

PREDICTION OF NUTRITIONAL PROPERTIES OF SNACKS PRODUCED FROM BAMBARA-NUT, MAIZE AND RIPE-PLANTAIN BLENDS USING MIXTURE RESPONSE SURFACE METHODOLOGY

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Abstract

The ratio (%) of bambara-nut (A): maize (B): ripe plantain (C) as variables in the blends used to produce snacks was designed using optimal mixture model of the Response Surface Methodology (RSM). Regression analysis was used to determine the effects of variations of the mixture on the responses (chemical composition) of the snacks. The snacks had 3.20-5.41% moisture and 3.20-6.04% protein contents. The minerals ranged from 10.84-17.79 phosphorous, and 0.43-0.90 mg/100 g iron. Linear and Quadratic models predicted the responses with high coefficient of determinations (R^2) range (0.7143-0.9978) and adequate precision values (>4). Bambara-nut had the lowest values (1.39-2.44) of variance inflation factors (VIF) close to ideal value (1.00) across the responses which confirm its adequate estimation. Snacks were well accepted in all the sensory attributes. The optimal mixture model as a statistical tool could find a useful application in predicting the chemical compositions of snacks made with similar materials.

Keywords: Snacks, Nutritional composition, Sensory properties, Mixture response methodology, Prediction

Introduction

There is the increasing trend of moving from the traditional pattern of eating three square meals a day to snacking in many parts of the world by all age groups; children, adolescents, and adults (Okpala and Okoli, 2010). Majorly, as a result of the busy

schedule of the daily activities that makes for a less available time in conventional meal preparations and encourages 'eating-on-the-go' (Idowu *et al.*, 2010). Most of the snacks range from biscuits, cookies, cakes, doughnut, buns, puff-puff, chin-

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chin, etc is made from 100% wheat flour while a few could be made from other flours composited with wheat.

Consequently, the development of snacks from indigenous gluten-free materials that could match for wider acceptability has received a lot of attention in recent times (Awolu *et al.*, 2015; Ifediba and Obasi, 2018; Wordu and Akusu, 2018; Adelekan *et al.*, 2019). The major purposes for this are; to assist patients with the challenge of coeliac diseases (gluten-intolerant) and to lessen the challenge of heavy duties associated with wheat importation in many developing countries (Awolu *et al.*, 2015).

The indigenous raw materials include cereals (such as sorghum, millet, maize, rice, acha rice), tubers (such as cassava, cocoyam, water yam, taro corms), legumes (such as groundnut, kersting's groundnut, bambara groundnut, soya beans, pigeon pea) and fruits (such as tigernut, coconut, fluted pumpkin, African breadfruit, and plantain). These were commonly exploited in form of composite flours with other ingredients for the production of snacks (Okpala and Okoli, 2010; Awolu *et al.*, 2015; Ifediba and Obasi, 2018; Wordu and Akusu, 2018; Adelekan *et al.*, 2019). Also, different methods of preparation were employed but basically, baking and frying are commonly used. Thus, manipulating these materials in a mixture of blends for enriched and acceptable snacks cannot be over emphasised.

The present work is design to use blends of bambara groundnut (bambara-nut), maize and ripe plantain in the preparation of an improved form of a traditional snack called *elekute*. *Elekute*, a traditional snack among the 'Akokos' in Ondo State, Southwest Nigeria; is produced from roasted maize flour and ripe plantain paste, wrapped in plantain leaves, cook overnight, and dried. Bambara-nut (*Vigna subterranean L.*) is a legume and a good source of protein; while a cereal, maize (*Zea mays*); and ripe plantain fruit (*Musa paradisiaca L.*) are good sources of carbohydrate and mineral elements (Adelekan *et al.*, 2019). In Nigerian homes, firmly ripe plantain is generally consumed in fried form as a meal with fried egg, or an accompaniment with cooked rice, or beans. As a snack, plantain (ripe and unripe) is majorly roasted and eaten with palm oil or roasted groundnut, or simply fried as chips or 'dodo-kire'. The inclusion of ripe plantain as a component in the production of a ready-to-eat snack will, therefore, makes for a novel way of consuming plantain.

Mixture response surface methodology (RSM) is a technique that can be employed to statistically determine the effects of multiple variables in a mixture on quality attributes while minimising the numbers of experiments to be performed. It is a special response experiment in which the design

factors are the components of a mixture, and the responses are the quality attributes. The change in quality of the attributes depends proportionally on the components that are present in the mixture and not on the quantity of the mixture (Okpala and Okoli, 2010).

Therefore, this study aimed at using Mixture RSM to develop models, which can be employed for predicting the proximate and mineral composition of the snack from blends of bambara-nut, maize, and ripe plantain.

Materials and methods

Bambara-nut (*Vigna subterranean L.*), maize (*Zea mays*), firmly ripe plantain (*Musa paradisiaca L.*), and other ingredients (salt, ginger, garlic, and chilli pepper) used were purchased from Ado-Ekiti Central market, Ekiti State, Nigeria. All reagents used were of analytical grades.

Experimental design for the preparation of snack's blends

The experimental design for the production of bambara-nut, maize, and ripe plantain blends ratios was carried out using the optimum mixture design of response surface methodology (Design-Expert software version 10.0.1, Stat-Ease Inc., Minneapolis, MN, U.S.A) which gave 16 experimental runs

Seven out of the developed sixteen RSM runs were randomly selected and used. The selected runs include; three of the runs that occurred in clear whole number ratios (runs 2, 10, and 13) and four others (runs 1, 6, 8, and 11) among those that occurred in decimals which were rounded up to the nearest whole numbers for ease of measurement during the experiment. The variables were bambara-nut, maize, and ripe plantain (%) while the responses were proximate (protein, ash, fat, fibre, carbohydrates, and moisture contents (%)) and mineral (phosphorous, iron, and copper) compositions (mg/100 g).

Preparation of the materials for snack production

The maize (5 kg) was sorted, cleaned, washed, and dried at 60°C for 24 h. Bambara-nut (5 kg) was sorted, cleaned, and soaked in hot water at 80°C for 2 h to enhance the manual removal of the seed coats. The dehulled bambara-nut was washed, drained and dried at 60°C for 24 h. The dried bambara-nut seeds and maize were roasted using a traditional method described by Okafor *et al.* (2014) with little modification; by roasting in a pot placed on an open flame at 200°C for 1 h. The seeds were continually turned until the desired colour was

Table1. Proximate and mineral composition of snacks from blends of bambara- nut, maize, and ripe plantain

R	Blend			Proximate composition						Mineral composition		
				(g/100 g)						(mg/100 g)		
	A:	B:	C	Moisture	Fat	Protein	Ash	Fibre	CHO	Fe	P	Cu
	(%)											
1	31	34	35	5.41 ^b	5.05 ^{cd}	5.06 ^d	2.49 ^a	2.17 ^b	80.84 ^{abcd}	0.60 ^d	10.84 ^f	0.06 ^a
2	35	35	30	3.20 0 ^f	5.85 ^{bcd}	3.20 ^h	2.16 ^a	3.83 ^a	79.40 ^{bcde}	0.67 ^c	12.52 ^e	0.06 ^a
6	34	33	33	5.00 ^{ab}	5.50 ^{bcd}	5.68 ^b	2.29 ^a	3.19 ^{ab}	76.67 ^{ef}	0.90 ^a	13.16 ^d	0.05 ^{ab}
8	38	32	30	4.40 ^{cd}	6.88 ^{ab}	5.06 ^d	2.49 ^a	4.48 ^a	76.23 ^{ef}	0.43 ^g	16.58 ^b	0.03 ^{cde}
10	40	30	30	3.50 ^{ef}	6.73 ^{ab}	4.08 ^f	1.88 ^a	2.08 ^b	82.84 ^{ab}	0.49 ^e	17.79 ^a	0.05 ^{ab}
11	38	30	32	4.71 ^{bcd}	6.02 ^{abcd}	6.04 ^a	1.85 ^a	1.98 ^b	82.00 ^{abc}	0.70 ^b	15.94 ^c	0.04 ^c
13	35	30	35	4.86 ^{bcd}	7.40 ^a	4.97 ^{ed}	2.24 ^a	4.28 ^a	82.98 ^a	0.46 ^f	16.69 ^b	0.02 ^e

Values are means of triplicate determinations. Mean values with different subscripts along the same column are significantly ($p < 0.05$) different R = Response Surface Methodology run; A = Bambara- nut; B = Maize; C = Ripe plantain; CHO = Carbohydrates; P = Phosphorous; Cu = Copper; Fe = Iron

obtained. Thereafter, the roasted seeds were cool at 32°C for 30 min and milled into flour using a Hammermill (Trojan TGS 228 E), sieved to pass through a 100 mm mesh sieve (British Standard), packaged in cellophane nylon and stored at 4°C prior to production of the snacks. The ripe plantains (8kg) were washed, peeled, and blended using a laboratory blender (Marlex Electroline Dabhel, Daman (UT)) and stored in an airtight container at 4°C.

Snacks blends formulation and production

The bambara-nut and maize flours were weighed into ripe plantain slurry at different graded levels (%). The different levels used were chosen based on experimental design (Mixture Response Surface Methodology developed runs). Thereafter, an equal amount (2.0g) of mixed spices (ginger, garlic, and pepper) and salt (4.0g) was added to each of the blend mixtures (500g). The flours, ripe plantain paste, spices, and salt were thoroughly mixed together in a mixing bowl. The mixture was extruded using a cold manual extruder. The extruded masses were arranged on an already greased oven tray; transferred into a preheated oven (PBS 118SF Genlab Widnes, England) and baked at 170°C for 20 min. The snacks were cooled at ambient temperature (32°C) and packaged in polyethylene bags prior to analyses.

Determination of proximate composition

The proximate analyses were determined using AOAC (2012) to determine the percentage of moisture, fat, protein, ash, and fibre contents, while carbohydrate content was estimated by the difference (i.e. 100-(% moisture+% fat+protein +% ash +% fibre contents).

Determination of mineral elements

Minerals elements; phosphorous (P), copper (Cu) and iron (Fe) were determined by the dry ash method described by AOAC (2012).

Sensory evaluation

Sensory evaluation was carried out on the snacks by twenty (20) untrained panellists drawn from the Department of Food Technology, Federal Polytechnic, Ado-Ekiti, Ekiti State, to assess the attributes of colour, aroma, taste, texture and overall acceptability using multiple comparison test with a 9-point hedonic scale where 9=liked extremely; 5=neither like nor dislike and 1=dislike extremely (Wordu and Akusu 2018).

Statistical analysis

All analyses were carried out in triplicates and mean scores of the results obtained in the experiment were subjected to analysis of variances (ANOVA), and Duncan multiple range tests (DMRT) were used to separate the means at $p < 0.05$ using SPSS version 18. The optimum mixture of Response Surface Methodology (RSM) was used to fit the quadratic polynomial equation generated by the Design-Expert software version 10.0.1 (Stat-Ease Inc., Minneapolis, U.S.A). In order to correlate the response variable to the independent variables, multiple regressions were used to fit the coefficient of the polynomial model of the response. The quality of the fit was evaluated using analysis of variance (ANOVA), coefficient of determination (R^2) and regression coefficients (Okpala and Okoli, 2010).

Table 2. ANOVA and VIF for responses (proximate composition) of snacks made from blends of bambara-nut, maize and ripe plantain

Response Model	Proximate composition					
	Moisture LMM	Fat QMM	Protein QMM	Ash QMM	Fibre QMM	CHO QMM
ANOVA Source	p-value					
Model	0.0816	0.2601	0.3794	0.1302	0.2550	0.1278
Linear Mixture	0.0816	0.2103	0.3483	0.1141	0.5412	0.1164
AB	-	0.3031	0.3219	0.0750	0.1530	0.0687
AC	-	0.2293	0.2624	0.1171	0.2794	0.2122
BC	-	0.2917	0.1906	0.2878	0.4935	0.0761
Coefficient of determination (R ²) value						
R ²	0.7143	0.9759	0.9474	0.9941	0.9769	0.9943
Adj- R ²	0.5714	0.8557	0.6841	0.9645	0.8615	0.9658
Pred- R ²	-0.1083	-153.5051	-337.2161	-36.9821	-147.3069	-35.6310
Adeq Precision	4.420	7.469	5.608	14.413	7.177	14.580
Coefficient components	VIF value					
A-Bambara	1.39	2.44	2.44	2.44	2.44	2.44
B-Maize	1.46	52.14	52.14	52.14	52.14	52.14
C-Ripe Plantain	1.42	40.92	40.92	40.92	40.92	40.92
AB	-	35.85	35.85	35.85	35.85	35.85
AC	-	23.00	23.00	23.00	23.00	23.00
BC	-	17.31	17.31	17.31	17.31	17.31

ANOVA = Analysis of variance; VIF = Variance Inflation Factors; CHO = Carbohydrate; LMM = Linear Mixture model; QMM = Quadratic Mixture model; A = Bambara-nut; B = Maize; C = Ripe plantain; Adj = Adjusted; Pred = Predicted; Adeq = Adequate.

Results and Discussions

Proximate composition of the snacks made from the various blends

The result of the experimented analysis for the responses (proximate and mineral analysis) of the snacks made from the blends of bambara nut, maize, and ripe plantain is shown in Table 1. Considering the effects of proximate properties on the responses, the corresponding values for the snacks range from 3.20-5.41% moisture, 5.05-7.40% fat, 3.20-6.04% protein, 1.98-4.48% crude fibre, 1.85-2.49% ash and 76.23-82.98% carbohydrate contents.

The moisture contents of the snacks were generally low and will support a long shelf life and encourage good storage quality as microbial growth will be greatly hindered at low moisture content.

The relative low-fat contents in all the snacks will also reduce oxidative rancidity for long shelf life. The low-fat content will encourage the consumption of the snack by a large range of people with different physiological status even the obese that normally are conscious of their fat intake. This result is in agreement with that of Okpala and Okoli (2010)

The regression model developed for predicting the moisture and fat contents of the snacks are shown in Equation 1 and Equation 2, while the contour plots describing the moisture and fat contents are presented in Figure 1(a) and Figure 1(b) respectively.

$$\text{Moisture} = +3.79 * A + 3.72 * B + 6.79 * C \quad (1)$$

$$\text{Fat} = +6.61 * A - 0.51 * B + 14.11 * C + 11.21 * AB - 12.09 * AC - 12.58 * BC \quad (2)$$

where A = Bambara-nut; B = Maize; C = Ripe plantain

The result of fitting the data from moisture and fat contents to models is depicted in Table 2. The results indicate that Linear and Quadratic Mixture models described moisture and fat content respectively, and contributions of the model terms were not significant ($p < 0.05$). However, the R² value (0.9759) was high for fat signifying adequate prediction (Otolowo *et al.*, 2018) while in the case of moisture content with an R² value of 0.7143 indicate the model could only predict 71% of the variation meaning that about 29% of the variation was due to external factors not included in the model. The R² value ≥ 0.75 is reported to be adequate for prediction purposes (Okpala and Okoli, 2010) which imply that the model developed for the moisture content may not be adequate for prediction purpose. Consequently, the predicted values for moisture content were not as close to the experimented values as in the case of fat content (Table 3) and negative predicted R² values in these responses (Table 3) imply that the overall means may be a better predictor than the current models.

Table 3. Experimental and predicted values for proximate composition of snacks made from blends of bambara-nut, maize, and ripe plantain

RSM run	Blends (%)			Proximate composition (%)			
	A	B	C	Experimental value	Predicted value	Experimental value	Predicted value
				Moisture		Fat	
1	31	34	35	5.41	5.26	5.05	5.15
2	35	35	30	3.20	3.76	5.85	5.85
6	34	33	33	5.00	4.72	5.50	5.32
8	38	32	30	4.40	3.78	6.88	6.97
10	40	30	30	3.50	3.79	6.73	6.61
11	38	30	32	4.71	4.47	6.02	6.19
13	35	30	35	4.86	5.29	7.40	7.34
				Protein		Ash	
1	31	34	35	5.06	4.89	2.49	2.47
2	35	35	30	3.20	3.19	2.16	2.16
6	34	33	33	5.68	5.99	2.29	2.32
8	38	32	30	5.06	4.91	2.49	2.48
10	40	30	30	4.08	4.29	1.88	1.90
11	38	30	32	6.04	5.75	1.85	1.82
13	35	30	35	4.97	5.08	2.24	2.25
				Fibre		CHO	
1	31	34	35	2.17	2.30	80.84	80.67
2	35	35	30	3.83	3.84	79.40	79.39
6	34	33	33	3.19	2.96	76.67	76.97
8	38	32	30	4.48	4.59	76.23	76.08
10	40	30	30	2.08	1.93	82.84	83.04
11	38	30	32	1.98	2.20	82.00	81.72
13	35	30	35	4.28	4.20	82.98	83.08

RSM = Response Surface Methodology; A = Bambara-nut; B = Maize; C = Ripe plantain; CHO = Carbohydrates

The protein and ash contents of the snacks were also presented in Table 1. The samples were significantly ($p < 0.05$) different in protein content except the snacks made with the two blends; 31:34:35 and 38:32:30 (runs 1 and 8, respectively) which showed no significant variation. Also, there was no observable significant difference in all the ash contents of the snacks from the various blends. However, the range of values (3.20-6.04%) obtained for protein was lower while that of ash content (1.85-2.49%) was higher than the report of Bolarinwa et al. (2019) for gluten-free cookies made from germinated brown rice flour (6.60-7.99 g/100 g protein and 0.66-1.38 g/100 g ash). This may be due to the differences in the materials used.

The effect of the blends on the predictions of the Quadratic Mixture model on protein and ash contents of the snacks is shown in Table 2. High R^2 values (0.9474 for protein and 0.9941 for ash) showed adequate predictions. This implies that the model could predict about 95% and 99% of the variations observed in protein and ash contents

while only 5% and 1% of the variations were respectively attributed to factors not included in the model. Moreover, the predicted and experimental values for protein and ash contents were relatively close (Table 3).

The final equations in terms of the coded factors for predicting the protein and ash contents of the snacks are shown in Equation 3 and Equation 4,

while the contour plots describing the protein and ash contents are presented in Figure 1(c) and Figure 1(d) respectively.

$$\text{Protein} = +4.29*A - 6.81*B - 3.02*C + 17.82*AB + 17.78*AC + 34.30*BC \quad (3)$$

$$\text{Ash} = +1.90*A - 1.36*B + 4.50*C + 7.56*AB - 3.79*AC + 1.98*BC \quad (4)$$

The results of the fibre and carbohydrates analysis of the snacks are depicted in Table 1. The obtained range of values (1.98-4.48% fibre and 76.23-82.98% carbohydrates) exhibit slight significant variations among the blends and were relatively higher in magnitudes than those reported by Okpala and Okoli (2010) but showed a comparable level of carbohydrates (79.03-83.01 g/100 g) in the report of Bolarinwa et al. (2019). These might possibly due to the variations in the components of the blends used by these authors in relation to those used in the present study. The models developed for predicting the fibre and carbohydrates contents of the snacks were stated in Equation 5 and Equation 6. Though the model terms were not insignificant ($p < 0.05$), R^2 values (0.9769 fibre and 0.9943 carbohydrates) of predictive purposes were produced by the Quadratic Mixture model. This implies that the model could predict 98% and 99% of the variations observed in fibre and

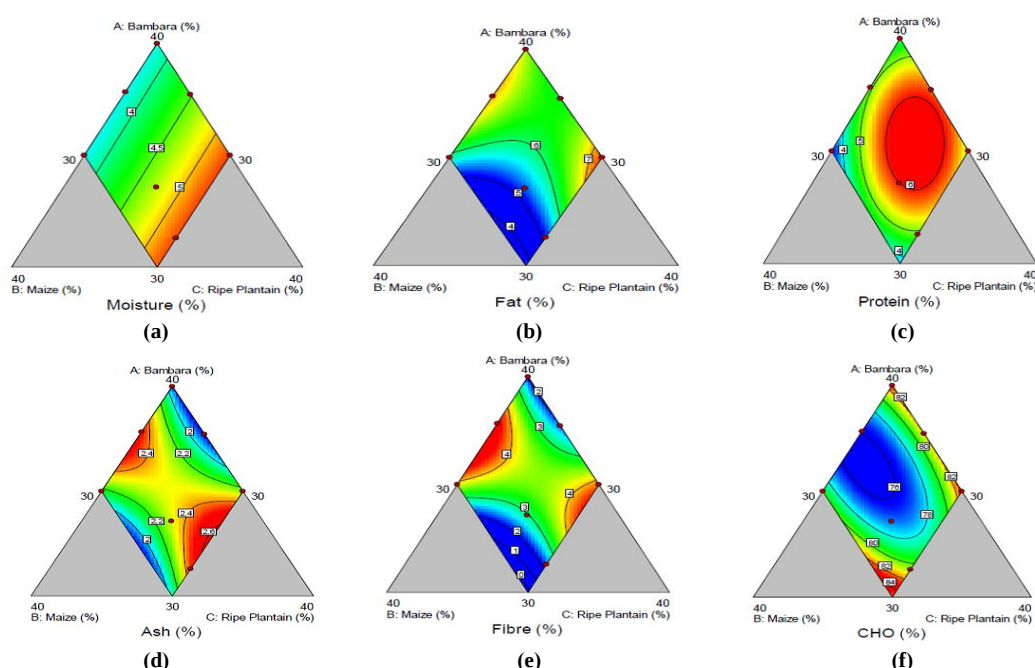


Figure 1. Mixture response contour plots showing the effect of mixture on the proximate composition (moisture, fat, protein, ash, fibre and CHO-carbohydrates contents (%), respectively) of the snacks produced from blends of bambara-nut, maize and ripe plantain

carbohydrate contents while only 2% and 1% of the variations were respectively attributed to external factors. As such the predicted and experimented values for the fibre and carbohydrate contents of the snacks were closely related (Table 3) showing the validity of the model. The contour plots describing the fibre and carbohydrate contents are presented in Figure 1(e) and Figure 1(f) respectively.

$$\text{Fibre} = +1.93*A - 9.25*B + 12.64*C + 29.98*AB - 12.33*AC - 8.05*BC \quad (5)$$

$$\text{CHO} = +83.04*A + 119.53*B + 93.93*C - 87.56*AB - 21.60*AC - 84.86*BC \quad (6)$$

where CHO = Carbohydrates; A = Bambara-nut; B = Maize; C = Ripe plantain

The mineral analysis of the snacks made from the various blends

The result for the mineral analysis as responses for the snacks made from the blends of bambara-nut, maize, and ripe plantain is shown in Table 1. The determined mineral elements that were considered ranged from 10.84-17.79 mg/100g phosphorous (P), 0.43-0.90 mg/100 g iron (Fe) and 0.02-0.06 mg/100 g copper (Cu).

Mineral elements are essential for human health, have important physiological roles on

different organs and cellular mechanisms of the body (Anon *et al.*, 2018). The trend of the obtained mineral contents of the snacks was such that the range was generally low for P and Cu while that of Fe were comparable in respect of the previous research reports (Wordu and Akusu 2018), and the standard recommended dietary allowance (RDA) and adequate intake (AI) for minerals (Lenntech.n.d., 1998-2016). This is an indication that the snack samples in the present work may not be a good source for P and Cu; though, they may complement the daily mineral requirements of the consumers. However, the values in the present work for P were far higher than those reported by Wordu and Akusu (2018). Nonetheless, the range of values for Fe contents meets the recommended dietary allowance (RDA) and adequate intake (AI) (Lenntech, n.d.). Iron (Fe) is an essential trace element that is vital to the health of all living things; it is an important constituent of haemoglobin (Otolowo and Olapade, 2017). Together with Copper (Cu), it enables the body to form red blood cells and helps maintain healthy blood vessels, nerves, and immune function. Also, Cu contributes to the iron absorption and maintenance of healthy bones (Anonymous, 2020).

The result of fitting the data from phosphorous, iron, and copper analyses to models is shown in Table 4. The results indicate that the contributions of the Linear mixture model and quadratic term; AB were significant ($p < 0.05$) for P and Cu contents,

Table 4. ANOVA and VIF for responses (mineral composition) of snacks made from blends of bambara-nut, maize and ripe plantain

Response Model	Mineral composition		
	Phosphorous (P) LMM	Copper (Cu) QMM	Iron (Fe) QMM
ANOVA Source		p-value	
Model	0.0078	0.0803	0.3957
Linear Mixture	0.0078	0.0700	0.4615
AB	-	0.0533	0.5634
AC	-	0.1887	0.1769
BC	-	0.6419	0.2839
Coefficient of determination (R ²) value			
R ²	0.9114	0.9978	0.9424
Adj-R ²	0.8672	0.9865	0.6546
Pred-R ²	0.7240	-13.4064	-368.7865
Adeq-Precision	10.669	25.201	4.464
Coefficient components	VIF value		
A-Bambara	1.39	2.44	2.44
B-Maize	1.46	52.14	52.14
C-Ripe Plantain	1.42	40.92	40.92
AB	-	35.85	35.85
AC	-	23.00	23.00
BC	-	17.31	17.31

ANOVA = Analysis of variance; VIF = Variance Inflation Factors; CHO = Carbohydrate; LMM = Linear Mixture model; QMM = Quadratic Mixture model; A = Bambara-nut; B = Maize; C = Ripe plantain; Adj = Adjusted; Pred = Predicted; Adeq = Adequate.

Table 5. Experimented and predicted values for mineral content (mg/100 g) of snacks made from blends of bambara-nut, maize and ripe plantain

RSM run	Blend (%) A: B: C	Phosphorous (P)		Copper (Cu)		Iron (Fe)	
		Exper value	Predicted value	Exper value	Predicted value	Exper value	Predicted value
1	31 34 35	10.84	11.52	0.060	0.061	0.60	0.63
2	35 35 30	12.52	12.54	0.060	0.060	0.67	0.67
6	34 33 33	13.16	12.94	0.050	0.049	0.90	0.84
8	38 32 30	16.58	15.71	0.030	0.031	0.43	0.46
10	40 30 30	17.79	18.14	0.050	0.049	0.49	0.45
11	38 30 32	15.94	17.01	0.040	0.041	0.70	0.75
13	35 30 35	16.69	15.66	0.020	0.020	0.46	0.44

RSM = Response Surface Methodology; A = Bambara nut; B = Maize; C = Ripe plantain; Exper = Experimented

respectively but all model terms were insignificant in the case of Fe. Nevertheless, the R² values (0.9114 P, 0.9978 Cu, and 0.9424 Fe) were high enough for adequate prediction (Otolowo *et al.*, 2018). It thus, means that only 9%, <1%, and 6% of the variations were due to external factors not included in the model for P, Cu, and Fe, respectively. The predicted and experimental values were very close for Cu; relatively close for Fe but not so for P (Table 5). However, P produced adjusted and predicted R² values that were in reasonable agreement (difference <20%); and a low range of variance inflation factors (1.39-1.46) for the linear model terms which suggested adequate estimation of the regression coefficient (Table 4).

The regression model developed for predicting the P, Fe, and Cu contents of the snacks are shown in

Equations 7, 8 and 9, while the contour plots describing these responses are presented in Figure 2 (I-III respectively).

$$P = +18.14 * A + 6.94 * B + 13.19 * C \quad (7)$$

$$Cu = +0.049 * A + 0.26 * B - 0.051 * C - 0.38 * AB + 0.083 * AC - 0.022 * BC \quad (8)$$

$$Fe = +0.45 * A + 1.62 * B - 2.04 * C - 1.46 * AB + 4.93 * AC + 4.01 * BC \quad (9)$$

where P = Phosphorous; A = Bambara-nut; B = Maize; C = Ripe plantain; Cu = Copper; and Fe = Iron.

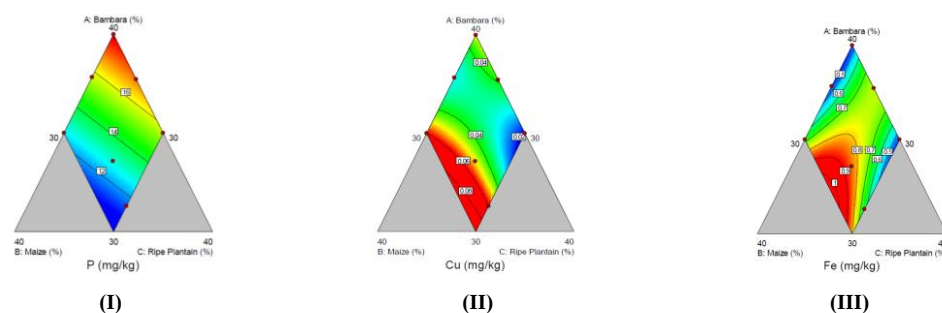


Figure 2. Mixture response contour plots showing the effect of mixture on the mineral composition (phosphorous (P), copper (Cu) and iron (Fe) contents (mg/100 g), respectively) of the snacks produced from blends of bambara-nut, maize, and ripe plantain

NB: Note the correct unit (mg/100 g) in the figure caption as against the one in the legends

Table 6. Sensory evaluation of snacks made from blends of bambara-nut, maize and ripe plantain

RSM run	Blends A B C			Aroma	Taste	Colour	Texture	Overall acceptability
1	31	34	35	7.40 ^{ab}	7.00 ^{ab}	7.40 ^a	6.20 ^a	6.80 ^{ab}
2	35	35	30	7.30 ^{ab}	6.70 ^{ab}	6.30 ^{ab}	7.10 ^a	7.20 ^{ab}
6	34	33	33	7.90 ^a	7.70 ^a	6.50 ^{ab}	6.70 ^a	7.00 ^{ab}
8	38	32	30	8.00 ^a	7.90 ^a	7.00 ^{ab}	6.60 ^a	8.00 ^a
10	40	30	30	7.50 ^{ab}	6.80 ^{ab}	7.00 ^{ab}	6.70 ^a	7.00 ^{ab}
11	38	30	32	6.80 ^{abc}	6.70 ^{ab}	6.70 ^{ab}	7.00 ^a	7.80 ^a
13	35	30	35	7.40 ^{ab}	7.60 ^a	7.00 ^{ab}	6.70 ^a	8.00 ^a

RSM = Response Surface Methodology; A = Bambara nut; B = Maize; C = Ripe plantain; Exper = Experimented

Sensory evaluation of attributes of snacks made from the various blends

There was no distinct significant difference ($p < 0.05$) in sensory attributes of snacks made from the blends of bambara-nut, maize, and ripe plantain as shown in Table 6 which implies that the mean values without further analysis could be adequate for the description. Hence, the sensory data were not fitted for response modelling as in the case of proximate and mineral compositions. All the samples from the various blend ratios were well accepted by the panellists and had high ratings (ranged 6.20-8.00) for all the sensory attributes evaluated especially the overall acceptability. The values were comparable to the report of Adegbanke and Ilesanmi (2018) in the sensory acceptability of cake-like snacks made from blends of plantain, sweet potato, cocoyam, and wheat flours. Thus, there is a possibility of using the blends of bambara-nut, maize, and ripe plantain within the presently experimented ratios for the production of an acceptable wheat (gluten)-free-snack. This could also reduce the importation of wheat to improve the nation's economy and enhance the local production of these indigenous crops.

Conclusions

The result showed that the snacks had good nutritional and sensory properties. The inclusion of ripe plantain in the blends will add novelty to the snacks' variety while the low moisture contents will support good shelf life and storage qualities. Desirable adequate precision (values > 4) obtained in the regression analysis for all the responses (proximate and mineral contents) indicates an adequate signal ratio that can be used to navigate the design space. Thus, the study has shown that the optimal mixture of RSM as a statistical tool could be used to determine the effect of variations in the ratio of bambara-nut, maize and ripe plantain blends on proximate and mineral compositions of the formulated snacks. The obtained models were adequate for prediction purposes and could be used to predict the proximate (except moisture content) and mineral composition of snacks made with similar blends and under the same conditions. The use of indigenous non-wheat-based materials for acceptable snacks will be pleasurable for coeliac disease patients and reduce the national duties on

the importation of wheat which has been widely used in snack production.

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