European Journal of Nutrition & Food Safety

Volume 16, Issue 12, Page 124-148, 2024; Article no.EJNFS.127886
ISSN: 2347-5641

Quality Characteristics of Bread Produced with Blends of Flour from Cassava, Wheat and Bambara Groundnut (*Vigna subterranea*)

John Praise Alimi [a*], Abubakar Adegboyega Akanni [a], Joseph Alaba Aina [a], Adenike Rukayat Ashonibare [a], Amazing Grace Kurrah [a], Newman Festus Okparavero [a] and Samson Oladipo Okunade [a]

[a] Durable Crops Research Department, Nigerian Stored Products Research Institute, P.M.B. 1489, Ilorin, Kwara State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ejnfs/2024/v16i121608

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/127886

Original Research Article

Received: 10/10/2024
Accepted: 13/12/2024
Published: 21/12/2024

ABSTRACT

Food fortification targeted at increasing the micronutrient contents of food with the view to improving its nutritional quality is a pragmatic approach in combating malnutrition which consequently engenders the achievement of 'sustainable development' goal three (SDG-3). Hence, this research assessed the quality attributes of bread produced with blends of flour from cassava, Bambara

---

**Corresponding author: Email: praise4palace2@gmail.com;*

Cite as: *Alimi, John Praise, Abubakar Adegboyega Akanni, Joseph Alaba Aina, Adenike Rukayat Ashonibare, Amazing Grace Kurrah, Newman Festus Okparavero, and Samson Oladipo Okunade. 2024. "Quality Characteristics of Bread Produced With Blends of Flour from Cassava, Wheat and Bambara Groundnut (Vigna Subterranea)". European Journal of Nutrition & Food Safety 16 (12):124-48. https://doi.org/10.9734/ejnfs/2024/v16i121608.*

groundnut and wheat. Wheat flour was obtained from production line while low postharvest physiologically deteriorated cassava root (IITA-TMS-IBA011368) and Bambara groundnut were processed into HQCF and Bambara flour, respectively. The flours were blended together as depicted by D-Optimal mixture using Design Expert software (Version 12.0) and total of sixteen (16) samples were generated. The bread baked with the blended flours were analyzed for physical, proximate, sensory and microbiological properties.
Range of value for crusts' lightness (L*), redness-bluishness (a*), yellowness-greenness (b*), browning index, crumb density, crumb porosity, loaf weight and overall acceptability was 29.57-39.52, 0.10-3.96, 8.28-15.27, 0.36-0.41, 0.15-0.29, 0.45-0.52, 56.30-66.30 g and 5.60-7.38, respectively. Moisture, ash, crude fibre, fat, crude protein, carbohydrate and energy value ranged from 1.26-1.87%, 0.31-0.59%, 7.25-26.56%, 4.46-9.91%, 30.98-56.34% and 314.51-415.67 kcal. Crumb elasticity, softness, crust appearance, color, flavor, taste and overall acceptability was 5.12-7.64, 4.96-7.88, 5.68-7.52, 6.28-7.36, 5.84-7.72, 5.44-7.72 and 5.60-7.96. The bread samples were acceptable sensorially as adjudged by the panels. Lower count (load) of viable organism found in composite bread was due to the lethal effect of baking temperature and good hygiene practice. Bread of acceptable quality was produced with blends of flours from cassava, Bambara groundnut and wheat but the optimized ingredient blend formulation obtained was high quality casava flour of 15.10%, wheat flour of 63.67% and Bambara nut flour 21.23% while the calculated desirability was 0.53.

Keywords: Functional properties; microbiological qualities; optimization; physicochemical properties; proximate properties.

1. INTRODUCTION

Wheat, has been the staple food of the major civilizations in Europe, Western Asia, and North Africa for 8,000 years. The composition of wheat flour includes moisture, protein, total ash, crude fibre and fatty acid with average values of 12.4%, 11.8%, 1.3%, 2.0% and 77 mg, respectively. The typical functional properties of wheat include emulsification, water binding capacity, viscosity, foaming, solubility, and gelation capacity. Wheat flour provides the shape of baked food products. It contains proteins that interact with each other when mixed with water, forming gluten (Shittu et al., 2008). The high cost of wheat importation has necessitated the need to source for alternative gluten-free flours that has complementary nutritional and functional properties to substitute wheat flour thereby reducing the over dependence on wheat importation (Alimi et al., 2023a). One of such gluten-free flours with promising food functional properties is high quality cassava flours (HQCF) and can be constituted into composite protein-enriched baking flour with the introduction of crop like Bambara groundnut.

HQCF can be produced with cassava varieties known to have carotene that can improve the immune response of human health. High quality cassava flour from cassava varieties such as IITA-TMS-IBA-011368 and IITA-TMS-IBA-070593 which are promising roots with regard to its pasting (high gel strength, starch granule stability to heating, low peak time and tendency for retrogradation) characteristics and physical properties such as appealing creamy color that constitute appeal which could influence consumer preference and acceptability when applied in baked food products such as bread, cake, cookies, chinchin etc. (Alimi et al., 2022). The pasting profile of HQCF produced from selected varieties of low postharvest physiologically deteriorated cassava revealed that flour from IITA-TMS-IBA-011368 followed by IITA-TMS-IBA-070593 are suitable for baking purpose. (Alimi et al., 2023b).

There is a fascinating fact about Bambara groundnuts. It is indeed a vital crop in many African households, providing essential nutrients, protein, and calories. Their affordability and nutritional value make them an excellent alternative to more expensive food options (Mayes et al., 2019). It is a potent nutraceutical with anti-diabetic and anti-cancer activities which can be attributed to the content of vitamin C which is an anti-oxidant. It has high soluble carbohydrate (Anthony, 2014) and good water absorption capacity (Azza et al., 2011) that correspond to increased finished product baking quality (loaf volume). Coupled with the oil absorption capacity that enhances flavor retention, flour from Bambara groundnut is suitable for the development of ready-to-eat food products such as bread, biscuits, cookies, sausage, chinchin etc.

High quality cassava flour from low postharvest physiologically deteriorated cassava is a gluten-free flour that could be beneficial to celiac patients (Alimi et al., 2023b). Therefore, this research was conducted to assess the quality characteristics of bread produced with blends of flour from cassava, wheat and Bambara groundnut.

2. MATERIALS AND METHODS

2.1 Materials

Cassava root (IITA-TMS-IBA-011368), Bambara nut seeds, refined wheat flour from production line was used. Other materials include Simas margarine (PT Intiboga Sejahtera, Jakarta, Indonesia), salt and sugar (Dangote Nigeria Plc., Lagos), Fermipan Baking yeast (DSM bakery ingredient, Dordrecht-Holland), Edlen Dough Conditioner (EDC) (Edlen International Inc., Nigeria).

2.2 Methods

2.2.1 Production of high quality cassava flour (HQCF)

Wholesome cassava roots used for this study were provided by IITA, low postharvest physiologically deteriorated cassava root (IITA-TMS-IBA011368) were processed into high quality cassava flour (HQCF) (Alimi *et al*., 2024; Iwe *et al*., 2017).

2.2.2 Production of Bambara nut flour

Wholesome Bambara groundnuts seeds were procured from Mokwa, Niger State. Foreign materials, insect-infested and broken seeds were removed by sorting. Bambara groundnut (SAMNUT 21) was used, soaking was done for 24 h. The soaking water was decanted at 6 h interval to facilitate dehulling, reduces nutrient loss associated with soaking, and also the anti-nutritional component from the nut into the soaking water. The unit operations involved are soaking (72 h), sprouting, malting, the nuts were subsequently allowed to drain properly, spread on the drying trays and dried using NSPRI parabolic shaped solar dryer (PSSD) at 60 ºC dried for 24 hours to obtain safe moisture content below 12% before milling. The dried Bambara nuts were packed from the dryer, allowed to cool, milled into fine flour, sieved with 250-micron mesh and packaged in high density polyethylene bags for subsequent analyses.

2.2.3 Wheat flour

The refined wheat flour from production line was used for this study.

2.3 Experiment Design for the Experiment

D-Optimal design was used for the combination of the flours. Therefore, a total of 16 samples (runs) were generated while the control (wheat) sample was the seventeenth. The experimental design is shown in Table 1. The optimum levels of the mixture components for the composite bread were obtained using the numerical optimization technique. The numerical criteria were to maximize and minimize for different attribute considered. To find out an effective solution, a multiple response method called desirability function was applied. Contour plot and 3D graphs was generated which will helped in understanding the effects of varying the ingredient combination and processing parameters on the response, (which direction the response is increasing or decreasing). Regression models used for the quality attributes were equations (a)-(c) are shown in Table 2.

2.4 Bread Baking

The blending of the flour and the ingredients used for the baking experiment are indicated in Table 3. The unit operations involved in the bread baking include mixing (manually done for 15 min), kneading, dividing (100 g each), proofing (29 ± 2ºC, 79% RH for 2 h). The fully proofed dough was baked in an oven (Macadams, UK, model: Convecta B) at 180°C for 25 min. Cooling as a unit operation was carried out and eventual packaging of the bread. Loaf weight loaf was taken using a weighing balance. The oven spring (height of fermented dough – height of baked bread) was computed for the bread samples.

2.5 Physical properties of composite bread

Physical properties of bread such as (L^* a^* b^*) color parameters were determined using Colorimeter (ColorTec PCMTM Accuracy microsensors Inc., USA). Crumb porosity, density and moisture using hot air oven method

(Gallenkamp Pty ltd.) were determined following the method described by Ahemen et. al. (2021).

The data was used to determine the crumb (ρc) and solid density (ρs) as follows:

$$\rho c = \frac{W1}{V1} \quad (1)$$

$$\rho s = \frac{V2}{W2} \quad (2)$$

V1 (volume of rectangular sample) = length x breadth x thickness. The crumb porosity was calculated as follows:

$$\ell c = \frac{1-\rho c}{\rho s} \quad (3)$$

Browning index was calculated as follows:

$$BI = \frac{100*[x-0.31]}{0.17} \quad (4)$$

$$x = \frac{(a+1.75*L)}{5.645*L+a-3.012*b)} \quad (5)$$

2.6 Proximate Composition of the Composite Bread

The proximate composition (moisture, ash, fibre, protein and fat content) of the composite bread was determined following the standard analytical procedure of AOAC (2019) methods. Carbohydrate content in percentage was estimated employing difference Equation (6). Equation (7) is a factor that was used in calculating the energy value expressed in Kcal/kg or KJ/kg.

Carbohydrate (%) = 100 - % (protein + fat + moisture + ash) (6)

Energy value Kcal/kg = (Protein cont. x 4 + fat cont. x 9 + carbohydrate cont. x 4) (7)

Cont: Content

Table 1. Composition of flour

Sample /Run	HQCF	WF	BNF
1	14.65	70.00	15.35
2	10.00	61.88	28.12
3	28.62	61.38	10.00
4	15.00	50.00	35.00
5	24.97	53.16	21.87
6	14.65	70.00	15.35
7	24.97	53.16	21.87
8	28.62	61.38	10.00
9	32.87	50.00	17.13
10	15.10	63.67	21.23
11	40.00	50.00	10.00
12	17.46	55.18	27.36
13	22.90	60.26	16.84
14	22.08	67.92	10.00
15	15.00	50.00	35.00
16	10.00	61.88	28.12
17	0.00	100.00	0.00

HQCF: High quality cassava flour; WF: Wheat flour; BNF: Bambara nut flour

Table 2. Multiple Regression Analysis fitted Models

Model	Equation	
Linear	$Y = \mu_1 X_1 + \mu_2 X_2 + \mu_3 X_3$	(a)
Quadratic	$Y = \mu_1 X_1 + \mu_2 X_2 + \mu_3 X_3 + \mu_{12} X_1 X_2 + \mu_{13} X_1 X_3 + \mu_{23} X_2 X_3$	(b)
Cubic	$Y = \mu_1 X_1 + \mu_2 X_2 + \mu_3 X_3 + \mu_{12} X_1 X_2 + \mu_{13} X_1 X_3 + \mu_{23} X_2 X_3 + \mu_{123} X_1 X_2 X_3$	(C)

Where, Y is the predicted dependent variable; μ, the equation coefficients

Table 3. Recipe for baked bread

Bread Sample	Yeast (%)	Water (%)	Shortening (%)	Sugar (%)	EDC (%)	Salt (%)
$HQCF_{14.65}WH_{70.00}BNF_{15.35}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{10.00}WH_{61.88}BNF_{28.12}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{28.62}WH_{61.38}BNF_{10.00}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{15.00}WH_{50.00}BNF_{35.00}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{24.97}WH_{53.16}BNF_{21.87}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{14.65}WH_{70.00}BNF_{15.35}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{24.97}WH_{53.16}BNF_{21.87}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{28.62}WH_{61.38}BNF_{10.00}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{32.87}WH_{50.00}$ $BNF_{17.13}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{15.10}WH_{63.67}$ $BNF_{21.23}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{40.00}WH_{50.00}$ $BNF_{10.00}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{17.46}WH_{55.18}BNF_{27.36}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{22.90}WH_{60.26}$ $BNF_{16.84}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{22.08}WH_{67.92}$ $BNF_{10.00}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{15.00}WH_{50.00}$ $BNF_{35.00}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{10.00}WH_{61.88}BNF_{28.12}$	2.00	62.00	5.00	10.00	0.30	1.00
$HQCF_{0.00}$ $WH_{100.00}$ $BNF_{0.00}$	2.00	62.00	5.00	10.00	0.30	1.00

The ingredients are in percentages (%) which are dependent on composite flour weight

2.7 Optimization Procedure

A mixture design (D-optimal design) was used to optimize the ingredients blends. Two levels of each of the independent variables were chosen for the study. The ingredient was optimized with respect to the responses. A numerical optimization technique was used for simultaneous optimization of the multiple responses. The desired goal for each processing parameter and response was chosen (Table 4). All the processing parameters were kept within the specified parameter ranges, and in order to search for a solution, goals were combined into an overall composite function, D(x), called the desirability function.

2.8 Sensory Evaluation

The sensory evaluation of bread samples was done according to Alimi et. al. (2023b). A 30-man sensory panel consisting staff of Nigerian Stored Products Research Institute (NSPRI) and students from the Nigerian tertiary Institutions on industrial training (SIWES) were used as panelists. Parameters that were evaluated includes: appearance, crumb structure, texture, crust color, taste, aroma (fresh) and overall acceptability. A 9-point Hedonic scale was used where 9 = Like extremely and 1 = Dislike extremely. The cooled fresh bread samples were served to 30-man panel comprising semi-trained and trained individuals made up of staff and students from the Nigerian tertiary Institutions on industrial training (SIWES) who are familiar with the sensory attributes such as taste, color, aroma and fluffiness of bread. The panelists were asked to tick expression that best describe their judgment ranging from 1 to 9 for each sensory descriptive parameter.

2.9 Microbiological Assay of the Bread Samples

Total bacteria and fungi count of the composite bread were determined using the pour-plate procedure as described by Alimi et al. (2023). The isolation of the constituting fungal colonies in the bread samples were carried out by doing a 10-fold serial dilution of the sample. One (1) gramme of the bread sample was put into a 9ml of peptone water, from this mixture 1ml of the aliquot was then taken and poured into another 9ml of peptone, this process was then repeated for 6 dilutions, then 1 ml of the 10^{-1}, 10^{-3} and 10^{-5} were plated on Potatoes Dextrose Agar (PDA) using the pour plate method, the plates were then incubated at 27^0C for 3-5 days however, 25µg of chloramphenicol was added to the agar medium before autoclaving. A plate count of emanating moulds and yeasts was carried out after 4 days of incubation, then the isolation of distinct colonies was done by using a flamed inoculating needle to transfer these colonies into freshly prepared agar medium. Then incubation was done at 27^oC for 4 days.

Table 4. The desired goal for each processing parameter and responses

Name	Goal
A: High quality cassava flour (g)	is in range
B: Bambara nut flour (g)	is in range
Lightness	Maximize
Yellowness	Maximize
Redness	Minimum
Moisture content (%)	Minimize
Fat content (%)	Minimize
Ash content (%)	Maximize
Fibre content (%)	Maximize
Protein content (%)	Maximize
Carbohydrate content (%)	Maximize
Overall Acceptability	Maximize
Browning index	Maximize
Loaf weigh	Maximize

2.10 Statistical Analyses

The pertinent data obtained was subjected to analysis of variance (ANOVA) while significant means were separated applying Duncan Multiple Range Tests (DMRTs) using Statistical Package for Social Sciences (SPSS version 25.0). The effect of ingredient combination and optimization procedure was investigated using Design expert version 12 based on D-optimal design. Regression analyses were performed, models were generated and significance effect of the ingredient combination at 5 % level was determined.

3. RESULTS AND DISCUSSION

3.1 Physical Properties of the Composite Bread

Physical properties of the composite bread produced with blends of flour from cassava, wheat and Bambara nut are presented in Table 5. Crust lightness ranged from 29.57 to 39.52, with sample $HQCF_{24.97}WH_{53.16}BNF_{21.87}$ having the lowest while sample $HQCF_{15.00}WH_{50.00}$ $BNF_{35.00}$ had the highest. Considering composite breads, 68.75 % of the bread samples were not significantly ($p>0.05$) different from each other while 12.5 % were not also significantly different but 18.75 were significantly ($p<0.05$) different in terms of crust lightness. In Table 5, the result of data obtained using multiple quadratic regression is presented. The main effects of HQCF and wheat flour were significant ($p<0.05$) model terms for lightness. The regression coefficient (R^2) was used to vet the fitness of models. The results confirmed the fitting of the models with (R^2) 0.68, which denotes that 68 % of the predicted values could be matched with the actual values. The lightness parameter for composite bread showed C.V. value of 6.18 (<10) in this study suggesting the possible reproducibility of the model. The experimental results obtained for the lightness were fitted to a second order polynomial model (Equation 8) to describe the relationship between the independent variable and responses. The equation in terms of coded factors can be used to make predictions about the response for given level of each factor.

$$\textit{Lightness} = 34.30A + 51.77B + 42.51C - 34.84AB - 15.69AC - 55.28BC \quad (8)$$

As shown in Equation 8, at linear level, HQCF, wheat flour and Bambara nut flour had a positive effect on lightness, while the interaction of HQCF and wheat flour, HQCF and Bambara nut flour, wheat flour and Bambara nut flour had a negative effect. The effects of lightness with HQCF, wheat flour and Bambara nut flour are shown in Fig. 1.

As the inclusion of wheat flour and Bambara nut flour increased, lightness increased. But as inclusion of HQCF increased, the lightness decreased, respectively.

The a* (redness to bluishness) of the composite bread varied significantly between 0.10 and 3.96, with sample $HQCF_{24.97}WH_{53.16}BNF_{21.87}$ having the lowest while sample $HQCF_{15.00}WH_{50.00}$ $BNF_{35.00}$ had the highest. The linear effects of HQCF and wheat flour had a significant effect ($p<0.05$) on the redness.

Table 5. Regression coefficient for physical properties of composite bread

Parameter	Lightness (l*)	Redn (a*)	Yellown (b*)	Brow. index	Cru. (ρc)	Cru. porosity (ℓc)	Loaf weight (g)	Overall Accept
A-HQCF (g)	34.30	0.57	10.01	0.37	0.22	0.49	60.61	6.37
B-WF (g)	51.77	6.11	22.17	0.43	0.32	0.50	67.93	5.41
C-BNF (g)	42.51	5.05	17.72	0.42	0.22	0.49	58.56	5.40
AB	-34.84*	-5.49*	-17.62*	-0.04	-0.16	-0.07	-15.57	2.66
AC	-15.69*	4.18*	-11.05*	-0.03	-0.08	0.02	27.56	1.07
BC	-55.28*	16.33*	-35.37*	-0.18	-0.17	0.20	-17.26	3.73
R^2	0.68	0.71	0.77	0.55	0.18	0.43	0.60	0.41
F-value	4.31	4.98	6.60	2.43	0.44	1.53	3.06	1.37
CV	6.18	41.27	10.86	3.02	18.97	4.05	3.36	6.29

Redn: Redness; Yellown: Yellowness; Brow index: Browning index; Cru.: Crumb; Accept: Acceptability

However, the interaction of all the flour blends had a negative significant ($p<0.05$) effect on redness. The Regression coefficient parameter showed that the quadratic model developed for redness had a coefficient of determination (R^2) of 0.71 indicating a 71% predictive accuracy and F-value of 4.98. The model graph depicting the trend of redness as influenced by the flour blends' ratio is shown in Fig. 2, an increase was observed in redness value with increase in wheat flour and Bambara nut flour. But as inclusion of HQCF increased, a decrease was observed in redness value. The redness parameter of the composite bread showed C.V value of 41.27 in this study suggesting the possible reproducibility of the model. The experimental results obtained for the redness were fitted to a second order polynomial model (Equation 9) to describe the relationship between the independent variables and responses. The empirical expression is shown below:

$$Redness = 0.57A + 6.11B + 5.05C - 5.49AB - 4.18AC - 16.33BC \quad (9)$$

As shown in Equation 9, at linear level, HQCF, wheat flour and Bambara nut flour had a positive effect on redness, while the interaction of HQCF and wheat flour, HQCF and Bambara nut flour, interaction of wheat flour and Bambara nut flour had a negative effect.

The *b** (yellowness-greenness) of the bread samples varied between 8.28 and 15.27, with sample $HQCF_{24.97}WH_{53.16}BNF_{21.87}$ having the lowest while sample $HQCF_{15.00}WH_{50.00}$ $BNF_{35.00}$ had the highest. In Table 8, the result of data obtained using multiple quadratic regression is presented. The linear effects of HQCF, the main effect of wheat flour had a significant effect ($p<0.05$) on the yellowness. The regression coefficient (R^2) was 0.77, which denotes that 77% of the predicted values could be matched with the actual values. The yellowness parameter of the composite bread showed C.V value of 10.86. The experimental results obtained for the yellowness fitted to a second order polynomial model (Equation 10) to describe the relationship between the independent variables and responses is shown below:

$$Yellowness = 10.01A + 22.17B + 17.72C - 17.62AB - 11.05AC - 35.37BC \quad (10)$$

At linear level, HQCF, wheat flour and Bambara nut flour had a positive effect on yellowness. The interaction of HQCF and wheat flour, that of HQCF and Bambara nut flour and interaction of wheat flour and Bambara nut flour had a negative effect on yellowness. The model graph depicting the trend of yellowness as influenced by the flour blends ratio is shown in Fig. 3, an increase was observed in yellowness value with increase in wheat flour and Bambara nut flour; But as inclusion of HQCF increased, a decrease was observed in yellowness.

The browning index of the bread was calculated using the values obtained for each sample in terms of their lightness, redness and yellowness and it was observed that bread sample with $HQCF_{15.00}WH_{50.00}BNF_{35.00}$ had the highest browning index while sample with $HQCF_{10.00}WH_{61.88}BNF_{28.12}$ had the lowest browning index. In Table 6, the result of data obtained using multiple quadratic regression is presented. The linear effects of HQCF, the main effect of wheat flour had a significant effect ($p<0.05$) on the Browning index. The regression coefficient (R^2) was 0.55, which denotes that 55% of the predicted values could be matched with the actual values. The browning index parameter of the composite bread showed C.V value of 3.02. The experimental results obtained for the Browning index fitted to a second order polynomial model (Equation 11) to describe the relationship between the independent variables and responses is shown below:

Browning index = 0.37A + 0.43B + 0.42C – 0.04AB -0.03AC -0.18BC … ………………..(11)

At linear level, HQCF, wheat flour and Bambara nut flour had a positive effect on browning index. The interaction of HQCF and wheat flour, the interaction of HQCF and Bambara nut flour and interaction of wheat flour and Bambara nut flour had a negative effect on yellowness. The model graph depicting the trend of browning index as influenced by the flour blends' ratio is shown in Fig. 4, an increase was observed in browning index value with increase in wheat flour and Bambara nut flour. But as inclusion of HQCF increased, a decrease was observed.

The composite breads were significantly ($p<0.05$) different in terms of crumb density, with bread sample $HQCF_{22.08}WH_{67.92}$ $BNF_{10.00}$ having the lowest while sample $HQCF_{14.65}WH_{70.00}BNF_{15.35}$ had the highest.

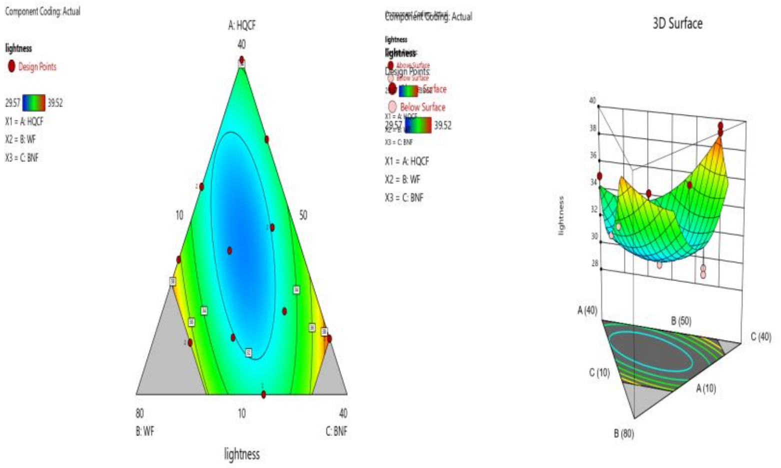

Fig. 1. Contour and 3D surface plots of lightness of composite bread from blends of HQCF, wheat flour and Bambara nut flour

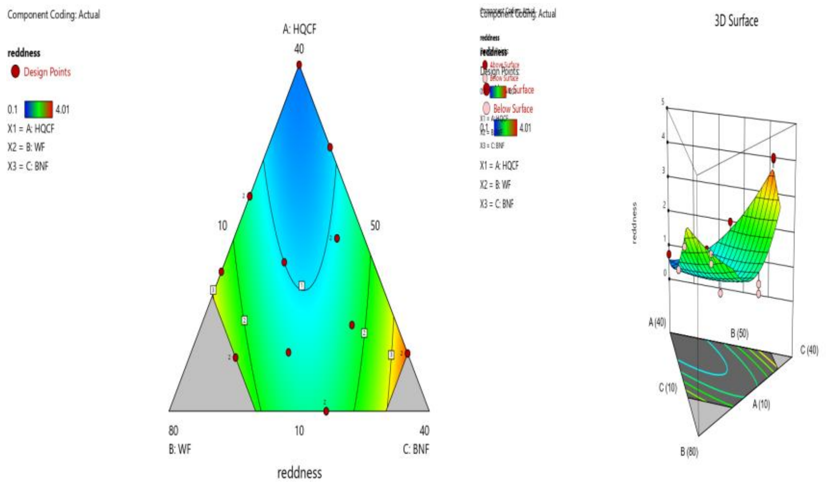

Fig. 2. Contour and 3D surface plots of redness of composite bread from blends of HQCF, wheat flour and Bambara nut flour

Table 6. Physical properties of the composite bread with blends of flour from cassava, wheat and Bambara nut

Bread sample	Lightness (*L**)	Redness-bluishness (*a**)	Yellowness-greenness (*b**)	Browning index (BI)	Crumb density(ρc)	Crumb porosity (ℓc)	Loaf weight (g)	Overall Acceptability
$HQCF_{14.65}WH_{70.00}BNF_{15.35}$	$37.21±4.59^{abc}$	$2.42±0.53^{abc}$	$13.18±1.91^{bc}$	$0.39±0.00^{ab}$	$0.29±0.01^{h}$	$0.46±0.01^{abc}$	$62.20±0.40^{abc}$	$6.00±0.33^{a}$
$HQCF_{10.00}WH_{61.88}BNF_{28.12}$	$31.35±1.44^{abc}$	$0.96±0.37^{ab}$	$9.92±0.98^{ab}$	$0.36±0.01^{ab}$	$0.21±0.01^{de}$	$0.46±0.01^{abcd}$	$56.30±5.00^{a}$	$6.28±0.34^{ab}$
$HQCF_{28.62}WH_{61.38}BNF_{10.00}$	$32.76±0.54^{abc}$	$1.20±1.03^{ab}$	$10.39±0.68^{ab}$	$0.38±0.01^{ab}$	$0.26±0.01^{g}$	$0.45±0.01^{a}$	$58.20±3.00^{ab}$	$6.08±0.37^{a}$
$HQCF_{15.00}WH_{50.00}BNF_{35.00}$	$39.07±1.82^{bc}$	$4.01±0.74^{a}$	$15.28±0.10^{c}$	$0.41±0.01^{ab}$	$0.22±0.01^{e}$	$0.49±0.01^{efg}$	$62.50±0.40^{abc}$	$5.60±0.40^{a}$
$HQCF_{24.97}WH_{53.16}BNF_{21.87}$	$29.62±0.57^{a}$	$0.10±0.25^{a}$	$8.28±0.23^{a}$	$0.37±0.01^{a}$	$0.19±0.01^{c}$	$0.48±0.01^{cdef}$	$64.65±0.25^{bc}$	$6.40±0.32^{ab}$
$HQCF_{14.65}WH_{70.00}BNF_{15.35}$	$37.21±3.59^{abc}$	$2.16±0.60^{abc}$	$13.15±0.25^{bc}$	$0.39±0.01^{ab}$	$0.28±0.01^{h}$	$0.45±0.01^{ab}$	$61.25±0.25^{abc}$	$5.96±0.37^{a}$
$HQCF_{24.97}WH_{53.16}BNF_{21.87}$	$29.57±0.55^{a}$	$0.95±0.35^{a}$	$8.29±0.25^{a}$	$0.37±0.01^{a}$	$0.17±0.01^{b}$	$0.48±0.01^{cdef}$	$64.30±0.20^{bc}$	$6.40±0.32^{ab}$
$HQCF_{28.62}WH_{61.38}BNF_{10.00}$	$32.66±0.46^{abc}$	$1.20±1.01^{ab}$	$10.38±0.68^{ab}$	$0.38±0.01^{ab}$	$0.25±0.01^{fg}$	$0.47±0.01^{abcd}$	$58.35±1.55^{ab}$	$6.36±0.35^{ab}$
$HQCF_{32.87}WH_{50.00}BNF_{17.13}$	$33.75±1.82^{abc}$	$1.08±0.40^{ab}$	$10.48±0.75^{ab}$	$0.38±0.01^{ab}$	$0.21±0.01^{cde}$	$0.50±0.01^{fgh}$	$62.55±1.85^{abc}$	$6.32±0.33^{ab}$
$HQCF_{15.10}WH_{63.67}BNF_{21.23}$	$34.60±0.82^{abc}$	$2.92±0.18^{bc}$	$12.63±0.47^{bc}$	$0.40±0.01^{ab}$	$0.19±0.01^{cd}$	$0.47±0.01^{bcde}$	$61.80±0.60^{abc}$	$6.64±0.32^{ab}$
$HQCF_{40.00}WH_{50.00}BNF_{10.00}$	$34.99±4.31^{abc}$	$0.75±0.38^{ab}$	$10.20±0.96^{ab}$	$0.37±0.00^{a}$	$0.21±0.01^{cde}$	$0.49±0.01^{efg}$	$62.65±0.05^{abc}$	$6.52±0.33^{ab}$
$HQCF_{17.46}WH_{55.18}BNF_{27.36}$	$35.90±3.45^{abc}$	$1.35±0.12^{ab}$	$11.22±1.25^{ab}$	$0.38±0.00^{ab}$	$0.24±0.01^{f}$	$0.46±0.01^{abc}$	$66.30±1.60^{c}$	$6.36±0.36^{ab}$
$HQCF_{22.90}WH_{60.26}BNF_{16.84}$	$33.26±2.31^{abc}$	$1.82±0.39^{abc}$	$10.94±0.81^{ab}$	$0.39±0.01^{ab}$	$0.22±0.01^{e}$	$0.49±0.01^{defg}$	$61.45±0.85^{abc}$	$6.72±0.28^{ab}$
$HQCF_{22.08}WH_{67.92}BNF_{10.00}$	$34.42±3.28^{abc}$	$2.34±2.25^{abc}$	$12.13±3.04^{bc}$	$0.39±0.02^{ab}$	$0.15±0.01^{a}$	$0.52±0.01^{hi}$	$63.60±2.70^{bc}$	$7.38±0.25^{bc}$
$HQCF_{15.00}WH_{50.00}BNF_{35.00}$	$39.52±1.35^{c}$	$3.96±0.70^{a}$	$15.27±0.11^{c}$	$0.41±0.01^{ab}$	$0.21±0.01^{cde}$	$0.50±0.01^{gh}$	$62.05±0.25^{abc}$	$5.69±0.38^{a}$
$HQCF_{10.00}WH_{61.88}BNF_{28.12}$	$30.90±0.21^{ab}$	$1.23±0.90^{ab}$	$10.31±0.37^{ab}$	$0.39±0.01^{b}$	$0.21±0.01^{cde}$	$0.45±0.01^{a}$	$58.15±2.85^{ab}$	$6.44±0.34^{a}$

Values are mean of duplicates ± standard deviation. Mean values with different superscripts within the same column are significantly different at 5% level
HQCF: High Quality Cassava Flour; BNF: Bambara Nut Flour; WH: Wheat flour

About 25 % of the bread samples were not significantly ($p>0.05$) different. In Table 6, the result of data obtained using multiple quadratic regression is presented. The main effects of HQCF and wheat flour were significant ($p<0.05$) for crumb density (Fig. 5).

The regression coefficient (R^2) was used to vet the fitness of models. The results confirmed the fitting of the models with (R^2) < 80 (0.18), which denotes that 18 % of the predicted values could be matched with the actual values. The coefficient of variation (C.V) is defined as the ratio of the standard deviation of the estimation to the mean of the observed dependent variables, and it also show the degree of reproducibility and repeatability of the model. The crumb density parameter of the composite bread showed C.V value of 18.97 (>10) in this study suggesting the possible reproducibility of the model. The experimental results obtained for the crumb density were fitted to a second order polynomial model (Equation 12) to describe the relationship between the independent variable and responses. The equation in terms of coded factors can be used to make predictions about the response for given level of each factor.

Crumb density = 0.22A +0.32B +0.22C – 0.16AB – 0.08AC -0.17BC …. (12)

As shown in Equation 12, at linear level, HQCF, wheat flour and Bambara nut flour had a positive effect on crumb density, while the interaction of HQCF and wheat flour, HQCF and

Bambara nut flour, wheat flour and Bambara nut flour had a negative effect. The effects of crumb density with HQCF, wheat flour and Bambara nut flour are shown in Fig. 5. As the Bambara nut flour increased, crumb density increased. But as inclusion of HQCF and wheat flour increased, the crumb density decreased.

The composite breads were significantly ($p<0.05$) different in terms of crumb porosity with value ranging from 0.45 to 0.52, with sample $HQCF_{10.00}WH_{61.88}BNF_{28.12}$ and $HQCF_{28.62}WH_{61.38}BNF_{10.00}$ having the lowest while sample $HQCF_{22.08}WH_{67.92}$ $BNF_{10.00}$ had the highest. In Table 6, the result of data obtained using multiple quadratic regression is presented.

The linear effects of HQCF, the main effect of wheat flour had a significant effect ($p<0.05$) on the crumb porosity. The regression coefficient (R^2) was 0.43, which denotes that 43% of the predicted values could be matched with the actual values. The crumb porosity parameter of the composite bread showed C.V value of 4.05. The experimental results obtained for the crumb porosity fitted to a second order polynomial model (Equation 13) to describe the relationship between the independent variables and responses is shown below:

Crumb porosity = 0.49A + 0.50B + 0.49C - 0.07AB +0.20AC +0.20BC (13)

At linear level, HQCF, wheat flour and Bambara nut flour had a positive effect on crumb porosity. The interaction of HQCF and wheat flour had a negative effect, the interaction of HQCF and Bambara nut flour and interaction of wheat flour and Bambara nut flour had a positive effect on crumble density. The model graph depicting the trend of crumb porosity as influenced by the flour blends substitution ratio is shown in Fig. 6, an increase was observed in crumble porosity value with decreases in wheat flour and Bambara nut flour. But as HQCF decreases, a decrease was observed in crumb porosity.

The composite bread varied in terms of loaf weight and it ranged from 56.30 to 66.30 g, with bread sample $HQCF_{10.00}WH_{61.88}BNF_{28.12}$ having the lowest while sample $HQCF_{17.46}WH_{55.18}BNF_{27.36}$ had the highest. Concerning the linear effects, HQCF and wheat flour had a significant effect ($p<0.05$) on the loaf weight. However, the interaction of all the flours had no significant ($p>0.05$) effect on loaf weight. The Regression coefficient parameter showed that the quadratic model developed for loaf weigh had a coefficient of determination (R^2) of 0.60 indicating a 60% predictive accuracy and F-value of 3.06. The model graph depicting the trend of loaf weigh as influenced by flour blends ratio is shown in Fig. 7, a decrease was observed in loaf weight value with increase in wheat flour.

Worth pointing out, as inclusion of HQCF and Bambara nut flour increased, an increase in loaf weight was observed. The loaf weight parameter of the composite bread showed C.V value of 3.36 (<10) in this study suggesting the possible reproducibility of the model. The experimental results obtained for the loaf weight were fitted to a second order polynomial model (Equation 14) to describe the relationship between the independent variables and responses. The empirical expression is shown below:

Loaf weigh = 60.61A + 67.93B + 58.56C -15.57 AB + 27.56AC - 17.26BC …. (14)

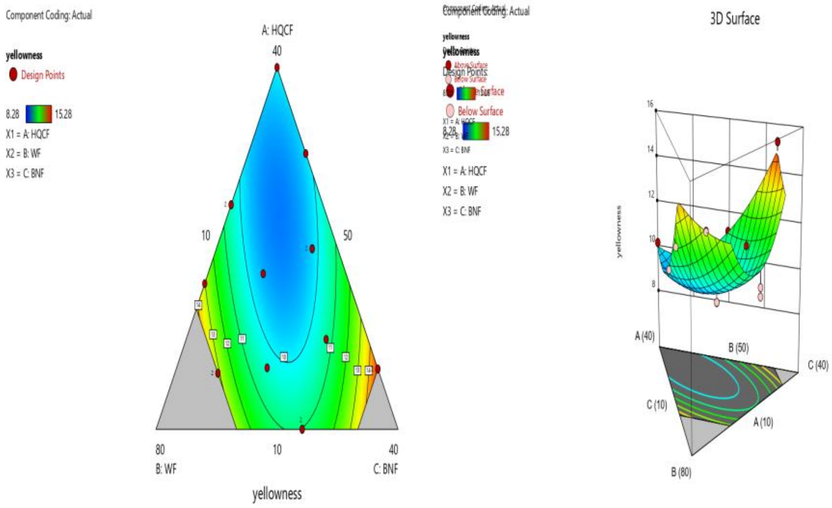

Fig. 3. Contour and 3D surface plots of yellowness of composite bread from blends of HQCF, wheat flour and Bambara nut flour

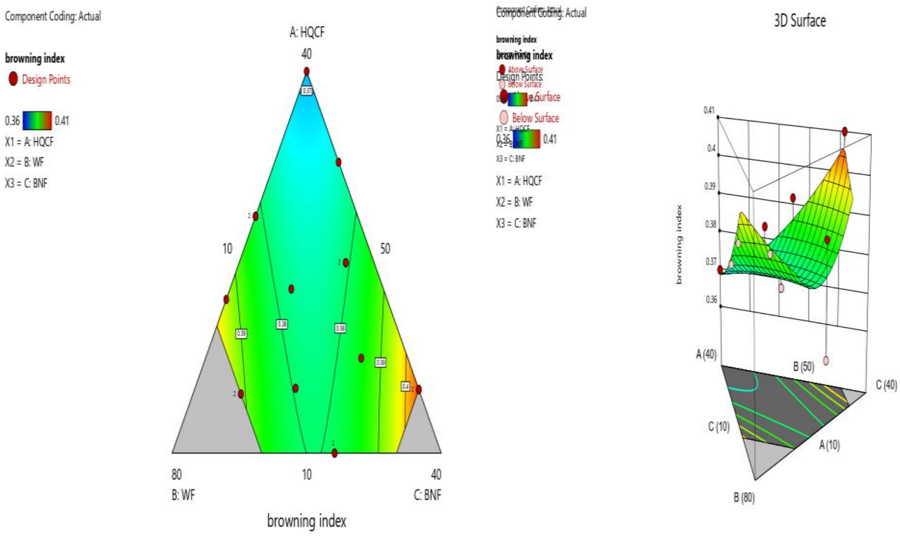

Fig. 4. Contour and 3D surface plots of browning index of composite bread from blends of HQCF, wheat flour and Bambara nut flour

As shown in Equation 14, at linear level, HQCF, wheat flour and Bambara nut flour had a positive effect on loaf weigh, while the interaction of HQCF and wheat flour, and interaction of wheat flour and Bambara nut flour, had a negative effect. Again, interaction of HQCF and Bambara nut was observed to have a positive effect.

The composite breads were significantly ($p<0.05$) different in terms of overall acceptability with value ranging from 5.60 to 7.38, with sample HQCF$_{15.00}$WH$_{50.00}$BNF$_{35.00}$ having the lowest while sample HQCF$_{22.08}$WH$_{67.92}$ BNF$_{10.00}$ had the highest. At the linear level, HQCF and wheat flour had a significant effect ($p<0.05$) on the overall acceptability. The Regression coefficient parameter showed that the quadratic model developed had a coefficient of determination (R^2) of 0.41 indicating a 41 % predictive accuracy and F-value of 1.37. The model graph depicting the trend of overall acceptability as influenced by the flour blends substitution ratio is shown in Fig. 8, a decrease was observed with increase in Bambara nut flour inclusion. But as inclusion of

HQCF and wheat flour increased, an increase was observed in overall acceptability. The overall acceptability of the composite bread showed C.V value of 6.29 suggesting the possible reproducibility of the model. The experimental results obtained for the overall acceptability fitted to a second order polynomial model (Equation 15) is shown below:

Overall Acceptability = 6.37A + 5.41B + 5.40C + 2.66AB +1.07AC + 3.73BC (15)

Interestingly, the linear and interactive effects of the three flours (HQCF, wheat flour, and Bambara nut flour) had a positive effect on overall acceptability of the composite bread.

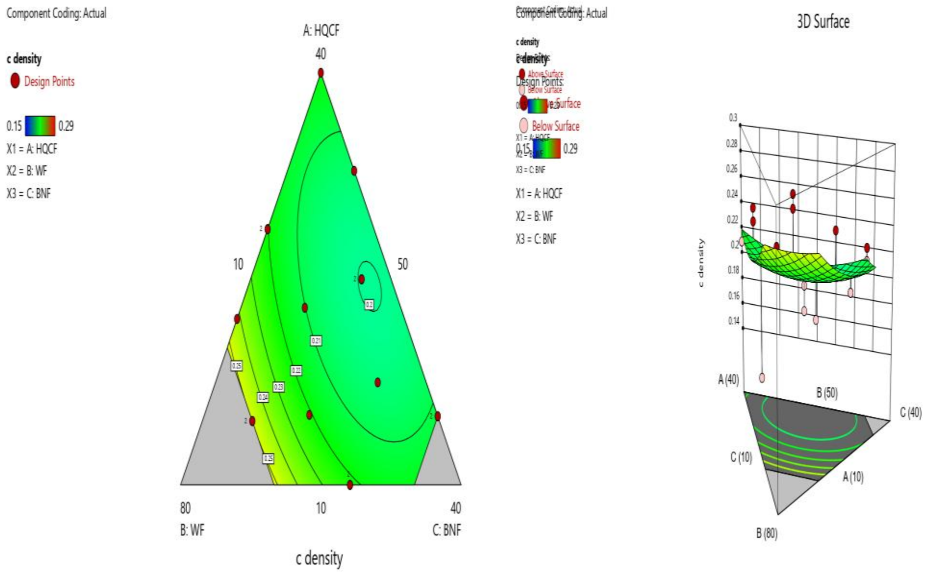

Fig. 5. Contour and 3D surface plots of crumb density of composite bread from blends of HQCF, wheat flour and Bambara nut flour

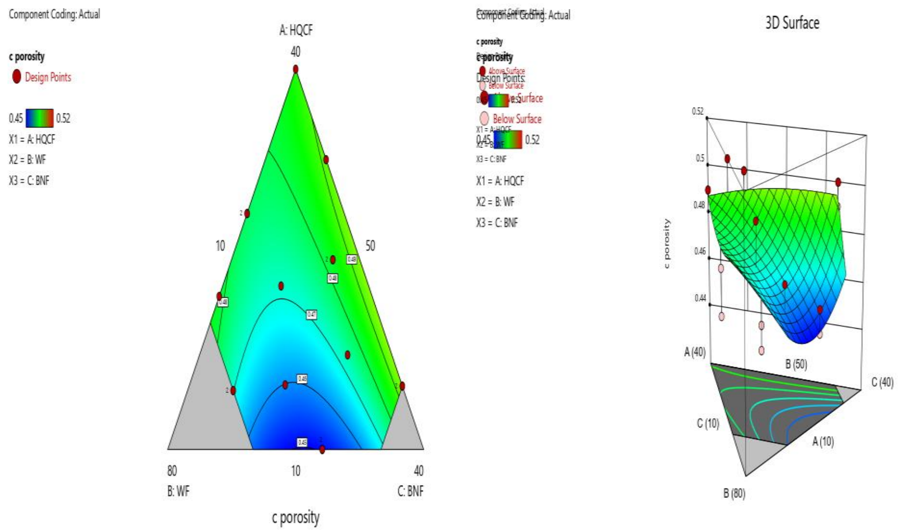

Fig. 6. Contour and 3D surface plots of crumb porosity of composite bread from blends of HQCF, wheat flour and Bambara nut flour

3.2 Proximate Composition of Composite Bread

Proximate composition of composite bread produced with blends of flour from cassava, wheat and Bambara nut is presented in Table 7. The moisture contents of the bread samples were significantly (p<0.05) different, with range from 25.56 to 32.36 %, with bread sample $HQCF_{22.90}WH_{60.26}$ $BNF_{16.84}$ having the lowest while sample $HQCF_{22.08}WH_{67.92}$ $BNF_{10.00}$ had the highest. The range of moisture (25.56-32.36 %) content in this study is relatively lower when compared with (27.59-34.00%), (22.11- 28.44%) and (33.37±0.66 %) reported by Toibudeen et al. (2020), Bibiana et al. (2019) and Okwunodulu et al. (2024) for bread produced from wheat and cassava flour, fortified with sorrel seed protein isolate, composite bread made with blends of flour from wheat, yam and brown hamburger bean flour and millet and Bambara sourdough bread, respectively. The moisture content of food product depicts its shelf stability, from the response surface plot (Fig. 9), the inclusion of the Bambara nut flour reduced the moisture content of the composite bread, meanwhile at increased inclusion of HQCF and wheat flour, moisture content increased.

Presented in Table 7 is the statistical results of the data obtained using multiple linear regression equation. The coefficient of determination (R^2) of the composite bread was 0.80 indicating a 80% predictive accuracy and F-value of 7.88. The model terms developed for moisture content showed that HQCF and wheat flour at linear level are significant (p<0.05). The experimental results obtained for the moisture content fitted to a second order polynomial model (Equation 16) is shown below:

$$\text{Moisture content} = 30.97A + 27.99B + 35.26C + 9.22AB - 15.94AC - 25.62.\ BC\ ... \quad (16)$$

As indicated in the equation generated from Table 7, the linear effect of HQCF, wheat flour, Bambara nut flour as well as interaction of HQCF and wheat flour had a positive effect. Again, the interaction of HQCF and Bambara groundnut, the interaction of wheat flour and Bambara groundnut also had a negative effect on moisture content.

The bread samples were significantly (p<0.05) different with regard to ash contents which ranged from 1.26 to 1.87 %, with sample $HQCF_{22.08}WH_{67.92}$ $BNF_{10.00}$ and $HQCF_{28.62}WH_{61.38}BNF_{10.00}$ having the lowest while sample $HQCF_{17.46}WH_{55.18}BNF_{27.36}$ had the highest. The additive effect of the ash content of constituent flour making up the composite could be adduced for the relatively higher ash content of the composite bread. The ash content of a food sample reveals the mineral element available in that food sample (Alimi et al., 2024). The range of ash (1.26-1.87 %) in this study is relatively higher than (0.66-1.22%) reported by Toibudeen et al. (2020) and in the range (1.09-1.99%) reported by Bibiana et al. (2019).

From Table 7, the model developed for ash content showed that the linear effects HQCF and wheat flour are the significant (p<0.05) model terms. The regression coefficient (R^2) confirmed the fitting of the models with (R^2) < 80 (0.63), which denotes that 63% of the predicted values could be matched with the actual values.

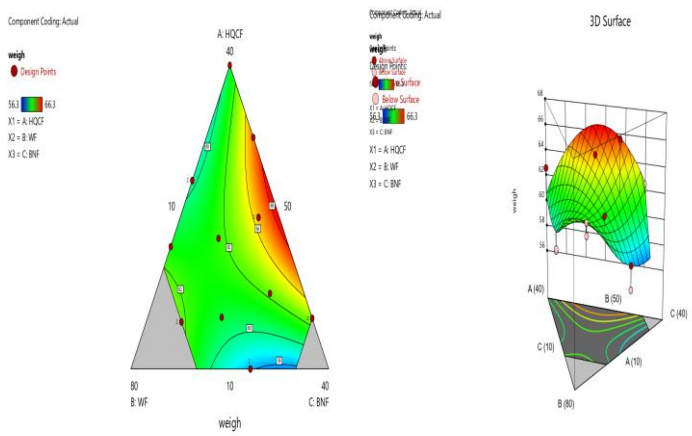

Fig. 7. Contour and 3D surface plots of loaf weigh of composite bread from blends of HQCF, wheat flour and Bambara nut flour

Table 7. Proximate composition of bread produced with blends of flour from cassava, wheat and Bambara nut

Bread sample	Moisture Content (%)	Ash (%)	Crude Fibre (%)	Fat (%)	Crude protein (%)	Carbohydrate (%)	Energy Value (kcal)
HQCF$_{14.65}$WH$_{70.00}$BNF$_{15.35}$	27.00±0.10^{c}	1.56±0.01^{d}	0.45±0.01^{e}	26.26±0.01^{i}	9.91±0.01^{k}	34.96±0.01^{d}	415.74±0.09^{a}
HQCF$_{10.00}$WH$_{61.88}$BNF$_{28.12}$	26.00±0.00^{b}	1.65±0.01^{e}	0.51±0.01^{f}	21.10±0.01^{f}	4.46±0.01^{a}	41.82±0.00^{g}	374.98±0.09^{ef}
HQCF$_{28.62}$WH$_{61.38}$BNF$_{10.00}$	32.10±0.10^{j}	1.26±0.01^{b}	0.36±0.01^{b}	13.14±0.04^{d}	6.84±0.01^{e}	46.28±0.01^{i}	330.72±0.42^{c}
HQCF$_{15.00}$WH$_{50.00}$BNF$_{35.00}$	31.87±0.02^{i}	1.80±0.01^{f}	0.34±0.01^{b}	26.30±0.10^{i}	5.96±0.01^{b}	33.66±0.01^{b}	395.16±0.84^{h}
HQCF$_{24.97}$WH$_{53.16}$BNF$_{21.87}$	28.75±0.05^{f}	1.36±0.01^{c}	0.40±0.01^{d}	7.26±0.01^{a}	8.59±0.01^{i}	53.73±0.01^{k}	314.54±0.09^{a}
HQCF$_{14.65}$WH$_{70.00}$BNF$_{15.35}$	26.90±0.11^{c}	1.55±0.01^{d}	0.44±0.01^{e}	26.25±0.01^{i}	9.91±0.01^{k}	34.96±0.01^{d}	415.67±0.10^{k}
HQCF$_{24.97}$WH$_{53.16}$BNF$_{21.87}$	28.55±0.05^{e}	1.37±0.01^{c}	0.40±0.02^{d}	7.25±0.01^{a}	8.58±0.01^{i}	53.75±0.01^{l}	314.51±0.02^{a}
HQCF$_{28.62}$WH$_{61.38}$BNF$_{10.00}$	32.35±0.05^{k}	1.26±0.01^{b}	0.36±0.01^{b}	13.10±0.10^{d}	6.84±0.01^{e}	46.28±0.01^{i}	330.34±0.90^{c}
HQCF$_{32.87}$WH$_{50.00}$ BNF$_{17.13}$	29.15±0.15^{g}	1.76±0.01^{c}	0.36±0.01^{b}	9.96±0.01^{c}	5.96±0.01^{f}	52.99±0.01^{e}	325.38±0.02^{b}
HQCF$_{15.10}$WH$_{63.67}$ BNF$_{21.23}$	27.55±0.05^{d}	1.80±0.01^{f}	0.56±0.01^{g}	19.06±0.01^{e}	7.54±0.01^{g}	43.48±0.01^{h}	375.54±0.09^{f}
HQCF$_{40.00}$WH$_{50.00}$ BNF$_{10.00}$	31.05±0.05^{h}	1.26±0.01^{b}	0.39±0.01^{cd}	26.56±0.01^{j}	6.32±0.01^{c}	34.44±0.00^{c}	402.02±0.06^{j}
HQCF$_{17.46}$WH$_{55.18}$BNF$_{27.36}$	31.08±0.03^{h}	1.87±0.09^{f}	0.59±0.01^{h}	23.55±0.05^{j}	6.93±0.01^{b}	36.33±0.01^{j}	384.95±0.45^{g}
HQCF$_{22.90}$WH$_{60.26}$ BNF$_{16.84}$	25.56±0.01^{a}	1.40±0.01^{c}	0.39±0.01^{cd}	9.56±0.01^{b}	6.58±0.01^{d}	56.34±0.01^{m}	337.64±0.09^{d}
HQCF$_{22.08}$WH$_{67.92}$ BNF$_{10.00}$	32.36±0.01^{k}	1.26±0.01^{b}	0.31±0.01^{a}	26.30±0.10^{i}	8.93±0.01^{j}	30.98±0.01^{a}	396.30±0.90^{hi}
HQCF$_{15.00}$WH$_{50.00}$ BNF$_{35.00}$	31.86±0.01^{i}	1.80±0.03^{f}	0.37±0.01^{bc}	26.55±0.05^{j}	5.97±0.01^{b}	33.67±0.01^{b}	397.47±0.49^{i}
HQCF$_{10.00}$WH$_{61.88}$BNF$_{28.12}$	26.00±0.01^{b}	1.64±0.01^{e}	0.50±0.01^{f}	20.96±0.06^{f}	4.46±0.01^{a}	41.84±0.01^{g}	373.80±0.54^{e}

Values are mean of duplicates ± standard deviation. Mean values with different superscripts within the same column are significantly different at 5% level.

HQCF: High Quality cassava Flour; BNF: Bambara Nut Flour; WF: Wheat Flour

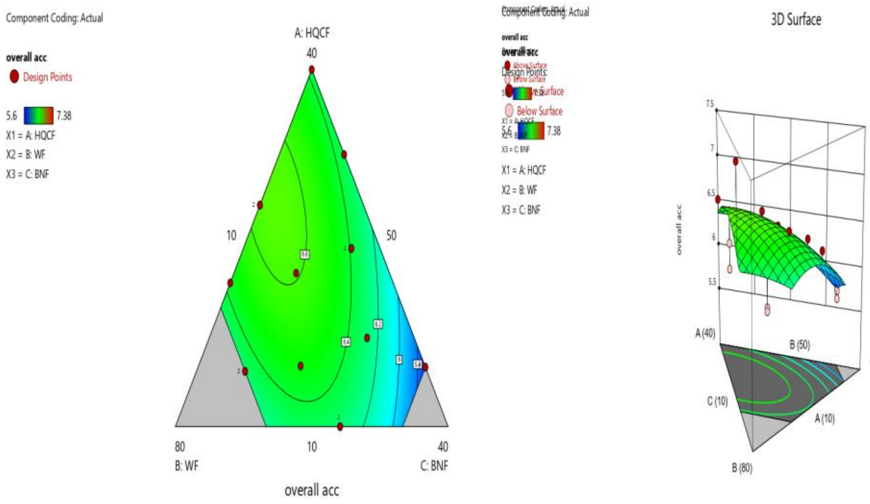

Fig. 8. Contour and 3D surface plots of overall acceptability of composite bread from blends of HQCF, wheat flour and Bambara nut flour

The coefficient of variation (C.V) that shows the degree of reproducibility and repeatability of the model was observed to be 10.58 (>10). The experimental results obtained for the ash content were fitted to a second order polynomial model (Equation 17) to describe the relationship between the independent variables and responses. The equation in terms of coded factors could be used to make predictions about the response for given level of each factor.

$$Ash\ content = 1.38A + 2.02B + 1.82C - 1.76\ AB + 0.04AC - 0.98\ BC \quad (17)$$

From equation 17, the flour blends (at linear level) had positive effects on ash content. While the interaction of HQCF and wheat flour, wheat flour and Bambara nut flour had a negative effect. Again, the interaction of HQCF and Bambara nut flour had a positive effect. The ash content of the composite bread increased (Fig. 10) as substitution of wheat flour and Bambara groundnut increased; however, inclusion of HQCF decreased the ash content of the composite bread.

The crude fibre of the bread samples was significantly ($p<0.05$) different and ranged from 0.31 to 0.59 %, with sample $HQCF_{22.08}WH_{67.92}$ $BNF_{10.00}$ having the lowest while sample $HQCF_{17.46}WH_{55.18}BNF_{27.36}$ had the highest. Fibre plays a significant role in the body by regulating the use of sugar in the body and by so doing keeps the level of blood sugar in the body under check. The range of fibre (0.31-0.59 %) content of these composite bread were relatively lower than (0.77-1.58%) and (1.88-3.66%) reported by Toibudeen et al. (2020) and Bibiana et al. (2019) and this could be attributed to the differences in the genetic make-up of the constituent flours making up the composite flours used for the baking experiment.

Linearly, the effects of HQCF and wheat flour was significant ($p<0.05$) model terms as seen in Table 7. The Regression coefficient parameter showed that the quadratic model developed for fibre had a coefficient of determination (R^2) of 0.69 indicating a 69% predictive accuracy and F-value of 4.46. The model graph depicting the trend as influenced by the flour blends ratio is shown in Fig. 11, an increase was observed in fibre value with increase in wheat flour and Bambara nut flour inclusion. But as inclusion of HQCF increased, a decrease in fibre was observed. The fibre content of the composite bread showed C.V value of 13.14 (>10) in this study suggesting the possible reproducibility of the model. The experimental results obtained for the fibre content were fitted to a second order polynomial model (Equation 18) to describe the relationship between the flour blends and the fibre content. The linear and interactive of the three flours was observed to have a positive effect on the fibre content. The empirical expression is shown below:

$$Fibre\ content = 0.36A + 0.28B + 0.33C + 0.10\ AB + 0.21AC + 0.10BC \quad (18)$$

The bread samples were significantly ($p<0.05$) different in terms of fat content and it ranged from 7.25 to 26.56 %, with sample $HQCF_{24.97}WH_{53.16}BNF_{21.87}$ having the lowest while sample $HQCF_{40.00}WH_{50.00}$ $BNF_{10.00}$ had the highest.

The model developed for fat content showed that the linear terms of HQCF and wheat flour were significant ($p<0.05$). The Regression coefficient parameter showed that the quadratic model developed for fat content had a coefficient of determination (R^2) of 0.82 indicating a 82% predictive accuracy and F-value of 8.82. The model graph depicting the trend of fat content as influenced by the flour blends ratio is shown in Fig. 12. An increase was observed in fat content with increase in wheat flour and Bambara nut flour substitution. As addition of HQCF increased, the fat content decreased. The fat content of the composite bread also showed a C.V value of 21.17(>10) suggesting the possible reproducibility of the model. The experimental results obtained for the fat content were fitted to a second order polynomial model (Equation 19) to describe the relationship between the flour blends and the fat content. The empirical expression is shown below:

$$\text{Fat content} = 23.28A + 61.38B - 41.50C - 95.43AB - 80.59AC - 108.92BC \quad (19)$$

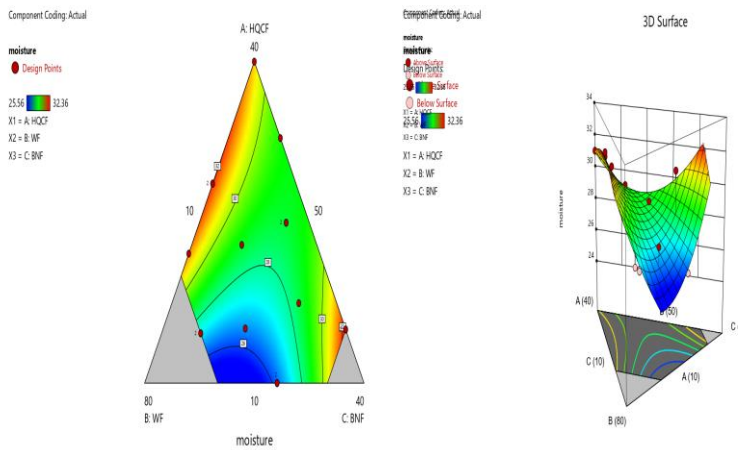

Fig. 9. Contour and 3D surface plots of moisture content (%) of composite cassava-wheat-bambara bread

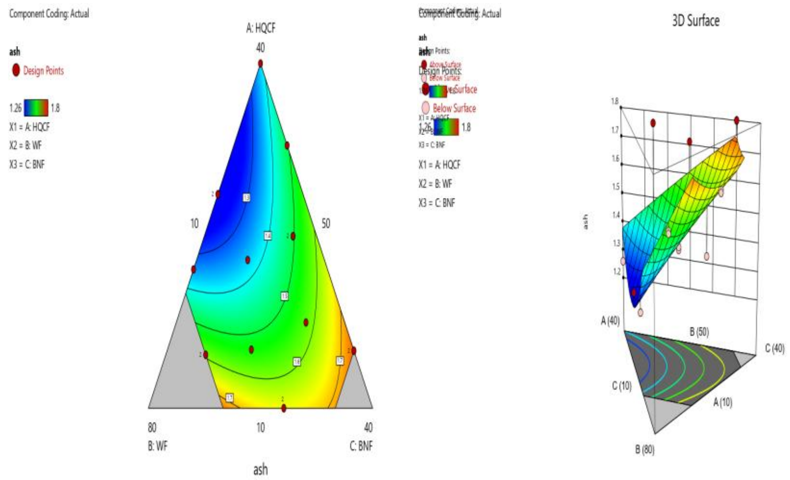

Fig. 10. Contour and 3D surface plots of Ash content (%) of composite cassava-wheat-bambara bread

HQCF, wheat flour and Bambara nut flour (linear terms), was observed to have a positive effect on fat content. The interaction effect of HQCF and wheat flour, interaction of HQCF and Bambara nut flour (interaction) as well as wheat flour and Bambara nut flour (interaction) was observed to have a negative effect on the fat content.

The bread samples were significantly ($p<0.05$) different with respect to protein contents, which ranged from 4.46 to 9.91 %, with samples HQCF$_{10.00}$WH$_{61.88}$BNF$_{28.12}$ and HQCF$_{10.00}$WH$_{61.88}$BNF$_{28.12}$ while samples HQCF$_{14.65}$WH$_{70.00}$BNF$_{15.35}$ and HQCF$_{14.65}$WH$_{70.00}$BNF$_{15.35}$ had the highest, respectively. Noteworthy, the additive effect in terms of quality and quantity of protein present in wheat and Bambara nut flour in the composite bread samples having highest protein could be adduced as a reason for the observed relatively high protein in contrast with the control and other composite bread samples. The range of crude protein (4.46 to 9.91 %) content recorded in this study is relatively higher than (9.84±0.08 %) reported for millet and Bambara sourdough bread by Okwunodulu et al. (2024) but lower than (8.80-18.70%) and (8.93- 14.47%) reported by Toibudeen et al. (2020) and Bibiana et al. (2019), respectively. This is not unconnected with the fact that the inherent protein in the constituent flours with which the composite flour used for the baking experiment was different.

There was a significant ($p<0.05$) difference across all the protein content values of the composite bread as seen in Table 7. The model developed for protein content showed that the linear terms of HQCF and wheat flour were the significant ($p<0.05$) model terms. The Regression coefficient parameter showed that the quadratic model developed had a coefficient of determination (R^2) of 0.83 indicating 83% predictive accuracy and F-value of 9.53. The model graph depicting the trend of protein content as influenced by the flour blends substitution ratio is shown in Fig. 13. An increase was observed in protein content with increase in wheat flour and Bambara nut flour of the blends. But as the addition of HQCF increased, the protein content decreased. The protein content of the composite bread also showed a C.V value of 12.09 (>10) suggesting the possible reproducibility of the model.

The experimental results obtained for the protein content were fitted to a second order polynomial model (Equation 20) to describe the relationship between the flour blends and the protein content of the composite bread. The empirical expression is shown below:

$$\textit{Protein content} = 5.47A + 16.22B + 3.47C - 11.39AB + 16.01AC - 15.44BC \qquad (20)$$

HQCF, wheat flour, and Bambara nut flour (linear terms), HQCF and Bambara nut flour (interaction) was observed to have a positive effect on the protein content. But the interactions of HQCF and wheat flour and interaction of wheat flour and Bambara nut flour had a negative effect on protein content.

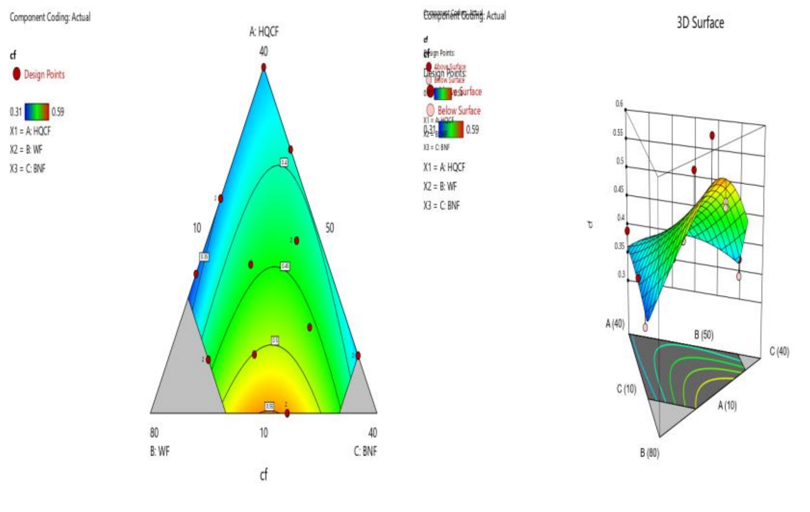

Fig. 11. Contour and 3D surface plots of crude fibre (%) of composite cassava-wheat-bambara bread

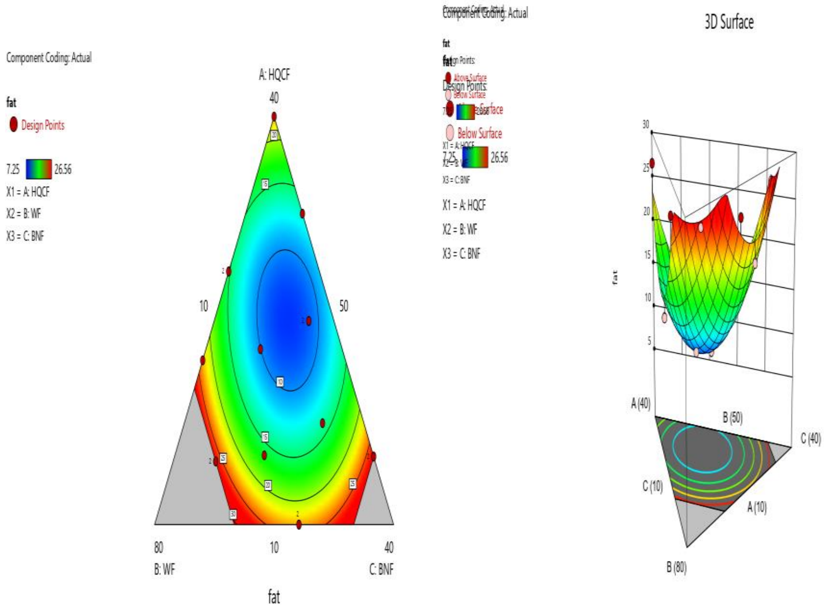

Fig. 12. Contour and 3D surface plots of fat content (%) of composite cassava-wheat-bambara bread

The bread samples were significantly ($p<0.05$) different with respect to carbohydrate content with range of value 30.98 to 56.34 %, with sample $HQCF_{22.08}WH_{67.92}$ $BNF_{10.00}$ having the minimum while sample $HQCF_{22.90}WH_{60.26}$ $BNF_{16.84}$ had the maximum.

Carbohydrate provides the body with energy to do work and subsequently helps in the regulation of blood glucose (Alimi et al., 2021). It was also observed that the additive effect of the carbohydrate contents of the constituent flours (HQCF, wheat and Bambara nut) culminated into the relatively high carbohydrate (56.34 %) content recorded for bread sample $HQCF_{22.90}WH_{60.26}$ $BNF_{16.84}$ which was significantly higher than that of the control (36.89 %) sample. The range of carbohydrate (30.98-56.34 %) content recorded in this study is relatively higher than (46.83-54.99%) reported by Toibudeen et al. (2020) and in the range reported by Bibiana et al. (2019).

From Table 7, the model developed for carbohydrate content showed that the linear effects of all the flour, and their interaction had a significant ($p<0.05$) model term. The regression coefficient (R^2) confirmed the fitting of the models with (R^2) 0.78, which denotes that 78% of the predicted values could be matched with the actual values. The coefficient of variation (C.V) that showed the degree of reproducibility and repeatability of the model was observed to be 6.90. The experimental results obtained for the carbohydrate content were fitted to a second order polynomial model (Equation 21) to describe the relationship between the three flour blends and the carbohydrate content of the composite flour. The equation in terms of coded factors could be used to make predictions about the response for given level of each factor.

$$\text{Carbohydrate content} = 37.95A - 4.05B + 16.00C + 94.83AB + 90.05AC + 132.24BC. \quad (21)$$

From this equation, at linear level HQCF and Bambara nut flour and the interaction of the three flours had positive effects on carbohydrate content. But a negative effect was observed at the linear effect of wheat flour. From Fig. 14, the carbohydrate showed a decrease in its value as the inclusion of wheat flour and Bambara nut flour addition increased. Meanwhile, the inclusion of HQCF increased the carbohydrate content of the composite bread.

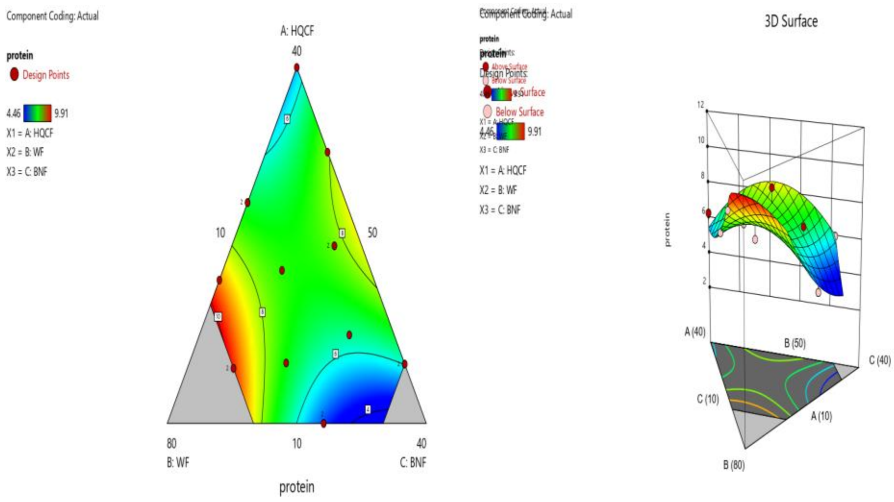

Fig. 13. Contour and 3D surface plots of protein content (%) of composite cassava-wheat-bambara bread

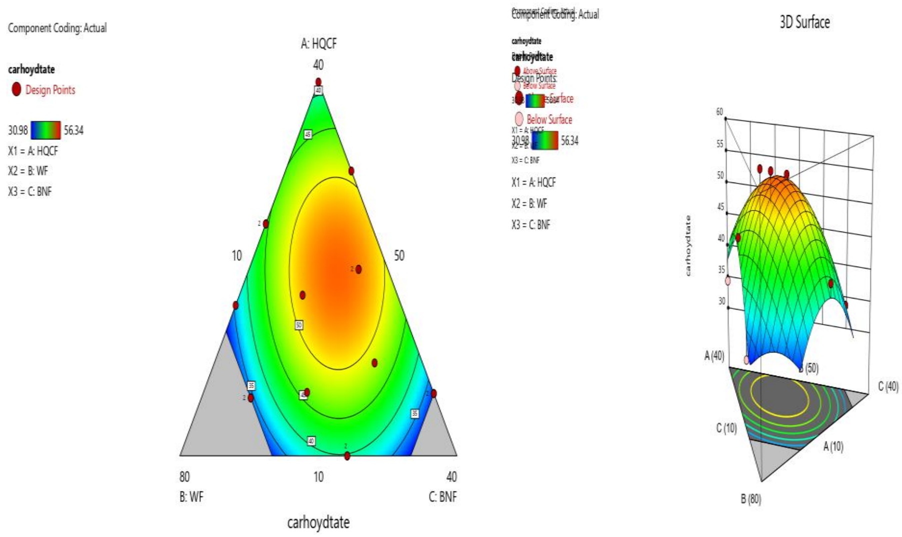

Fig. 14. Contour and 3D surface plots of carbohydrate content (%) of composite bread from blends of HQCF, wheat flour and Bambara nut flour

Generally, composite flour technology and ingredient optimization employed in this study improved the nutritional composition of the composite bread samples, especially the ash, protein, fat and carbohydrate which are the critical parameters determining the caloric value of a food product. The bread samples were significantly (p<0.05) different with respect to energy content, with range of value 314.51 to 415.67%, with sample $HQCF_{24.97}WH_{53.16}BNF_{21.87}$ having the minimum while sample $HQCF_{14.65}WH_{70.00}BNF_{15.35}$ had the maximum. The range (314.51- 415.67 kcal) for the caloric (energy) value of the composite bread was significantly higher than (286.39-305.16 kcal) reported by Bibiana et al. (2019). The model developed for energy value showed that the linear terms of HQCF and wheat flour were the significant (p<0.05) model terms. The Regression coefficient parameter showed that the quadratic model developed had a coefficient of determination (R^2) of 0.81 indicating a 81% predictive accuracy and F-value of 8.49. The model graph depicting the trend of energy content as influenced by the flour blends ratio is shown in Fig. 15. An increase was observed in energy value with increase in wheat flour and Bambara nut flour substitution. But as addition of HQCF increased, the energy value decreased. The energy value of the composite bread also showed a C.V value of 5.28 (<10) suggesting the possible reproducibility of the model. The experimental results obtained for the energy value were fitted to a second order polynomial model (Equation 22) to describe the relationship between the flour blends and the energy value of the composite bread. The empirical expression is shown below:

Energy value = 383.16A + 601.05B + 451.33C - 524 2.98AB -301.30AC – 513.15BC (22)

HQCF, Wheat flour and Bambara nut flour at linear terms was observed to have a positive effect on the energy content. But the interactions of HQCF and wheat flour, interaction of HQCF and Bambara nut flour and wheat flour and Bambara nut flour had a negative effect on energy value.

Optimum Level of the Constraint for The Optimization of Ingredient Combination of high-quality cassava wheat flour and Bambara nut composite bread.

Table 8 shows the conditions of the optimization process that gave a desirable processing condition using the following constraints. Lightness, yellowness, loaf weigh, and overall acceptability were maximized. Redness and browning index parameter were minimized. While moisture and fat content (%) were minimized. Also, crude protein, fibre, and carbohydrate (%) and energy were all maximized. The optimized ingredient blend formulation obtained was high quality casava flour of 15.10%, wheat flour of 63.67% and Bambara nut flour 21.23% while the calculated desirability was 0.53.

3.3 Sensory Properties of Composite Bread

The sensory properties of the bread produced with blends of flour from cassava, Bambara nut and wheat are presented in Table 9. There was no significant difference amongst the composite breads except the control sample (HQCF$_{0.00}$WH$_{100.00}$ BNF$_{0.00}$). Crumb elasticity of the composite breads ranged from 5.12 to 7.64, with sample HQCF$_{15.00}$WH$_{50.00}$BNF$_{35.00}$ being least elastic while sample HQCF$_{0.00}$WH$_{100.00}$ BNF$_{0.00}$ (control sample) had highest elasticity. This observation for crumb elasticity is expected because the viscoelastic nature of gluten present in 100 % wheat flour used in preparing the control sample was not diluted whereas in the composite bread, the dilution effect consequently resulted into the observed relatively low crumb elasticity. The trend of result obtained in this study regarding relative reduction in crumb elasticity of bread when wheat is partially substituted in bread making is similar to the report of previous studies (Shittu et al., 2008; Ahemen et al., 2021).

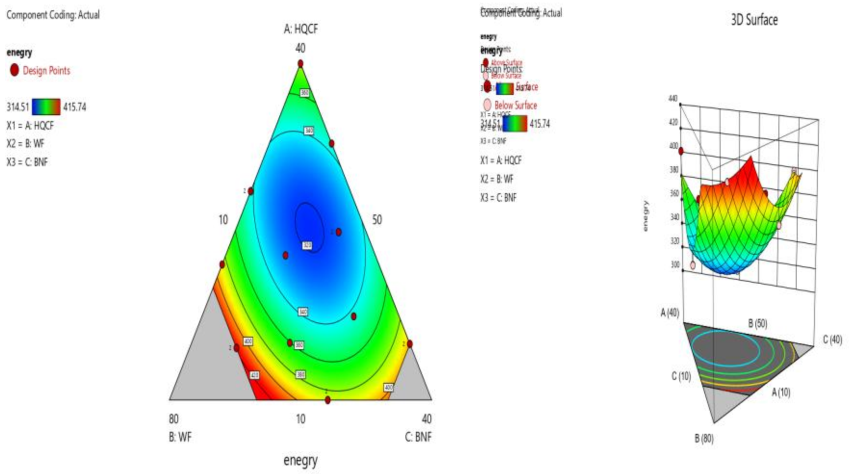

Fig. 15. Contour and 3D surface plots of energy content (kcal) of composite bread from blends of HQCF, wheat flour and Bambara nut flour

The bread texture as measured by crumb softness for the bread samples varied significantly between 4.96 and 7.88, with sample $HQCF_{15.00}WH_{50.00}BNF_{35.00}$ having the lowest while sample $HQCF_{0.00}WH_{100.00}BNF_{0.00}$ (control) had the highest. Unit operation such as proofing involves allowing the dough to rise at 43ºC, 80% R.H for 50 min. Gas production and retention occurs during proofing, diffusion of the gas cells into the air spaces created by the gluten network helps in trapping air, this aids oven spring and consequently improves crumb softness better in bread sample with the highest quantity of gluten.

This possibly explains the observed relative reduction in the crumb softness of the composite bread when compared with 100 % wheat bread owing to the reduction in gluten content attributed to wheat substitution with Bamabara nut flour and HQCF. This observation was noted by Ahemen et al. (2021) and Alimi et al. (2016) in similar work where wheat was substituted with HQCF and cowpea, respectively.

The crust appearance of the bread samples varied and ranged from 5.68 to 7.52, with sample $HQCF_{15.00}WH_{50.00}BNF_{35.00}$ having the lowest while sample $HQCF_{0.00}WH_{100.00}BNF_{0.00}$ (control) had the highest. Crust appearance is characterized by browning which occur as a result of mallard reaction. Maillard reaction is expected to be highest in the bread baked with 100 % wheat flour owing to the quality and quantity of protein available in wheat flour (Ahemen et al., 2021).

The bread samples varied in color and this ranged from 6.28 in samples $HQCF_{32.87}WH_{50.00}BNF_{17.13}$ and $HQCF_{40.00}WH_{50.00}BNF_{10.00}$ to 7.36 in sample $HQCF_{0.00}WH_{100.00}BNF_{0.00}$ (control). The same observation as discussed above for crust appearance applies for the color parameter except that the color scored by the assessors involved the crumb and crust. The color of the crumb is noted to be influenced by the additive effect of the constituent flours and the ingredient used while that of the crust is dependent on the quality and quantity of protein present in the dough prior baking (Alimi et al., 2016).

The flavor of the bread samples varied and ranged from 5.84 to 7.72, with samples $HQCF_{10.00}WH_{61.88}BNF_{28.12}$ and $HQCF_{10.00}WH_{61.88}BNF_{28.12}$ having the lowest while sample $HQCF_{0.00}WH_{100.00}BNF_{0.00}$ (control) had the highest.

The same observation holds for taste and overall acceptability of the bread samples. The taste ranged from 5.44 to 7.72, with sample $HQCF_{15.00}WH_{50.00}BNF_{35.00}$ having the lowest while sample $HQCF_{0.00}WH_{100.00}BNF_{0.00}$ (control) had the highest. Generally, as adjudged by the assessors, sample $HQCF_{0.00}WH_{100.00}BNF_{0.00}$ (control) was the most preferred while amongst the composite breads sample $HQCF_{22.08}WH_{67.92}BNF_{10.00}$ was the most preferred.

Table 8. Optimum level of the constraint for the optimization of ingredient combination for high-quality cassava wheat flour and Bambara nut composite bread Constraints

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A: HQCF	is in range	10	40	1	1	3
B:WF	is in range	50	70	1	1	3
C: BNF	is in range	10	35	1	1	3
Moisture	Minimize	25.56	32.36	1	1	3
Ash	Maximize	1.26	1.8	1	1	3
Crude fibre	Maximize	0.31	0.59	1	1	3
Fat	Minimize	7.25	26.56	1	1	3
Protein	Maximize	4.46	9.91	1	1	3
Carbohydrate	Maximize	30.98	56.34	1	1	3
Lightness	Maximize	29.57	39.52	1	1	3
Redness	Minimize	0.1	4.01	1	1	3
Yellowness	Maximize	8.28	15.28	1	1	3
Overall accept	Maximize	5.6	7.38	1	1	3
browning index	Minimize	0.36	0.41	1	1	3
Loaf weigh	Maximize	56.3	66.3	1	1	3
Crumble density	None	0.15	0.29	1	1	3
Crumble porosity	None	0.45	0.52	1	1	3
Energy	Maximize	314.51	415.74	1	1	3

Accept: Acceptability

Table 9. Sensory properties of bread produced with blends of flour from cassava, wheat and Bambara nut

Bread sample	Crumb elasticity	Crumb softness	Crust appearance	Color	Flavor	Taste	Overall acceptability
$HQCF_{14.65}WH_{70.00}BNF_{15.35}$	$5.48±0.39^{a}$	$5.36±0.39^{ab}$	$6.64±0.29^{abc}$	$6.80±0.26^{ab}$	$5.96±0.36^{a}$	$5.88±0.30^{a}$	$6.00±0.33^{a}$
$HQCF_{10.00}WH_{61.88}BNF_{28.12}$	$5.88±0.23^{a}$	$5.84±0.37^{abc}$	$5.96±0.34^{ab}$	$6.68±0.32^{ab}$	$5.84±0.31^{a}$	$5.60±0.29^{a}$	$6.28±0.34^{ab}$
$HQCF_{28.62}WH_{61.38}BNF_{10.00}$	$5.64±0.40^{a}$	$5.88±0.40^{abc}$	$6.28±0.32^{ab}$	$6.36±0.29^{a}$	$6.04±0.29^{ab}$	$6.00±0.3^{a}$	$6.08±0.37^{a}$
$HQCF_{15.00}WH_{50.00}BNF_{35.00}$	$5.12±0.43^{a}$	$4.96±0.42^{a}$	$5.68±0.47^{a}$	$6.52±0.32^{ab}$	$5.88±0.31^{a}$	$5.44±0.43^{a}$	$5.60±0.40^{a}$
$HQCF_{24.97}WH_{53.16}BNF_{21.87}$	$5.60±0.35^{a}$	$6.08±0.37^{abc}$	$6.52±0.30^{abc}$	$6.88±0.30^{ab}$	$6.52±0.28^{ab}$	$6.16±0.33^{ab}$	$6.40±0.32^{ab}$
$HQCF_{14.65}WH_{70.00}BNF_{15.35}$	$5.60±0.34^{a}$	$5.40±0.39^{ab}$	$6.72±0.28^{abc}$	$6.80±0.26^{ab}$	$6.08±0.37^{ab}$	$6.04±0.35^{a}$	$5.96±0.37^{a}$
$HQCF_{24.97}WH_{53.16}BNF_{21.87}$	$5.76±0.33^{a}$	$6.32±0.34^{bc}$	$6.64±0.26^{abc}$	$6.88±0.30^{ab}$	$6.56±0.29^{ab}$	$6.24±0.3^{ab}$	$6.40±0.32^{ab}$
$HQCF_{28.62}WH_{61.38}BNF_{10.00}$	$5.76±0.35^{a}$	$6.04±0.39^{abc}$	$6.28±0.32^{ab}$	$6.36±0.28^{a}$	$6.04±0.29^{ab}$	$6.12±0.3^{ab}$	$6.36±0.35^{ab}$
$HQCF_{32.87}WH_{50.00}BNF_{17.13}$	$5.52±0.30^{a}$	$5.48±0.36^{ab}$	$6.04±0.32^{ab}$	$6.28±0.25^{a}$	$5.92±0.34^{a}$	$5.84±0.36^{a}$	$6.32±0.33^{ab}$
$HQCF_{15.10}WH_{63.67}BNF_{21.23}$	$5.68±0.32^{a}$	$5.56±0.34^{ab}$	$6.20±0.25^{ab}$	$6.68±0.27^{ab}$	$6.28±0.27^{ab}$	$5.80±0.35^{a}$	$6.64±0.32^{ab}$
$HQCF_{40.00}WH_{50.00}BNF_{10.00}$	$5.76±0.34^{a}$	$5.84±0.35^{a}$	$6.16±0.39^{ab}$	$6.28±0.33^{a}$	$6.04±0.34^{ab}$	$6.20±0.34^{ab}$	$6.52±0.33^{ab}$
$HQCF_{17.46}WH_{55.18}BNF_{27.36}$	$5.92±0.36^{a}$	$6.04±0.40^{abc}$	$6.44±0.36^{ab}$	$6.52±0.33^{a}$	$6.32±0.34^{ab}$	$6.28±0.46^{ab}$	$6.36±0.36^{ab}$
$HQCF_{22.90}WH_{60.26}BNF_{16.84}$	$5.28±0.41^{a}$	$5.36±0.39^{ab}$	$5.96±0.31^{ab}$	$6.72±0.36^{ab}$	$6.52±0.19^{ab}$	$6.32±0.33^{ab}$	$6.72±0.28^{ab}$
$HQCF_{22.08}WH_{67.92}BNF_{10.00}$	$6.21±0.39^{a}$	$6.79±0.31^{b}$	$7.00±0.30^{bc}$	$6.71±0.25^{a}$	$7.00±0.23^{bc}$	$7.21±0.2^{bc}$	$7.38±0.25^{bc}$
$HQCF_{15.00}WH_{50.00}BNF_{35.00}$	$5.38±0.37^{a}$	$5.27±0.42^{ab}$	$5.85±0.45^{a}$	$6.62±0.28^{ab}$	$6.08±0.30^{a}$	$5.62±0.40^{a}$	$5.69±0.38^{a}$
$HQCF_{10.00}WH_{61.88}BNF_{28.12}$	$5.84±0.38^{a}$	$6.12±0.37^{abc}$	$5.96±0.35^{ab}$	$6.76±0.32^{ab}$	$5.84±0.31^{ab}$	$5.76±0.25^{a}$	$6.44±0.34^{a}$
$HQCF_{0.00}WH_{100.00}BNF_{0.00}$	$7.64±0.21^{b}$	$7.88±0.19^{c}$	$7.52±0.27^{b}$	$7.36±0.26^{b}$	$7.72±0.21^{c}$	$7.72±0.20^{c}$	$7.96±0.17^{c}$

Values are mean of duplicates ± standard deviation. Mean values with different superscripts within the same column are significantly different at 5% level
HQCF: High Quality Cassava Flour; BNF: Bambara Nut Flour; WF: Wheat Flour

Table 10. Microbiological qualities of the composite bread

Sample(s)	NA (TBC) cfu/g x 10^{-3}	EMB (TECC) cfu/g x 10^{-3}	SSA (TSSCC) cfu/g x 10^{-3}	PDA (TFC) cfu/g x 10^{-3}
$HQCF_{14.65}WH_{70.00}BNF_{15.35}$	$2.33±1.53^{ab}$	0.00±0.00	0.00±0.00	0.00±0.00
$HQCF_{10.00}WH_{61.88}BNF_{28.12}$	$6.33±2.31^{c}$	0.00±0.00	0.00±0.00	0.00±0.00
$HQCF_{28.62}WH_{61.38}BNF_{10.00}$	$10.00±0.05^{d}$	0.00±0.00	0.00±0.00	1.00±0.00
$HQCF_{15.00}WH_{50.00}BNF_{35.00}$	$2.00±1.00^{ab}$	0.00±0.00	0.00±0.00	0.00±0.00
$HQCF_{24.97}WH_{53.16}BNF_{21.87}$	$0.00±0.00^{a}$	0.00±0.00	0.00±0.00	2.00±0.00
$HQCF_{14.65}WH_{70.00}BNF_{15.35}$	$2.31±1.48^{ab}$	0.00±0.00	0.00±0.00	0.00±0.00
$HQCF_{24.97}WH_{53.16}BNF_{21.87}$	$0.00±0.00^{a}$	0.00±0.00	0.00±0.00	2.00±0.00
$HQCF_{28.62}WH_{61.38}BNF_{10.00}$	$9.97±0.12^{d}$	0.00±0.00	0.00±0.00	1.00±0.00
$HQCF_{32.87}WH_{50.00}BNF_{17.13}$	$4.67±2.08^{bc}$	0.00±0.00	0.00±0.00	1.00±0.00
$HQCF_{15.10}WH_{63.67}BNF_{21.23}$	$0.00±0.00^{a}$	0.00±0.00	0.00±0.00	1.00±0.00
$HQCF_{40.00}WH_{50.00}BNF_{10.00}$	$2.67±1.16^{ab}$	0.00±0.00	0.00±0.00	0.00±0.00
$HQCF_{17.46}WH_{55.18}BNF_{27.36}$	$0.00±0.00^{a}$	0.00±0.00	0.00±0.00	0.00±0.00
$HQCF_{22.90}WH_{60.26}BNF_{16.84}$	$1.00±0.00^{a}$	0.00±0.00	0.00±0.00	0.00±0.00
$HQCF_{22.08}WH_{67.92}BNF_{10.00}$	$1.00±0.00^{a}$	0.00±0.00	0.00±0.00	0.00±0.00
$HQCF_{15.00}WH_{50.00}BNF_{35.00}$	$1.98±1.00^{ab}$	0.00±0.00	0.00±0.00	0.00±0.00
$HQCF_{10.00}WH_{61.88}BNF_{28.12}$	$6.35±1.28^{c}$	0.00±0.00	0.00±0.00	0.00±0.00
$HQCF_{0.00}WH_{100.00}BNF_{0.00}$	$2.00±0.00^{ab}$	0.00±0.00	0.00±0.00	0.00±0.00

Values are mean of duplicates ± standard deviation. Mean values with different superscripts within the same column are significantly different at 5% level.
NA (TBC): Nutrient Agar (Total Bacterial Count); EMB (TECC): Eosin Methylene Blue agar (Total Escherichia coli colony count); SSA (TSSCC): Salmonella Shigella Agar (Total Salmonella Shigella colony count)
PDA (TFC): Potato Dextrose Agar (Total fungal count)

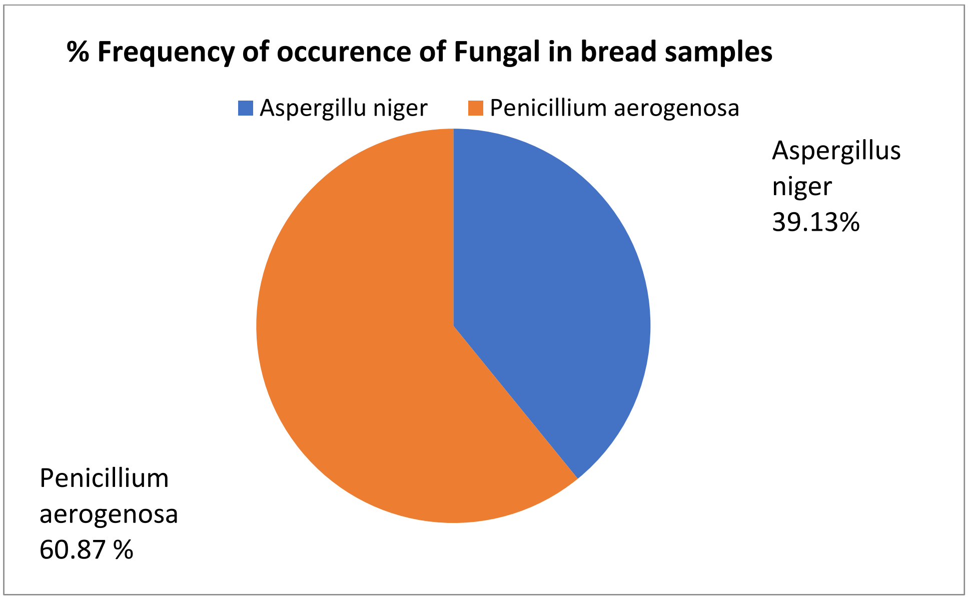

Fig. 16. Percentage frequency of occurence of fungi in bread samples

3.4 Microbiological Qualities of the Composite Bread

The microbiological qualities of the composite bread samples are presented in Table 10. The frequency of *Penicillium aerogenosa* isolated from composite bread produced with blends of flour from cassava, wheat and Bambara nut flour was estimated successfully. Ijah *et al.* (2014) also isolated *Aspergillus niger,* and *Penicillium* species from wheat and potato flour blends. *Aspergillus niger* was present in composite bread $HQCF_{28.62}WH_{61.38}BNF_{10.00}$ and $HQCF_{15.10}WH_{63.67}BNF_{21.23}$. Generally, the total percentage frequency of occurrence for *Penicillium aerogenosa* in bread samples was 60.87% while that of *Aspergillus niger was* 39.13% (Fig. 16). Fungi isolates were not detected in some of the bread samples produced, especially *Aspergillus niger.* The observation in this present study is similar to the report of Ijah et al. (2014) and Daniyan & Nwokwu, (2011). The results of this research are within the limits set by the ICMSF (1996) and the Standard Organization of Nigeria, which states that mold counts must not exceed 100 cfu/g in bread samples irrespective of the formulations used in production. The low count of viable organism in the bread samples could be attributed to the lethal effect of the baking temperature on the microorganisms and good hygiene practices that was effective in preventing post-production contamination by microorganisms (Igbabul et al. 2019).

4. CONCLUSION

Bread of acceptable quality with respect to physical and proximate properties was successfully produced with blends of flours from cassava, Bambara groundnut and wheat. The bread samples were acceptable sensorially as adjudged by the panels. Lower count (load) of viable organism isolated in composite bread was due to the lethal effect of baking temperature and good hygiene practice during the production process. The optimized ingredient blend formulation obtained was high quality casava flour of 15.10%, wheat flour of 63.67% and Bambara nut flour 21.23% ($HQCF_{15.10}WH_{63.67}$ $BNF_{21.23}$) while the calculated desirability was 0.53.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ACKNOWLEDGEMENT

The authors sincerely acknowledge and appreciate the management of Nigerian Stored Products Research Institute (NSPRI) headed by Prof. Lateef Oladimeji Sanni for funding this research project. The authors appreciate cassava unit of the International Institute of Tropical Agriculture (IITA), for technical support and provision of low postharvest physiologically deteriorated (PPD) cassava roots used for the research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Ahemen, S. A., Alimi, J. P., Alimi, J. O., & Iluebbey, P. O. (2021). Physical and microstructural properties of composite cassava-wheat bread produced from blend of wheat and low postharvest physiological deterioration cassava flours. *American Journal of Food Science and Technology*, 9(4), 142-148. https://doi.org/10.12691/ajfst-9-4-5

Alimi, J. O., Ogunbanwo, S. T., & Alimi, J. P. (2023). Antimicrobial effects of lactic acid bacteria on food-borne pathogens isolated from fruits sold in Ibadan, Nigeria. *South Asian Journal of Research in Microbiology*, *15*(4), 38-45. https://doi.org/10.9734/SAJRM/2023/v15i4294

Alimi, J. P., Ahemen, S. A., Alimi, J. O., & Iluebbey, P. O. (2023). Effect of varietal differences on chemical and pasting properties of composite wheat-cassava flours produced from low postharvest physiologically deteriorated cassava roots (*Manihot esculenta* Crantz). *Croatian Journal of Food Science and Technology*, *15*(1), 1-10. https://doi.org/10.17508/CJFST.2023.15.1.09

Alimi, J. P., Ahemen, S. A., Alimi, J. O., Ajisafe, S. S., & Oke, O. A. (2023). Sensory and microstructural properties of cakes made with flour from low postharvest physiologically deteriorated cassava. *Journal of Food Industry*, 6(1), 46-58. https://doi.org/10.5296/jfi.v6i1.20682

Alimi, J. P., Akanni, A. A., Odutola, B. S., Akande, E. J., Haruna, P. B., Adegbola, R. Q., Sanni, L. O., & Okunade, S. O. (2024). Effect of Bambara groundnut flour (*Vigna subterranea*) inclusion on the functional, pasting, physical and proximate properties of composite cassava-Bambara flour. *Asian Food Science Journal*, 23(6), 44–57. https://doi.org/10.9734/afsj/2024/v23i6719

Alimi, J. P., Shittu, T. A., Oyelakin, M. O., Olagbaju, A. R., Sanu, F. T., Alimi, J. O., Abel, O. O., Ogundele, B. A., Ibitoye, O., Ala, B. O., & Ishola, D. T. (2016). Effect of cowpea flour inclusion on the storage characteristics of composite wheat-cowpea bread. *Journal of Agricultural and Crop Research*, 4(4), 49-59. Retrieved from http://sciencewebpublishing.net/jacr/archive/2016/June/pdf/Alimi%20et%20al.pdf

Anthony, N. M., Sawi, M. K., Ayelaagbe, O. O., Taiwo, A., Winnebah, I., & Fomba, S. N. (2014). Proximate characteristics and complimentary assessments of five organic sweet potato cultivars and cowpea varieties. *International Journal of Engineering Sciences*, 3, 38-42. Retrieved from http://dx.doi.org/10.1094/AACCIntMethod

Azza, A. A., Eltayeb, A. R., Ali, S. M., & Abu-Salem, F. M. (2011). Chemical composition and functional properties of flour and protein isolate extracted from Bambara groundnut (*Vigna subterranea*). *African Journal of Food Sciences*, 5(2), 82-90.

Daniyan, S. Y., & Nwokwu, O. E. (2011). Enumeration of microorganisms associated with the different stages of bread production in FUTMIN bakery, Nigeria. *International Research Journal of Pharmacy*, 2(7), 88-91.

Igbabul, B. D., Onoja, E. C., & Ukeyima, M. T. (2019). Quality evaluation of composite bread produced from wheat, water yam, and brown hamburger bean flours. *African Journal of Food Science and Technology*, 10(2), 42-48. https://doi.org/10.14303/ajfst.2019.008

International Committee of Microbiological Specification for Foods (ICMSF). (1996). *Microorganisms in Foods 2: Sampling for Microbiological Analysis: Principles and Specific Applications* and *Microorganisms in Foods 7: Microbiological Testing in Food Safety Management*.

Ijah, U. J. J., Auta, H. S., Aduloju, M. O., & Aransiola, S. A. (2014). Microbiological, nutritional, and sensory quality of bread produced from wheat and potato flour blends. *International Journal of Food Science*, Article ID 671701, 6 pages. https://doi.org/10.1155/2014/671701

Iwe, M. O., Michael, N., Madu, N. E., Obasi, N. E., & Onwuka, G. I. (2017). Physicochemical and pasting properties of high quality cassava flour (HQCF) and wheat flour blends. *Agrotechnology*, 6, 1-8. https://doi.org/10.4172/2168-9881.1000167

Association of Official Analytical Chemists (AOAC). (2019). *Official methods of analysis* (21st ed., Vol. I).

Okwunodulu, I. N., Egbuta, G. N., Okwunodulu, F. U., Ojinnaka, C. M., & Onyeiwu, S. C. (2024). Gluten-free sourdough breads from pearl millet-Bambara nut and pearl millet-soybean paste: Evaluation of the proximate, functional properties of the flour blends and the bread nutritional indexes. *Food Chemistry Advances*, 4, 100633.

Sanni, L. O., Alimi, J. P., Jimoh, M. O., Aremu, M. B., Ihum, T. A., Fashanu, T. A., Okunade, S. O., & Akanni, A. A. (2024). Quality attributes of chinchin produced with blends of flour from cassava (*Manihot esculenta*) and Bambara groundnut (*Vigna subterranea*). *European Journal of Nutrition & Food Safety*, 16(7), 134-150. https://doi.org/10.9734/ejnfs/2024/v16i71463

Shittu, T. A., Dixon, A., Awonorin, S. O., Sanni, L. O., & Maziya-Dixon, B. (2008). Bread from composite cassava–wheat flour. II: Effect of cassava genotype and nitrogen fertilizer on bread quality. *Food Research International*, 41(6), 569-578.

Toibudeen, A. S., Eunice, M. O., Cordelia, N. J., & Kudirat, T. A. (2020). Nutritional and sensory characteristics of bread produced from wheat and cassava flour, fortified with sorrel seed protein isolate. *FUOYE Journal of Engineering and Technology (FUOYEJET)*, 5(1), 6-10. https://doi.org/10.46792/fuoyejet.v5i1.445

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/127886