Quality Attributes of Chinchin Produced with blends of flour from Cassava and Bambara Groundnut (*Vigna subterranea*)

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ABSTRACT

Food fortification has been shown to be an impactful approach in improving micro-nutrient and related functional characteristics of nutrients in some food vehicles. Some of the challenges staring at Nigeria as a nation in the face include postharvest losses, high importation cost of crops (e.g. wheat etc.) and malnutrition and this underscore the need to explore the possibilities of developing flour-based food products with functional ingredients from under-utilized indigenous food crops by processing cassava containing carotenoid and Bambara groundnut into composite flour with the view to producing functional food products thereby contributing to food and nutrition security via nutritious and healthy foods and as such addressing the sustainable development goal (SDG – 3) set by United Nation. This research was conducted to assess quality attributes of chinchin produced with blends of flour from cassava and Bambara groundnut.

Objective: Wheat flour is important base flour in the production of good number of baked food products. The short-fall in nutrient and bioavailability of wheat and food products from it, incidence of celiac disease and high importation cost of wheat to Nigeria necessitate prospecting flour from crops that are gluten-free, abundant and rich in nutritional composition for baking purpose.

Study Design

Low postharvest physiologically deteriorated cassava root (IITA-TMS-IBA011368) and Bambara nut were processed into flour and blended together. A total of eight (8) samples were generated as depicted by D-Optimal mixture using Design Expert software (Version 12.0).

Methodology

The composite flour and ingredient were mixed thoroughly; the stiff dough was rolled tightly to 1cm thickness on a board and cut into small cubes, fried in a deep hot vegetable oil until golden brown at 190 °C for 10 mins using deep fryer (Model: Moulimex). After frying, the chin-chin was allowed to cool, packed and sealed for subsequent analyses. The chinchin produced were analyzed for physical, proximate compositions, sensory and microbiological qualities. The pertinent data obtained were subjected to analysis of variance using Statistical Package for Social Science (SPSS) version 25.0 (SPSS Inc. USA) and significant means were separated using Duncan's Multiple Range Tests.

Result:

The physical (lightness, greenness, yellowness, overall acceptability) and proximate compositions (moisture, fat ash, crude fibre, crude protein and carbohydrate) ranged from (27.22 – 29.32, -2.71 – (-1.33), 6.26 – 8.09, 6.24 – 7.44) and (3.56 - 4.91%, 5. 21 - 8.14%, 0.69 - 2.16%, 0.85 - 2.67%, 5.87 - 9.15%, 76.50 - 81.70%), respectively. Sensory properties: appearance, color, texture, taste, crispiness, aroma and overall acceptability ranged from 5.92 – 7.00, 5.92 - 7.36, 5.72 – 6.88, 5.84 - 7.56, 5.84 - 6.80, 6.16 - 6.96 and 6.24 – 7.44, respectively. There were no growth of Coliforms, Salmonella and Shigella on all samples indicating the hygienic condition of processing and production.

Conclusion:

Acceptable and added value chinchin of comparable quality with that produced with wheat flour were produced with flour blends from cassava and Bambara groundnut. The optimum level for the composite flour is 56.25% HQCF and 43.75% BNF resulting in chin- chin of lower moisture and fat content.

Keywords: Crunchiness, sensory properties, proximate composition, nutritional properties, overall acceptability

1. INTRODUCTION

Exploring and prospecting flours from underutilized, abundant, low cost food crop rich in micro-nutrients for industrial application is very important. The high cost of wheat importation and incidence of celiac disease has necessitated the need for usage of alternative gluten-free flours that has complementary nutritional and food functional properties to substitute wheat flour thereby reducing the over dependence on wheat importation [1]. 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 [2]. There is an increasing interest in the use of HQCF (gluten-free) for food and industrial purpose especially in the baking industry in Nigeria [2, 3]. HQCF is can be derived from low postharvest physiologically deteriorated cassava known to have carotenoid content that can improve the immune response of human health [4].

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There is an undeniable fact that many African homes resort to Bambara groundnuts as their sole meal due to its significance as a highly nutritive food crop ranked next to cereals in caloric and protein content, an inexpensive food, and an essential leguminous food commodity after cowpea and groundnut [5]. Bambara is a potent nutraceuticals with anti-diabetic and anit-cancer activities which can be attributed to the content of vitamin C which is an anti-oxidant. It has high soluble carbohydrate [6] and good water absorption capacity [7] 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.

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High quality cassava flour from low postharvest physiological deteriorated cassava is a gluten-free flour that could be beneficial for celiac patients [8, 9]. Chin-chin is a fried snack popular in Nigeria and West Africa. It is sweet, hard, doughnut-like baked or fried dough of wheat flour. Chin-chin may also contain cowpeas. Many people bake it with ground nutmeg for desirable flavor. It is usually kneaded and cut into small squares of one square inch or to about a quarter of an inch thick before frying. Therefore, this research was conducted to assess the quality of chinchin produced with blends of flour from high quality cassava flour and Bambara groundnut.

2. MATERIALS AND METHODOLOGY

2.1 Materials

The low postharvest physiologically deteriorated cassava (IITA-TMS-IBA-011368) was obtained from International Institute of Tropical Agriculture (IITA) Ibadan and Bambara groundnut from a local farm at Mokwa, Niger state. Other ingredients are granulated sugar from Dangote Nigeria Plc., Lagos, Other materials used include baking powder, Simas margarine (PT Intiboga Sejahtera, Jakarta, Indonesia), nutmeg, eggs. The functional, pasting, physical and proximate properties of composite cassava-bambara flour is presented in Alimi et al. [10].

2.1.1 Processing of Cassava into High Quality Cassava Flour (HQCF)

Wholesome cassava roots used for this study were provided by IITA. The roots were processed into HQCF following the protocol described by Iwe et al. [11] and Alimi et al. [4]. The weight of cassava roots processed was 143.20 g, the weight after pulverization was 34.70 g, weight after flash-drying was 22.22 g, the weight after sieving was 21.92 g while the weight of the spent grain was 0.3 g.

2.1.2 Production of Bambara nut flour (BNF)

Wholesome Bambara groundnuts seeds were obtained from Mokwa, Niger State. The seeds were manually sorted to remove broken, insect-infested seeds and other foreign materials. The selected variety of Bambara groundnut (SAMNUT 21) were soaked for 24 h, and thereafter dried at 70 ^oC for 14 h to obtain moisture content of 12% and below. 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 soaking process was followed by sprouting for up to 72 hours [12] purposely to reduce the leaching of carbohydrate and lipid content of the sprouts [13], so as to enhance the protein content and amino acid profile. The malted nuts were allowed to drain properly, spread on the drying trays and was subsequently dried using parabolic shaped solar dryer (PSSD) at 60 ^oC dried for 24 hours. The dried Bambara nuts were packed, allowed to cool, milled into fine flour, sieved with 250-micron mesh and packaged in high density polyethylene bags for subsequent analyses.

2.1.3 Preparation of the flour blends

One hundred grams (100 g) of each of HQCF and BNF was prepared according to each formulation using D-Optimal mixture design with an outcome of eight experimental samples generated with Design Expert Software (Version 12.0) while wheat is the control sample.

2.2 Recipe and formulation for chinchin production

The recipe and formulation used for the production of the chinchin is presented in Table 2. The method described by Yepshak et al. [4] was adapted. One-quarter measure of the composite flour was pre-gelatinized. The composite flours, wheat, sugar, margarine, baking powder, eggs, and vanilla essence were thoroughly dry mixed together at appropriate rate in a large bowl to achieve homogenous mixing. The pre-gelatinized portion was admixed with the dried-mixed flour and was thoroughly mixed together to make fairly stiff dough. After mixing, the stiff dough was rolled tightly to 1cm thickness on a board and cut into small cubes. Cut dough was fried in a deep hot vegetable oil until golden brown at 190 °C for 10 mins using deep fryer (Model: Moulimex). After frying, the chin-chin was allowed to cool, packed and sealed for subsequent analyses.

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

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Table 2. Recipe and Formulation for the preparation of chin-chin

Sample /Run	Sugar (g)	Margarine (g)	Baking Powder (g)	Eggs (g)	Nutmeg (g)	Water (mls)
$HQCF_{62.50}BNF_{37.50}$	16.67	16.67	3.33	30	1	33.3
$HQCF_{50.00}BNF_{50.00}$	16.67	16.67	3.33	30	1	33.3
$HQCF_{50.00}BNF_{50.00}$	16.67	16.67	3.33	30	1	33.3

$HQCF_{62.50}BNF_{37.50}$	16.67	16.67	3.33	30	1	33.3
$HQCF_{68.75}BNF_{31.25}$	16.67	16.67	3.33	30	1	33.3
$HQCF_{56.25}BNF_{43.75}$	16.67	16.67	3.33	30	1	33.3
$HQCF_{75.00}BNF_{25.00}$	16.67	16.67	3.33	30	1	33.3
$HQCF_{75.00}BNF_{25.00}$	16.67	16.67	3.33	30	1	33.3
Control (Wheat)	16.67	16.67	3.33	30	1	33.3

HQCF: High Quality Cassava Flour; BNF: Bambara Nut Flour

2.3 Colour attributes of the chinchin

A colour measurement was performed using Minolta colourimeter. The colour of the chinchin was expressed as the average of three L^*, and b^* readings, where L^* stands for brightness, + a^* redness, - a^* greenness, +b^* yellowness, - b^* blueness [14].

2.3.1 Determination of proximate composition of chinchin

The moisture, protein, fat, ash, fibre and total carbohydrate contents of the chinchin made with the flour blends were determined following standard analytical procedure of AOAC [15].

2.4 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. 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.

Table 3. 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
Greenness	Minimum
Moisture content (%)	Minimize
Fat content (%)	Minimize
Ash content (%)	Maximize
Fibre content (%)	Maximize
Protein content (%)	Maximize
Carbohydrate content (%)	Maximize
Overall Acceptability	Maximize

2.5 Sensory Evaluation

The method described by Iwe, [16] was adapted. The sensory panel consisted of twenty-five trained panelists and regular consumers of chin-chin who were asked to score the chin-chin using a 9-point hedonic scale based on their degree of likeness where 1= like extremely; 5= neither like nor dislike; 9= dislike extremely. Chin-chin attributes evaluated were: appearance, color, texture, taste, crispiness, aroma and overall acceptability

2.6 Microbiological assay

The microbiological qualities of the chin-chin (bacteria and fungi counts) were determined using the pour-plate procedure as described by ICMSF [17]. One gram from each ground sample was weighed into 9 ml of 0.1% (w/v) peptone water in a beaker and allowed to stand for 5 min with occasional stirring using a sterile glass rod. Aliquots (1 ml) of serial dilutions of 10^{-6} were aseptically inoculated on Nutrient Agar. This was employed for the analysis of the total viable bacteria count. The determination of mould counts was enumerated using Potatoes Dextrose Agar supplemented with 0.01% chlorophenicol. Dilutions of 10^{-6} were incubated at 37 ^{o}C for 24 h (total viable bacteria count) and 30 ^{o}C for 4 days (mould count). The colonies were counted and expressed as colonies forming unit per gram (cfu/g).

2.7 Statistical analysis

The pertinent data (sensory, physical, nutritional, and microbiological) obtained were subjected to analysis of variance (ANOVA) using Statistical Package for Social Science (SPSS) version 25.0 (SPSS Inc. USA) and significant means were separated using Duncan's Multiple Range Tests (DMRTs). 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 Colour and overall acceptability of chin-chin produced with blends of flour from high quality cassava flour and Bambara nut composite flour

The colour properties and overall acceptability of the chinchin are presented in Table 4. There was no significant ($p>0.05$) difference in all lightness parameter on the chinchin. Table 5 presents the results of data obtained using multiple quadratic regression. 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 3 was seen to be 0.18, these values are quite low for response surfaces and indicated that the fitted quadratic models accounted for 18% of the 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 Figure 1. Lightness decreased as Bambara flour inclusion increased while as HQCF increased, lightness increased. The decrease in the lightness of the chinchin could be due to Maillard reaction involving amino groups and carbonyl groups, which leads to dark browning of the chinchin. This observation of brownness in the color of food products as a result of Maillard reaction involving amino groups and carbonyl groups in the presence of heat had been reported by several investigators [18, 19, 20].

The crust greenness (-a*) varied between -2.71 and -1.33, with sample $HQCF_{50.00}BNF_{50.00}$ having the lowest while sample $HQCF_{75.00}BNF_{25.00}$ had the highest. There was a significant ($p<0.05$) difference between the chin-chin samples as seen in Table 4. The main effect of high-quality cassava flour and Bambara nut flour was significant ($p<0.05$) on greenness (-a*) respectively. However, the interactive of high-quality cassava flour and Bambara nut flour had no significant ($p>0.05$) effect on greenness.

Table 4. Colour and overall acceptability of the chin-chin

Sample	Lightness (L*)	Greenness (a*)	Yellowness (b*)	Overall acceptability
$HQCF_{62.50}BNF_{37.50}$	27.56± 0.47^{a}	-2.22±0.36^{ab}	6.83±0.55^{a}	7.44±0.22^{b}
$HQCF_{50.00}BNF_{50.00}$	27.22±0.18^{a}	-2.71±0.27^{a}	6.26±0.29^{a}	6.76±0.25^{ab}
$HQCF_{50.00}BNF_{50.00}$	27.84±0.48^{a}	-2.01±0.33^{ab}	6.92±0.39^{a}	6.56±0.25^{ab}

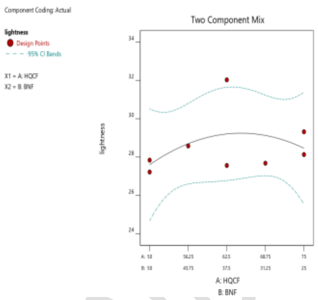
HQCF$_{62.50}$BNF$_{37.50}$	32.03± 4.68^{a}	-1.72±0.91^{ab}	7.83±1.47^{a}	6.96±0.39^{a}
HQCF$_{68.75}$BNF$_{31.25}$	27.68±0.36^{a}	-2.43±0.13^{ab}	6.60±0.15^{a}	6.68±0.27^{ab}
HQCF$_{56.25}$BNF$_{43.75}$	28.58±0.22^{a}	-1.41±0.18^{ab}	7.54±0.17^{a}	6.24±0.35^{a}
HQCF$_{75.00}$BNF$_{25.00}$	28.13±0.70^{a}	-2.02±0.25^{ab}	7.04±0.20^{a}	6.32±0.39^{a}
HQCF$_{75.00}$BNF$_{25.00}$	29.32±0.59^{a}	-1.33±0.33^{b}	8.09±0.45^{a}	6.56±0.33^{ab}

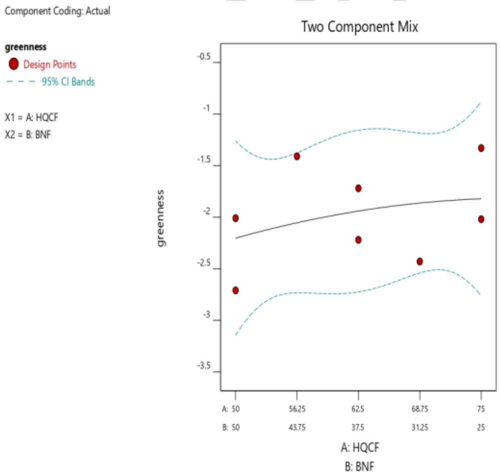
Values are mean of duplicates ± standard deviation. Mean values with different superscripts within the same column are significantly different at 5% level.

HQCF=High Quality Cassava Flour, BNF=Bambara Nut Flour

Table 5. Regression coefficient for colour and overall acceptability of the chin-chin

Parameter	Lightness	Greenness	Yellowness	Overall acceptability
A -High-quality cassava flour	28.46*	-1.82*	7.39*	6.46*
B- Bambara nut flour	27.60*	-2.20*	6.73*	6.55*
AB	4.71	0.29	0.70	1.69
R^2	0.18	0.11	0.19	0.29
F-value	0.55	0.30	0.60	1.03
p-value	0.61	0.75	0.58	042





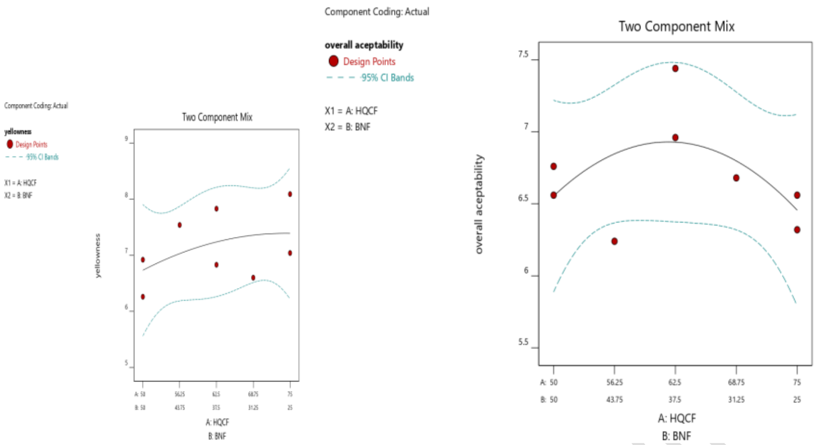


Fig.1. Model graph depicting the trend of lightness, greenness, yellowness and overall acceptability content (%) of chinchin as influenced by HQCF and BNF at different blending ratio
HQCF: High quality cassava flour; BNF: Bambara nut flour; cho: Carbohydrate

Regression coefficient parameter showed that the quadratic model developed for greenness had a coefficient of determination (R^2) of 0.11 indicating 11% predictive accuracy and F-value of 0.30. The model graph depicting the trend of greenness as influenced by the flour blends is shown in Figure 1, an increase was observed in greenness value as high-quality cassava flour increased, meanwhile reverse is the case when BNF inclusion increased. It was observed that the interaction of BNF and HQCF had a negative effect on greenness.

The crust yellowness (b*) of the chinchin ranged from 6.26 to 8.09, with sample $HQCF_{75.00}BNF_{25.00}$ having the highest while sample $HQCF_{50.00}BNF_{50.00}$ had the lowest. There was a significant ($p<0.05$) difference between the chinchin as indicated in Table 4. Presented in Table 5 is the results of data obtained using multiple quadratic regression. The main effect of HQCF and BNF had a significant ($p<0.05$) effect on yellowness, respectively. Similarly, the interactive effect of the flour sample 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 0.19 indicating 19% predictive accuracy, and F-value of 0.60. The model graph depicting the trend of yellowness as influenced by HQCF and BNF at different blending ratio changed as shown in Figure1. An increased yellowness was observed in the chinchin as content of HQCF increased, but decrease was observed as BNF increased. It was observed that the interaction of HQCF and BNF had a positive effect on the yellowness value of the chinchin, this could be attributed to the fact that the color of the constituent flours (raw materials) to a reasonable extent influence the resulting color of the final products. This fact was observed in the previous study by Alimi et al. [18] when wheat flour was substituted by cowpea flour at 5-20% for bread production. However, the differences in the colour properties (lightness, redness and yellowness) of chinchin can be related to the biological nature (genetic make-up) of the raw materials before they were processed into flour, chemical reactions during cooking, residence time and temperature during frying. These factors were also noted by Sue et al. [21] and Omaima et al. [22].

The mean value for overall acceptability ranged from 6.24 to 7.44, $HQCF_{56.25}BNF_{43.75}$ having the lowest while $HQCF_{62.50}BNF_{37.50}$ had the highest Table 4. There was a significant ($p<0.05$) difference in the overall acceptability of the chin-chin. Table 5 presents the results of data obtained using multiple quadratic regression. The main effect of HQCF and BNF was significant ($p<0.05$) on the overall acceptability, respectively. The interactive effect of HQCF and BNF 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 0.39 indicating a 39% predictive accuracy and F-value of 1.03. The model graph depicting the trend of overall acceptability as influenced by HQCF and BNF as blending ratio changed is shown in Figure 1. This depicts an increase as BNF inclusion increased while the additions of HQCF result into a decrease in overall acceptability. The aforementioned observation could be adduced as one of the reasons for the acceptance of the chinchin by the panelists.

3.3 Proximate composition of the chin-chin produced with blends of flour from HQCF and BNF

The proximate compositions of the chinchin produced from different combinations of HQCF and BNF is presented in Table 6. The moisture content ranged from 3.56 to 4.77 %, with chin-chin sample $HQCF_{56.25}BNF_{43.75}$ having the least while $HQCF_{75.00}BNF_{25.00}$ had the highest moisture content. There was a significant ($p<0.05$) difference in all moisture content of the chinchin. The results obtained using multiple quadratic regression is presented in Table 7. The main effect of HQCF and BNF was significant ($p<0.05$) on moisture content. The interactive effect of flour blends had no 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 0.63 indicating 63% predictive accuracy and F-value of 4.17. The model graph depicting the trend of moisture content as influenced by HQCF and BNF at different ratios is shown in Figure 2. It was observed that as BNF increased, the moisture content decreased. But increase in the inclusion of HQCF increased the moisture content of the chinchin. The values were within the range reported to have no adverse effect on quality attribute of the product [23]. The lower the moisture content of a product to be stored, the better the shelf stability of such product [10, 24]. The low moisture content could reduce the growth of microorganisms thereby increasing the shelf life of the product.

The fat content of the chinchin ranged from 5.21 to 8.14 as seen in Table 6. There was a significant ($p<0.05$) difference between the chinchin with respect to fat content. The results of data obtained using multiple quadratic regression is presented in Table 7. The main effect of HQCF as well BNF has a significant ($p<0.05$) on fat content respectively. However, the interactive effect of the blends shows no significant ($p>0.05$) effect on fat content. Regression coefficient parameter showed that the quadratic model developed for fat content had a coefficient of determination (R^2) of 0.09 indicating a 9% predictive accuracy and F-value of 0.79. Fat is important in human diets as it provides essential fatty acids and facilitates the absorption of fat-soluble vitamins [25]. The increase in the fat content could be due to the additive effect of the residual fat content in the BNF. The relative increase in fat content of chinchin observed in this study is similar to what observed by Rani et al. [26] when defatted peanut flour was applied in the production of flour-based cookie. The range (5.21-8.14%) recorded for fat content in this study is lower than (11.67-17.34%) reported by Rani et al. [26]. This relatively high fat content recorded in this study could also be attributed to absorption of oil by the samples during frying as well as the difference in the recipes as noted by Alimi et al. [10] and Bongjo et al. [27].

The total ash content varied between from 0.69 and 2.16 %, with $HQCF_{50.00}BNF_{50.00}$ having the least while chinchin sample $HQCF_{75.00}BNF_{25.00}$ had the highest. There was a significant ($p<0.05$) difference between the chinchin. The results of data obtained using multiple quadratic regression is presented in Table 7. The main effect of HQCF and BNF was significant ($p<0.05$) on total ash content. The interactive effect (AB) of HQCF and BNF blends had a 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 0.86 indicating 86% predictive accuracy and F-value of 16.01. The model graph depicting the trend of ash content as influenced by the flour blends at different blending ratio is shown in Figure 2. At increasing inclusion of HQCF, ash content was observed to increase. Ash content of the chin-chin were relatively high, indicating that the chin-chin were likely to be good sources of mineral elements. The range of mean value for ash (0.69-2.16%) contents of the chin-chin samples obtained in this study was relatively higher than (1.16±0.00) reported for chin-chin made from 100% wheat flour by Falola et al. [28].

The fibre content varied between 0.85 and 2.67%, with chinchin sample $HQCF_{62.50}BNF_{37.50}$ having the least while $HQCF_{75.00}BNF_{25.00}$ had the highest. There was a significant ($p<0.05$) difference in the fibre contents of the chinchin samples as indicated in Table 6. The main effect of HQCF and BNF was significant ($p<0.05$) on the fibre content, respectively. Also, the interactive effect of HQCF and BNF had a negative 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 0.95 indicating a 95% predictive accuracy and F -value of 46.32. The model graph depicting the trend of the fibre content as influenced by the flour blends at different blending ratios is shown in Figure 2. However, lower value obtained for fibre content in the chinchin could be due to relatively low fibre content of one of the constituent flour (HQCF) used in the production of the chinchin.

The protein content ranged from 5.87 to 9.15 %, with chinchin sample $HQCF_{68.75}BNF_{31.25}$ having the least while $HQCF_{50.00}BNF_{50.00}$ had the highest. There was a significant ($p<0.05$) difference with respect to the protein contents of the chinchin. The results of data obtained using multiple quadratic regression is presented in Table 7. The main effect of HQCF and BNF 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 4.25. The model graph depicting the trend of protein content as influenced by HQCF and BNF at different blending ratio change is shown in Figure 2. A decrease in protein content was observed as the content of HQCF increased in the blend, but at increasing content of BNF, the protein content increased. Protein is an amino source that contains elements Carbon (C), Hydrogen (H), Oxygen (O) and Nitrogen (N). The main function of proteins is to form new tissue and maintain existing tissue. Protein also functions as a regulator of the body's metabolic processes [29]. The range (5.87-9.15%) of mean value for protein content in this study was is relatively higher than range (5.32-7.94%) reported by Ramakrishna et al. [30] for wheat-soursop flour chinchin, indicative of the fact that the chinchin produced are very rich in protein.

The carbohydrate content of the chinchin is presented in Table 6. The values ranged from 76.50 to 81.70. There was a significant ($p<0.05$) difference in the protein content of the chinchin. The results of data obtained using multiple quadratic regression is presented in Table 7. The main effect of HQCF as well BNF has a significant ($p<0.05$) on carbohydrate content, respectively.

However, the interactive effect of the blends shows 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 0.41 indicating a 41 % predictive accuracy and F-value of 1.70. A decrease in the content of carbohydrate was observed in the chinchin as BNF inclusion increased whereas inclusion of HQCF raised the level of the carbohydrate content (Figure 3). This trend of reduced carbohydrate content when flour from a high carbohydrate food material is blended or substituted with flour from a crop with relatively high protein content as observed in this study is similar to the observation noted by other investigators and this could be attributed to dilution effect in the resulting composite flour. The range of mean value for carbohydrate contents of chinchin that were produced from wheat-walnut and wheat-tiger nut flour are (55.14-42.94%) and (62.76-52.95%), respectively were lower than range (76.50-81.70%) recorded in this study. The relatively high carbohydrate content of chinchin produced with flour blends from HQCF and BNF is beneficial nutritionally in replenishing energy after rigorous physical and physiological activities.

3.4 Optimum level of constraint for the optimization of ingredient combination of chinchin

The conditions of the optimization process that would give a desirable processing condition using the constraints set is presented in Table 8. Lightness and yellowness were maximized, greenness was minimize, while moisture and fat content (%) were minimize. Also, crude protein, fibre, and carbohydrate (%) were all maximize. The optimized ingredient blend formulation obtained was $HQCF_{56.25}BNF_{43.75}$ while the calculated desirability was 0.50.

Table 6. Proximate compositions of the chinchin produced with blends of flour from HQCF and BNF

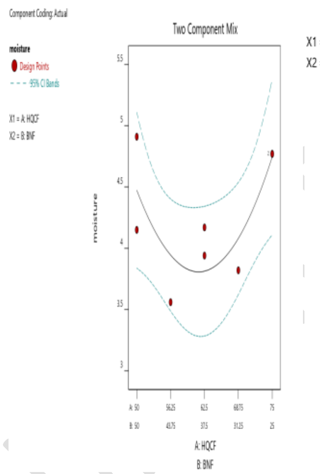
Sample	Moisture (%)	Fat (%)	Ash (%)	Crude fibre (%)	Crude protein (%)	Carbohydrate (%)
$HQCF_{62.50}BNF_{37.50}$	3.94±0.09[b]	7.41±0.01[d]	1.58±0.01[c]	0.85±0.18[a]	5.90±0.05[a]	80.30±0.73[c]
$HQCF_{50.00}BNF_{50.00}$	4.91±0.46[c]	6.04±0.03[c]	0.99±0.01[b]	2.34±0.10[d]	9.15±0.22[f]	76.50±0.61[a]
$HQCF_{50.00}BNF_{50.00}$	4.15±0.11[b]	8.01±0.01[f]	0.69±0.02[a]	2.24±0.20[d]	7.78±0.11[d]	77.10±0.19[b]
$HQCF_{62.50}BNF_{37.50}$	4.17±0.34[b]	8.14±0.01[g]	1.98±0.01[e]	1.36±0.03[c]	7.88±0.09[e]	76.50±0.31[d]
$HQCF_{68.75}BNF_{31.25}$	3.82±0.07[ab]	5.87±0.01[b]	1.75±0.02[d]	1.31±0.04[bc]	5.87±0.23[a]	81.40±0.10[d]
$HQCF_{56.25}BNF_{43.75}$	3.56±0.00[a]	5. 21±0.01[a]	1.66±0.01[d]	1.17±0.04[b]	6.72±0.12[c]	81.70±0.17[d]
$HQCF_{75.00}BNF_{25.00}$	4.77±0.00[c]	7.64±0.01[e]	2.16±0.01[f]	2.67±0.06[e]	6.27±0.15[b]	76.50±0.10[a]
$HQCF_{75.00}BNF_{25.00}$	4.77±0.00[c]	7.64±0.01[e]	2.16±0.01[f]	2.67±0.06[e]	6.27±0.15[b]	76.50±0.10[a]

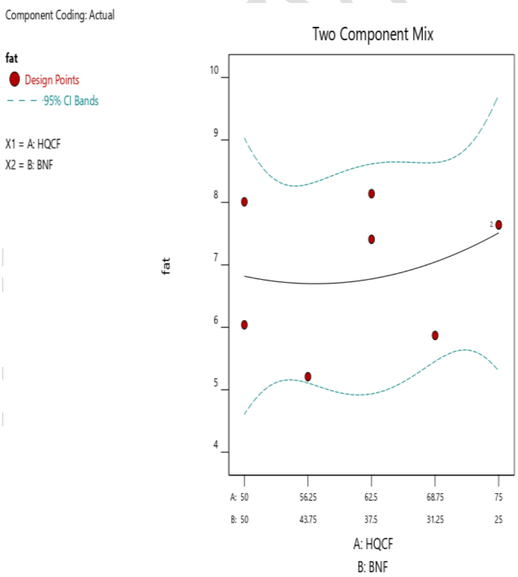
Values are mean of duplicates ± standard deviation. Mean values with different superscripts within the same column are significantly different at 5% level;

HQCF: High Quality cassava Flour: BNF: Bambara Nut Flour,

Table 7. Regression coefficient for proximate composition of chinchin produced with flour blends from high quality cassava flour and Bambara nut flour

Parameters	Moisture content (%)	Fat content (%)	Ash content (%)	Fibre content (%)	Protein content (%)	Carbohydrate content (%)
A: High quality cassava flour	4.75*	7.51*	2.10*	2.65*	6.24*	76.76*
B: Bambara nut flour	4.47*	6.82*	0.93*	2.88*	8.38*	77.10*
AB	-3.19	-1.56	1.11*	-5.83*	-3.03	12.63
R^2	0.63	0.09	0.86	0.95	0.63	0.41
F-value	4.17	0.25	16.01	46.32	4.25	1.70
P-value	0.09	0.79	0.01	0.00	0.08	0.27





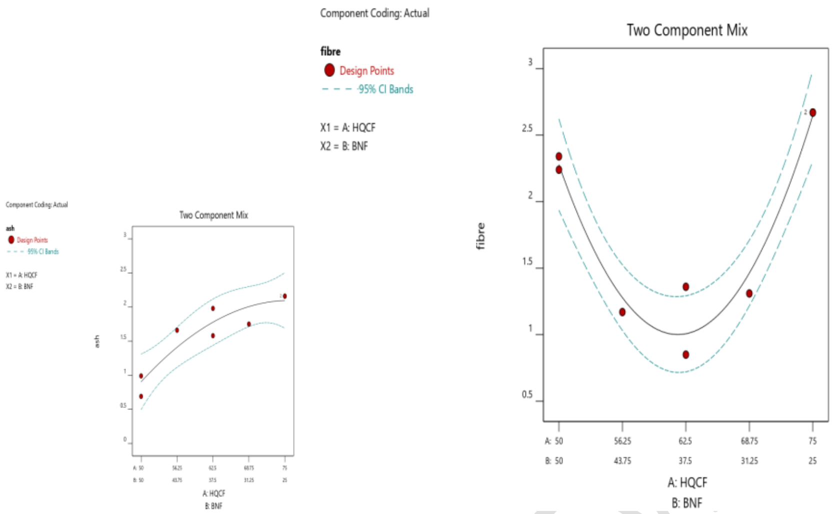


Fig. 2. Model graph depicting the trend of moisture, fat, ash and crude fibre content (%) of chinchin as influenced by High quality cassava flour and Bambara nut flour at different blending ratio

HQCF: High quality cassava flour; BNF: Bambara nut flour; cho: Carbohydrate

3.5 Sensory properties of the chinchin

The mean sensory scores for the chinchin samples (appearance, colour, texture (crispiness), aroma, taste and overall acceptability) are presented in Table 9. The score (5.92 ± 0.35 to 7.00 ± 0.22) for appearance of the chinchin sample. This result revealed that chinchin sample $HQCF_{62.50}BNF_{37.50}$ was neither like nor dislike while sample $HQCF_{68.75}BNF_{31.25}$ was like moderately and there was significant ($p<0.05$) difference in their values. The range of mean score for colour attributes of the chinchin samples was (5.92 ± 0.37 to 7.36±0.19). This shows that the control sample was neither like nor dislike while sample $HQCF_{62.50}BNF_{37.50}$ was moderately liked and there was a significant ($p<0.05$) difference in their mean values. The range of mean score for texture (crispiness) of the chinchin samples was (5.72±0.72 to 6.88±0.28). This revealed that both samples $HQCF_{56.25}BNF_{43.75}$ and $HQCF_{62.50}BNF_{37.50}$ were neither like nor dislike while sample $HQCF_{62.50}BNF_{37.50}$ was liked slightly and there was a significant ($p<0.05$) difference in their values.

The range of mean sensory score for taste of the chinchin is (5.96 ±0.37 to 7.56 ±0.40). There was significant ($p<0.05$) difference in their mean values, with chinchin sample $HQCF_{56.25}BNF_{43.75}$ reflecting neither like nor dislike while sample $HQCF_{62.50}BNF_{37.50}$ was moderately liked as indicated in Table 9. Crispness had its mean sensory score to be (5.84 ±0.38 to 6.56±0.38) for the chinchin samples, respectively. There was no significant (p>0.05) difference in mean values $HQCF_{62.50}BNF_{37.50}$ reflecting neither like nor dislike while sample with $HQCF_{50.00}BNF_{50.00}$, was slightly liked. Furthermore, aroma had its sensory mean value to be (6.16 ± 0.42 and 6.96 ± 0.29) for the chinchin samples. There was no significant (p>0.05) difference in their mean values with $HQCF_{75.00}BNF_{25.00}$ and $HQCF_{62.50}BNF_{37.50}$ being liked slightly as adjudged by the panelists.

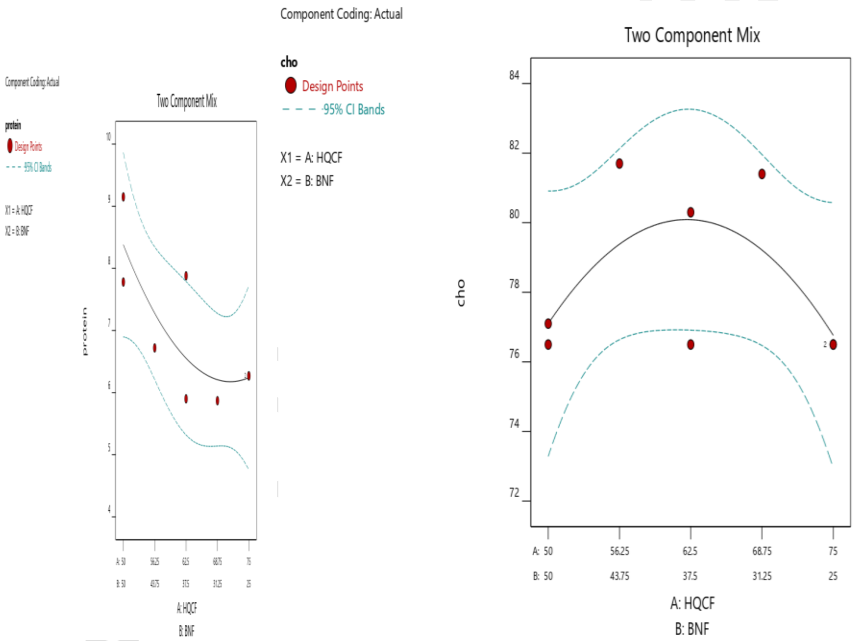


Fig. 3. Model graph depicting the trend of crude protein and carbohydrate content (%) of chinchin as influenced by High quality cassava flour and Bambara nut flour at different blending ratio

HQCF: High quality cassava flour; BNF: Bambara nut flour; cho: Carbohydrate

Table 8. Optimum level of constraint for the optimization of ingredient combination of chinchin

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	3.56	4.91	1	1	3
Ash	maximize	0.69	2.16	1	1	3
Fibre	maximize	0.85	2.67	1	1	3
Fat	minimize	5.21	8.14	1	1	3
Protein	maximize	5.87	9.15	1	1	3
Carbohydrate	maximize	76.5	81.7	1	1	3
Lightness	maximize	27.22	32.03	1	1	3
Greenness	minimize	-2.71	-1.33	1	1	3
Yellowness	maximize	6.26	8.09	1	1	3
Overall Acceptability	maximize	6.24	7.44	1	1	3

All the chinchin samples were generally accepted. The chinchin sample $HQCF_{56.25}BNF_{43.75}$ was slightly liked while sample $HQCF_{62.50}BNF_{37.50}$ was moderately liked. Generally, there was significant ($p<0.05$) difference in the overall acceptance of all the chinchin samples. From this study, it is evident that panelists are ready for a change in chinchin with respect to all the sensory attributes from the usual taste of chinichin prepared with wheat flour as indicated in their preference for chinchin made with composite flours.

Blending HQCF and BNF could improve the aroma profile of the chinchin. However, the addition of other flours could complement the aroma, thereby enhancing the overall taste and making the chinchin more enjoyable [31] (Liem and Russell, 2019). However, incorporating HQCF and Bambara nut flour can improve the smoothness, creaminess, or other desirable mouthfeel attributes, making the snacks more enjoyable to eat [32] (Sharanagat et al., 2022). The combined effect of improved appearance, texture, taste, aroma, and mouthfeel leads to a more satisfying and enjoyable snacking experience, resulting in higher overall acceptability ratings.

3.4 Microbiological qualities of the chinchin

The result revealed that only the chinchin sample prepared with wheat flour had the highest bacteria occurrence of eight (8) while chinchin samples $HQCF_{62.50}BNF_{37.50}$, $HQCF_{56.25}BNF_{43.75}$, $HQCF_{62.50}BNF_{37.50}$ and $HQCF_{75.00}BNF_{25.00}$ had no evident bacteria growth. Overall, there were no growth of Coliforms, Salmonella and Shigella on all samples indicating the hygienic condition of processing and production.

Table 9. Sensory properties of the chin-chin

Sample	Appearance	Colour	Texture	Taste	Crispness	Aroma	Overall acceptability
$HQCF_{62.50}BNF_{37.50}$	6.92 ± 0.30^{ab}	7.36 ± 0.19^{d}	6.88 ± 0.28^{a}	7.52 ± 0.25^{b}	6.80 ± 0.24^{a}	6.96 ± 0.29^{a}	7.44 ± 0.22^{b}
$HQCF_{50.00}BNF_{50.00}$	6.72 ± 0.29^{ab}	7.04 ± 0.21^{d}	6.32 ± 0.32^{ab}	5.84 ± 0.34^{a}	5.92 ± 0.35^{a}	6.28 ± 0.32^{a}	6.76 ± 0.25^{ab}
$HQCF_{50.00}BNF_{50.00}$	6.88 ± 0.25^{ab}	7.24 ± 0.18^{d}	6.36 ± 0.32^{ab}	5.92 ± 0.29^{a}	6.56 ± 0.31^{a}	6.24 ± 0.28^{a}	6.56 ± 0.25^{ab}
$HQCF_{62.50}BNF_{37.50}$	5.92 ± 0.35^{a}	6.00 ± 0.34^{abc}	5.84 ± 0.42^{ab}	7.56 ± 0.41^{a}	5.84 ± 0.38^{a}	6.86 ± 0.35^{a}	6.96 ± 0.39^{a}
$HQCF_{68.75}BNF_{31.25}$	7.00 ± 0.22^{b}	6.88 ± 0.29^{cd}	6.52 ± 0.25^{ab}	6.36 ± 0.27^{a}	6.48 ± 0.27^{a}	6.52 ± 0.22^{a}	6.68 ± 0.27^{ab}
$HQCF_{56.25}BNF_{43.75}$	6.04 ± 0.38^{ab}	5.96 ± 0.37^{ab}	5.72 ± 0.30^{a}	5.96 ± 0.37^{a}	5.88 ± 0.33^{a}	6.20 ± 0.32^{a}	6.24 ± 0.35^{a}
$HQCF_{75.00}BNF_{25.00}$	6.88 ± 0.34^{ab}	6.84 ± 0.26^{d}	6.04 ± 0.39^{ab}	6.00 ± 0.38^{a}	6.24 ± 036^{a}	6.28 ± 0.32^{a}	6.32 ± 0.39^{a}
$HQCF_{75.00}BNF_{25.00}$	6.64 ± 0.30^{ab}	6.64 ± 0.33^{abcd}	6.20 ± 0.37^{ab}	6.00 ± 0.42^{a}	6.04 ± 0.47^{a}	6.16 ± 0.42^{a}	6.56 ± 0.33^{ab}
Control	5.96 ± 0.38^{a}	5.92 ± 0.37^{a}	6.28 ± 0.34^{ab}	6.32 ± 0.34^{a}	6.08 ± 0.35^{a}	6.24 ± 0.31^{a}	6.40 ± 0.39^{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 10. Microbiological qualities of chinchin

Sample	NA (TBC) cfu/g			EMB (TECC) cfu/g			SSA (TSSCC) cfu/g			PDA (TFC) cfu/g		
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
$HQCF_{62.50}BNF_{37.50}$	0	0	0	0	0	0	0	0	0	5	5	4
$HQCF_{50.00}BNF_{50.00}$	2	1	1	0	0	0	0	0	0	4	4	4
$HQCF_{50.00}BNF_{50.00}$	2	1	1	0	0	0	0	0	0	4	4	4
$HQCF_{62.50}BNF_{37.50}$	0	0	1	0	0	0	0	0	0	3	2	7
$HQCF_{68.75}BNF_{31.25}$	1	0	0	0	0	0	0	0	0	2	2	2
$HQCF_{56.25}BNF_{43.75}$	0	0	0	0	0	0	0	0	0	4	4	4
$HQCF_{75.00}BNF_{25.00}$	0	1	0	0	0	0	0	0	0	3	5	7
$HQCF_{75.00}BNF_{25.00}$	0	0	0	0	0	0	0	0	0	3	1	2
Control (wheat)	1	0	0	0	0	0	0	0	0	8	8	6

NA (TBC): Nutrient Agar (Total Bacterial Count); EMB (TECC): Eosin Methylene Blue agar (Total Escherichia coli colony count) SSA (TSSCC): Salmonella Shigella Agara (Total Salmonella Shigella colony count); PDA (TFC): Potato Dextrose Agar (Total fungal count)

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 samples irrespective of the formulations used in production.

CONCLUSION

Acceptable and added value chinchin of comparable quality with that produced with wheat flour were successfully developed with blends of flour from cassava and Bambara groundnut. The optimum level for the composite flour is 56.25% high quality cassava and 43.75% Bambara nut flour resulting in chin- chin of lower moisture and fat content.

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