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The Effect of Extrusion Conditions on the Physicochemical Properties and Sensory Characteristics of Millet – Cowpea Based Fura

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Research Article

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ABSTRACT

A three-factor three level Response surface methodology central composite retortable design (CCRD) was adopted to study the effect of feed composition (X_1), feed moisture content (X_2) and screw speed (X_3) on proximate compositin, amino acid and sensory evaluation during extrusion of pearl millet and cowpea flour mixtures for the purpose of fura production. The mean observed value of protein for the fura extrudates ranged from 11.2 – 16.8%. Analysis of variance indicates that linear and quadratic effects significantly ($P<0.05$) affected the protein content of fura extrudates as expected. The mean value of lysine for the extrudates ranged from 5.1 - 6.6g/100g protein and the methionine content ranged from 1.3 - 3.8g /100g protein. The regression models fitted to the experimental data showed high coefficients of determinants with R^2 = 0.96, 0.94, 0.94, 0.85 and 0.80 for protein (CHON), carbohydrate (CHO), fat (FAT), ash (ASH) and water (HOH) respectively. The R^2 = were 0.90, 0.85, 0.86, 0.92, 0.88, 0.85 and 0.93 for lysine, i/leucine, leucine, valine, methionine – cystine, threonine and tryptophan respectively. The coefficients shows good fit. The importance of process variables on system parameters and physical properties could be ranked in the following order: Feed Composition (X_1)>Feed Moisture (X_2)>Screw Speed (X_3). The optimum values obtained for feed composition, feed moisture and screw speed are 36.5% cowpea level, 22.3% feed moisture content and 186.7 rpm

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respectively. The corresponding optimum values of lysine, protein content, expansion ratio and bulk density are 6.6g/100g protein, 16.6%, 2.8 and 0.52 Kgm^{-3} respectively. The data obtained from the study could be used for control of product characteristics and possible projection for the commercial production of fura or any enriched protein based food from the blends pearl millet and cowpea.

Keywords: Millet; cowpea; extrusion; fura; protein; amino acid; feed composition.

1. INTRODUCTION

Fura is a semi-solid dumpling cereal based meal (Jideani et al., 2002). It is produced principally from millet or sorghum flour blended with spices, compressed into flour balls and boiled for 30 minutes (Jideani et al., 2002). The mode of processing may vary slightly among different communities, but the basic ingredient remains the same. The product lacks process specifications governing composition, ingredients, additives and shelf life. Processing has remained a home-based or artisanal activity that is carried out with rudimentary equipment and techniques. Depending on the community fura is usually consumed after mashing with *nono* (local yoghurt) or mashed in water before consumption in the form of porridge (Filli et al., 2010).

Extrusion technology is one of the contemporary food processing technologies applied to foods (Harper and Jansen, 1985) and can be applied to mitigate the problems associated with processing of traditional cereal based products in terms of improvement in functionality, physical state and shelf stability. It offers many advantages over other process technologies in terms of, preparation of ready – to – eat foods of desired shape, size, texture and sensory characteristics at relatively low processing cost (Sumathi et al., 2007). Extrusion is a powerful food processing operation, which utilizes high temperature and high shear force to produce a product with unique physical and chemical characteristics (Pansawat et al., 2008). Excess water is not available in extrusion and the starch granules do not swell and rapture, as in classical gelatinization, but are instead mechanically disrupted by high shear forces and drastic pressure changes resulting in disappearance of native starch crystallinity, plasticization, expansion of the food structure, reduced paste viscosity, loss of water holding, increased reconstitutability of the extrudate, softer product texture and changes in colour (Onyango et al., 2004).

Pearl millet (*Pennisetum glaucum* [L.] R.Br.), is grown extensively in the dry areas of western and southern India and along the West African sub region where it is used as food for an estimated 400 million people (Hoseney et al., 1992). Pearl millet is an important cereal, contributing to the calorie and protein requirements of people in the semi-arid tropics (SAT). It is grown mostly in regions of low rainfall and is capable of withstanding adverse agro climatic conditions. More than 80% of the production is used for human consumption, particularly in the SAT region of Africa and Asia. Several food preparations are made from pearl millet in Africa and India (Vogel and Graham, 1979). Many countries in the developing world have become heavily dependent on imported staple foods which conditions for local production are poor or non-existent making the demand for traditional based products not attractive. In Nigeria pearl millet has remained as a staple food in the form of gruels for the poor especially in the northern part of the country. Limited efforts has been made by the scientific community to diversify its food uses by the application of modern technology to upgrade the traditional methods of contemporary food processing technology for millet utilization, despite the advancement in scientific research. The application of a contemporary technology for the traditional products in our fast growing social environment can enhance the development and acceptability of indigenous traditional based foods. Filli et al. (2010) reported that the extrusion cooking of 'fura' from blends of millet – soybean constituted a great improvement on the shelf stability of traditional fura that is usually at high moisture content of between 60 - 75% which readily deteriorates on storage at room temperature when compared with fura extrudates obtained that had moisture content less than 7 g/100g which did not require refrigeration for storage.

The cowpea is indigenous to Africa which is consumed in various forms in different African countries. The cowpea is probably the most popular grain legume in West Africa. Cowpeas like other starchy legumes are an important source of protein and B vitamins in developing countries. The common bean is an important food on a world basis and provides significant amounts of proteins, calories, minerals and vitamins to many human populations. Beans are important constituents of the diet and provide economical sources of proteins and energy. They have also been indicated to show apparent benefits of soluble fiber in preventing heart disease. However, the long cooking time required and presence of anti-nutritional substances in the whole bean limit their use. In view of the increasing population growth in developing countries, the production and utilization of grain legumes will have to be increased. Improved productivity, availability and utilization of grain legumes in the diet of people can help to alleviate the protein-calorie malnutrition problem prevalent in most developing sub Sahara African countries. Although the chemical composition of cowpea has been reported in some publications (Mwasaru et al., 1999), little information is available on the extrusion of millet – cowpea flour mixtures. A review of the available literature reveals that more effort has been invested in the nutritional and chemical evaluation of these legumes rather than applications of processing technology to it. According to Gujska et al. (1996), extrusion cooking has good potential for making desirable forms of beans economically available in developing countries. Nontraditional methods of processing cowpea such as thermal extrusion are needed for expanded utilization of dry edible beans. It is well known fact that addition of legumes to cereals increases both content and quality of protein mix (Obatolu, 2002). Wu et al. (2010) reported the inclusion of flaxseed to maize to improve the protein content and quality. Therefore, with respect to lysine and the sulphur containing amino acids, legume and cereal proteins are nutritionally complimentary. The inclusion of cowpea as a basic ingredient in producing fura through extrusion can improve its physical state and functionality. The poor quality of protein and high viscosity of traditional fura gruel makes it difficult to consume enough quantity to meet both energy and protein requirements. Nkama and Filli (2006) and Filli and Nkama (2007), reported that extruded fura from cereal legume blends provided consumers with a fast, easy way to prepare nutritious fura which is similar to the traditional fura. Extrusion enhanced the water uptake of the product, with reduction in viscosity which is an indication of concomitant increase in nutrient density, but the process method was not optimized.

Response surface method (RSM) is a statistical – mathematical tool which uses quantitative data in an experimental design to determine, and simultaneously solve multivariate equations, to optimize processes or products (Sefa – Dedeh et al., 2003); it has been successfully used for developing, improving and optimizing processes (Wang et al., 2007).

The objectives of this work was to study the effect of process conditions (feed composition, feed moisture and screw speed) on the physicochemical properties of fura from pearl millet and cowpea flour mixtures using response surface methodology.

2. MATERIALS AND METHODS

2.1 Flour Preparation from Pearl Millet

The process of flour preparation consists of dry cleaning of millet i.e. winnowing using an aspirator Vegvari Ferenc (OB125, Hungary). The kernels were thereafter dehulled after mild wetting of the grain using a rice dehuller (India) at the Jimeta Main Market, Yola, Nigeria. After dehulling, the grains were washed and then dried in a Chirana convection oven model (HS 201A, Czech Republic) at 50℃ for 24 h to 14% moisture content. The dried grain was milled using a Brabender roller mill (OHG DUISBURG model 279002, Germany) equipped with a 150 µm screen.

2.2 Flour Preparation from Cowpea

The cowpea was steeped in tap water at 28℃ for a period of 30 minutes to loosen the seed coat in a plastic bowl. This was followed by decorticating using pestle and mortar made of wood. The kernels of decorticated mass was dried at 50℃ to approximately14% moisture content in a Chirana convection oven model (HS 201A, Czech Republic) for 24 hours. The grain mass was winnowed to remove the hulls and other lighter materials using an aspirator Vegvari Ferenc (OB125, Hungary). The winnowed cowpea kernels were ground in a laboratory disc mill (made in Nigeria) to fine flour. The flour obtained was sieved using a 150µm screen size Brabender (OHG Duisburg type, Germany) and the underflow was used for extrusion after blending with millet.

2.3 Spice Preparations

Kimba (Negro pepper) and ginger were sorted and cleaned manually before drying in a Chirana convection oven model (HS 201A, Czech Republic) at 60℃ for five h. The seeds were then milled by pounding using pestle and mortar. The ground mass was sieved using a 150 µm screen size.

2.4 Blend Preparations and Moisture Adjustment

Millet flour (M_F) and cowpea flour (C_F) were mixed at various weight ratios, and the total moisture contents of the blends adjusted to the desired values with a mixer as described by Zasypkin and Tung-Ching Lee, (1998). Weights of the components mixed were calculated using the following formula:

$$C_{CF} = \frac{[r_{CF} \times M \times (100 - w)]}{[100 \times (100 - w_{CF})]} \quad (1)$$

$$C_{MF} = \frac{[r_{MF} \times M \times (100 - w)]}{[100 \times (100 - w_{MF})]} \quad (2)$$

$$W_X = M - C_{CF} - C_{MF} \quad (3)$$

C_{CF} and C_{MF} are the masses of cowpea flours (C_F) and millet flour (M_F), respectively, r_{CF} or r_{MF} are respective percentages of either cowpea flours (C_F) or millet flour (M_F) in the blend, d.b.; (r_{CF} + r_{MF} = 100%); *M* is the total mass of the blend; *w*, the moisture content of the final blend, percentage wet weight basis (w.w.b.); W_X is the weight of water added; and w_{CF} and w_{MF} are the moisture contents of C_F and M_F , respectively. The blends were mixed in a plastic bowl with the addition of the spices (Kimba & Ginger) at 1% level based on traditional formulation; and the whole mass packed in polyethylene bags which was kept in the refrigerator overnight to allow moisture equilibration. The samples were however brought to room temperature before extrusion process.

2.5 Experimental Design and Data Analysis

A three-factor three levels central composite rotatable composite design (CCRD) (Box and Hunter, 1957) was adopted to study the effect of feed composition (X_1), feed moisture content (X_2) and screw speed (X_3) on the expansion ratio, bulk density, proximate composition and amino acid profile during extrusion of pearl millet and cowpea flour mixtures for fura production. The outline of the experimental design is outlined in (Table 1).

Table 1. Independent Variables and Levels used for Central Composite Rotatable Design[1]

Variable	Symbol (X_i)	Coded variable level (x_i)				
		-1.68(∝)	-1	0	1	1.68(∝)
Feed composition (%)	X_1	3.2	10	20	30	36.8
Feed moisture (%)	X_2	16.6	20	25	30	33.4
Screw speed (Rpm)	X_3	116	150	200	250	284

[1] *Transformation of coded variable (x_i) levels to uncoded variables (X_i) levels could be obtained from $X_1 = 10x_1 + 20$; $X_2 = 5x_2 + 25$; $X_3 = 50x_3 + 200$*

The levels of each variables were established according to literature information and preliminary trials. The outline of the experimental layout with the coded and natural values are presented in (Table 2). Homogeneous variances or homoscedasticity is a necessary pre-requisite for (linear) regression models. Therefore, a reduction in variability within the objective response (dependent variables) was carried out by transforming the data to standardized scores ($z = \frac{x - \bar{x}}{s}$ where x = dependent variable of interest; $\bar{x}$ = mean of dependent variable of interest and s = standard deviation). For each standardized scores, analysis of variance (ANOVA) was conducted to determine significant differences among the treatment combinations. Also, data were analyzed using multiple regression procedures (SPSS, 2008). A quadratic polynomial regression model was assumed for predicting individual responses (Wanasundara and Shahidi, 1996). The model proposed for each response of Y was:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3 \tag{4}$$

where Y = the response X_1 = Feed Composition, X_2 = Feed Moisture, X_3 = Screw Speed, b_0 = intercepts, b_1, b_2, b_3 are linear, b_{11}, b_{22}, b_{33} are quadratic and b_{12}, b_{13} and b_{23} are interaction regression coefficient terms. Coefficients of determination (R^2) were computed. The adequacy of the models was tested by separating the residual sum of squares into pure error and lack of fit. For each response, response surface plots were produced from the fitted quadratic equations, by holding the variable with the least effect on the response equal to a constant value, and changing the other two variables.

Table 2. Experimental design of extrusion experiment in their coded form and natural units[1, 2]

Design point	Independent variables in coded form			Experimental variables in their natural units		
	(X_1)	(X_2)	(X_3)	(X_1)	(X_2)	(X_3)
1.	-1	-1	-1	10	20	150
2.	-1	+1	-1	10	30	150
3.	-1	-1	+1	10	20	250
4.	-1	+1	+1	10	30	250
5.	+1	-1	-1	30	20	150
6.	+1	+1	-1	30	30	150
7.	+1	-1	+1	30	20	250
8.	+1	+1	+1	30	30	250
9.	-1.68	0	0	3.2	25	200
10.	+1.68	0	0	36.8	25	200
11.	0	-1.68	0	20	16.6	200
12.	0	+1.68	0	20	33.4	200
13.	0	0	-1.68	20	25	116
14.	0	0	+1.68	20	25	284
15.	0	0	0	20	25	200

[1]Duplicate tests at all design point except the centre point (0, 0, 0) which was carried out five times and the result averaged. [2]Experiment was carried out in randomized order; (X_1) = feed composition (%), (X_2) = feed moisture (%) and (X_3) = Screw speed (rpm)

2.6 Extrusion Exercise

Extrusion cooking was performed in a single screw extruder, model (Brabender Duisburg DCE-330, Germany) equipped with a variable speed D-C drive unit, and strain gauge type torque meter. The screw has a linearly tapered rod and 20 equidistantly positioned flights. The extruder was fed manually through a screw operated conical hopper at a speed of 30 rpm which ensures the flights of the screw filled and avoiding accumulation of the material in the hopper. This type of feeding provides the close to maximal flow rate for the selected process parameters (constant temperature, constant die and screw geometry but with three variable screw speeds) and three designed feed composition and feed moisture contents. A round channel die with separate infolding heater was used. The die used was a cone shaped channel with 45 degrees entrance angle, a 3 mm diameter opening and 90 mm length. The screw was a 3:1 compression ratio. The inner barrel is provided with a grooved surface to ensure zero slip at the wall. The barrel is divided into two independent electrically heated zones that is (feed end and central zone). There is a third zone at the die barrel, electrically heated but not air cooled. The extruder barrel has a 20 mm diameter with length to diameter ratio (L:D) of 20:1. Desired barrel temperature was maintained by a circulating tap water controlled by inbuilt thermostat and a temperature control unit. The feed material was fed into a hopper mounted vertically above the end of the extruder which is equipped with a screw rotated at variable speed. The rotating hopper screw kept feed zone completely filled to achieve a 'choke fed' condition. Experimental samples were collected when steady state was achieved that is when the torque variation of ±0.28 joules (Nm) or about (0.5%) of full scale (Likmani et al.,1991). The extrusion process consisted of 15 individual runs and was conducted randomly.

2.7 Expansion Ratio (puff ratio)

Expansion ratio can be of two indices, diametral and longitudinal as described by Sopade and Le Grys (1991). Diametral expansion is defined as the diameter of the extrudate whilst longitudinal expansion is defined as the length per unit dry weight. The diameter was determined after cooling of the extrudate, 10 samples were assessed for each extrudate and for each sample; diameters at three different positions were taken using vernier calipers and the result averaged. Expansion ratio was expressed as the diameter of the extrudate to the diameter of the die.

2.8 Bulk Density of Extrudates

The bulk density (ρ) of extrudates was calculated using the methods described by Qing-Bo et al. (2005) as follows:

$$\text{Density } (\rho) = (4 \times \dot{m}) / (\pi \times D^2 \times L) \quad (5)$$

where $\dot{m}$ is the mass of extrudate with length L and diameter D. The samples were randomly selected and replicated 10 times and the average result value taken.

2.9 Moisture Analysis

Moisture contents of raw and extrudates were determined as described by (AOAC, 1984). Triplicate determinations were carried out and the result averaged.

2.10 Crude Fat Determination

Crude fat of samples was determined using soxhlet fat extraction system (AOAC, 1984).

2.11 Crude Protein Determination

Protein content was determined by Kjeldahl Method (AOAC, 1984). Triplicate determinations were carried out and the result averaged.

2.12 Ash Determination

Ash was determined by the method of AOAC (1984). Triplicate determinations were carried out and the result averaged.

2.13 Determination of Carbohydrates

The percentage carbohydrate was determined by difference (Egan et al., 1981).

2.14 Amino Acid Analysis

The method of Sotelo et al. (1994) was used in determining the amino acid content of the extrudates. One gram of sample was dissolved in 20 ml of 6N HCL. This was then poured into a hydrolysis tube with screw cap and hydrolyzed for 22 hour under a nitrogen atmosphere. The acid was evaporated using a rotary evaporator and residue washed three times with distilled water. The extracted sample was dissolved in 1ml acetate buffer of pH 3.1. After dilution to a known volume, the hydrolysate was transferred into a Beckman system (model 6300) high performance amino acid analyzer. Amino acid scores were calculated as gram per 100 gram protein (g/100g protein). Triplicate determinations were carried out and the result averaged.

2.15 Sensory Evaluation

One hundred gram of pulverized extruded fura was added to 500 ml of water in a 1000ml beaker each for all the 15 extruded fura samples, 100g sugar was added to each of the preparations based on traditional recipe and these samples were used for sensory evaluation test. Twenty untrained member judges (28 – 45 year old males and females) were employed. The prepared samples were placed on tables inside a plastic bowl provided with individual booths. The panelists were to taste and swallow each of the fura gruel and rinse their mouth with tap water between samples. The panelists were familiar with fura and were asked to indicate their opinion on four sensory attributes, namely the colour, flavour, texture (gritness) and the overall acceptability using Hedonic scale rating of 9 = liked extremely to 1 = disliked extremely. Acceptability scores using the mean of the observations were recorded.

3. RESULTS AND DISCUSSIONS

3.1 Model Description

Studies was conducted using the response surface method in modeling the chemical composition and amino acid profile of extruded millet – cowpea based fura as affected by the process variables feed composition level of cowpea added to millet (X_1), feed moisture (X_2), and screw speed (X_3). The independent and dependent variables were fitted to the second – order model equation and examined for the goodness of fit. The analysis of variance were performed to evaluate the lack of fit and the significance of the linear, quadratic and interaction effects of the independent variables on the dependent variables. The lack of fit test is a measure of the failure of a model to represent data in the experimental domain at which points were not included in the regression (Varnalis et al., 2004). Coefficient of determinant, R^2, is defined as the ratio of the explained variation to the total variation and is a measure of the degree of fit (Singh et al., 2007). It is also the proportion of the variability in the response variables, which is accounted for by the regression analysis (Mclaren et al., 1977). When R^2 approaches unity, the better the empirical model fits the actual data. The smaller is R^2, the less relevant the dependent variables in the model have in explaining the behavior of variation (Myers and Montgomery, 2002). It is suggested that for good fit model, R^2 should be at least 80%. The results showed that the model for all the response variables were highly adequate because they have satisfactory levels of R^2 of more than 80% and that there is no significant lack of fit in all the response variables. If a model has a significant lack of fit, it is not a good indicator of the response and should not be used for prediction (Myers and Montgomery, 2002). We may probably conclude that the proposed models approximates the response surfaces and can be used suitably for prediction at any values of the parameters within experimental range.

3.2 Expansion Ratio (ER) and Bulk Density (BD)

The expansion characteristic of extruded snacks is important especially for the acceptability by the consumer. Most extruded snack products are expected to have a puffed structure. Property index such as expansion ratio and density may be used to quantify this structure. Sectional expansion is a measure of sectional expansion area of fura extruded. The mean values of expansion ratios (ER) and bulk density (BD) of the extruded millet – cowpea fura are shown in (Table 3). From the result it shows that lowest value for the ER was 1.6 and the highest value was 4.3 representing (20% cowpea, 33.4 % feed moisture and 200 rpm screw speed) and (20% cowpea, 25 % feed moisture and 284 rpm screw speed) respectively. It appears that ER decreased with increasing moisture content. The expansion ratio is a vital factor for instant products because of the short hydration time for which this study was intended. Bulk density has been linked with the expansion ratio in describing the degree of puffing in extrudates. The observed values for the bulk density (BD) varied from 0.1 – 0.4 kgm^{-3} for both samples (10% cowpea, 20 % feed moisture and 250 rpm screw speed; 20% cowpea, 25 % feed moisture and 284 rpm screw speed) and (20% cowpea, 33.4 % feed moisture and 200 rpm screw speed) respectively. Response surfaces analysis was applied to the experimental data and a quadratic polynomial regression response surface model Eq. (4) was fitted to all the response parameters. The multiple regression equation representing the effect of processing variables on ER and BD is given by the second order model; the models explained the variability in the experimental data obtained. The sign and magnitude of coefficients in equations (6) and (7) indicate the effect of parameters on the response. A negative sign of coefficient indicates a decrease in the response when the level of the parameter is increased, while a positive sign indicates increase in the response with increase in the level of the parameter:

$$ER = 0.25 + 0.01X_1 – 0.72X_2 + 0.56X_3 - 0.05X_1^2 - 0.13X_2^2 + 0.54X_3^2 + 0.11X_1X_2 - 0.23X_1X_3 - 0.28X_2X_3 \quad (6)$$

$$BD = 0.19 + 0.09X_1 + 0.87X_2 - 0.53X_3 - 0.07X_1^2 + 0.21X_2^2 - 0.42X_3^2 + 0.08X_1X_2 + 0.07X_1X_3 + 0.08X_2X_3 \quad (7)$$

where X_1 refers to coded value of feed composition, X_2 refers to the coded value of feed moisture content, X_3 refers to coded value of screw speed.

Analysis of variance (table not shown) indicates that the linear effects of the independent variables (feed moisture content and screw speed) significantly ($P<0.05$) affected the expansion ratio (Table 3). The model of the regression equation showed good fit with R^2 = 0.92 for ER. This suggests a very good fit to the experimental data and the model could be used to describe the process. The negative significant ($P<0.05$) effect of linear coefficients of feed moisture indicated that this variable influenced the ER in reverse order. This observation is in agreement with Kokini et al. (1991) who reported that moisture plays a key role in the mechanism responsible for expansion. Harmann and Harper (1973) postulated two factors in governing expansion: (a) dough viscosity, and (b) elastic force (die swell in the extrudate. The elastic forces will be dominant at low moisture and temperature. The bubble growth, which is driven by the pressure difference between the interior of the growing bubble and atmospheric pressure resisted primarily by the viscosity of the bubble wall, will usually dominate the expansion at high moisture content and high temperature (Panmanabhan & Bhattacharyya, 1989). A viscoelastic melt in a food extruder expands due to flashing of moisture at the die exit. The expansion process can be described as nucleation in the die, extrudate swelling immediately beyond the die, followed by bubble growth and collapse (Kokini et al., 1991). Increased water content in the melt would soften the amylopectin molecular structure and reduce its elastic characteristics to decrease diametral expansion (Alvarez-Martinez et al., 1988). Feed moisture has been identified as the main factor affecting extrudate expansion and density (Gujral et al., 2001). Extrudates can expand in both the cross-sectional (diametrical) direction and the longitudinal direction (Launary and Lisch, 1983). A porous, expanded, sponge-like structure is formed inside extrudates as a result of many tiny steam bubbles created by the rapid release of pressure after exiting the die (Conway, 1971). Increased feed moisture during extrusion would provoke change in the amylopectin molecular structure of the material reducing the melt elasticity thus decreasing the expansion and increasing the density of extrudate (Qing-Bo et al., 2005). The extrusion variable screw speed indicated significant ($P<0.05$) effect on the ER positively. The quadratic effect of the variable screw speed significantly ($P<0.05$) influenced the ER. Seker, (2005) reported that increasing screw speed improved sectional expansion and reduced bulk density of extrudate during extrusion of soybean protein and corn starch. The extrusion variables feed composition i.e. level of cowpea and the feed moisture had negative quadratic effect on the ER but it was not significant ($P<0.05$). There was marginal increase in ER as cowpea flour was added. Though some workers have reported increase in levels of whole bean flour resulted in a significant decrease in expansion. They attributed the decrease as a result of interference of fibre with bubble formation, this is on the basis that fibre can rupture cell walls and prevent air bubbles from expanding to their maximum potential. The disagreement of our result with this report may be attributed to that fact that we used dehulled flour for our studies which resulted in reduced fibre content. Ainsworth et al. (2007) reported increased expansion of snack produced from mixtures of corn and dehulled chickpeas flours.

The BD regression equation coefficients for millet – cowpea based fura is presented in (Table 5). The expansion ratio (BD) was influenced significantly by linear and quadratic terms significantly ($p<0.05$). The interaction term effect did not affect BD significantly ($p>0.05$). The coefficient of determinant R^2 for the BD was 0.94, which shows good fit for the model in describing the effects of feed composition, feed moisture and screw speed on the BD. It was observed that an increase in screw speed resulted in an extrudate with lower density. Higher screw speeds may be expected to lower melt viscosity of the mix which can increase the elasticity of the dough, resulting in a reduced extrudate density. Increasing screw speed tends to increase the shearing effect, this causes protein molecules to be stretched farther apart, weakening bonds and resulting in a puffer product. Longer residence times associated with low screw speeds may be responsible for decreased ER, which suggests that such materials require more shear for a better developed dough, resulting in better expansion. Singh et al. (2007) reported decrease in ER with increase in feed moisture of rice – pea grits extrudates. Extruded snacks possess the typical texture of puffed, light and crispy. Some physical properties of extruded snack were reported including bulk density of 48-64 g/L, 50-160 g/L (Moore, 1994) and 59 10g/L (Boonyasirikool et al., 1996) and expansion ratio of 3.1 - 3.8 (Mohamed, 1990) and 4.03 (Boonyasirikool et al., 1996). These relationships have been reported elsewhere for corn and wheat based snacks (Ilo et al., 1999).

Table 3. Experimental design and observed values of expansion ratio (ER), bulk density (BD) and proximate composition of extruded millet-cowpea based fura

Independent variables[b]			Dependent variables[a]						
X_1	X_2	X_3	ER(Ratio)	BD(Kgm^{-3})	CHON	FAT	FAT	ASH	HOH
10	20	150	2.8 ± 0.7	0.2 ±0.03	12.7±0.3	3.2±0.3	3.2±0.3	1.8±0.3	5.4±0.3
10	30	150	1.7 ± 0.8	0.3 ± 0.05	12.9±0.5	3.2±0.3	3.2±0.3	1.8±0.1	5.2±0.2
10	20	250	4.2 ± 1.0	0.1 ±0.02	12.9±0.2	3.2±0.7	3.2±0.7	1.7±0.1	5.2±0.3
10	30	250	2.3 ± 0.4	0.2 ± 0.08	12.7±0.5	3.2±0.3	3.2±0.3	1.8±0.2	5.5±0.4
30	20	150	2.8 ± 0.3	0.2 ±0.06	15.8±0.5	1.7±0.2	1.7±0.2	1.9±0.2	5.0±0.3
30	30	150	2.2 ± 0.2	0.3 ±0.02	15.8±0.8	1.7±0.4	1.7±0.4	1.9±0.2	5.1±0.4
30	20	250	3.5 ± 0.3	0.1 ±0.03	15.7±0.4	1.7±0.4	1.7±0.4	2.0±0.2	5.7±0.7
30	30	250	2.0 ± 0.8	0.3 ±0.01	15.8±0.5	1.5±0.4	1.5±0.4	2.0±0.5	5.3±0.2
3.2	25	200	2.0 ± 0.7	0.3 ±0.01	11.2±0.3	3.6±0.3	3.6±0.3	1.7±0.2	5.7±0.4
36.8	25	200	2.3 ± 0.6	0.3 ±0.01	16.8±0.5	2.0±0.3	2.0±0.3	2.0±0.2	5.3±0.3
20	16.6	200	2.7 ± 0.7	0.2 ±0.01	14.5±0.7	2.9±0.3	2.9±0.3	1.8±0.3	5.3±0.5
20	33.4	200	1.6 ±0.5	0.4 ±0.02	14.3±0.3	2.9±0.7	2.9±0.7	1.8±0.3	5.6±0.3
20	25	116	2.4 ±0.7	0.3 ±0.02	14.3±0.8	3.0±0.4	3.0±0.4	1.9±0.2	5.3±0.7
20	25	284	4.3 ± 0.6	0.1 ±0.04	14.4±0.9	2.7±0.3	2.7±0.3	1.8±0.1	5.3±0.2
20	25	200	2.3 ± 0.9	0.2 ±0.03	14.3±0.5	2.9±0.3	2.9±0.3	1.9±0.3	5.5±0.2

bX1 = Feed composition (%); X2 = Feed moisture (%) and X3 = Screw speed (rpm). CHON = Protein; FAT = Fat; CHO = Carbohydrate; ASH = Ash; HOH = Water. aValues are means and ± standard deviation of triplicate determinations.

3.3 Proximate Composition

The mean result of proximate composition of fura extrudates is shown in (Table 3). From the result it shows that the mean observed value of protein for the fura extrudates ranged from 11.2 – 16.8 % suggesting proportional increase in protein content with fortification of pearl millet with cowpea flour. Protein content was measured as nitrogen (N x 6.25); hence the apparent protein content was not affected by extrusion temperature, as nitrogen is not affected by heat treatment (Pelembe et al., 2002). The average value of the fat content for the fura extrudates showed a general low values which ranged from 1.5 – 3.6 %. The mean observed values for the carbohydrates relatively remained within a narrow range of 74.1 – 77.3 %. The carbohydrate level relatively remained high as expected as cowpea is equally high in carbohydrates. The ash content showed that it remained within a narrow range of 1.7 – 2.0 %. Regression coefficients for objective responses for extruded fura composition are presented in (Table 5). Analysis of variance (table not shown) indicates that linear and quadratic effects significantly ($P<0.05$) affected the protein content of fura extrudates as expected. The result indicated that increasing the amount of cowpea flour resulted in linear increase in the protein contents of extruded fura. The influence of feed moisture and screw speed independent variables linear terms indicated negative effects on the protein content but was not significant ($P<0.05$). This negative effect suggests that increasing the feed moisture and screw speed resulted in decreased amount of protein content in the extrudate. This reduction in protein content may be attributed to the complex nature of interactions between extruder conditions, these changes might not be related to a single factor. Hence, the role of feed moisture, screw speed and other interactions of other parameters on the protein nutritional value is a point that obviously needs further investigation. The quadratic effect of feed composition showed significant ($P<0.05$) influence on the protein content. The effect of square term on the protein content was a positive effect. However, there was no significant effect observed by the interaction terms on the protein content of extrudates. The regression analysis for the carbohydrate indicated that the linear effect of feed composition affected the carbohydrate contents significantly ($P<0.05$). This result indicates that increase in the amount cowpea flour translates to lower values of carbohydrates of the fura extrudates. The linear effect of feed moisture and screw speed indicated insignificant ($P<0.05$) effect on the carbohydrate content of extrudates. Experimental design points 5, 6, 7, 8, & 10 have attained the least protein contents if compared with the FAO/WHO/UNU (1985) minimum protein level of 15.7 % recommended for supplementary mixtures of protein (Table 3).

The carbohydrate and fat content was significantly ($P<0.05$) influenced by the linear term. This influence was negative effect suggesting that increase in the amount of cowpea flour resulted in the decrease in the carbohydrates and fat contents of fura extrudates. This effect is expected as millet flour has higher amounts of carbohydrates and fats than cowpea (result not shown). It appears that increasing the level of cowpea flour resulted in decreased fat content; as both millet and cowpea are low in fat content. In addition it may be attributed to the fact that cowpea is relatively lower in fat than millet (result not shown). An implication of this low fat content is the need for fat fortification in millet – cowpea mixtures, to meet up with the minimum fat requirement of 6% for complementary formulations (Mitzner et al., 1984). However, the low energy content as a result of low fat can be compensated for by the reduced viscosity due extrusion, therefore allowing a high level of solid matter in the gruel. The linear effect of feed composition indicated significant ($P<0.05$) influence on the ash content. The effect was a positive, suggesting increase in the ash content as cowpea flour was added to millet flour. Though generally the amount of ash was so low in the formulations of this study, Obatolu (2002) similarly observed low ash contents of mixtures of cereal/legume blends. This could be explained probably because cowpea flour relatively has more amount of ash content when compared with millet flour (result not shown).

The regression models fitted to the experimental data showed high coefficients of determinants with R^2 = 0.96, 0.94, 0.94, 0.85 and 0.80 for protein (CHON), carbohydrate (CHO), fat (FAT), ash (ASH) and water (HOH) respectively. This indicates that the regression models can be considered adequate to study response tendencies. Among the three extrusion variables feed composition was analyzed to be most important factor affecting the proximate composition of fura extrudates.

The major constituents of pearl millet flour are carbohydrate (70.8%) and protein (10.8%) (result not shown). This study has shown increase in the protein content of millet as a result of fortification with cowpea flour. In addition legume proteins are rich sources of lysine and threonine (Alonso et al., 2000a). From the view point of protein content, the basis of advocating cereal – based complementation as a method of improving the protein content of cereal – based traditional foods is justified by the results of this study. Several workers have also reported marked improvements in the protein content of cereals when fortified with legumes (Lazou and Krokida, 2010).

3.4 Amino Acid Profile

The mean result of amino acid profile of the fura extrudates is presented in (Table 4). As already known, lysine and methionine are generally limiting in cereals and legumes, respectively. From the result it shows that the mean observed value of lysine for the extrudates ranged from 5.1 - 6.6g /100g protein; representing (feed composition 3.2% cowpea, 25% feed moisture content and 200rpm screw speed) and (36.8% cowpea, 25% feed moisture content and 200rpm screw speed) respectively. The methionine content ranged from 1.3 - 3.8g /100g protein; representing (36.8% 25% and 200rpm screw speed) and (feed composition 3.2% cowpea, 25% feed moisture content and 200rpm screw speed) respectively (Table 4). Response surfaces analysis was applied to the experimental data and a quadratic polynomial regression response surface model Eq. (4) was fitted to all the response parameters. The multiple regression equation representing the effect of processing variables on amino acid profile is given by the second order model; the models explained the variability in the experimental data obtained. The sign and magnitude of coefficients in equations (8, 9, 10, 11, 12, 13 and 14) for the amino acids content of fura samples indicating the effect of process variables on their responses. A negative sign of coefficient indicates a decrease in the response when the level of the parameter is increased, while a positive sign indicates increase in the response with increase in the level of the parameter:

$$LYSINE = 0.15 - 0.67X_1 - 0.0.12X_2 - 0.22X_3 - 0.47X_1^2 + 0.02X_2^2 + 0.26X_3^2 - 0.13X_1X_2 + 0.2X_1X_3 + 0.33X_2X_3 \quad (8)$$

$$LEUCINE = 0.54 - 0.70X_1 + 0.08X_2 - 0.46X_3 - 0.45X_1^2 - 0.24X_2^2 + 0.01X_3^2 - 0.22X_1X_2 + 0.10X_1X_3 + 0.38X_2X_3 \quad (9)$$

$$VALINE = -0.49 + 0.91X_1 + 0.03X_2 + 0.004X_3 + 0.34X_1^2 + 0.4X_2^2 - 0.12X_3^2 - 0.02X_1X_2 - 0.04X_1X_3 - 0.8X_2X_3 \quad (10)$$

$$METHCYT = -0.96 + 0.67X_1 - 0.01X_2 + 0.03X_3 + 0.75X_1^2 + 0.24X_2^2 + 0.21X_3^2 + 0.02X_1X_2 + 0.05X_1X_3 - 0.02X_2X_3 \quad (11)$$

$$THRENINE = 0.56 + 0.85X_1 + 0.004X_2 + 0.01X_3 - 0.56X_1^2 - 0.06X_2^2 - 0.08X_3^2 - 0.02X_1X_2 + 0.01X_1X_3 + 0.01X_2X_3 \quad (12)$$

$$TRYPHYL = -0.15 + 1.03X_1 + 0.01X_2 - 0.02X_3 + 0.16X_1^2 - 0.02X_2^2 + 0.05X_3^2 + 0.02X_1X_2 + 0.004X_1X_3 - 0.04X_2X_3 \quad (13)$$

$$TRYTPHAN = -0.31 - 0.95X_1 - 0.08X_2 - 0.041X_3 + 0.24X_1^2 + 0.13X_2^2 + 0.01X_3^2 - 0.13X_1X_2 - 0.02X_1X_3 + 0.05X_2X_3 \quad (14)$$

where X_1 refers to coded value of feed composition, X_2 refers to the coded value of feed moisture content, X_3 refers to coded value of screw speed.

Regression coefficients for objective responses for fura extrudates amino acid profile are presented in (Table 5). Analysis of variance (table not shown) indicates that the amino acid content were influenced significantly ($P<0.05$) by the linear and quadratic terms for lysine, leucine, valine and threonine. The linear effects of feed composition was positive for lysine content, which suggests increasing the amount of cowpea resulted in increased in the amount of lysine content of extrudates. The lysine content was however negatively influenced by the linear effects of feed moisture and screw speed. This result confirms the same effects of feed moisture and screw speed on protein content earlier mentioned. The quadratic effect of feed composition influenced the lysine content of extrudates significantly ($P<0.05$). The result indicates positive effect of quadratic term on the lysine contents of extrudates. The i/leucine was influenced significantly ($P<0.05$) by the quadratic term effect of feed composition. The result indicates positive effect by the quadratic effect of feed composition on the i/leucine content. The amino acid leucine content of fura extrudates was influenced significantly ($P<0.05$) by the linear term of feed composition and screw speed. This effect was negative which suggested that there was decrease in the leucine content of extrudates as cowpea flour and screw speed was increased.

The coefficients of determinant R^2 = 0.90, 0.85, 0.86, 0.92, 0.88, 0.85 and 0.93 for lysine, i/leucine, leucine, valine, methionine – cystine, threonine and tryptophan respectively, suggesting good fit of the model (Table 5). From the result of this study it shows that the level of lysine contents of fura extrudates increased generally as the amount of cowpea flour was increased. Tyrosine-phenylalanine, i/leucine, valine and leucine all increased as the level of cowpea flour was increased in the extrudates, from the regression analysis Table 6. Similar observations have been reported by other authors for blends of cereals and legumes (Obatolu, 2002). Nkama and Malleshi (1998) reported that, lysine increased by 75% as a result of supplementation of millet with cowpea at (83:17) ratio. They also reported similar increase of other essential amino acids as a result of supplementation; these amino acids include histidine, threonine, valine and i/leucine. Legumes provide a larger protein intake and amino acid balance when consumed with cereals, which significantly improves the protein quality (Bressani, 1975). Pelembe et al. (2002) reported that protein content of extrudates increased proportionally with the amount of cowpea flour in sorghum. The mean values of the amino acids profile from this study revealed that some of the essential amino acids were present in adequate amount if compared with the recommended values of FAO/WHO (1973). From the point of view of utilization, cooking quality of grain legumes is very important. It may be expected that grain legumes will be utilized more extensively if quick legume processing technology is adopted on a commercial basis and more acceptable, nutritious and digestible food products are developed from such technologies like extrusion cooking. It can be inferred that extrusion cooking and supplementation of pearl millet and cowpea flour mixtures can be employed in the improvement of the nutritional quality of traditional or millet based foods like fura.

Digestibility is considered the most determinant of protein quality in adults, according to FAO/WHO/UNU (1985). Although digestibility test was not conducted in this study, Singh et al. (2007) reported that protein digestibility value of extrudates is higher than non extruded products. The possible cause might be denaturation of proteins and inactivation of antinutritional factors that impair digestion especially in cowpea which was used as a basic ingredient in this study. The nutritional value of vegetable protein is usually enhanced by mild extrusion cooking conditions, owing to increase in digestibility (Areas, 1992). Benefits of beans extrusion – cooking are deactivation of heat labile inhibitors (Aguilera, et al., 1984). An advantage of destruction is the destruction of antinutritional factors, especially trypsin inhibitors, haemagglutinins, tannins and phytates, all of which inhibit protein digestibility (Singh et al., 2007). Extrusion has been shown to be very effective in reducing or eliminating lectin activity in legume flour (Alonso et al., 2000ab).

Thus, extrusion cooking is more effective in reducing or eliminating lectin activity as compared with traditional aqueous heat treatment.

3.5 Extrudate Photographic Responses

The visual effects of extrusion variables (feed composition, feed moisture and screw speed) can be seen as shown in Plates 1-15. The effect of the independent variables on the expansion ratio and colour of extrudates is evident. The results shown in the photographs describes the changes occurred during extrusion as influenced by the extrusion variables. It is evident that design points 3, 4 and 12 had the least expansion because of the high feed moisture levels 30, 30 and 33.4% respectively. These samples consequently have smooth body and darker colour because they are denser. Those samples with higher expansion ratios indicated more wrinkles and lighter colour as expected for design points 1, 3, 5, 7, 10, and 11 as a result of fading of colour with increase in expansion resulting from the air bubbles produced during extrusion. Colour changes in extruded products have been reported to be due to decomposition of pigments, product expansion causing colour fading and chemical reactions such as caramelisation of carbohydrates (Chen et al., 1991).

3.6 Sensory Evaluation

The statistical sensory qualities of millet – cowpea fura extrudates is presented in (Table 6). From the result it shows that design point 11 representing 20 % feed composition (X_1), 16.6 % feed moisture (X_2) and 200 rpm screw speed (X_3) recorded the highest value of acceptability for colour. This design point was significantly different ($P<0.05$) from other extrudates with the exception of design point 13 representing 20 % feed composition, 25 % feed moisture and 116 rpm screw speed. The flavour shows that there was no significant difference ($P<0.05$) between design point 1, 3, 5, and 11 (Table 6). The same design point 11 recorded the same pattern of highest acceptance for the flavor, texture and overall acceptability of extrudates. The design point 11 had the lowest processing extrusion feed moisture and recorded the highest sectional expansion and lowest bulk density (result not shown) probably influenced the acceptability of this sample more than others. Due to more expansion which resulted in fading of the dark colour of extrudate to brighter form might have made the sample much acceptable to the panelists. Colour changes in extruded products have been reported to be due to decomposition of pigments, product expansion causing colour fading and chemical reactions such as caramelisation of carbohydrates (Chen et al., 1991).

3.7 Optimization

Numerical optimization was carried out for the process variables for processing of fura extrudates from millet – cowpea mixtures for obtaining the best product. Desired goals were assigned for all the parameters for obtaining the numerical optimization values for the responses. All the processing parameters were kept in range. Lysine, protein content and expansion ratio were maximized while bulk density was minimized. The optimum values obtained for feed composition, feed moisture and screw speed are 36.5% cowpea level, and 22.3% feed moisture and 186.7 rpm respectively. The corresponding optimum values of lysine, protein content, expansion ratio and bulk density are 6.6g/100g protein, 16.6%, 2.80 and 0.52 Kg m^{-3} respectively.

Table 4. Experimental design and observed amino acid profile of millet – cowpea based fura extrudates (g/100 g protein)

Independent variables[b]			Dependent variables[a]							
X_1	X_2	X_3	[1]Lysine	[2]I/Leucine	[3]Leucine	[4]Valine	[5]Meth+Cyt	[6]Threonine	[7]Tyr+Phyl	[8]Tryptophan
10	20	150	5.2±0.1	2.9±0.1	9.1±0.3	3.2±0.3	3.5±0.1	3.6±0.3	4.3±0.3	0.9 ±0.01
10	30	150	5.2±0.3	2.8±0.2	9.2±0.6	3.2±0.5	3.5±0.1	3.8 ±0.3	4.2±0.4	0.9 ±0.04
10	20	250	5.2±0.5	2.8±0.2	9.2 ±0.8	3.3±0.3	3.5±0.2	3.8±0.2	4.3±0.4	0.9±0.02
10	30	250	5.2±0.3	2.8±0.2	9.1±0.4	3.1±0.2	3.5±0.2	2.7±0.2	4.2±0.3	0.8±0.01
30	20	150	5.7±0.6	3.1±0.4	10.3±0.7	4.3±0.5	1.9±0.1	4.2±0.3	4.8±0.2	1.0±0.05
30	30	150	5.9±0.4	3.1±0.2	10.1±0.6	4.3±0.3	1.7 ±0.2	4.2±0.2	4.8±0.4	1.0±0.03
30	20	250	5.8±0.5	3.2±0.5	10.2±0.5	4.4±0.6	1.8±0.2	3.3±0.3	5.0±0.5	1.0±0.08
30	30	250	5.8±0.3	3.2±0.4	10.3±0.5	4.3±0.8	1.8 ±0.2	3.2±0.3	4.8±0.3	1.0±0.06
3.2	25	200	5.1±0.5	2.5±0.2	6.9±0.4	2.4±0.4	3.8±0.2	3.4±0.2	5.9±0.3	0.7±0.02
36.8	25	200	6.6±0.8	3.4±0.3	11.4±0.5	5.5±0.5	1.3±0.3	4.6±0.2	4.7±0.3	1.3±0.05
20	16.6	200	5.9±0.4	2.5±0.4	10.5±0.7	3.5±0.7	2.0±0.2	4.4±0.3	4.5±0.2	1.2±0.04
20	33.4	200	6.0±0.7	2.6±0.4	10.6±0.4	3.7±0.5	2.0±0.2	4.3±0.3	4.5±0.2	1.3±0.06
20	25	116	5.2±0.4	2.5±0.3	10.5±0.4	3.8±0.4	1.9±0.2	4.4±0.3	4.5±0.2	1.2±0.04
20	25	284	5.4±0.8	2.5±0.4	10.6±0.6	3.6±0.4	1.8±0.2	4.4 ±0.2	4.5±0.3	1.3±0.02
20	25	200	5.4±0.7	2.5±0.2	10.5±0.6	3.5±0.4	1.8±0.2	4.3±0.4	4.44±0.3	1.2±0.07

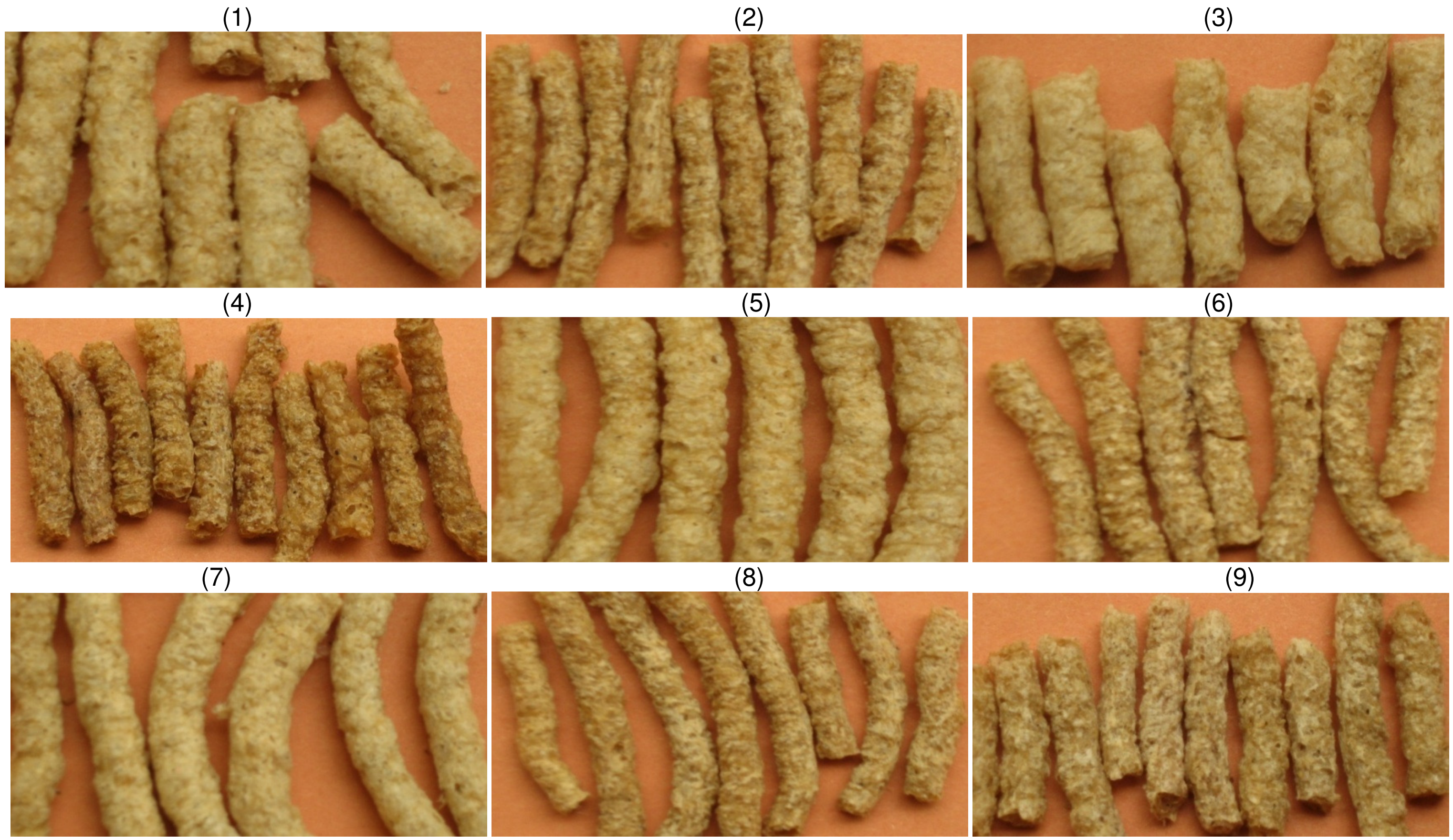
[b]X_1 = Feed composition (%); X_2 = Feed moisture (%) and X_3 = Screw speed (rpm). [a]Values are means and ± standard deviation of triplicate determinations. 1=Lysine; 2= Isoleucine; 3= Leucine; 4=Valine; 5=Methionine + Cystine; 6=Threonine; 7= Tyrosine + Phenylalanine; 8 =Tryptophan

Table 5. Regression equation coefficients for objective responses a, b expansion ratio (ER), bulk density (BD), proximate composition and amino acid

Coefficient	ER	BD	[1]CHON	[2]CHO	[3]FAT	[4]ASH	[5]HOH	[6]LYSINE	[7]I/LECNE	[8]LEUCINE	[9]VALINE	[10]MET-CYT	[11]TRENE	[12]TRPTPHN
Linear														
B_0	-0.246	0.188	0.676*	-0.169	-0.306	0.491	-0.161	0.144	-0.844	0.539	-0.492	-0.959	0.558	-0.152
B_1	0.014	0.088	1.289*	0.107*	1.254*	0.772*	-0.535	0.665*	0.650	0.691*	0.908*	0.673	0.849*	1.030*
B_2	-0.722*	0.866*	-0.158	-1.6 5	-0.133	0.038	0.471	-0.123	0.103	0.080	0.035	-0.011	0.004	0.013
B_3	0.586*	0.527*	-0.264	-1.404	0.364	-0.067	0.589	-0.220	0.065	0.458*	0.004	0.027	0.012	-0.027
Quadratic														
B_{11}	-0.047	-0.067	0.108*	0.621	0.166	-0.324	0.179	0.468*	0.729*	0.445*	0.336*	0.745	-0.562*	0.164
B_{22}	-0.133	0.210*	-0.285	0.690	-0.214	-0.373	-0.488	0.024	0.305	-0.239	0.396*	0.242	-0.057	-0.021
B_{33}	0.541*	0.419*	-0.346	0.012	-0.217	-0.022	0.289	0.265	0.142	0.012	-0.119	0.208	-0.076	0.0467
Interaction														
B_{12}	0.112	0.076	-0.249	0.529	0.343	0.172	-0.723	-0.127	-0.259	-0.219	-0.018	0.020	-0.021	0.018
B_{13}	-0.219	0.068	-0.134	-0.470	-0.224	0.557*	0.260	0.198	-0.324	0.101	-0.036	0.053	0.006	0.004
B_{23}	0.282*	0.079	-0.189	0.727	-0.173	-0.089	-0.316	0.333	0.266	0.377	-0.079	-0.020	0.013	-0.037
R^2	0.933	0.935	0.963	0.939	0.938	0.849	0.801	0.897	0.848	0.855	0.921	0.879	0.849	0.929
Adjusted R^2	0.873	0.869	0.882	0.836	0.938	0.623	0.343	0.836	0.894	0.880	0.821	0.874	0.856	0.838
Lack of fit	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Model	*	*	*	*	*	*	*	**	*	*	*	*	*	*

[a] $Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$ *X_1 = Feed Composition, X_2 = Feed Moisture, X_3 = Screw Speed*[b] **, ** Significant at $P < 0.05$ and $P < 0.01$, respectively; NS, not significant.*

1=Protein2=Carbohydrate3=Fat4=Ash5=Water6=Lysine7=Isoleucine8= Leucine9=Valine10=Methionine-Cystine11=T hreonine12=Tryptophan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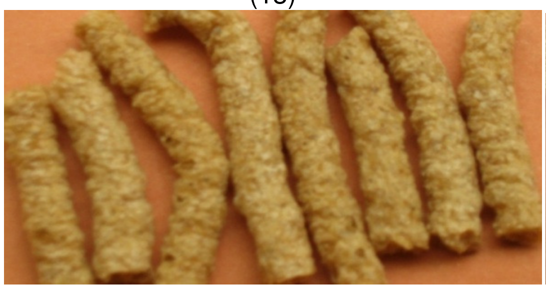

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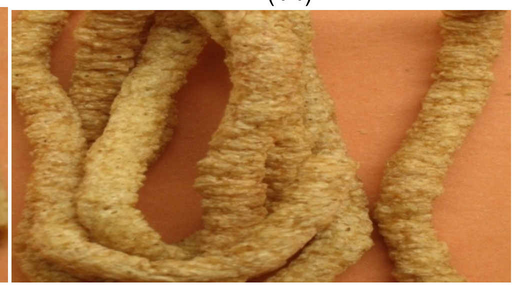

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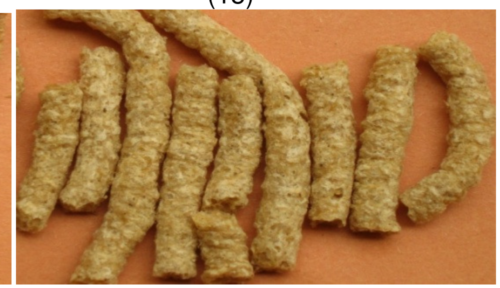

Plates 1 – 15: (1) 10% Cowpea, 20% moisture, 150rpm; (2) 10% Cowpea, 30% moisture, 150rpm; (3) 10% Cowpea, 20% moisture, 250 rpm; (4) 10% Cowpea, 30% moisture, 250rpm; (5) 30% Cowpea, 20% moisture, 150rpm; (6) 30% Cowpea, 30% moisture, 150rpm; (7) 30% Cowpea, 20% moisture, 250rpm; (8) 30% Cowpea, 30% moisture, 250rpm; (9) 3.2% Cowpea, 25% moisture, 200 rpm; (10) 36.8% Cowpea, 25% moisture, 200rpm; (11) 20% Cowpea, 16.6% moisture, 200rpm; (12) 20% Cowpea, 33.4% moisture, 200rpm; (13) 20% Cowpea, 25% moisture, 116rpm; (14) 20% Cowpea, 25% moisture, 284rpm; (15) 20% Cowpea, 25% moisture, 200rpm;

Table 6. Sensory qualities of extruded millet – cowpea mixtures[a]

Independent variables[b]			Dependent variables[a]			
X_1	X_2	X_3	Colour	Flavour	Texture	Overall/Acceptability
10	20	150	6.45b	6.87ab	6.67b	6.50b
10	30	150	6.30b	6.70b	6.43b	5.34c
10	20	250	6.54b	6.88ab	6.88ab	6.66b
10	30	250	6.30b	6.34b	6.38	6.45b
30	20	150	6.41b	6.87ab	6.56b	6.55b
30	30	150	5.50c	6.12b	6.34b	5.59c
30	20	250	5.40c	6.34b	6.41b	5.65c
30	30	250	5.60c	5.55c	5.65c	5.78c
3.2	25	200	6.35b	6.78b	6.57b	6.44b
36.8	25	200	5.36c	5.56c	5.65c	5.34c
20	16.6	200	7.30a	7.56a	7.54a	7.55a
20	33.4	200	5.89bc	5.76c	5.79c	5.68c
20	25	116	6.89ab	6.76b	6.66b	6.75b
20	25	284	5.53c	5.25c	6.54b	5.55c
20	25	200	5.40c	5.35c	6.53b	5.34c

[b]*X_1 = Feed composition (%); X_2 = Feed moisture (%) and X_3 = Screw speed (rpm).* [a]*Mean values in the same column with different letters are significantly different ($P<0.05$)*

4. CONCLUSION

Designed experiments were conducted following Response Surface Methodology (RSM) for the extrusion of pearl millet and cowpea based fura using a single screw extruder. The RSM was found to be effective technique to investigate the expansion ratio, bulk density, proximate composition and amino acid profile of fura extrudates. From the result it shows that the three extrusion variables were found to influence the extrudate properties either independently or intereractively. Feed moisture content was found to be the most significant factor that affected the expansion ratio and the bulk density, The extrusion variable feed composition i.e the level cowpea was found to influence the proximate composition and the amino acid profile. The high correlation coefficient of multiple determinations at 95% confidence level and the model equation developed can be used for predicting expansion ratio, bulk density, proximate composition and amino acid profile of millet – cowpea based fura. Using RSM the combined effect of three variables on extrudate response can be predicted which is difficult to achieve with conventional methods. The understanding of the effect of the process variables on quality parameters of fura extrudates such as expansion ratio, bulk density, proximate composition and amino acid profile is important to facilitate industrial adoption of this technology. Extruded fura provides consumers with a fast, easy way to prepare which compares favourably with traditional fura. Aesthetic presentation will enhance and increase acceptability of this product. Fura production has potential of increased provision of food especially in the aviation industry, refugee camps, food aids, for areas prone to protein energy malnutrition and those living in war torn famine ravaged areas of west Africa. This product could make a great contribution to food supply in West Africa sub region especially to mitigate the problem of famine in the region.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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