Onwulata CI, Konstance RP (2006) Extruded corn meal and whey protein concentrate: effect of particle size. J Food Process Preserv 30:475–487
20. Pankyamma V, Basu S, Bhadran SS, Chouksey MK, Gudipati V (2014) Fish oil-fortified extruded snacks: evaluation of physical properties and oxidative stability by response surface methodology. J Food Process Eng 37:349–361
21. Purohit C, Rajyalakshmi P (2011) Quality of products containing defatted groundnut cake flour. J Food Sci Tech 48:26–35. https://doi.org/10.1007/s13197-010-0125-y
22. Rais M, Acharya S, Sharma N (2013) Food processing industry in India: S&T capability, skills and employment opportunities. J Food Process Technol 4:260. https://doi.org/10.4172/2157-7110.1000260
23. Ranganna S (2000) Sensory evaluation. In: Handbook of analysis and quality control for fruits and vegetable products, pp. 623–629. Tata Mc Graw Hill Publishing Co Ltd, New Delhi
24. Shahmohammadi HR, Jamilah B, Russly AR, Noranizan MA (2016) Optimization of puffed corn-fish snack extrusion conditions using response surface methodology. Int Food Res J 23:1685–1693
25. Singh N, Smith AC (1997) A comparison of wheat starch, whole wheat meal and oat flour in the extrusion cooking process. J Food Eng 34:15–32
26. Sun Y, Muthukumarappan K (2002) Changes in functionality of soybased extrudates during single-screw extrusion processing. Int J Food Prop 5:379–389
27. Thachil MT, Subrato B, Chouksey MK, Venkateshwarlu G (2016) Modeling the inclusion of fish powder and fish oil into extruded snacks by response surface methodology. J Aquat Food Product Technol 25:46–64. https://doi.org/10.1080/10498850.2013.826316
28. Thymi S, Krokida MK, Pappa A, Maroulis ZB (2005) Structural properties of extruded corn starch. J Food Eng 68:519–526
29. van der Sman RGM, Broeze J (2013) Structuring of indirectly expanded snacks based on potato ingredients: a review. J Food Eng 114:413–425
30. Venkataraghavan U (1998) Newer dimensions in the processing of oilseeds for food uses Indian. Food Ind 17:272–275
31. Wu W, Huff HE, Hsieh F (2007) Processing and properties of extruded flaxseed–corn puff. J Food Process Preserv 31:211–226
32. Yagci S, Goguş F (2008) Response surface methodology for evaluation of physical and functional properties of extruded snack foods developed from food-by-products. J Food Eng 86:122–132
33. Yu L, Ramaswamy HS, Boye J (2012) Protein rich extruded products prepared from soy protein isolate-corn flour blends. LWT-Food Sci Technol 50:79–289. https://doi.org/10.1016/j.lwt.2012.05.012
34. Zhao X, Chen J, Du F (2012) Potential use of peanut by-products in food processing: a review. J Food Sci Tech 49:521–529