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Sensory Properties of Extruded Blends of 'Acha' and Soybean Flour – A Response Surface Analysis

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ABSTRACT

Blends of 'acha' and soybean flours with moisture contents of between 15 and 35% were extruded in a single screw extruder. A response surface design (central composite nearly orthogonal) was used in the investigation with four independent variables comprising of feed moisture content (FMC), feed composition (FC), screw speed (SS) and barrel temperature (TP) combined at 5 levels. The extruded products were subjected to sensory evaluation using a 20-man panelist. The results of the study showed that maximum aroma and colour rating of extrudate blends were observed at high SS with FC playing the determinant factor. Increased feed composition and barrel temperature resulted in decreased texture rating of extrudates. Extrudates of 37.5: 62.5% (soybean: acha) had the highest sensory rating compared to other blend ratios evaluated. This indicated that acceptable extruded blends of 'acha' and soybean products could be obtained at 37.5% soybean addition. This is was higher than the 30% already reported in literature for cereal/legume mixes.

Keywords: Acha, soybean, sensory properties, extrusion, extrudates.

Introduction

Victor and James (1991) report that 'acha' (*Digitaria exilis [Kippist] Stapf)* which is also known as 'Fonio', *'fundi'* or hungry rice in different savannah zones of West Africa has a unique protein composition that has greater methionine content than other cereal proteins.

Soybean (*Glycine max, [L] Merrill)*, a versatile pulse constitutes the staple food in many parts of the globe. It is the richest, cheapest and best source of vegetable protein available to mankind. Soybeans are high in protein with an excellent source of the essential amino acids vital for body growth, maintenance and reproduction; it also contains a high amount of polyunsaturated fat and absence of cholesterol and lactose. It is also a good source of minerals and vitamins (Iwe, 2003).

Blending of acha and soybean, therefore, would provide a wide range of both high calorie and high protein food if properly processed. This development would enhance the scope of utilization of acha, which was hitherto marginally used because of its localization. Again, the blending of acha (high in methionine and deficient in other essential amino acids) and soybean (deficient in methionine and rich in other essential amino acids), is envisaged to provide reasonable levels of complementality (Anuonye, 2006). The retention of essential amino acids would be enhanced through the application of flash processing system such as extrusion cooking. This is so because extrusion cooking principles have been widely applied for the retention of nutrients, adequate heat treatment against antinutritional factors such as trypsin inhibitor in soybeans, production of broad based products with a wide

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range of textural and nutritional qualities, and for the purpose of cutting down on overall cost of production during food processing (FAO, 1985; Harper, 1981).

The extrusion technology has been employed in developing a wide range of raw materials such as cereal flour, starch granules, tubers and legumes, etc. as breakfast cereals, flakes, quick cooking paste products, instantised legume powders and breakfast gruel (Iwe and Ngoddy, 1998; Iwe, 2001).

The pre-cooking of cereal/legume mixes has been advocated. Iwe (2003) explained that pre-cooking would be important in developing countries where quick cooking saves scarce fuel and simplifies preparation. It was further explained that partial cooking can serve to destroy enzyme action such as lipases and lypoxygenases, which if active could cause off-flavour development. Again, a pre-cooked product that requires minimal further cooking before serving has the advantage that water and other added ingredients are pasteurized in the process. To achieve such aims of pre-cooking, targeting enzyme denaturation and inhibition, microbial inactivation, general product acceptability, etc., extrusion cooking presents the best option. Iwe (2003) and FAO (1985) reported that cereal/legume blending of 70: 30 ratios with a large number of substituting materials, flexibility of application and numerous successful market acceptability and probable industrial scale trials is now feasible. The objective of this study, therefore, was to determine the effects of extrusion variable combinations on organoleptic parameters of taste, aroma, colour, texture and overall acceptability. It was also aimed at establishing the combination level of acha/soybean that gives the best organoleptic acceptance using response surface methods.

Materials and Methods

The materials used in this study were soybean (*Glycine max [L] Merrill*) TGX 1448 – 2E and acha (*Digitaria exilis*). Soybean seeds were obtained from the seed store of the National Cereals Research Institute Bida, Niger State, Nigeria, while acha seeds were purchased from Vom Local Market in Plateau State of Nigeria.

Soybean seeds were cleaned to remove immature grains and other foreign materials. The sorted grains were washed in clean tap water. The washed grains were sun dried for 4 h at 34 – 40^{o}C, cracked in a commercial attrition mill and winnowed manually to remove hulls. The grits were further milled in attrition mill into flour. Acha was also sorted and winnowed manually. Cleaned grains were milled using the attrition mill. The flours (soybean and acha) were separately sieved to pass a laboratory sieve mesh of 0.75 – 1 mm. The moisture content of the flours was determined and adjusted to 15, 20, 25, 30 and 35%, respectively, according to Wilmot (1998).

Extrusion process

Extrusion was carried out using a Branbender Laboratory single screw extruder (DUISBURG DCE – 330 Model Germany). It was powered by a decoder drive (Type 832, 500) and driven by a 5.94 kw motor. The grooved band had a length/diameter ratio of 20: 1. The extruder had variable screws and heaters with a fixed die diameter of 2 mm and length of 40 mm. A feed hopper mounted vertically above the end of the extruder and equipped with a screw that rotated at a constant speed of 80 rpm on a vertical axis takes feed into the extruder. The blends were mixed according to the experimental design (Table 1). The extruder runs was stabilized using acha flour. Extrusion of the blends was then carried out as shown in the transformed matrix (Table 2).

Sensory evaluation

Organoleptic assessment of extruded blends was carried out following the procedure described by Iwe (2001) by a twenty-member semi-trained panelist comprising of research scientist, technical staff, students, homemakers and private practitioners who consume acha and soybeans. The order of presentation of samples to the panel was randomized. Tap water was provided for each panelist to rinse their mouth in-between evaluations.

About 8 to 10 strands of extrudate samples in translucent petri dishes were served each panelist randomly in a two-session serving. Eighteen coded samples were presented to each panelist in each sensory evaluation session. The samples were evaluated for appearance, aroma, taste, texture and overall acceptability of the extruded samples. Each sensory attribute was rated on a 9-point Hedonic scale (1 = disliked extremely while 9 = liked extremely).

Table 1: Experimental layout

Independent variables	Levels of combinations				
	–2	–1	0	1	2
Feed Composition (%)	0	12.5	25	37.5	50
Feed Moisture (%)	15	20	25	30	35
Screw Speed (RPM)	90	120	150	180	210
Barrel Temperature (°C)	100	125	150	175	200

–2, –1, 0, 1, and 2 = Coded levels of combination

Statistical analysis

Data obtained were subjected to step-wise multiple regression analysis. The generalized regression model fitted was:

$$Y = b^o + b_1 x_1 + b_2x_2 + b_3x_3 + b_4x_4 + bnx_{12} + b_{22}x_{22} + b_{33}x_{23} + b_{44}x_{24} + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{14}x_1x_4 + b_{23}x_2x_3 + b_{24}x_2x_4 + b_{34}x_3x_4 + \acute{\varepsilon}$$

Where Y = objective response, X_1 = feed composition, X_2 = feed mixture content, X_3 = extruder screw speed; X_4 = extruder barrel temperature and $\acute{\varepsilon}$ = random error in which the linear, quadratic and interaction effects were involved.

The resulting models were tested for significant differences using analysis of variance (ANOVA) and coefficient of determination (R^2). Significant differences were accepted at 5% probability according to Jin *et al.* (1994) and Howard (1983). The R^2 of 0.6 was accepted for predictive purposes. The terms that were not significant were deleted from the model equation. For each significant model equation, response surfaces in three dimensional plots were generated using a computer statistical software (STAT SOFT INC.USA) version 5.0 (1984-1995) by holding the two variables with the least and second least effects on the response constant (centre points) and changing the other two variables.

Results and Discussion

Colour of extrudate

The response surface relating the feed composition, feed moisture content and extrudate colour is shown in Figure 1. The figure shows the significant ($p < 0.05$) dependence of extrudate's colour on feed composition. Decreasing the level of soybean flour substitution in the feedstock and lowering the feed moisture content below 20% resulted in decreased acceptable rating of extrudate colour. Minimum colour rating was observed at 12.5% feed composition, 30 % feed moisture content, 180 rpm screw speed at 175°C.

Table 2: Matrix transformation of the experimental design runs and extrusion conditions

	Feed composition	Feed moisture content	Screw speed	Barrel temperature		Die temp.
				1	2	
1	125	20	120	125	125	125
2	125	20	120	125	125	175
3	125	20	180	125	125	125
4	125	20	180	125	125	175
5	125	30	120	125	125	125
6	125	30	120	125	125	175
7	125	30	180	125	125	125
8	125	30	180	125	125	175
9	375	20	120	125	125	125
10	375	20	120	125	125	175
11	375	20	180	125	125	125
12	375	20	180	125	125	175
13	375	30	120	125	125	125
14	375	30	120	125	125	175
15	375	30	180	125	125	125
16	375	30	180	125	125	175
17	500	25	150	125	125	150
18	0	25	150	125	125	150
19	250	15	150	125	125	150
20	250	35	150	125	125	150
21	250	25	90	125	125	150
22	250	25	210	125	125	150
23	250	25	150	125	125	100
24	250	25	150	125	125	200
25	250	25	150	125	125	150
26	250	25	150	125	125	150
27	250	25	150	125	125	150
28	250	25	150	125	125	150
29	250	25	150	125	125	150
30	250	25	150	125	125	150
31	250	25	150	125	125	150
32	250	25	150	125	125	150
33	250	25	150	125	125	150
34	250	25	150	125	125	150
35	250	25	150	125	125	150
36	250	25	150	125	125	150

The figure shows that below 25% feed composition and 20% feed moisture content, colour rating of extrudates was below 4.0, implying rejection by panelists. On the other hand, increasing the moisture content with increased level of soybean substitution at the same barrel temperature and screw speed resulted in increased colour rating of extrudate samples. Maximal colour rating (7.7) on a nine-point Hedonic scale was recorded at 37.5% feed composition, 20% feed moisture content and 180 rpm screw speed at 125°C barrel temperature. These results are in agreement with earlier reports (Ramparsad *et al.*, 2003; Iwe and Ngoddy, 1998; Iwe et al., 2000). Iwe and Ngoddy (1998) had explained this phenomenom as being related to the activity of the amino groups in soy protein triggering off maillard reactions with the melt carbohydrate of acha. Hoskin and Dimick (1995) and Ramparsad *et al.* (2003) noted that continuous production of re-arranged products of maillard or non-enzymatic browning would result in complex set of reactions between amines and carboxyl compounds at elevated temperature which will decompose and eventually condense into insoluble brown pigments.

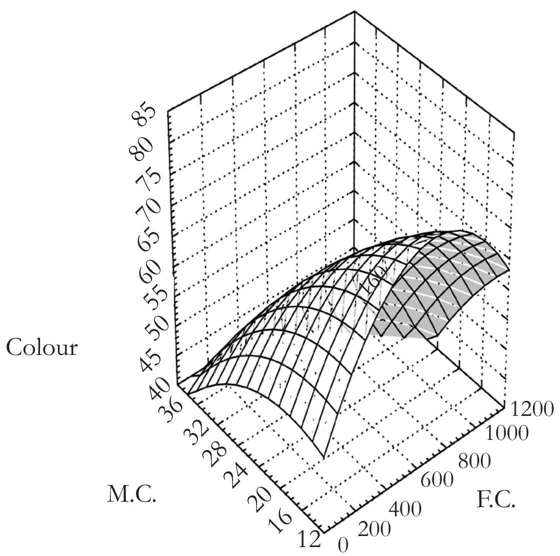

Fig. 1: Response surface plot of the effect of feed consumption (FC) and feed moisture content (MC) on extrudate colour

Aroma of extrudates

The results of the aroma of extrudates (Table 3) followed the trend of colour though its results were not significant (p > 0.05). It was therefore not used for predictive purpose.

Taste of extrudates

The result of the taste perception of extrudates is shown in Table 4. The results followed a similar trend with those of aroma. Increasing the level of soybean substitution in the blend beyond 37.5% resulted in decreased taste rating of the extrudates. However, like aroma, sole acha extrudate was not rated higher than blended extrudates except for the 50: 50 blend. Iwe (2001) reported a similar trend of results for potato/soybean flour blends. They reported that the taste of the samples closely resembled those of aroma, noting that taste and aroma interact and are physiologically and physically connected and depending on the respondents, identities could be confused. These observations are reflected in the results obtained from this study. Results from this work show that the highest contributor to aroma and taste of extrudates was the FC, and of lesser consequence, the SS and FMC. Further, Iwe (2001) explained that lower values for taste and aroma might be due to the non-full development and release of adequate heterocyclics with diverse aromas, due to low shear effect.

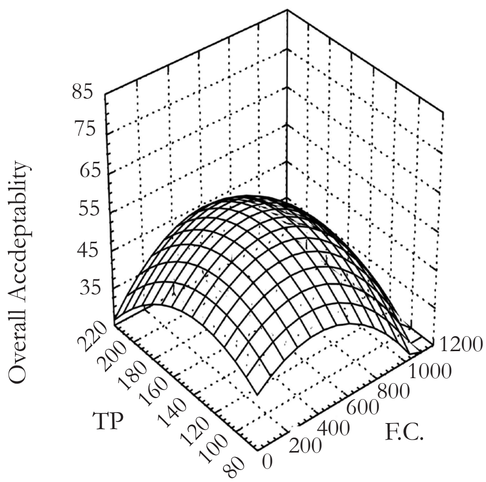

Fig. 2: Response surface plot of the effect of feed composition (FC) and barrel temperature (TP) on extrudate texture

The response surface plots for texture, feed composition and barrel temperature (Figure 2) show a falling ridge. This indicated that increased feed composition (FC) and barrel temperature (BT) resulted in decreased texture rating of extrudates. This trend was expected since high BT favoured greater gelatinization and starch degradation. It also encouraged higher vapour pressure resulting in increased expansion ratio (Halek and Chang, 1992).

Higher expansion, however, lowered extrudates smoothness but promoted its roughness. This resulted in low textural rating of extrudates. Increased soybean flour addition increased the protein content of the melt, thus decreasing expansion and increasing bulkiness leading to extrudates with smoother geometry. On the other hand, higher levels of acha flour encouraged greater expansion and less dense extrudate with increased roughness, leading to lower textural ratings. These observations are consistent with reports in literature. For instance, Rampersad (2003) reported that addition of pigeon pea flour to cassava flour above 5% resulted in hard extrudates that could be ground.

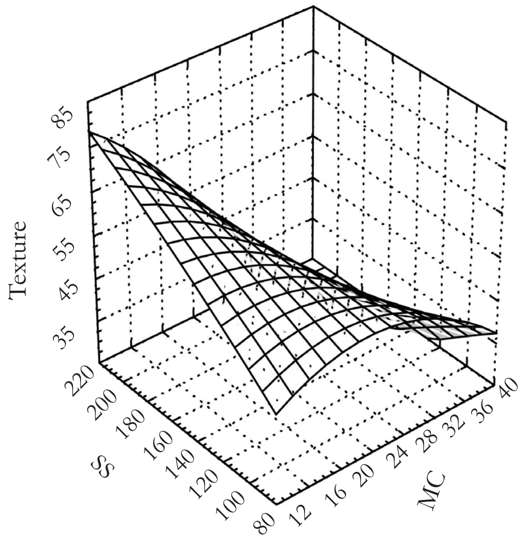

Fig. 3: Response surface plot of the effect of feed moisture content (MC) and screw speed (SS) on extrudate texture

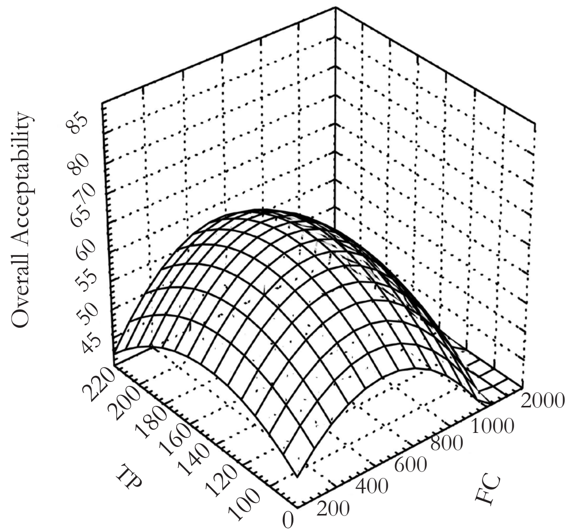

Fig. 4: Response surface plot of the effect of feed composition (FC) and barrel temperature (TP) on extrudate overall acceptability

Also, Areas (1992) reported that addition of protein to starch-rich flours above a certain level could change behaviour or transformation into a protein-type extrudate, where less expansion occurred; the products were harder, more resistant to water disruption and less appropriate for consumption. The results from this study indicated that increase in soybean flour above 25% FC resulted in decreased texture rating. Increasing the moisture content at lower SS lowered the shearing and extruder internal temperature resulting in bulkier extrudates with less cohesiveness (Halek and Chang, 1992).

This lowered texture rating. On the other hand, lowering FM levels at increased SS favoured increased extruder shear, with resultant higher temperature and less residence time, thus producing more expanded extrudates with increased crispness resulting in higher textural rating and acceptability (Figure 3). The results also show that reducing the FMC below 24% resulted in increased texture rating. The results obtained from this work show that the model for texture fitted the linear regression with predictive ability. The results show that the highest textural rating predicted by this work was 6.51 and this could be obtained at 25% soybean flour, 15% FMC, 150 rpm and 150°C BT.

Table 3: Estimated regression coefficients and annova for extrudates' aroma

Regression constants	Coefficients	Standard Error	P-values	R^2
FMC	– 3.97	0.77	0.54	.55
SS	– 3.61	0.13	0.57	
TP	– 3.90	0.13	0.49	
FC*FC	– 2.32	1.46	0.01	
FMC*FMC	– 0.20	0.00	0.89	
SS*SS	0.51	9.25	0.72	
TP*TP	0.61	1.33	0.72	
FC*FMC	1.06	7.09	0.30	
FC*SS	1.73	1.18	1.00	
FC*TP	1.71	1.18	0.10	
FMC*SS	4.00	0.00	0.63	
FMC*TP	5.69	0.00	0.48	
SS*TP	5.76	7.92	0.45	
FMC*SS*TP	– 5.33	3.06	0.57	
FC*FMC*SS*TP	– 2.34	3.14	0.04	
ANNOVA				
	DF	SS	MS	
REGRESSION	15	4.78377	0.31892	
RESIDUAL	20	3.95123	0.19756	
F 1.61427	SIGN. F.0.16			

Table 4: Estimated regression coefficients and annova for extrudate taste

Regression on constants	Coefficients 14.78377	Standard error	P-values	R2
FMC	1.050.87	0.80	0.89	0.55
SS	2.01	0.13	0.75	
TP	0.67	0.14	0.99	
FC*FC	– 2.07	1.51	0.01	
FMC*FMC	– 0.05	0.00	0.97	
SS*SS	– 1.25	9.57	0.38	
TP*TP	– 1.14	1.38	0.50	
FC*FMC	0.64	7.34	0.53	
FC*SS	2.37	1.23	0.03	
FC*TP	1.91	1.21	0.07	
FMC*SS	– 2.70	0.00	0.74	
FMC*TP	0.56	0.00	0.94	
SS*TP	0.40	8.20	0.96	
FMC*SS*TP	1.54	3.18	0.87	
FC*FMC*SS*TP	– 3.10	3.25	0.01	
ANNOVA				
	DF	SS	MS	
REGRESSION	15	4.78377	0.31892	
RESIDUAL	20	3.95123	0.19756	
F 1.61427	SIGN. F.0.16			

Overall acceptability of extrudates

The quadratic influence of FC and lowered BT resulted in decreased extrudate overall acceptability (Figure 4). However, above 100°C and increasing acha flour substitution in the blend, overall acceptability rating increased, forming a saddle. Experimental results showed that maximum acceptability (8.05) was obtained at 37.5% FC, 20% FMC, 180 SS and 125°C BT. However, highest predicted acceptability was 7.00 and this was obtained at 25% soybean flour substitution, 15% FMC, 150 rpm and 150°C BT. The results from organoleptic assessment of extrudates as reported in this study showed that FMC was the major factor determining extrudate acceptability.

Conclusion

The organoleptic evaluation showed that extrudates of mixtures of 37.5% soybean substitution had greater colour and taste appeal. Anuonye and Ekwu (2011) had reported that extrudate colour is one major factor that determines extrudate acceptability. This work shows that with extrusion, soybean could be substituted above the 30% already reported for cereal/legume mixes. It is therefore concluded that acceptable extrudates of cereal/soybean blends could be obtained at 35.7% soybean inclusion.

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