Asian Food Science Journal

Volume 23, Issue 12, Page 99-116, 2024; Article no.AFSJ.128037
ISSN: 2581-7752

Quality Characteristics of Cake Produced with Blends of Flour from Bambara Nut Seeds (*Vigna subterranea*) and Cassava (*Manihot esculenta*)

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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/afsj/2024/v23i12762

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/128037

Original Research Article

Received: 08/10/2024
Accepted: 10/12/2024
Published: 21/12/2024

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Cite as: *Alimi, John Praise, Olufunke Grace Otitodun, Abubakar Adegboyega Akanni, Medinat Oyiza Jimoh, Rukayat Queen Adegbola, Patience Bahago Haruna, Esther Jesutomilayo Akande, David Taiwo Ishola, Olufunmilayo Adeola Ajayi, Aaron Isaac Yissa, and Bamidele Samuel Odutola. 2024. "Quality Characteristics of Cake Produced With Blends of Flour from Bambara Nut Seeds (Vigna Subterranea) and Cassava (Manihot Esculenta)". Asian Food Science Journal 23 (12):99-116. https://doi.org/10.9734/afsj/2024/v23i12762.*

ABSTRACT

Developing food products with functional and high nutritional potentials to engender promising solutions to malnutrition is a practical step in addressing SDG-3. This investigation was done to assess the quality of cakes produced with blends of flour from cassava and Bambara nuts seeds. High quality cassava flour (HQCF) and Bambara flour were prepared from cassava (IITA-TMS-IBA011368) and Bambara nut seeds (SAMNUT 21) as depicted by Design Expert Version 12 and subsequently used for baking. Analyses carried out on the cakes were sensory, physical, nutritional, microbiological and crumb cell properties. Statistical tools of Statistical Package for Social Scientist (SPSS version 25) were employed in analyzing data generated, separation of significant means was done with the application of Duncan Multiple Range Tests. The cakes were not different in terms of color parameters (*L*, a**) *with values* 8.88 to 9.82 and 0.70 to 8.88, respectively. The range of value for appearance, color, texture, taste, aroma and overall acceptability of the cake was 6.84-7.52, 7.04-7.52, 6.56-7.32, 6.72-7.56, 6.76-7.52 and 6.96-7.64; moisture, ash, fibre, fat, protein, carbohydrate and energy with range of value 15.56 to 19.69 %, 1.08 to 1.47 %, 1.29 to 3.04 %, 20.03 to 24.96 %, 5.89 to 8.61 %, 43.44 to 51.90 % and 414.09 to 451.66 Kcal/kg, respectively. Microbiological qualities of cakes are within the limits set by the ICMSF (1996) and the Standard Organization of Nigeria. Cakes of acceptable qualities were produced with composite flours prepared; the optimized ingredient blend formulation obtained was high quality cassava flour of 50% and Bambara nut flour 50% while the calculated desirability was 0.56.

Keywords: Sensory properties; malnutrition; celiac disease; nutritional properties; crumb cell structure.

1. INTRODUCTION

The production of wheat rose from 600 million tonnes in year 2000 to 800 million tonnes in 2021 almost at the same rate with that of rice production (FAOSTAT 2022). Characteristically, wheat has been noted to have propensity to give the shape of food product that is being baked. Dough formation is brought about when wheat flour is mixed with water, this is made possible as a result of its proteins units interacting together (Shittu et al. 2008). The typical functional properties of wheat include emulsification, water binding capacity, viscosity, foaming, solubility, and gelation capacity.

Currently, due to economic realities particularly with respect to the exchange rate, cost of purchasing wheat flour is relatively high which in turn has attendant effect on the eventual cost of food products prepared from wheat. From the foregoing, crops having promising baking potentials free of gluten but have resemblance with wheat considering the inherent functional properties should be explored with the view to partially or completely replace wheat flour; this will reduce to the barest minimum the overdependence on wheat importation knowing fully well that wheat is produced in few states in Nigeria due to unfavorable soil and climatic condition (Alimi et al. 2023). One of such gluten-free flours with promising food functional properties is high quality cassava flours (HQCF) which can be constituted into composite protein-enriched baking flour from crop like Bambara groundnut (Alimi et al. 2023b).

High quality cassava flour has gained popularity for use as food at domestic and industrial level especially in Nigerian baking industry (Shittu et al. 2008, Alimi et al. 2023b). Previous investigation on cassava varieties having low postharvest physiological deterioration revealed that that flour from IITA-TMS-IBA-011368 followed by IITA-TMS-IBA-070593 can find application for baking purpose (Alimi et al. 2024). An array of food products such as cookies, cake and chin-chin were produced with the variants of cassava aforementioned. Varieties of cassava with beta carotene have a prospect of improving the immune response of human health.

Considering nutritional value, amongst many crops Bambara groundnut ranked next to cereal with regard to calories and proteins that can be derived, it is less-expensive and known to be an essential leguminous food commodity after cowpea and groundnut (Mayes et al. 2019). Bambara groundnut is a potent nutraceutical with anti-diabetic and anti-cancer activities which can be attributed to the content of vitamin C with its anti-oxidative properties. It has high soluble carbohydrate (Anthony et al. 2014) and good water absorption capacity (Azza et al. 2011) that correspond to increased finished product baking quality (loaf volume).

Food product development involving the use of HQCF having precursor of vitamin A and Bambara groundnut is beneficial to celiac patients while providing consumers with a change in taste of cake prepared with wheat flour and the one produced with blends of flour from cassava and Bambara groundnut seeds.

Cake is typically a baked snacks that is eaten across the globe and is basically prepared with wheat flour with other relevant ingredients (Alimi et al. 2022). Cake is a dessert, sweet to taste, with different shapes depending on the consumers' preference. Exploring the baking potentials of flour from Bambara groundnut seeds when composited with flours from other crops such as cassava and wheat is crucial. Baked food product such as cake prepared with High quality cassava flour from low postharvest physiologically deteriorated cassava is beneficial to celiac patients owing to its gluten-free properties (Alimi et al. 2023). Therefore, this investigation was done to assess the quality of cakes produced with blends of flour from cassava and Bambara groundnut seeds.

2. MATERIALS AND METHODOLOGY

2.1 Materials

High quality cassava flour (HQCF) was prepared IITA-TMS-IBA-011368 cassava, Bambara nut flour granulated sugar from Dangote Nigeria Plc., Lagos, Other materials used include baking powder, Simas margarine (PT Intiboga Sejahtera, Jakarta, Indonesia), vanilla essence, eggs, mixed fruits and evaporated milk. The functional, pasting, physical and proximate properties of composite cassava-bambara (CCB) flour used for the production of the cake are as presented in Alimi et al. (2024).

2.2 Production of High Quality Cassava Flour (HQCF)

Wholesome cassava (IITA-TMS-IBA-011368) used for this investigation were provided by IITA which was processed into HQCF following the protocol described by Iwe et al. (2017) and Alimi et al. (2022). The flow chart for the production of HQCF is presented in Fig. 1.

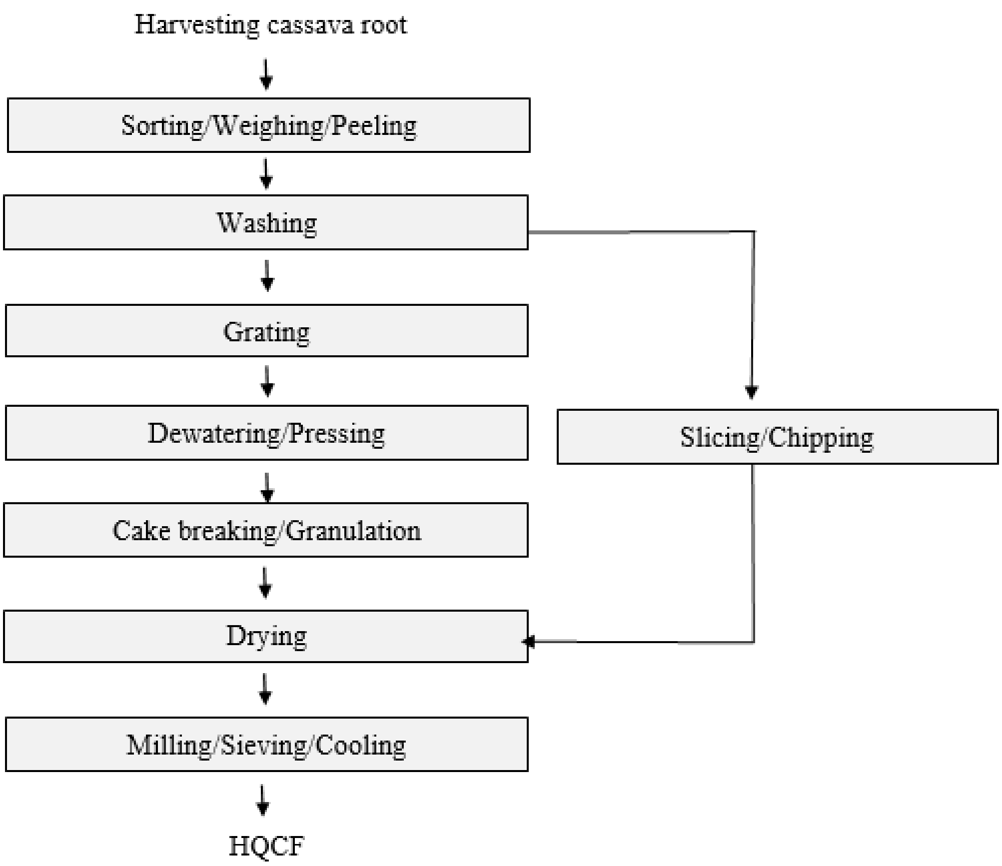


Fig. 1. Flow chart for the production of high quality cassava flour

2.3 Production of Bambara Nut Flour

Wholesome Bambara groundnuts seeds were procured from Mokwa, Niger State. The seeds were processed into flour as described by Alimi et al. (2024). The unit operations involved in the processing of Bambara groundnut seeds into fine flour is presented in Fig. 2.

2.4 Experiment Design for the Cake Production Experiment

D-Optima design was used for the combination of the flours. Therefore, a total of 8 samples (runs) were generated. The experimental design with which the high quality cassava flour and Bambara groundnut flour were blended is as indicated in Table 1.

2.5 Flour Composition for Cake Production

The flour composition with which the composite flour used for the cake production is presented in Table 2.

2.6 Production of Cake

Composite flour prepared using the processed flour (HQCF and Bambara groundnut flour) based on D-Optimal mixture design with an outcome of eight experimental runs (Table 1 and 2) was used for the production of the cakes Alimi et al. (2022). The unit operations involved in the production of the cakes is presented in Fig. 2.

2.7 Sensory Analysis of the Cakes

Twenty Panelists were trained for the assessment; 12 were males and 8 females. Students (interns) and staff in Nigerian Stored Products Research Institute, Ilorin, Kwara State, Nigeria assessed the baked cake samples. The assessors had age ranging from 20 to 50 year of which 70% of them were undergoing tertiary educational training. The cake samples were packaged in aluminum foils, assigned code, was subsequently presented to the assessors three (3) hours after baking exercise. The panelists scored the cake samples using sensory descriptive terms such as color, texture, aroma, taste, flavor and overall acceptability using a 9-point hedonic scale based on their degree of likeness, where 1= Dislike extremely; 5= neither like nor dislike; 9= like extremely (Iwe 2002).

2.8 Proximate Composition of the Cake Samples

The proximate parameters (moisture, ash, fibre, protein and fat content) of the cakes produced with blends of flour from cassava and Bambara groundnut seeds cassava (IITA-TMS-IBA-011368) and Bambara nut were determined following the standard analytical procedure of AOAC methods. Carbohydrate content in percentage was estimated employing difference Equation (1). An equation which was a factor was used in calculating the energy value expressed in Kcal/kg or KJ/kg (2).

$$\text{Carbohydrate (\%)} = 100 - \%\,(\text{protein} + \text{fat} + \text{moisture} + \text{ash}) \quad (1)$$

$$\text{Energy value Kcal/kg} = (\text{Protein cont.} \times 4 + \text{fat cont.} \times 9 + \text{carbohydrate cont.} \times 4) \quad (2)$$

Cont: Content

Table 1. Composition of flour

Sample /Run	High quality cassava flour (HQCF)	Bambara nut flour (BNF)
1	62.50	37.50
2	50.00	50.00
3	50.00	50.00
4	62.50	37.50
5	68.75	31.25
6	56.25	43.75
7	75.00	25.00
8	75.00	25.00

Table 2. Recipe and formulation for the cake production

Sample /Run	Sample	Sugar (g)	Margarine (g)	Baking Powder (g)	Eggs (g)	Evaporated Milk (mls)	Vanilla Essence (mls)	Mixed fruits (g)
1	$HQCF_{62.50}BNF_{37.50}$	66.70	50.00	1.70	100.00	22	1.70	34
2	$HQCF_{50.00}BNF_{50.00}$	66.70	50.00	1.70	100.00	22	1.70	34
3	$HQCF_{50.00}BNF_{50.00}$	66.70	50.00	1.70	100.00	22	1.70	34
4	$HQCF_{62.50}BNF_{37.50}$	66.70	50.00	1.70	100.00	22	1.70	34
5	$HQCF_{68.75}BNF_{31.25}$	66.70	50.00	1.70	100.00	22	1.70	34
6	$HQCF_{56.25}BNF_{43.75}$	66.70	50.00	1.70	100.00	22	1.70	34
7	$HQCF_{75.00}BNF_{25.00}$	66.70	50.00	1.70	100.00	22	1.70	34
8	$HQCF_{75.00}BNF_{25.00}$	66.70	50.00	1.70	100.00	22	1.70	34
C:9	Control ($WF_{100.00}$)	66.70	50.00	1.70	100.00	22	1.70	34

C: 9: Control sample; BNF: Bambara nut flour

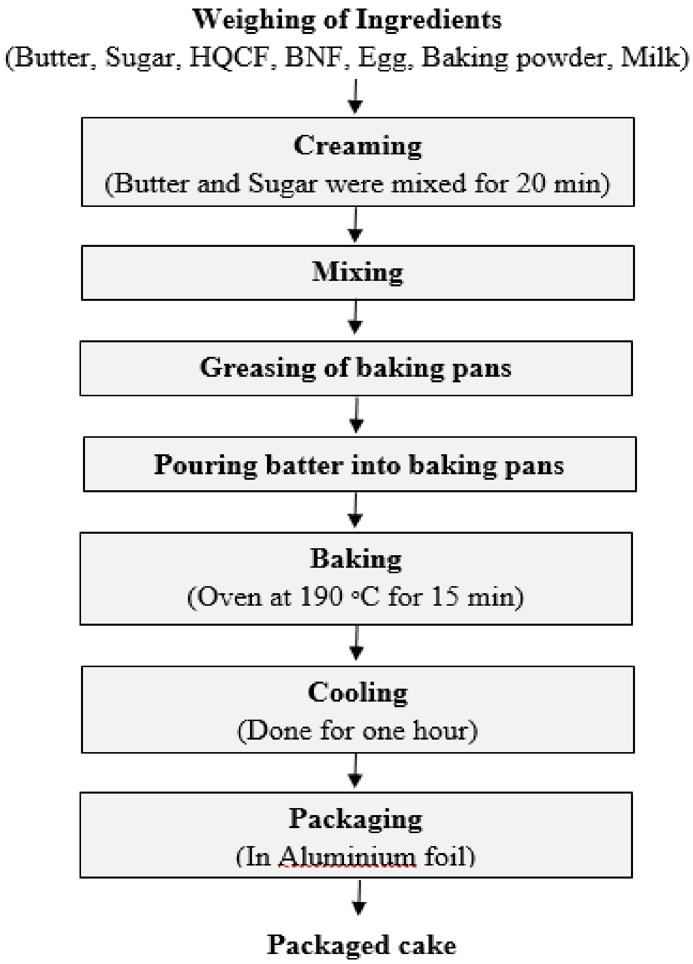


Fig. 2. Flow chart for the production of HQCF-BNF cake
(Source: Alimi et al., 2022)

2.9 Microbiological Assay of the Cake Samples

Total bacteria and fungi count of the cake samples were determined using the pour-plate procedure as described by Alimi et al. (2021). The isolation of the constituting fungal colonies in the cake samples were carried out by doing a 10-fold serial dilution of the sample. One gramme (1g) of the cake 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^{0}C 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 follows at 27^{o}C for 4 days.

2.10 Microstructural Characteristics of the Cake Samples

The crumb cell structural characteristics of the cake samples were determined following the method described by Shittu et al. (2008) and (Alimi et al. 2016, Ahemen et al. 2021).

2.11 Statistical Analyses

Statistical tools of Statistical Package for Social Scientist (SPSS version 25) were employed in analyzing data generated, separation of significant means was done with the application of Duncan Multiple Range Tests (DMRTs). The effect of ingredient combination and the 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 Cakes

The physical (color) properties of the cake samples are presented in Table 3. The cake lightness as measured by the *L** value ranged from 8.88 to 9.82, with cake sample $HQCF_{62.50}BNF_{37.50}$ having the highest; values for *a**ranged from 0.70 to 8.88, with cake sample $HQCF_{62.50}BNF_{37.50}$ having the lowest. The reason to be adduced for insignificant differences in the color parameters measured for the cake samples may not be unconnected with the fact that the same proportion of ingredients were added to all the blends of the composite HQCF-BNF.

The results of data obtained using multiple quadratic regression is presented in Table 4. The main effect of high-quality cassava flour and Bambara flour significantly ($p<0.05$) affect lightness, respectively. The interactive effect of high-quality cassava flour and Bambara nut flour had no significant ($p>0.05$) effect on lightness. The coefficient of determination (R^2) in Table 4 was seen to be 0.46 indicating a 46% of variance in the experimental data, which were found to be insignificant. The model graph depicting the trend of lightness as influenced by high quality cassava flour and Bambara flour at the blending ratio is shown in Fig. 2. Lightness increased as Bambara flour inclusion increased while decrease in lightness was observed as HQCF increased in the blend. The observation in this present study is similar to what Murphy et al. (2000) reported.

The main effect of HQCF and BNF was significant ($p<0.05$) on Redness (a*). However, the interaction of high-quality cassava flour and Bambara nut flour had no significant ($p>0.05$) effect on redness. Regression coefficient parameter showed that the quadratic model developed for redness had a coefficient of determination (R^2) of 0.46 indicating a 46% predictive accuracy and F-value of 2.17. The model graph depicting the trend of redness as influenced by the flour blends at substitution ratio is shown in Fig. 2, an increase was observed in redness value as Bambara nut flour increased, this observation could be attributed to the increased protein content of the formulations, which favored Maillard (browning) reactions in carbohydrate-rich food matrix, same observation was made by Obatolu et al. (2016) whereas a decrease in (a*) value was observed as HQCF inclusion increased in the blends.

The data obtained on yellowness (b*) using multiple quadratic regression is presented in Table 4. The main effect of HQCF and Bambara nut flour had a significant ($p<0.05$) on yellowness. Similarly, the interactive effect of the flour samples had no significant ($P>0.05$) effect on yellowness. Regression coefficient parameter showed that the quadratic model developed for yellowness had a coefficient of determination (R^2) of 0.49 indicating 49% predictive accuracy, and F-value of 2.36. The model graph depicting the trend of yellowness as influenced by HQCF and Bambara nut flour as the blending ratio changed is shown in Fig. 2. An increase was observed as inclusion of Bambara nut flour increased, but reverse is the case when HQCF increased in the blend. Notably, increase in (b*) value corresponds to the increase in yellowness, which occurs in the beginning of non-enzymic browning, these findings are similar to the report of Hussein et al. (2010).

Table 3. Physical (Color) properties and overall acceptability of the cakes

Sample	Lightness (*L**)	Redness (*a**)	Yellowness (*b**)	Overall acceptability
$HQCF_{62.50}BNF_{37.50}$	29.82 ± 0.32^a	0.70 ± 0.31^{ab}	8.88 ± 0.34^a	7.08 ± 0.19^a
$HQCF_{50.00}BNF_{50.00}$	30.81 ± 0.15^a	1.59 ± 0.18^b	9.81 ± 0.25^a	6.96 ± 0.24^a
$HQCF_{50.00}BNF_{50.00}$	38.01 ± 2.24^b	2.22 ± 0.41^b	13.9 ± 1.05^b	7.64 ± 0.20^a
$HQCF_{62.50}BNF_{37.50}$	29.29 ± 1.15^a	-0.48 ± 0.35^a	8.23 ± 0.77^a	7.16 ± 0.27^a
$HQCF_{68.75}BNF_{31.25}$	30.61 ± 0.26^a	1.53 ± 0.42^b	9.90 ± 0.46^a	7.32 ± 0.24^a
$HQCF_{56.25}BNF_{43.75}$	29.36 ± 0.89^a	1.36 ± 1.27^{ab}	8.91 ± 1.01^a	7.28 ± 0.32^a
$HQCF_{75.00}BNF_{25.00}$	29.97 ± 0.45^a	0.93 ± 0.20^{ab}	9.26 ± 0.42^a	7.16 ± 0.20^a
$HQCF_{75.00}BNF_{25.00}$	29.87 ± 1.07^a	0.73 ± 0.50^{ab}	9.04 ± 0.85^a	7.28 ± 0.23^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

Table 4. Regression coefficient for color and overall acceptability of cakes

Parameters	Lightness	Redness	Yellowness	Overall acceptability
A: high-quality cassava flour	30.34*	0.99*	9.44*	7.24*
B: Bambara nut flour	34.01*	1.99*	11.62*	7.30*
AB	-10.91	-3.43	-7.22	-0.33
R^2	0.46	0.46	0.49	0.05
F-value	2.14	2.17	2.36	0.14
P-value	0.21	0.21	0.19	0.87

The results of data obtained on overall acceptability using multiple quadratic regression is presented in Table 4. The main effect of HQCF and Bambara nut flour was significant ($p<0.05$) on the overall acceptability. The interactive effect of HQCF and Bambara nut had no significant ($p>0.05$) effect on the overall acceptability. Regression coefficient parameter showed that the quadratic model developed for overall acceptability had a coefficient of determination (R^2) of 0.05 indicating a 5% predictive accuracy and F-value of 0.14. The model graph depicting the trend of overall acceptability as influenced by HQCF and Bambara nut flour as blending ratio changed. As shown in Fig. 2, a decrease in overall acceptability was observed as Bambara nut flour inclusion increase in the blend, whereas the addition of HQCF resulted in increase in overall acceptability of the cake samples. This observation is in consonance with the report of Alimi (2023b) where preference of consumers for cake was influenced by change of taste from conventional cakes baked with wheat flour only to cakes baked with composite flour containing high quality cassava flour.

3.2 Sensory Properties of the Cakes

The sensory properties of cakes produced from blends of flour from high quality cassava flour and Bambara nut are presented in Table 5. There was no significant difference in the sensory attributes (appearance, color, texture, taste, aroma and overall acceptability) measured as adjudged by the assessors, indicating that the cake samples baked with wheat flour and those baked with blends of flour from HQCF and Bambara flour were equally acceptable by the panelist with reference to sensorial quality attributes.

Interestingly, sample $HQCF_{50.00}BNF_{50.00}$, which is the sample baked with equal proportion of HQCF and Bambara nut flour (i.e. HQCF: BNF 50:50) compared favorably with cake baked using wheat flour as indicated in Table 5. The most preferred cake sample amongst the cakes baked with composite flour from HQCF and Bambara flour is $HQCF_{50.00}BNF_{50.00}$.

3.3 Nutritional Composition of the Cake Samples

The nutritional composition of the cakes baked with blends of flour from HQCF and Bambara nut flour are presented in Table 6. The cake samples were significantly ($p\leq0.05$) different with respect to the nutritional properties. The moisture content of the cakes varied and ranged from 15.56 to 19.69%, with sample $HQCF_{50.00}BNF_{50.00}$ having the lowest while sample $HQCF_{62.50}BNF_{37.50}$ had the highest. Food products such as cakes and bread are regarded as intermediate moisture foods with range of moisture content (18-25 %) for cake, (35-42 %) for bread and (1-5 %) for that of biscuit.

The range (15.56 to 19.69 %) of value for moisture contents of the cakes produced with blends of flour is within the value for intermediate moisture foods (IMFs). The lower the moisture content of foods, the more shelf stable they are. Table 7 presents the results obtained using multiple quadratic regression. The main effect of high-quality cassava flour and Bambara nut flour was significant ($p<0.05$) on moisture content. The interactive effect of flour blends had a significant ($p<0.05$) effect on moisture content. Regression coefficient parameter showed that the quadratic model developed for moisture content had a coefficient of determination (R^2) of 0.76 indicating 76% predictive accuracy and F-value of 8.00.

The model graph depicting the trend of moisture content as influenced by high quality cassava flour and Bambara nut at substitution ratio change is shown in Fig. 3. As Bambara nut flour increased, the moisture content decreased. But the inclusion of HQCF increased the moisture content of the cake. The lower the moisture content of a food product to be stored, the better the shelf stability of such product (Alimi et al. 2023, Sanni et al. 2006). High moisture content and water activity in food materials could encourage microbial activities which consequently will lead to spoilage of the food [5, 13, 20]. (Alimi et al. 2024, Alimi et al. 2016, Anno et al. 2022).

The ash content of the cakes ranged from 1.08 to 1.47 %, with sample $HQCF_{75.00}BNF_{25.00}$ having the minimum while sample $HQCF_{68.75}BNF_{31.25}$ had the maximum. The ash contents of the constituent flours tend to have influence on the overall ash content of the cake samples. The ash content of a food sample reveals the mineral element present in that food sample. Table 7 presents the results of data obtained using multiple quadratic regression.

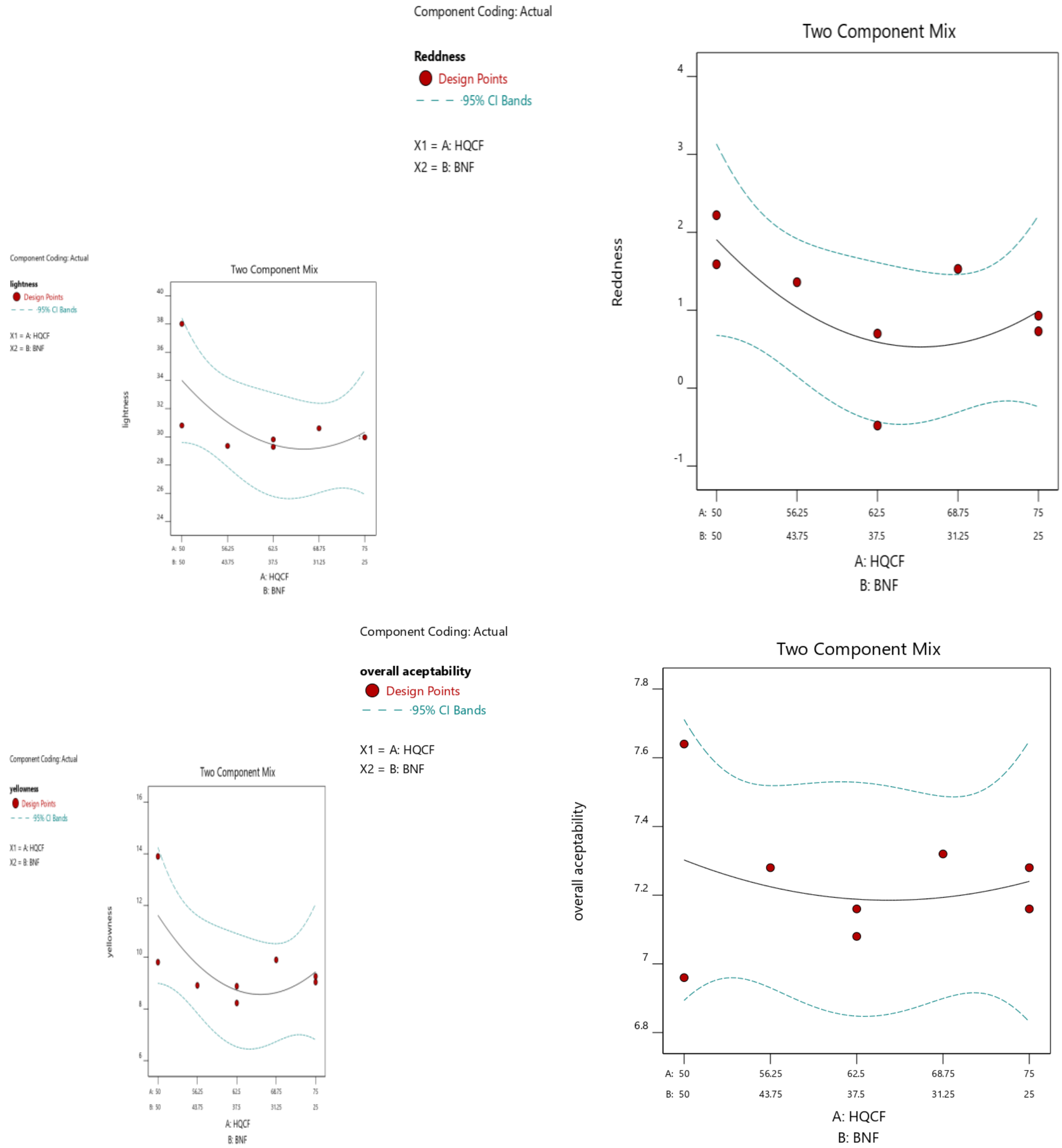


Fig. 3. model graph depicting the trend of lightness, greenness, yellowness and overall acceptability content (%) of cake as influenced by high quality cassava flour and Bambara nut flour at blending ratio

Table 5. Sensory properties of cake produced with blend of flour from HQCF and Bambara nut

Sample	Appearance	Color	Texture	Taste	Aroma	Overall Acceptability
$HQCF_{62.50}BNF_{37.50}$	7.32±0.19^{a}	7.40±0.18^{a}	6.56±0.22^{a}	6.80±0.27^{a}	6.76±0.28^{a}	7.08±0.19^{a}
$HQCF_{50.00}BNF_{50.00}$	6.88±0.29^{a}	7.12±0.21^{a}	6.92±0.24^{a}	6.72±0.31^{a}	6.96±0.22^{a}	6.96±0.24^{a}
$HQCF_{50.00}BNF_{50.00}$	7.52±0.24^{a}	7.52±0.17^{a}	7.32±0.21^{a}	7.44±0.23^{a}	7.08±0.23^{a}	7.64±0.20^{a}
$HQCF_{62.50}BNF_{37.50}$	7.36±0.23^{a}	7.36±0.19^{a}	7.16±0.23^{a}	7.20±0.31^{a}	6.76±0.30^{a}	7.16±0.27^{a}
$HQCF_{68.75}BNF_{31.25}$	6.84±0.26^{a}	7.32±0.24^{a}	7.08±0.27^{a}	7.40±0.25^{a}	6.96±0.30^{a}	7.32±0.24^{a}
$HQCF_{56.25}BNF_{43.75}$	7.00±0.29^{a}	7.04±0.27^{a}	7.12±0.24^{a}	7.08±0.32^{a}	7.00±0.27^{a}	7.28±0.32^{a}
$HQCF_{75.00}BNF_{25.00}$	7.36±0.24^{a}	7.32±0.27^{a}	7.00±0.22^{a}	6.88±0.31^{a}	6.88±0.25^{a}	7.16±0.20^{a}
$HQCF_{75.00}BNF_{25.00}$	7.12±0.33^{a}	7.32±0.24^{a}	6.96±0.22^{a}	7.00±0.27^{a}	6.92±0.29^{a}	7.28±0.23^{a}
Control ($WF_{100.00}$)	7.28±0.29^{a}	7.24±0.21^{a}	7.24±0.25^{a}	7.56±0.19^{a}	7.52±0.23^{a}	7.64±0.26^{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; WF: Wheat flour

Table 6. Proximate composition of cake produced with blend of flour from cassava and Bambara groundnut

Samples	Moisture (%)	Ash (%)	Fibre (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Energy (Kcal/kg)
$HQCF_{62.50}BNF_{37.50}$	18.73±0.31^{d}	1.184±0.08^{ab}	1.63±0.01^{ab}	24.42±0.00^{d}	6.59±0.08^{c}	47.45±0.19^{b}	435.97^{d}
$HQCF_{50.00}BNF_{50.00}$	16.92±0.77^{bc}	1.24±0.03^{ab}	2.25±0.07^{c}	23.97±0.01^{c}	7.33±0.05^{d}	48.30±0.03^{bc}	438.22^{d}
$HQCF_{50.00}BNF_{50.00}$	15.56±0.83^{a}	1.36±0.03^{bc}	1.29±0.03^{a}	24.90±0.01^{g}	8.61±0.12^{f}	48.29±0.75^{bc}	451.66^{f}
$HQCF_{62.50}BNF_{37.50}$	19.69±0.18^{d}	1.28±0.07^{bc}	3.04±0.70^{c}	24.96±0.01^{h}	7.59±0.08^{e}	43.44±0.83^{a}	428.76^{c}
$HQCF_{68.75}BNF_{31.25}$	19.40±0.20^{d}	1.47±0.11^{c}	2.34±0.04^{bc}	22.81±0.00^{b}	6.08±0.02^{ab}	47.89±0.24^{bc}	421.39^{b}
$HQCF_{56.25}BNF_{43.75}$	17.44±0.19^{c}	1.34±0.06^{bc}	2.73±0.02^{c}	20.03±0.04^{a}	6.56±0.01^{c}	51.90±0.23^{d}	414.09^{a}
$HQCF_{75.00}BNF_{25.00}$	15.85±0.56^{ab}	1.33±0.06^{bc}	1.30±0.08^{a}	24.53±0.01^{e}	5.89±0.01^{a}	51.10±0.59^{d}	448.64^{ef}
$HQCF_{75.00}BNF_{25.00}$	17.38±0.24^{c}	1.08±0.01^{a}	1.34±0.10^{a}	24.71±0.00^{f}	6.26±0.07^{b}	49.22±0.23^{c}	444.41^{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

The main effect of high-quality cassava flour and Bambara nut flour was significant ($p<0.05$) on total ash content respectively. The interactive effect (AB) of high quality cassava flour and Bambara nut flour blends had no significant ($p>0.05$) effect on total ash content. Regression coefficient parameter showed that the quadratic model developed for ash content had a coefficient of determination (R^2) of 0.07 indicating 7% predictive accuracy and F-value of 0.18 The model graph depicting the trend of ash content as influenced by flour blends at substitution ratio change as shown in Fig. 3 showed that at increased inclusion of HQCF and reduced Bambara nut flour, a decrease in ash content was observed. Again, increased inclusion of Bambara nut flour and reduced HQCF content resulted into an increased ash content of the cake. The aforementioned point indicated that inclusion of Bambara nut flour enhanced the ash content of the cakes. Similar trend of result was reported by [Alimi et al. (2024) for chin-chin and cookies produced from wheat and banana flours. The ash content of food gives an idea of the total quantity of the mineral elements in the food (Alimi et al. 2021, Iwe et al. 2017). Based on this fact, high ash content as observed in cake samples with high proportions of Bambara nut flour would be a good source of mineral to the consumer.

The cake samples were significantly ($p\leq0.05$) different in terms of fibre content, which ranged from 1.29 to 3.04 %, with sample $HQCF_{50.00}BNF_{50.00}$ having the lowest while sample $HQCF_{62.50}BNF_{37.50}$ had the highest. The prime role of fibre in the regulation of blood sugar level cannot be overemphasized. The main effect of high quality cassava and Bambara nut flour was significant ($p<0.05$) on fibre content. The interactive effect of HQCF and Bambara nut had no significant ($p>0.05$) effect on the fibre content. Regression coefficient parameter showed that the quadratic model developed for fibre had a coefficient of determination (R^2) of 0.50 indicating a 50% predictive accuracy and F-value of 2.54.

The model graph depicting the trend of the fibre content as influenced by the flour blends at different blending ratio change is shown in Fig. 3 indicating a decrease in fibre content as inclusion of Bambara nut flour increased. But an increase in fibre content was observed as HQCF content increased. Similar result was also obtained in the other study conducted by Ubbor et al. (2022) on production and quality evaluation of cake from wheat and red banana flour blends. Result of this present study attests to the fact that HQCF contains relatively high amount of fibre and has the propensity to increase the same when composited with other flour. The aforementioned observation has been corroborated by studies by Etong et al. (2014) and the report of Kiin-Kabari et al. (2017) for increased fibre content of wheat flour cookies fortified with moringa leaf powder. Removal of carcinogens and prevention of excessive cholesterol absorption from the body are typical digestive tract cleansing impact of fibre when present in ingested food.

The cake samples were significantly ($p\leq0.05$) different in terms of the fat content, which ranged from 20.03 to 24.96 %, with sample $HQCF_{56.25}BNF_{43.75}$ having the lowest while sample $HQCF_{62.50}BNF_{37.50}$ had the highest. Relatively, Bambara nut flour has higher fat content when compared with high quality cassava flour. The fat content of food product plays a significant role in the caloric value of such food product. Table 7 presents the results of data obtained using multiple quadratic regression. The main effect of high-quality cassava flour as well Bambara nut flour has a significant ($p<0.05$) effect on fat content. However, the interactive effect of the blends showed no significant ($p>0.05$) effect on fat content. Regression coefficient parameter indicated that the quadratic model developed for

Table 7. Regression coefficient for proximate composition of cakes

Parameter	Moisture	Ash	Fibre	Fat	Protein	Carbohydrate	Energy
A High-quality cassava flour	16.80*	1.24*	1.33*	24.67*	6.07*	9.89*	445.84*
B Bambara nut flour	16.04*	1.29*	1.82*	23.88*	7.86*	49.12*	442.81*
AB	10.98*	0.18	3.78	-4.42	-0.91	-9.64	-81.65
R^2	0.76	0.07	0.50	0.14	0.63	0.22	0.55
F-Value	8.00	0.18	2.54	0.39	4.20	0.69	3.07
P-Value	0.03	0.84	0.17	0.70	0.09	0.54	0.14

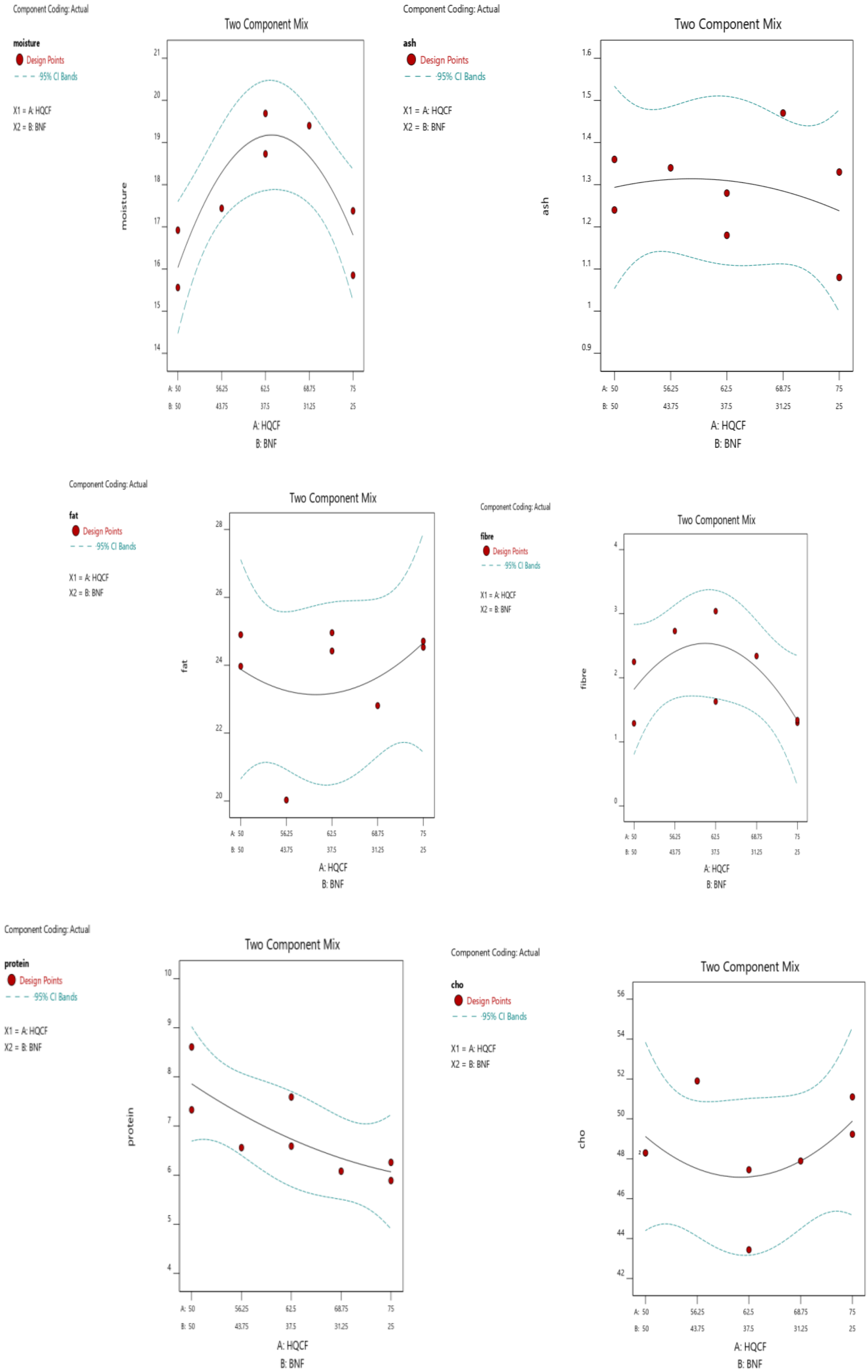
fat content had a coefficient of determination (R^2) of 0.14 indicating a 14% predictive accuracy and F-value of 0.39. An increase was observed in the fat content as Bambara nut flour inclusion increased, while a decrease was noted as the inclusion in HQCF increased as indicated in Fig. 3. Similar observation was reported by Etong et al. (2014) and Ubbor et al. (2022).

The cake samples were significantly (p≤0.05) different in terms of the protein content, which ranged from 5.89 to 8.61 %, with sample $HQCF_{75.00}BNF_{25.00}$ having the lowest while sample $HQCF_{50.00}BNF_{50.00}$ had the highest, and the observed relatively high protein (8.61 %) content could be attributed to the additive effect of comparatively high protein content of Bambara nut flour in sample $HQCF_{50.00}BNF_{50.00}$. The results of data obtained on protein using multiple quadratic regression is presented in Table 7. The main effect of HQCF and Bambara nut flour was significant ($p<0.05$) on protein content. The interactive effect of flour blends had no significant ($p>0.05$) effect on protein content. Regression coefficient parameter showed that the quadratic model developed for protein content had a coefficient of determination (R^2) of 0.63 indicating 63% predictive accuracy and F-value of 4.20. The model graph depicting the trend of protein content as influenced by HQCF and BNF as blending ratio change is shown in Fig. 3. A decrease was observed in the protein content as inclusion of HQCF increased, but as the addition of BNF increased, the protein content increased.

Similar trend of increased protein content on blending cowpea flour with wheat flour for bread production was reported by Alimi et al. (2016). A progressive reduction in the protein values of the cakes was observed as the proportion of HQCF increased in the blend. Noteworthy, HQCF contains low protein when compared with Bambara nut flour. Observations in this study are similar to the report by Ubbor et al. (2022) on the production and quality evaluation of cake from wheat and red banana flour blends.

The cake samples were significantly (p≤0.05) different in terms of the carbohydrate content, which ranged from 43.44 to 51.90 %, with sample $HQCF_{62.50}BNF_{37.50}$ having the minimum while sample $HQCF_{56.25}BNF_{43.75}$ had the maximum. The results of data obtained on carbohydrate using multiple quadratic regression is presented in Table 7. The main effect of HQCF as well BNF was significant ($p<0.05$) on carbohydrate content. However, the interactive effect of the blends showed no significant ($p>0.05$) effect. Regression coefficient parameter showed that the quadratic model developed for carbohydrate content had a coefficient of determination (R^2) of 0.22 indicating a 22% predictive accuracy and F-value of 3.07. Inclusion of HQCF raised the carbohydrate content (Fig. 3). The result showed progressive increase in the carbohydrate content as the level of HQCF inclusion increased attesting to the fact that HQCF is rich sources of carbohydrate when compared to BNF. The cake samples with HQCF are rich in carbohydrate, thereby serving as a source of energy to consumers. Similar result of improved carbohydrate contents of cookies made with flour blends from cardaba banana being higher than cookies from 100% wheat flour. Ubbor et al. (2022) reported a similar result of increase in carbohydrate content of cookies as the proportion of acha and orange fleshed sweet potato increased.

The cake samples were significantly (p≤0.05) different in terms of the energy content, which ranged from 414.09 to 451.66 Kcal/kg, with sample $HQCF_{56.25}BNF_{43.75}$ having the lowest while sample $HQCF_{50.00}BNF_{50.00}$ had the highest. The results obtained on energy content using multiple quadratic regression is presented in Table 7. The main effect of high-quality cassava flour as well Bambara nut flour has a significant ($p<0.05$) on energy content. However, the interactive effect of the blends showed no significant ($p>0.05$) effect. Regression coefficient parameter showed that the quadratic model developed for energy content had a coefficient of determination (R^2) of 0.55 indicating a 55 % predictive accuracy and F-value of 3.07. An increase was observed in energy content of the cake as Bambara nut flour inclusion increased (Fig. 3). The observed increase in energy value of the cake samples could be attributed to the significant improvement in fat, protein and carbohydrate contents of the composite flour used for the baking experiment which may not be unconnected with the inherent protein and fat in Bambara groundnut and additive effect of carbohydrate contents of the constituent flours. The energy (414.09 to 451.66 Kcal/100g) value reported in this study is higher than (339 – 359Kcal/100g) reported by Kiin-Kabari et al. (2017) but comparable to the (403 – 460 Kcal/100g reported by Eke et al. (2008) for Nigerian cakes sold in Portharcourt. These differences may be due to recipe formulation (constituent flours) and methods of preparation.


Component Coding: Actual
moisture
Design Points
95% CI Bands
X1 = A: HQCF
X2 = B: BNF
Two Component Mix
moisture
A: HQCF
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Component Coding: Actual
ash
Design Points
95% CI Bands
X1 = A: HQCF
X2 = B: BNF
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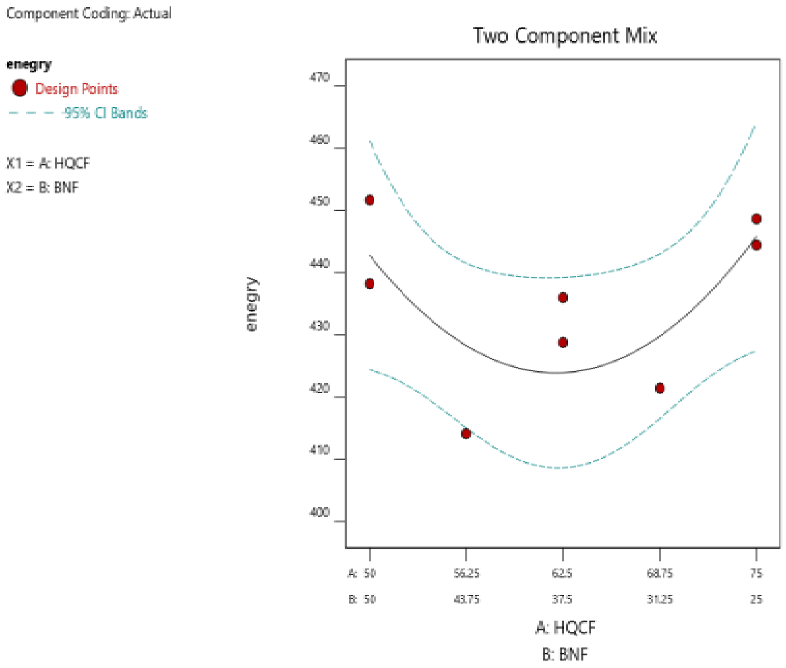

Fig. 4. Model graph depicting the trend of moisture, fat, ash, crude fibre, protein, carbohydrate and energy content (%) of cake as influenced by High quality cassava flour and Bambara nut flour at substitution ratio

3.4 Microbiological Quality of the Cake

The microbiological qualities of the cake samples are presented in Table 8. The observed infinitesimal count in viable organism in the cake samples could be attributed to the lethal effect of the baking temperature on the microorganisms. 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 food (baked) samples irrespective of the formulations used in production.

3.5 Microstructural (Crumb Cell Structure) Properties of the Cake

Knowledge of the structure and properties of cake crumb is critical in the optimization of its quality with propensity to influence the consumer acceptability of the product. "The averages of frequency of gray color intensity for each crumb area (200 × 200 squared pixels) were obtained while the coefficient of variation (CV) of GL intensity was taken as a measure of uniformity of crumb structure". This approximation was assumed since there is a relationship between cellular structures of cake crumb and the intensity of light reflected during image acquisition. The gray images of cake crumb cells obtained at the different combination of HQCF and Bambara groundnut flour are presented in Fig. 5.

The gray image figures typify the differences in the crumb structure formed as a result of the differences in the composition of the composite flour (i.e. ratio of combination of the constituent flours) used in the baking experiment. The region with finer structure reflects more light (lower gray level intensity) while regions with coarser texture reflect less light. The higher the CV value the less uniform the crumb structure (Shittu et al. 2008, Alimi al. 2016, Ahemen et al. 2021). The number of crumb cells, total area, average size and percentage area varied between the cake samples with ranges 44.33-195.00, 9054.33-20895.00, 88.75-305.65 and 43.95-67.24 %, respectively (Table 7).

When carefully viewed with human eye, the similarities and differences in the crumb cell structures could be observed; even though the shapes of the cake samples baked with composite flour was relatively irregular (Shittu et al. 2008, Alimi al. 2016, Ahemen et al. 2021). but cake sample having equal proportion of HQCF and Bambara nut flour ($HQCF_{50.00}BNF_{50.00(b)}$) had relative uniformity in terms of distribution of crumb cells which is comparable to that of cake baked with 100 % wheat flour. The differences in the crumb structure (cell distribution) of the control (cake baked wheat flour) and those baked with composite cassava-bambara nut flour could be attributed to the starch pasting characteristics of the constituent flours (Ragaee & Abdel-Aal 2006), reduced alpha amylase activity of the composite flour (Tohver et al. 2005). The observation in this present study on crumb cell distribution is similar to what was reported by Shittu et al. (2008), Alimi et al. (2016) and Ahemen et al. (2021) Paraskevopoulou et al. (2012) regarding observed relative irregularity in crumb cell structure of baked food products such as bread and cake with composite flours with a view to optimizing product quality which will in turn ultimately improve the consumer acceptability. Amongst the cake samples baked with composite flour, the optimized sample is $HQCF_{50.00}BNF_{50.00(b)}$ followed by cake sample $HQCF_{62.50}BNF_{37.50(b).}$

3.6 Optimum Level of the Constraint for the Optimization of Ingredient Combination of High-Quality Cassava and Bambara Nut Cakes

The conditions of the optimization process that gave a desirable processing condition using the following constraints are presented in Table 9. Lightness, redness yellowness and overall acceptability were maximized, while moisture and fat content (%) were minimize. Also, crude protein, fibre, and carbohydrate (%) and energy were all maximize. The optimized ingredient blend formulation obtained was high quality cassava flour of 50% and Bambara nut flour 50% while the calculated desirability was 0.56.

Table 8. Microbiological qualities of cake samples

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}
$HQCF_{62.50}BNF_{37.50}$	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00^{a}
$HQCF_{50.00}BNF_{50.00}$	0.00±0.00	0.00±0.00	0.00±0.00	3.00±0.01^{c}
$HQCF_{50.00}BNF_{50.00}$	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00^{a}
$HQCF_{62.50}BNF_{37.50}$	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00^{a}
$HQCF_{68.75}BNF_{31.25}$	0.33±0.57^{a}	0.00±0.00	0.00±0.00	1.00±0.00^{b}
$HQCF_{56.25}BNF_{43.75}$	0.67±1.15^{a}	0.00±0.00	0.00±0.00	3.00±0.01^{c}
$HQCF_{75.00}BNF_{25.00}$	5.33±0.61^{b}	0.00±0.00	0.00±0.00	1.00±0.00^{b}
$HQCF_{75.00}BNF_{25.00}$	0.67±2.08^{b}	0.00±0.00	0.00±0.00	1.00±0.00^{b}
Wheat (100%)	3.00±0.57^{ab}	0.00±0.00	0.00±0.00	1.00±0.00^{b}

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)

Table 9. Optimum level of the constraint for the optimization of ingredient combination for high-quality cassava and Bambara nut cake

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A: HQCF	is in range	50	75	1	1	3
B: BNF	is in range	25	50	1	1	3
Moisture	Minimize	15.56	19.69	1	1	3
Ash	Maximize	1.08	1.47	1	1	3
Fibre	Maximize	1.29	3.04	1	1	3
Fat	Minimize	20.03	24.96	1	1	3
Protein	Maximize	5.89	8.61	1	1	3
Carbohydrate	Maximize	43.44	51.9	1	1	3
Energy	Maximize	414.09	451.66	1	1	3
Lightness	Maximize	29.29	38.01	1	1	3
Redness	Maximize	-0.48	2.22	1	1	3
Yellowness	Maximize	8.23	13.9	1	1	3
overall Accept	Maximize	6.96	7.64	1	1	3

Overall Accept: Overall Acceptability

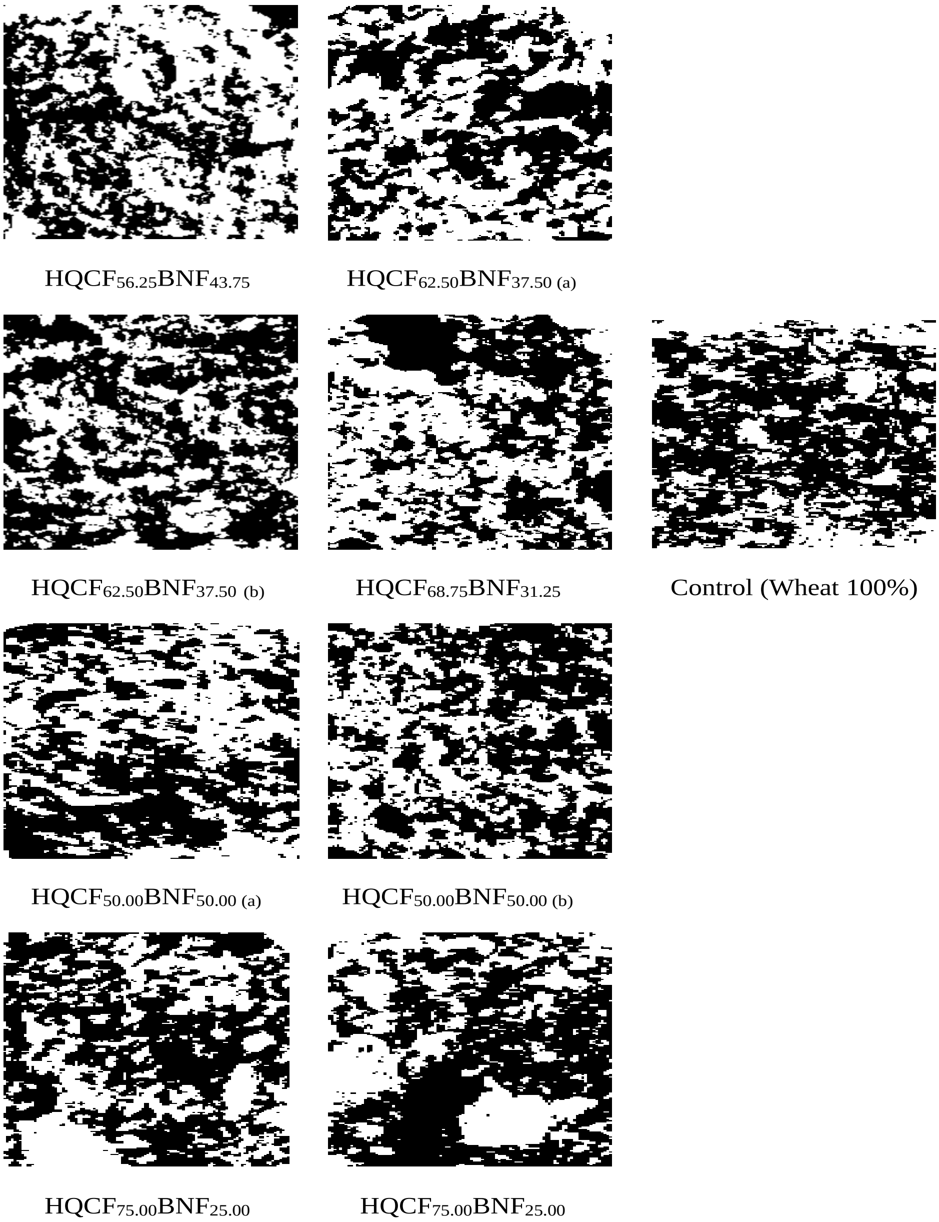

Fig. 5. crumb cell distribution of cake at different combination of HQCF and Bamb Flour

4. CONCLUSION

Cakes of acceptable and comparable quality with that produced with wheat flour with respect to the physical, sensory, nutritional, microstructural properties and microbiological safety were produced with blends of flour from cassava and Bambara groundnut. Regarding cake crumb structure, amongst the cake samples baked with composite flour, cake samples $HQCF_{50.00}BNF_{50.00(b)}$ and $HQCF_{62.50}BNF_{37.50(b)}$ had a close resemblance with the control (cake sample baked 100% wheat flour). The optimized sample is the one containing the flour blend with 50% HQCF and 50% Bambara nut flour (i.e. $HQCF_{50.00}BNF_{50.00}$).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare 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.

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 blends 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. 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., & Iluebbey, P. O. (2021). Functional, physical, and rheological properties of composite cassava-wheat flour produced from low postharvest deterioration cassava (*Manihot esculenta* Crantz). *Asian Food Science Journal, 20*(10), 62-72. https://doi.org/10.9734/AFSJ/2021/v20i1030362

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., Ahemen, S. A., Zaka, K. O., Yepshak, N. B., Alimi, J. O., & Balogun, D. A. (2021). Microbiological quality of high-quality cassava flours produced from selected varieties of low postharvest physiological deterioration cassava (*Manihot esculenta* Crantz). *South Asian Journal of Research in Microbiology, 11*(2), 27-35. https://doi.org/10.9734/SAJRM/2021/v11i230248

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 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

Alimi, J. P., Yepshak, N. B., Ahemen, S. A., Alimi, J. O., & Adarabierin, I. G. (2022). Sensory properties of chin-chin produced with high-quality cassava flour from varieties of low postharvest physiologically deteriorated cassava. In *Proceedings of the 46th Conference and Annual General Meeting of the Nigerian Institute of Food Science and Technology (NIFST)* (pp. 164-170). Retrieved from https://doi.org/10.22271/foodsci.2022.v3.i1a.60

Anno, A., Konan, H., Kouadio, J., Dué, E., & Kouamé, L. (2022). Chemical composition and nutritional value of two edible mushrooms from three regions of Côte d'Ivoire. *Journal of Basic and Applied Research in Biomedicine, 2*(2), 119-125. Retrieved from https://jbarbiomed.com/index.php/home/article/view/61

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.

Eke, J., Achinewhu, S. C., & Sanni, L. O. (2008). Nutritional and sensory qualities of some Nigerian cakes. *Nigerian Food Journal, 26*(2), 12-13.

Etong, D. I., Mustapha, A. O., Lawrence, I. G., Jacob, A. G., & Oladimeji, M. O. (2014). Nutritional and physicochemical properties of wheat (*Triticum vulgare*), cassava (*Manihot esculenta*), and sweet potato (*Ipomoea batatas*) flours. *Pakistan Journal of Nutrition, 13*(8), 439-445.

FAOSTAT. (2022). *Production: Crops and livestock products*. In: FAO. Rome. Retrieved December 2022, from https://www.fao.org/faostat/en/#data/QCL

Hussein, A. M. S. (2010). Technological properties of some Egyptian new wheat varieties. *Journal of American Science, 6*(10), 1160-1171.

Iwe, M. O. (2002). *Handbook of sensory methods and analysis*. Rojoint Communication Service Ltd.

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

Kiin-Kabari, D. B., Emelike, N. J. T., & Ebere, C. O. (2017). Influence of drying techniques on the quality characteristics of wheat flour cookies enriched with moringa (*Moringa oleifera*) leaf powder. *International Journal of Food Science and Nutrition, 2*(3), 94-99.

Mayes, S., Ho, W. K., Chai, H. H., Gao, X., Kundy, A. C., & Mateva, K. I. (2019). Bambara groundnut: An exemplar underutilized legume for resilience under climate change. *Planta, 250*, 803–820. https://doi.org/10.1007/s00425-019-03191-6

Murphy, A., Peer, W. A., & Taiz, L. (2000). Regulation of auxin transport by aminopeptidases and endogenous flavonoids. *Planta, 211*, 315-324.

Obatolu, V. A., Omueti, O. O., & Adebowale, E. A. (2006). Qualities of extruded puffed snacks from maize/soybean mixture. *Journal of Food Process Engineering, 29*(2), 149-161.

Paraskevopoulou, M. D., Georgakilas, G., & Kostoulas, N. (2012). DIANA-LncBase: Experimentally verified and computationally predicted microRNA targets on long non-coding RNAs. *Nucleic Acids Research, 41*, D239-D245. https://doi.org/10.1093/nar/gks1246

Ragaee, S., & Abdel-Aal, E. S. M. (2006). Pasting properties of starch and protein in selected cereals and quality of their products. *Food Chemistry, 95*, 9-18.

Sanni, L. O., Adebowale, A. A., & Tafa, S. O. (2006). Proximate, functional, pasting, and sensory qualities of instant yam flour. Paper presented at the 14th ISTRC Symposium, Central Tuber Crops Research Institute, Trivandrum.

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.

Tohver, M., Kann, A., That, R., Mihhalevski, A., & Hakman, J. (2005). Quality of triticale suitable for growing and bread making in northern conditions. *Food Chemistry, 89*, 125-132.

Ubbor, S. C., Ekeh, J. I., Agwo, O. E., Iguh, B. N., & Egwu, S. N. (2022). Physicochemical and sensory properties of cookies produced from composite flour of wheat, acha, and whole orange fleshed sweet potato. *Nigerian Agriculture Journal, 53*(1), 248-259.

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