__Original Research__

Response Surface Methodology Approach for the Production of Enriched Rice-based Breakfast Cereal

Abstract

This study was aimed at the use of blend of rice flour (*Oryza sativa),* pigeon pea flour (*Cajanus cajan*), and banana flour (*Musa paradisiaca*) to produce enriched rice-based breakfast cereal. The control was done without blending the three flours (100% pre-gelatinized rice flour). The proximate composition was evaluated according to standard methods. The proximate composition showed that moisture, ash, fat, protein, carbohydrate and fibre content in % ranged from 5.66-7.95, 0.40-2.51, 0.50-1.51, 2.78-11.21, 79.12-89-62 and 0.10-1.42 respectively. Enrichment of rice-based breakfast cereals could contribute to improvement of nutritional status if adopted as a nutritious, healthy indigenous breakfast cereal.

Keywords: Rice, Response Surface Methodology, Cereals, Pigeon Pea, Banana, Breakfast Cereals

Introduction

Breakfast cereal products are originally sold as milled grains of wheat, oat, rice and other cereals that required further cooking in home prior to consumption. In this century, due to efforts to reduce the amount of in-home preparation time, breakfast cereal technology has evolved from simple procedure of milling grains for cereal products that required cooking for manufacturing to highly sophisticated ready-to-eat products that are convenient and quickly prepared (Brockway, B. 1990). They can be categorized into traditional (hot) cereal that require further cooking or heating before consumption and ready-to-eat (cold) cereal that can be consumed from the box or with the addition of milk (Fast, 2000). Some recent work in school children has suggested that breakfast cereals may help maintain mental performance over the morning compared to no breakfast or a glucose drink (Wesnes *et al*., 2003). A larger study found an association between breakfast cereal consumption and subjected reports of health, with those adults who ate breakfast cereal every day reporting better mental and physical health, compared to those who consumed it less frequently (Smith, 1991). Breakfast cereals are regularly consumed in the US and a popular choice for breakfast among children and adults making them a relevant product to study. There is controversy regarding their overall nutritional benefit. At the same time, there is concern regarding the nutritional content of breakfast cereals, particularly for children and infants as weaning food.

Rice gruel (Congee in British English) is eaten primarily as a breakfast cereal which is often given to babies just starting to eat food as weaning food because it is soft and easy to digest (Rohman *et.al*., 2014). It can be eaten as plain rice congee when served with side dishes and can be enriched with protein rich foods because of its protein deficiency.

Pigeon pea (*Cajanus cajan*) is among the dry leguminous seeds cultivated for food in Nigeria which are important source of proteins, energy and other nutrients in the diets of large population groups around the world, forming an excellent source lysine, methionine, and tryptophan and other water-soluble vitamins and minerals (Ramcharran and Walker, 1985). The high protein content in the seed calls for blending it with cereals in food product development.

Banana is a food of great value recommended for several physiological diseases, including constipation and diarrhea, due to its ability to normalize colon functions. Since it has the ability to stimulate the proliferation of beneficial acidophilus bacteria in humans, its intake is recommended in cases of colitis, ulcerative colitis, gastric ulcer, uremia, nephritis, gout, cardiovascular disease, and celiac disease. When it is in the green stage, banana is considered to be a functional food of the prebiotic type and the flour of unripe banana might be an important source of polyphenol compounds that are considered as natural antioxidants. The clear advantage presented by banana flour include a high total starch (73.4%), resistant starch (17.5%) and dietary fiber content (14.5%) (Juarez *et.al*., 2006). Due to the high content of these functional ingredients, regular consumption of banana flour can be expected to confer beneficial health benefits for human (Rodriguez *et.al*., 2008). The overall goal of this study is to investigate on the response surface methodology approach for the production of enriched rice based breakfast cereal using the combination of rice flour, pigeon pea flour and green banana flour which can as well serve as weaning food for infants.

Materials and Method

Source of raw materials.

Rice grain, pigeon pea seeds and matured unripe banana was obtained from Eke-Akwa market in Akwa South L.G.A, Anambra state. They were identified at Botany Department in Nnamdi Azikiwe University, Awka, Anambra State and transported to the laboratory for subsequent study. Other materials used include the equipment's for the work which include oven, sieve, steel knife, weighing balance, bowls, beaker, thermometer, gas cooker and milling machine.

Table 1: Key depicting independent variables and their levels.

	-1	0	+1
Pigeon Pea	2	4	6
Banana	1	3	5

Experimental Design

Table 2: Experimental design for selecting the best quality rice flour

Sample	Cooking time	Drying Time
1	10.00	80.00
2	15.00	80.00
3	10.00	60.00
4	5.00	80.00
5	10.00	100.00
6	15.00	60.00
7	5.00	60.00
8	15.00	100.00
9	5.00	100.00
10	10.00	80.00
11	10.00	80.00
12	10.00	80.00
13	10.00	80.00

Table 3. Shows the experimental design that was used for selecting the best process combination that gave the best quality rice flour as a preliminary investigation.

Table 3: Recipe for formulating the breakfast cereals

Sample	Pigeon pea flour (%) (x_1)	Banana Flour (%) (x_2)	Rice flour (%) (Base Imgrdient)
1	4	3	93
2	6	5	89
3	4	3	93
4	4	5	91
5	4	3	93
6	2	3	95
7	6	1	93
8	6	3	91
9	2	1	97
10	4	3	93
11	4	3	93
12	2	5	93
13	4	1	95

Table 4 shows the experimental design. It is a Face Centered Central Composite Design have three major factors: x_1 (Pigeon pea flour) x_2 (Banana flour), and rice flour (The base ingredient). The design was carried out using statistical software (Design Expert, Version 8.0.7.1).

Proximate Analysis

Moisture content determination

The moisture content of the samples was determined in triplicate by hot-air oven method according to AOAC (2010). Each sample (2g) was weighed into thoroughly washed previously dried dishes and placed in an oven at 100-102°C for 2-3 hours. The dishes were cooled in a desiccator and weighed. Drying, cooling and weighing were continued until a constant weight is obtained. Thereafter, the dried weight of the sample plus dishes were recorded and used to calculate moisture content with the expression below:

Calculation:

$$\% \, Moisture \, Content = \frac{w_3 - w_1}{w_2 - w_1} \, x \, \frac{100}{1} \qquad (1)$$

Where W_1 = Initial weight of the empty crucible

W_2 = Weight of crucible + food before drying

W_3 = Final weight of the crucible + food after drying

Crude protein determination

This was determined using Kjeldahl method as described by AOAC (2010). Each sample (1.0g) was weighed into a Kjedahl flask and 3.0g of hydrated cupric sulphate (catalyst), 20ml of sodium sulphate solution and 1.0ml of concentrated sulphuric acid (H_2SO_4) was added to the sample in the flask. The flask was clamped and heated until the solution becomes colourless. The clear solution was cooled and diluted with distilled water to make up the volume to 100ml. 10ml of the digest was mixed with 5ml of 40% sodium hydroxide solution in a distillation flask and distilled to reduce the ammonia which was titrated with 0.1ml hydrochloric acid (HCl). The titre value or end point at which the colour changes from green to pink was noted and the crude protein will be calculated using the expression below.

$$\% \, Total \; Nitrogen = \frac{Titre - (blank\;) \; x \; Normality \;\; of \;\; acid \;\; x \; 0.014 \; x \; 100}{Weight \; of \;\; sample} \; x \, \frac{100}{1} \qquad (2)$$

Nitrogen factor = 6.25

Crude Protein = % total N x 6.25

Crude fibre determination

The crude fiber content was determined using the method of AOAC (2010). The whole sample was first defatted with n-hexane, dried and then 2g was weighed (W_1) into a beaker, boiled for 30 minutes with 100ml of H_2SO_4, then filtered through a filter paper. The residue was washed with boiling water until the washing was no longer acidic. The washed residue was boiled for another 30 minutes with 100ml of 0.02M NaOH solution, filtered and washed with hot water for three minutes. The residue was then transferred into a previously ignited, cooled and weighed crucible and dried in the oven for 1 hour. The crucible with its content was cooled in a desiccator and then weighed (W_2) using digital balance. The cooled sample was then ignited in a muffled furnace at 600°C for 3 hours, cooled and weighed (W_3) using a digital balance. The percentage crude fibre was calculated in the expression below.

$$\% \, Crude \; Fiber = \frac{Oven \; dried \;\; sample \; - Weight \; of \;\; sample \;\; after \;\; incineration}{Weight \; of \;\; Sample \;\; taken} \, x \, \frac{100}{1} \qquad (3)$$

Crude fat determination

The Soxhlet extraction method (AOAC, 2010) was used in determining fat content of the sample. The sample (2g) was weighed in a digital balance and put in a cellulose thimble. The thimble and its content were placed in the extraction tube or the Soxhlet apparatus. A weighed round bottom flask was filled to about three-quarter (3/4) of its volume with petroleum ether (BP 40-60°C) fitted to the extraction tube and set on a heating mantle. The sample was refluxed for 6-8 hours after which the solvent (petroleum ether) was recovered and the extracted oil in the flask was dried in the oven at 80°C for 30 minutes to remove solvent traces, cooled in a dessicator and finally weighed using digital balance. The fat content was expressed as a percentage of the raw materials. The difference in the weight of empty flask and the flask with oil gave the oil content which was calculated with the expression below.

$$\% \, Fat = \frac{A-C}{B} \, x \, \frac{100}{1} \tag{4}$$

Where A = Weight of flask + oil

B = Weight of sample in gram

C = Weight of empty flask

Ash content determination

The ash content was determined using the method of AOAC (2010). Each sample (2g) was weighed into a silica dish previously washed, heated to about 600°C and cooled in a desiccator, then weighed using digital weighing balance. The silica dish and the sample were heated in a muffle furnace at about 700°C. This temperature was maintained until whitish-grey coloured ash was obtained indicating that all the organic matter in the product has been destroyed.

The dish was cooled in a desiccator and weighed using a digital balance. The percentage ash content was calculated using the expression below,

$$Ash \, Content = \frac{w_3 - w_1}{w_2 - w_1} \, x \, \frac{100}{1} \tag{5}$$

Where: W_1 = Weight of the empty crucible

W_2 = Weight of crucible + Sample before drying

W_3 = Final Weight of Crucible + Ash

Carbohydrate content determination.

The carbohydrate content was determined by difference. Sum of all the proximate components was subtracted from hundred (100). The balance was assumed to be carbohydrate.

% carbohydrate = 100 – (% protein + fat + fibre + ash + moisture) (6)

Result and Discussion

The result in Table 4 shows the Moisture, Ash, Fiber, Protein, Fats and Carbohydrate of the foam mat dried tomato powder. The Ideal regression equation showing the response variables as a function of the independent (Process Variables) is presented in equation 7

$$Y = b_0 + b_1A + b_2B + b_3C + b_{11}A^2 + b_{22}B^2 + b_{33}C^2 + b_{12}AB + b_{13}AC + b_{23}BC + e \quad (7)$$

Moisture Content

From table 4, the moisture content (%) of samples ranged between (5.66-7.95). Similar results had been reported by Oko and Ugwu (2011). Statistical analysis result showed that sample 1,3,5,10 and 11 with mean scores of (6.30, 6.30, 6.30,6.30 and 6.30) have no significant different ($P>0.05$), while sample 2,4,6,7,8,9,12,13 and 14 with mean scores of 6.66, 6.52, 6.72, 7.75, 6.34, 5.66, 7.46, 7.06 and 5.99 respectively differed significantly with other samples ($P< 0.05$).

The moisture content directly influences the texture of breakfast cereals. Cereals with higher moisture content tend to be softer and less crispy, while those with lower moisture content are crispier and more desirable. Optimal moisture levels are often sought to maintain the desired crunchiness and mouthfeel of the cereal.

Ash Content

The ash content ranged from (0.40-2.51%) and exhibited close relationship with the values reported by Folake *et. al* (2015) in rice flour blends (0.20-1.15). The statistical analysis showed that there was no significant difference ($P>0.05$) between sample 1,3,5,10 and 11 with mean scores of (0.77, 0.77, 0.77, 0.77 and 0.77). Ash content is an indicator of mineral content, including essential nutrients like calcium, magnesium, and potassium. Higher ash content suggests a relatively higher mineral concentration, contributing to the nutritional profile of the cereal. Consistent ash content among specific samples, as observed in this study, could imply a controlled source of minerals, thereby affecting the cereal's overall nutritional composition.

As well the uniform ash content in certain samples indicates a potential consistent choice of ingredients or sourcing methods. This effect might be attributed to the use of particular rice varieties, fortification strategies, or processing techniques that maintain the mineral composition at a similar level. Ingredient selection and sourcing decisions significantly influence the final nutritional quality of the cereal.

Also sample 4 and 12 are significantly the same with a mean score of (1.50 and 1.51) respectively, and sample 6 and 14 are also significantly the same with mean scores of (0.42 and 0.40). Meanwhile, sample 2,7,8,9 and 13 with mean scores (2.52, 0.58, 1.66, 2.00 and 0.64) differed significantly from other samples.

Table 4: Mean scores ± SEM for % Proximate Composition.

S/N	Samples P:B:R(%)	Moisture	Ash	Fat	Protein	Carbohydrate	Fibre	Energy value (Kcal/g)
1	4 : 3 : 93	6.30^{a} ± 0.2000	0.77^{a} ± 0.0200	1.51^{a} ± 0.0100	7.28^{a} ± 0.0200	84.14^{a} ± 0.0200	0.10^{a} ± 0.0000	379.27^{a}
2	6 : 5 : 89	6.66^{b} ± 0.0173	2.51^{b} ± 0.0200	0.50^{b} ± 0.100	11.21^{b}± 0.0200	79.12^{b} ± 0.0100	1.42^{b}± 0.0200	365.82^{c}
3	4 : 3 : 93	6.30^{a} ± 0.2000	0.77^{a} ± 0.0200	1.51^{a} ± 0.0100	7.28^{a} ± 0.0200	84.14^{a} ± 0.0200	0.10^{a} ± 0.000	379.27^{a}
4	4 : 5: 91	6.52^{c} ± 0.0116	1.50^{c} ± 0.0100	0.78^{c} ± 0.0300	7.67^{c} ± 0.0200	83.54^{c} ± 0.0100	0.33^{c} ± 0.0100	371.86^{b}
5	4 : 3 : 93	6.30^{a} ± 0.2000	0.77^{a} ± 0.0200	1.51^{a} ± 0.0100	6.68^{a} ± 0.0100	84.14^{a} ± 0.0100	0.10^{a} ± 0.0000	379.27^{a}
6	2 : 3 : 95	6.72^{d} ± 0.0100	0.42^{d} ± 0.0058	0.71^{a} ± 0.0173	6.67^{d} ± 0.0100	85.47^{d} ± 0.0100	1.07^{d}± 0.0200	374.99^{e}
7	6 : 1 : 93	7.92^{e} ± 0.0200	0.58^{e} ± 0.0173	1.15^{a} ± 0.0200	10.74^{e}± 0.0200	80.65^{e} ± 0.0200	1.35^{e} ± 0.0200	371.63^{b}
8	6 : 3 : 91	6.34^{f} ± 0.0200	0.58^{f} ± 0.0173	0.85^{f} ± 0.0100	10.21^{f}± 0.0100	80.41^{f} ± 0.0200	1.42^{b}± 0.0173	372.25^{d}
9	2 : 1 : 97	5.66^{g} ± 0.0100	2.00^{g} ± 0.0173	1.02^{k} ± 0.0173	6.28g ± 0.0200	86.01^{g} ± 0.0000	1.03^{g}± 0.0173	374.06^{e}
10	4 : 3 : 93	6.30^{a} ± 0.0200	0.77^{a} ± 0.0200	1.51^{a} ± 0.0100	7.28^{a} ± 0.0200	84.14^{a} ± 0.0200	0.10^{a} ± 0.000	379.27^{a}
11	4 : 3 : 93	6.30^{a} ± 0.0200	0.77^{a} ± 0.0200	1.51^{a} ± 0.0100	7.28^{a} ± 0.0200	84.14^{a} ± 0.0200	0.10^{a} ± 0.000	379.27^{a}
12	2 : 5 : 93	7.46^{h} ± 0.0200	1.51^{c} ± 0.0100	1.48^{g} ± 0.0100	6.86^{h} ± 0.0100	82.69^{h} ± 0.0100	0.69^{h} ± 0.000	371.52^{b}
13	4 : 1 : 95	7.06^{i} ± 0.0200	0.64^{i} ± 0.0100	0.96^{h} ± 0.0173	7.12^{j} ± 0.0200	83.42^{i} ± 0.0200	0.46^{i} ± 0.0100	370.80^{f}
14	0 : 0 : 100	5.99^{J} ± 0.0100	0.40^{d} ± 0.0173	1.21^{i} ± 0.0100	2.78^{J} ± 0.0100	89.68^{a} ± 0.0100	0.39^{j} ± 0.0100	380.73^{g}

Values are means of triplicate determination ± SEM. Data in same column bearing different superscript differ significantly ($P<0.05$).

P:B:R = Proportions of Pigeon pea flour: Banana flour: Rice flour.

Tables 5: ANOVA for Response surface Quadratic Model for Ash

Source	Sum of square	df	Mean square	F-value	p-value	Prob>F
Model	4.30	5	0.86	10.93	0.0033	Significant
A-Pigeon Pea	0.011	1	0.011	0.14	0.7163	
B-Banana	0.88	1	0.88	11.21	0.0123	
AB	1.46	1	1.46	18.62	0.0035	
A^2	0.054	1	0.054	0.69	0.4330	
B^2	1.39	1	1.39	17.72	0.0040	
Residual	0.55	7	0.079			
Lack of Fit	0.55	3	0.18			
Pure Error	0.000	4	0.000			
C or Total	4.85	12				

The model F-value of 10.93 implies the model is significant. This is only a 0.33% chance that a "Model F-value" this large could occur due to noise. Adjusted R-Squared = 80.53%.

From table 5 above the regression model for ash content was found to be significant, which means that the model is a good fit for the data and can be used to make accurate predictions about the ash content of the cereal based on the levels of the factors.

The R^2 adjusted value of 80.53% indicates that the model explains 80.53% of the variation in the ash content of the cereal. This is a good value, as it means that the model is able to capture a large portion of the variability in the data. The statement also suggests that pigeon pea flour and banana flour have a negative effect on the ash content of the cereal. This means that as the levels of these factors increase, the ash content of the cereal decreases. However, the interaction between the two factors (pigeon pea flour and banana flour) has a positive effect on the ash content, which means that when these factors are used together, they increase the ash content of the cereal.

Final Equation in Terms of Actual Factors:

Ash	=	*+ 4.13908*
-0.75611		** Pigeon pea*
-1.47885		** Banana*
+0.15125		** Pigeon pea * Banana*
+0.035086		** Pigeon pea*^{2}
+0.17759		** Banana*^{2}

$$Ash = 4.13908 - 0.75611A - 1.47885B + 0.15125AB + 0.035086A^2 + 0.17759B^2 \quad (8)$$

Equation 8 above is a second-order polynomial equation, which means that it includes both linear and quadratic terms for the factors A and B. The linear terms (A and B) represent the effects of each factor on the ash content, while the quadratic terms (A^2 and B^2) represent the curvature of the response surface. The coefficients in the equation represent the strength and direction of the effects of each term. The coefficient -0.75611 for the A term indicates that increasing the level of factor A (pigeon pea flour or some other variable) will decrease the ash content of the cereal. Similarly, the coefficient 0.17759 for the B^2 term indicates that increasing the level of factor B (banana flour or some other variable) will increase the ash content of the cereal.

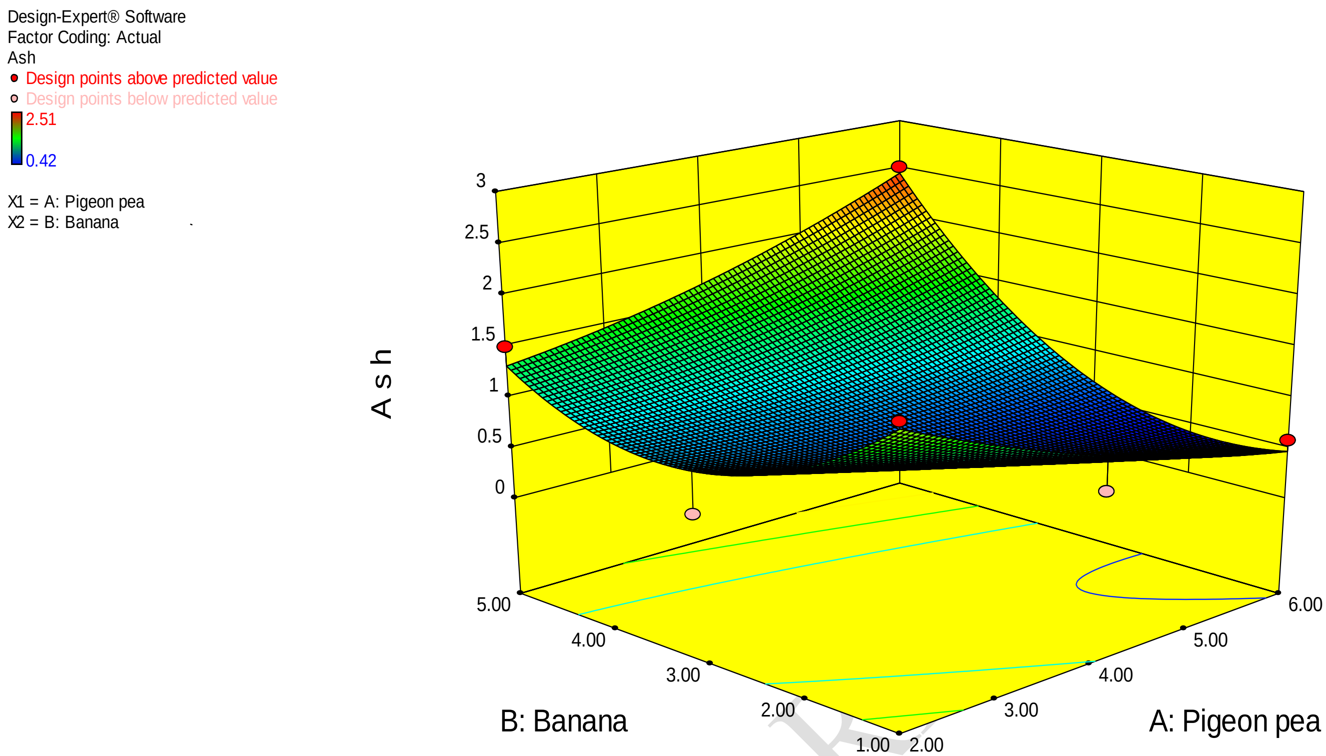

Fig: 1: Surface plot for Ash content of the enriched rice-based breakfast cereal

Fig. 1 above shows the surface plot of ash content in enriched rice-based breakfast cereal as a function of varying levels of pigeon pea flour (A) and banana flour (B). The plot illustrates the three-dimensional relationship between the two independent variables (A and B) and the response variable (ash content). The color-coded surface represents the predicted values of ash content based on the regression equation. The plot shows the impact of changing the levels of pigeon pea flour and banana flour on the ash content of the cereal. The x-axis represents the levels of pigeon pea flour, the y-axis represents the levels of banana flour, and the z-axis represents the predicted values of ash content. The plot shows the optimal levels of pigeon pea flour and banana flour that minimize ash content in the cereal.

Fat Content

From table 5 the fat content ranged from (0.50-1.51%) and showed significant difference in all the samples except sample 1, 3, 5, and 11 with a mean score of (1.51, 1.51, 1.51, 1.51 and 1.51%). This means that the cereal had relatively low-fat content, with most samples falling within the range of 0.50% to 1.51%. The significant differences observed in the fat content among most of the samples suggest that the levels of the factors used in the production of the cereal (i.e., the blend of rice flour, pigeon pea flour, and banana flour) had an effect on the fat content of the cereal. It is also worth noting that similar ranges of fat content were reported in a previous study by Rohman *et al*. (2014), which suggests that your findings are consistent with other research in the field. The observed fat content variations directly impact the nutritional profile of the breakfast cereals. The difference in fat levels influences the calorie content of the product, which is a critical consideration for consumers seeking low-fat options. he variation in fat content could be attributed to differences in processing techniques, including the extraction of fats from ingredients like pigeon pea flour and banana flour. Understanding how processing affects fat retention can lead to optimization strategies.

Protein Content

The protein content ranged from 2.78-11.21% with sample 14 having the least value and sample 2 having the highest value. This is because of the use of 100% rice flour in sample 14 and 89% rice flour with blend of pigeon pea (6%) and banana (5%) flours in sample 2 which yield higher protein content. This is in close relationship with the values reported by Folake *et. al* (2015) in Rice-based masa enriched with soybean and crayfish with protein content of (2.90-8.35%). The statistical analysis showed that there was no significant difference (P>0.05) between sample 1, 3, 5, 10 and 11 with a mean score of (7.28, 7.28, 7.28, 7.28 and 7.28 respectively. All other samples differed significantly from each other.

Table 6: ANOVA for response surface Quadratic model for Protein

Source	Sum of square	df	Mean square	F-value	p-value	Prob>F
Model	32.72	5	6.54	84.17	<0.0001	Significant
A-Pigeon Pea	25.42	1	25.42	327.00	<0.0001	
B-Banana	0.43	1	0.43	5.49	0.0516	
AB	3.025E-003	1	3.025E-003	0.039	0.8492	
A^2	4.86	1	4.86	62.57	<0.0001	
B^2	0.22	1	0.22	2.83	0.1366	
Residual	0.54	7	0.078			
Lack of Fit	0.26	3	0.085	1.19	0.4206	not Significant
Pure Error	0.29	4	0.072			
C or Total	33.26	12				

The model F-value of 84.17 implies the model is significant. There is only a 0.01% chance that a "Model F-value" this large could occur due to noise. Adjusted R-squared = 97.20%

From table 6 it was observed that the pigeon pea had a positive effect on the protein content of the cereal, which suggests that increasing the level of pigeon pea flour in the blend could lead to an increase in the protein content of the cereal. Similarly, banana also had a positive effect on the protein content, albeit to a lesser extent than pigeon pea. However, the interaction between pigeon pea and banana had a negative effect on the protein content of the cereal, which means that increasing the levels of both pigeon pea and banana in the blend simultaneously may decrease the protein content of the cereal. This finding have important implications for the formulation of the cereal, as it suggests that careful balancing of the levels of each factor may be necessary to achieve a desired protein content in the final product.

Find Equation in terms of Actual factors:

Protein	=	*+ 7.15*
+2.06		** Pigeon pea*
+0.27		** Banana*
-0.027		** Pigeon pea * Banana*
+1.33		** Pigeon pea*^{2}
+ 0.28		** Banana*^{2}

$$Protein = 7.15 + 2.06A + 0.27B - 0.027AB + 1.33A^2 + 0.28B^2 \quad (9)$$

The equation 9 above is a regression model that was developed to predict the protein content of enriched rice-based breakfast cereal based on the levels of two independent variables, A and B. The regression model was found to be statistically significant, as indicated by the high adjusted R-squared value of 97.20%. This suggests that the model is a good fit for the data and can be used to accurately predict the protein content of the cereal.

The coefficients in the equation represent the strength and direction of the effect that each independent variable has on the predicted protein content. A positive coefficient, such as 2.06A and 0.27B, indicates that an increase in the level of that factor will lead to an increase in the predicted protein content. Conversely, a negative coefficient, such as -0.027AB, indicates that an increase in the level of that factor will lead to a decrease in the predicted protein content.

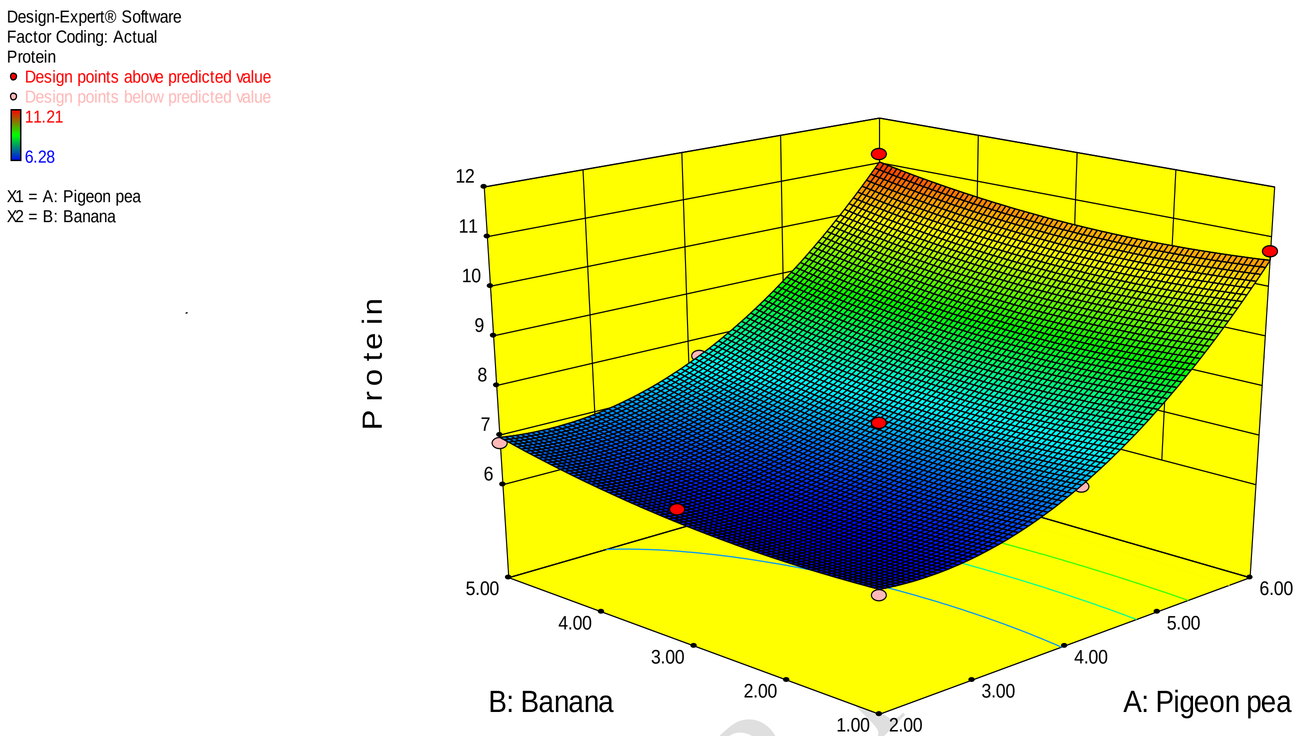

Fig. 2: Surface plot of protein content in enriched rice-based breakfast cereal

Fig. 2 shows the surface plot of protein content in enriched rice-based breakfast cereal as a function of varying levels of pigeon pea flour (A) and banana flour (B). The plot illustrates the three-dimensional relationship between the two independent variables (A and B) and the response variable (protein content). The color-coded surface represents the predicted values of protein content based on the regression equation. The plot shows the impact of changing the levels of pigeon pea flour and banana flour on the protein content of the cereal. The x-axis represents the levels of pigeon pea flour, the y-axis represents the levels of banana flour, and the z-axis represents the predicted values of protein content. The plot shows the optimal levels of pigeon pea flour and banana flour that maximize protein content in the cereal.

Carbohydrates Content

The carbohydrate content ranged from 79.12-89.68% with sample 2 having the least and sample 14 having the highest. It was observed that sample 14 has 100% of rice four which yielded more carbohydrate to it compared to sample 2 with 89% of rice flour, 6% of pigeon pea flour and 5% of banana flour. The statistical analysis showed that there was no significant difference (P>0.05) between sample 1, 3, 5, 10 and 11 with a mean score of 84.14, 84.14, 84.14, 84.14 and 84.14 respectively while all other samples differed significantly from each other which include sample 2,4, 6, 7, 8, 9, 12, 13 and 14 with a mean score of 79.12, 83.54, 85.47, 80.65, 80.41, 86.01, 82.69, 83.42 and 80.68 respectively. The range of the values had close relationship with the values reported by Morsy *et al.* (2015).

Fiber Content

The fiber content ranged from 0.10-1.41% with sample 1 having the least and sample 2 and 8 having the highest. This is in close range with Folake *et al* (2015) report with the range of (0.20-1.15%). The statistical analysis shows that there was no significant difference between sample 1, 3, 5, 10 and 11 with mean scores of 0.01, 0.10, 0.10, 01.0 and 0.10, also sample 2 and 8 showed no significant difference (P> 0.05) but other samples differs significantly from each (P< 0.05).

Table 7: ANOVA for response surface Quadratic model for fibre

Source	Sum of square	df	Mean square	F-value	p-value	Prob>F
Model	3.52	5	0.70	37.74	<0.0001	Significant
A-Pigeon Pea	0.33	1	0.33	17.53	0.0041	
B-Banana	0.027	1	0.027	1.43	0.2705	
AB	0.042	1	0.042	2.26	0.1768	

A^2	2.46	1	2.46	131.94	<0.0001
B^2	0.024	1	0.024	1.29	0.2927
Residual	0.13	7	0.019		
Lack of Fit	0.13	3	0.043		
Pure Error	0.000	4	0.000		
C or Total	3.65	12			

The model F-value of 37.74 implies the model is significant. There is only a 0.01% chance that a "Model F-value" this large could occur due to noise. Adjusted R-squared = 93.87%

From table 7 the model F-value is 37.74, means that the model is significant, and the probability of this value occurring by chance is only 0.01%. This suggests that the model is a good fit for the data and can accurately predict the response variable.

The adjusted R-squared value is 93.87%, which indicates that the model can explain 93.87% of the variability in the data, while taking into account the number of predictor variables included in the model. This means that the model is a strong predictor of the response variable and can be used to make accurate predictions about the outcome of the experiment.

Final Equation in terms of Actual factors:

Fibre =	*+ 4.08247*
- 1.84710	** Pigeon pea*
- 0.27601	**Banana*
+ 0.025625	** Pigeon pea * Banana*
+ 0.23586	** Pigeon pea^2*
+ 0.023362	** Banana^2*

$$Fibre = 4.08247 - 1.84710A - 0.27601B + 0.025625AB + 0.23586A^2 + 0.023362B^2 \quad (10)$$

From equation 10 shows the coefficients of the independent variables which indicate their respective contribution to the fiber content. From the equation, it can be observed that pigeon pea flour has a negative effect on the fiber content, while banana flour has a smaller negative effect. The interaction between pigeon pea and banana flour has a positive effect on the fiber content. Rice flour, on the other hand, has the highest negative effect on the fiber content.

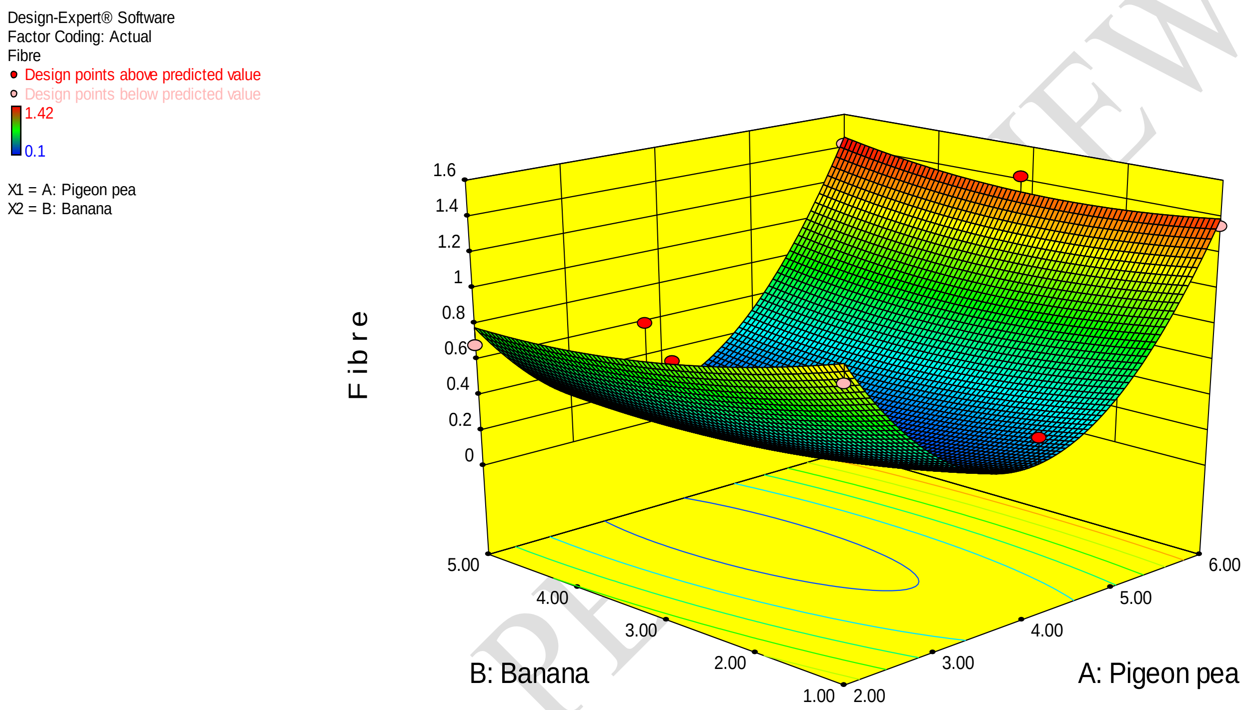

Fig.3: Surface plot for the fibre content of the enriched rice-based breakfast cereal

Fig.3 shows the surface plot for the fibre content of the enriched rice-based breakfast cereal. The plot is a three-dimensional representation of the relationship between the two independent variables, pigeon pea flour (A) and banana flour (B), and the dependent variable, fibre content. The plot shows the variation in the fibre content across different combinations of pigeon pea flour and banana flour. The contour lines on the plot represent constant values of fibre content. The darker the contour line, the higher the value of fibre content. From the plot, it can be observed that increasing the percentage of pigeon pea flour in the blend leads to a decrease in the fibre content, while increasing the percentage of banana flour leads to an increase in the fibre content. The interaction of pigeon pea flour and banana flour also has a slight positive effect on the fibre content. The surface plot provides a visual representation of the relationship between the variables and helps to identify the optimal combination of pigeon pea flour and banana flour to achieve the desired fibre content.

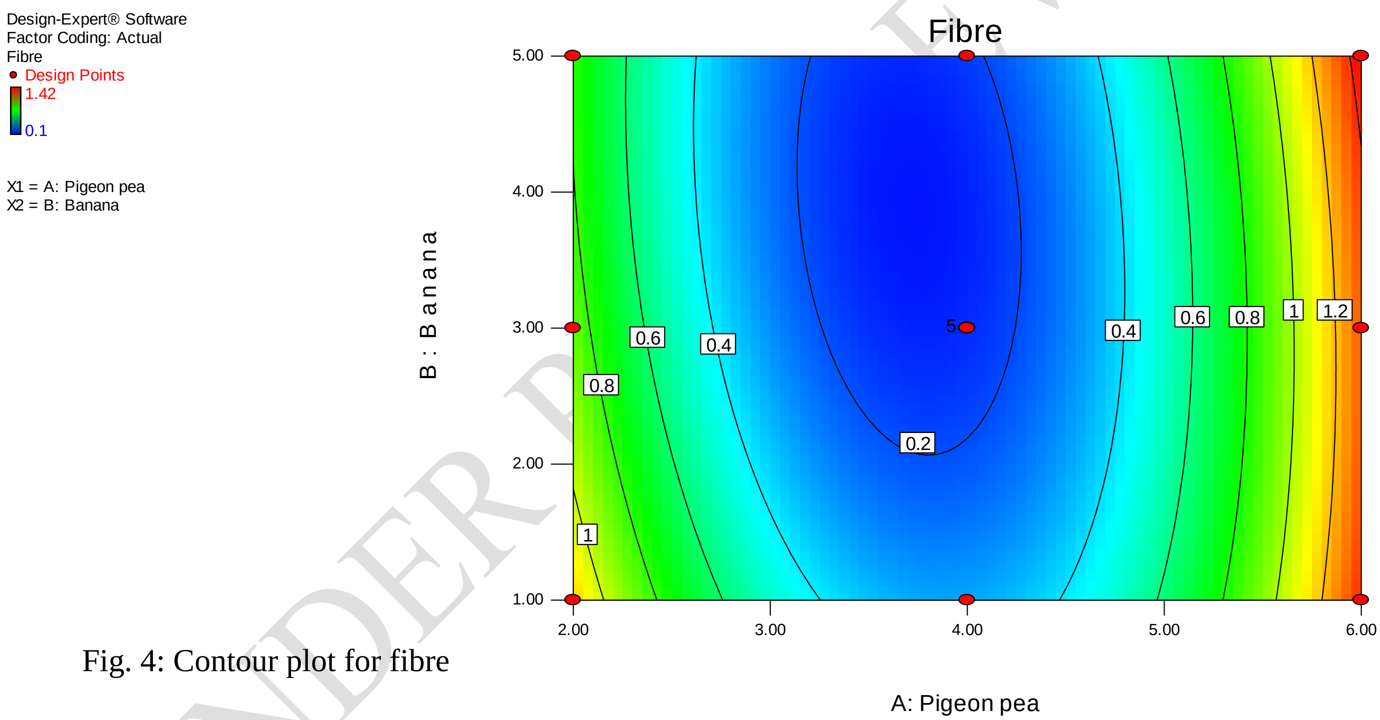

Fig. 4: Contour plot for fibre

Energy

The metabolizable energy value ranged from 365.82-380.73Kcal/100g with sample 2 having the least and sample 14 having the highest. The high energy values in sample 14 could be attributed to the breakdown of carbohydrate (starch) to simple assailable sugars thereby increasing the calories. The range of the values is in close range with the report of Rohman *et. al* (2014). The statistical analysis shows that there was no significant difference ($P > 0.05$) between sample 1, 3, 5, 10 and 11 with mean scores of 379.27, 379.27, 379,27, 379.27 and 379.27 respectively. Sample 4, 7 and 12 with mean scores of 371.86, 371.63 and 371.52Kcal/100g are significantly the same ($P < 0.05$), also sample 6 and 9 with mans scores 374.99 and 374.06 do not differ significantly ($P > 0.05$) while sample 2, 8, 13 and 14 with mean scores 365.82, 372.25, 370.80 and 380.73 differed significantly ($P < 0.05$) from each other and other samples. he substantial protein content variation allows manufacturers to tailor the nutritional composition of the cereals. Cereals with higher protein content cater to consumers seeking protein-rich breakfast options, such as athletes and individuals looking to increase their protein intake. The inclusion of pigeon pea and banana flours in sample 2 demonstrates how ingredient synergy can contribute to nutritional enhancement. This effect underscores the potential of leveraging complementary ingredients to achieve desired nutritional outcomes.

Conclusion

From the results of the study, breakfast cereals (Convenient foods) could be formulated from rice, pigeon pea and banana flour. It is apparent from the study that the products from the composite flours were acceptable. The uses could be much more effective in children and adult feeding because of the increased protein and energy content. The carbohydrate, protein and energy value increased, while fat and ash content decreased, thus the supplementation increased the protein content of the samples. The high nutrient density is important in young children feeding.

Furthermore, the products could probably serve as a source of nutrients for children as well as adults. They could be incorporated into infant and children formula. It may be concluded that the formulation of rice-based breakfast cereal in sample 2 (6% pigeon pea, 5% banana, and 89% rice flour) had the highest taste, aroma and general acceptability with highest protein content showing that the product should be produced, introduced and made a popular breakfast food in Nigeria and beyond. Hence, the enrichment of rice-based breakfast cereal could contribute significantly as a means of tackling under-nutrition, as well as improving nutritional status when promoted in Nigeria.

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