Quality Attributes of Chinchin Produced with Blends of Flour from Cassava (*Manihot esculenta*) and Bambara Groundnut (*Vigna subterranea*)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors LOS, JPA and SOO conceptualized and designed the research work. Authors JPA, MOJ, TAF, MBA, TAI and AAA executed field/lab experiments and collected the data. Authors JPA and AAA monitored the work. The results have been interpreted collectively by authors JPA, TAI and AAA contributed to the final draft of the manuscript. Authors JPA and AAA supervised the study. All authors read and approved the final manuscript.

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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) three 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: The short-fall in nutrient and bioavailability of wheat, 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).

Location and Duration of Study: This work was carried out in Ilorin, Kwara State, Nigeria for six (6) months.

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.

Results: 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 chinchin produced with the flour blends were acceptable by the sensory panels, but the optimum level for the composite flour is 56.25% HQCF and 43.75% BNF resulting in chinchin of lower moisture and fat content.

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 replace or substitute

wheat flour thereby reducing the over dependence on wheat importation [1,2]. It is important to note that there is no pharmaceutical treatment or cure for celiac disease but the remedial management measure is simply 100% gluten-free diets. 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 can be derived from low postharvest physiologically deteriorated cassava known to have carotenoid content that can improve the immune response of human health [4].

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 [5-7]. Bambara groundnut is a potent nutraceuticals with anti-diabetic and anti-cancer activities which can be attributed to its vitamin C content which is a potent water-soluble anti-oxidant in humans. It has high soluble carbohydrate [8] and good water absorption capacity [9] that correspond to increased finished product baking quality (loaf volume). Coupled with the oil absorption capacity that enhances flavor retention. Flour from Bambara groundnut is suitable for the development of ready-to-eat food products such as bread, biscuits, cookies, sausage, chinchin etc.

High quality cassava flour from low postharvest physiologically deteriorated cassava is a gluten-free flour that could be beneficial for celiac patients [10,11]. 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. [12].

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. [13] 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 °C for 14 h to obtain moisture content of 12% and below. The soaking water was decanted at 6 h interval to facilitate dehulling, to reduce 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 [14] purposely to reduce the leaching of carbohydrate and lipid content of the sprouts [15], 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 °C for 24 hours. The dried Bambara nuts were packed from the drying trays and 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 (Table 1).

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 Alimi 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
Control (WF$_{100}$)		

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 (WF$_{100}$)	16.67	16.67	3.33	30	1	33.3

HQCF: High Quality Cassava Flour; BNF: Bambara Nut Flour; WF: Wheat flour

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

2.3 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 [16].

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 [17].

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.

2.5 Sensory Evaluation

The method described by Iwe, [18] 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 Alimi et al. [19]. 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°C for 24 h (total viable bacteria count) and 30°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 significant 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 ($P = .05$) difference in the 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 nut flour significantly ($P = .05$) affect lightness, respectively. The interactive effect of high quality cassava flour and Bambara nut flour had no significant ($P = .05$) 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 nut flour at the blending ratio is shown in Fig. 1. Lightness decreased as Bambara nut flour inclusion increased while

increased HQCF content resulted in increased lightness. 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 [20,21,22].

The crust greenness (-a*) varied between -2.71 and -1.33, with chinchin 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 = .05) difference between the chin-chin samples as indicated in Table 4. The main effect of high-quality cassava flour and Bambara nut flour was significant (P = .05) on greenness (-a*) respectively. However, the interactive effect of high-quality cassava flour and Bambara nut flour had no significant (P = .05) effect on greenness.

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 Fig. 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 between 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 = .05) difference between the chinchin as indicated in Table 4. The result of data obtained using multiple quadratic regression is presented in Table 5. The main effect of HQCF and BNF had a significant (P = .05) effect on yellowness, respectively. Similarly, the interactive effect of the flour sample had no significant (P = .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 Fig. 1. An increased yellowness was observed in the chinchin as content of HQCF in the blend increased, but decrease was observed as BNF increased. It was observed that the interaction between 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 colour of the final products. This fact was observed in the previous study by Alimi et al. [20] 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 equally noted by Sue et al. [23] and Omaima et al. [24].

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

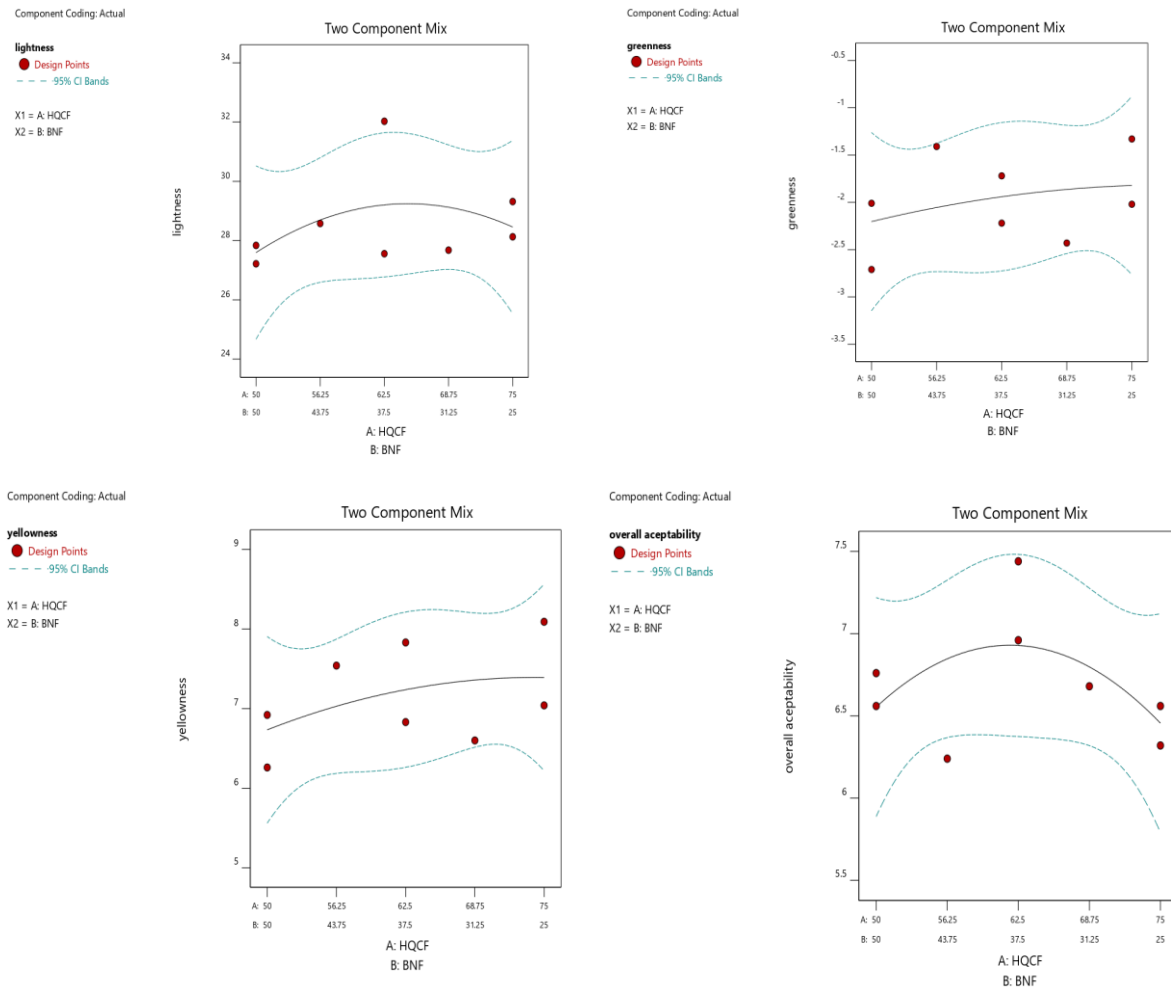| Parameter	Lightness	Greenness	Yellowness	Overall acceptability
A -High-quality cassava flour	28.46[*]	-1.82[*]	7.39[*]	6.46[*]
B- Bambara nut flour	27.60[*]	-2.20[*]	6.73[*]	6.55[*]
AB	4.71	0.29	0.70	1.69
R^2	0.18	0.11	0.19	0.29
F-value	0.55	0.30	0.60	1.03
p-value	0.61	0.75	0.58	042

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

The mean value for overall acceptability ranged from 6.24 to 7.44, with chinchin sample $HQCF_{56.25}BNF_{43.75}$ having the lowest while $HQCF_{62.50}BNF_{37.50}$ had the highest (Table 4). There was a significant (P = .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 = .05) on the overall acceptability, respectively. The interactive effect of HQCF and BNF had no significant (P = .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 Fig. 1. This correspond to 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 sensory panels.

3.2 Proximate Composition of the Chinchin Produced with Blends of Flour from HQCF and BNF

The proximate compositions of the chinchin produced from different combinations of HQCF and BNF are presented in Table 6. The moisture content ranged from 3.56 to 4.77%, with chinchin 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 = .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 = .05) on moisture content. The interactive effect of the flour blends had no significant (P = .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 Fig. 2. It was observed that as BNF increased in the blend, the moisture content decreased; but increase in the inclusion of HQCF resulted into increased moisture content of the chinchin. The values recorded for moisture content in this study were within the range reported to have no adverse effect on quality attribute of the product [25]. The lower the moisture content of a product to be stored, the better the shelf stability of such product [12,26]. 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 = .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 = .05) on the fat content. However, the interactive effect of the blends showed no significant (P = .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 [27]. The increase in the fat content could be due to the additive effect of the residual fat content in the BNF and HQCF. The relative increase in fat content of chinchin observed in this study is similar to what observed by Rani et al. [28] 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. [28]. 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 (flour blending ratio) as noted by Alimi et al. [12] and Bongjo et al. [29].

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 = .05) difference between the chinchin with respect to ash contents. The results obtained using multiple quadratic regression is presented in Table 7. The main effect of HQCF and BNF was significant (P = .05) on total ash content. The interactive effect (AB) of HQCF and BNF blends had a significant (P = .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 Fig. 2. At increasing inclusion of HQCF, ash content was observed to increase. Ash content of the chinchin 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±0.01) reported for chin-chin made from 100% wheat flour by Falola et al. [30].

The fibre content ranged from 0.85 to 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 = .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 = .05) on the fibre content. Also, the interactive effect of HQCF and BNF had a negative significant (P = .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 Fig. 2. However, lower value obtained for fibre content in the chinchin could be due to relatively low fibre content of one of the two 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 = .05) difference with respect to the protein contents 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 = .05) on protein content. The interactive effect of flour blends had no significant (P = .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 Fig. 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 [31]. The range (5.87-9.15%) of mean value for protein content in this study is relatively higher than range (5.32-7.94%) reported by Ramakrishna et al. [32] 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 = .05) difference in the protein content of the

chinchin. The results obtained using multiple quadratic regression is presented in Table 7. The main effect of HQCF as well BNF has a significant (P = .05) on carbohydrate content.

However, the interactive effect of the blends had no significant (P = .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 content was observed in the chinchin as BNF inclusion increased whereas inclusion of HQCF raised the level of the carbohydrate content (Fig. 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.

3.3 Optimum Level of Constraint for the Optimization of Ingredient Combination for 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.

3.4 Sensory Properties of the Chinchin

The mean sensory scores for the chinchin samples such as appearance, colour, texture (crispiness), aroma, taste and overall acceptability are presented in Table 9. The mean score for appearance of the chinchin is 5.92 ± 0.35 to 7.00 ± 0.22. This result revealed that chinchin sample HQCF$_{62.50}$BNF$_{37.50}$ was neither

liked nor disliked while sample $HQCF_{68.75}BNF_{31.25}$ was liked moderately and there was significant

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

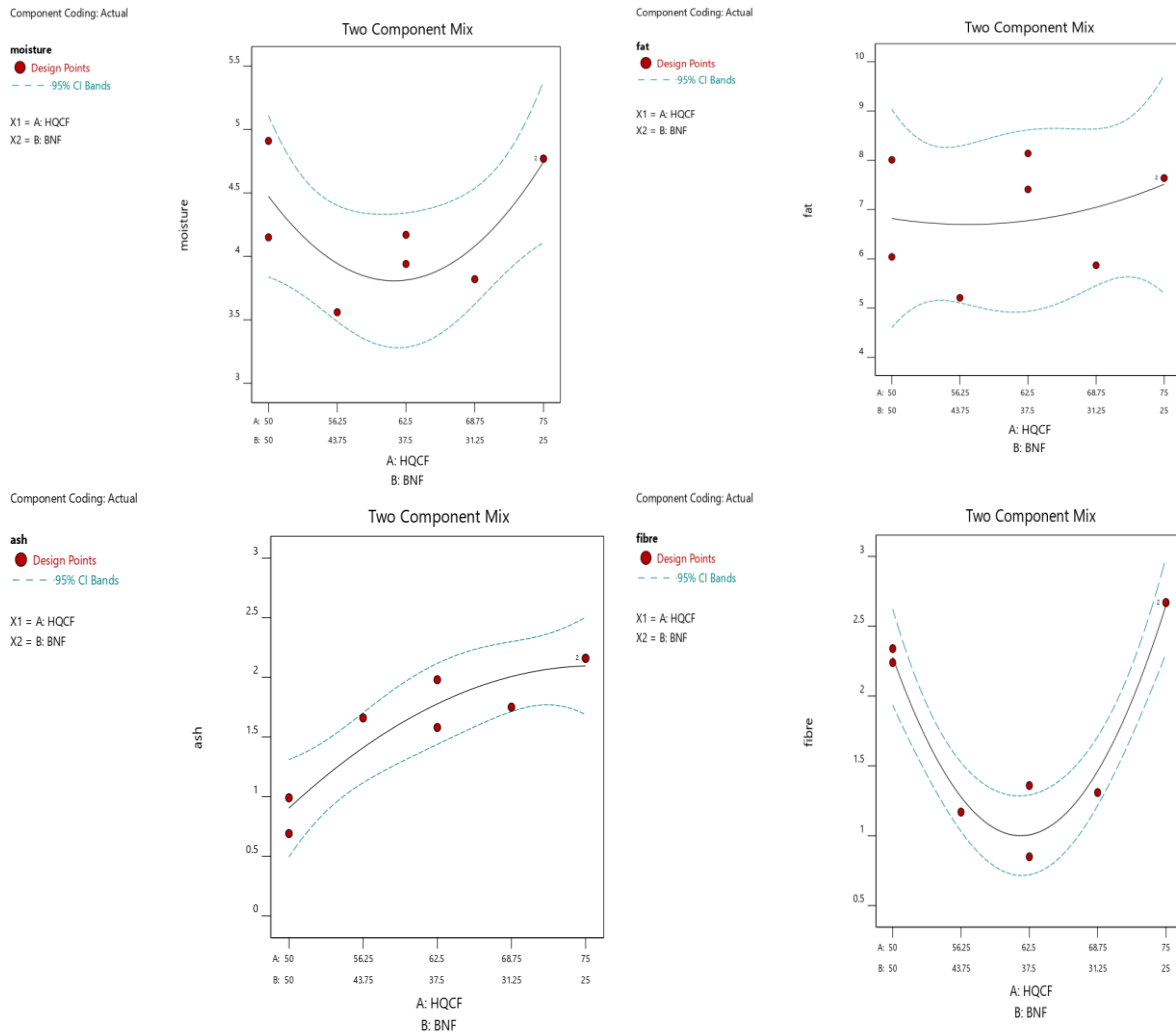| Parameters	Moisture content (%)	Fat content (%)	Ash content (%)	Fibre content (%)	Protein content (%)	Carbohydrate content (%)
A: High quality cassava flour	4.75*	7.51*	2.10*	2.65*	6.24*	76.76*
B: Bambara nut flour	4.47*	6.82*	0.93*	2.88*	8.38*	77.10*
AB	-3.19	-1.56	1.11*	-5.83*	-3.03	12.63
R^2	0.63	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

(P = .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 liked nor disliked while sample $HQCF_{62.50}BNF_{37.50}$ was moderately liked and there was a significant (P = .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 liked nor disliked while sample $HQCF_{62.50}BNF_{37.50}$ was liked slightly and there was a significant (P = .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). The

chinchin samples were significantly (P = .05) different with respect to taste, with chinchin sample $HQCF_{56.25}BNF_{43.75}$ reflecting neither liked nor disliked while sample $HQCF_{62.50}BNF_{37.50}$ was moderately liked as indicated in Table 9. Crispness had its mean sensory score ranging from 5.84 ±0.38 to 6.56±0.38 for the chinchin samples. There was no significant (P = .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, the chinchin samples were not significantly (P = .05) different with regard to aroma having range of mean value to be (6.16 ± 0.42 and 6.96 ± 0.29), with $HQCF_{75.00}BNF_{25.00}$ and $HQCF_{62.50}BNF_{37.50}$ being liked slightly as adjudged by the sensory panels.

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

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 (WF$_{100}$)	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 the chinchin

Sample	NA (TBC) cfu/g $\times 10^{-3}$	EMB (TECC) cfu/g $\times 10^{-3}$	SSA (TSSCC) cfu/g $\times 10^{-3}$	PDA (TFC) cfu/g $\times 10^{-3}$
HQCF$_{62.50}$BNF$_{37.50}$	1.3±0.58[a]	0.00	0.00	4.0±0.00[a]
HQCF$_{50.00}$BNF$_{50.00}$	0.33±0.06[a]	0.00	0.00	4.0±2.60[a]
HQCF$_{50.00}$BNF$_{50.00}$	0.00	0.00	0.00	2.0±1.00[a]
HQCF$_{62.50}$BNF$_{37.50}$	1.3±0.58[a]	0.00	0.00	4.0±0.00[a]
HQCF$_{68.75}$BNF$_{31.25}$	0.33±0.06[a]	0.00	0.00	2.0±0.00[a]
HQCF$_{56.25}$BNF$_{43.75}$	0.00	0.00	0.00	4.7±0.58[a]
HQCF$_{75.00}$BNF$_{25.00}$	0.00	0.00	0.00	4.0±0.00[a]
HQCF$_{75.00}$BNF$_{25.00}$	0.33±0.06[a]	0.00	0.00	8.0±2.00[a]
Control (WF$_{100}$)	0.33±0.006[a]	0.00	0.00	5.0±2.00[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

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):
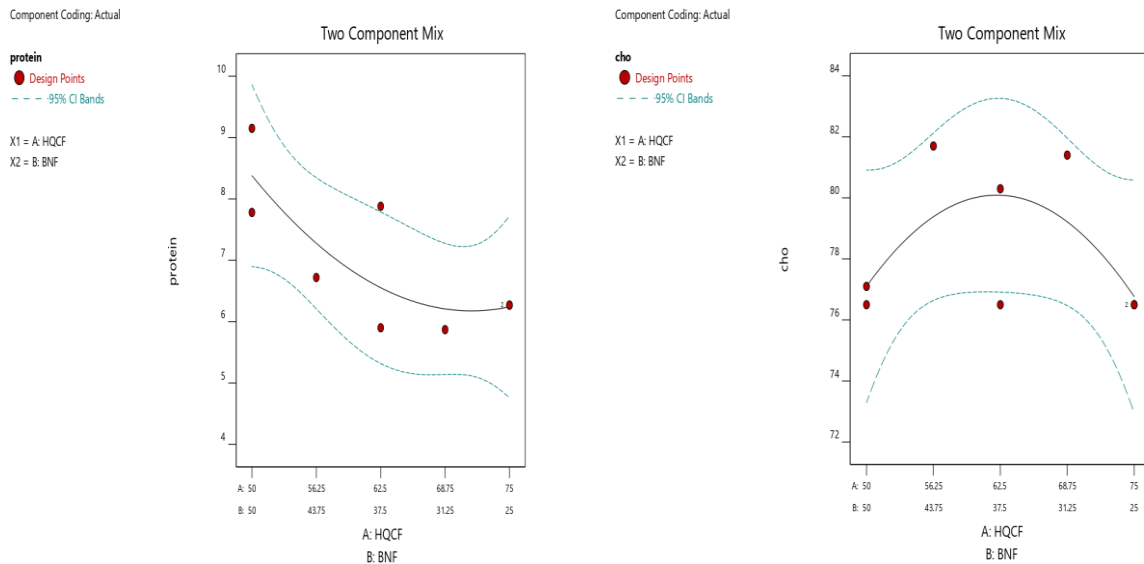*Potato Dextrose Agar (Total fungal count)*

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

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 = .05) difference in the overall acceptability 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 with 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 [33]. However, incorporating HQCF and Bambara nut flour can improve the smoothness, creaminess, or other desirable mouthfeel attributes, making the snacks more enjoyable to eat [34]. 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 by the sensory panels.

3.5 Microbiological Qualities of the Chinchin

The chinchin samples were not significantly different (P = .05) with respect to bacteria count,

Chinchin samples HQCF$_{62.50}$BNF$_{37.50}$ and HQCF$_{62.50}$BNF$_{37.50}$ has the highest bacteria count of 1.3±0.58 although not significantly different from other samples. The result revealed that only the chinchin sample prepared with wheat flour had the highest fungal colony occurrence of 8.0±2.00 while chinchin samples HQCF$_{50.00}$BNF$_{50.00}$, 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.

The results of this research are within the limits set by the ICMSF (1996) and the Standard Organization of Nigeria, which state that mold counts must not exceed 100 cfu/g in food samples irrespective of the formulations used in production.

4. 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 chinchin produced with the flour blends were acceptable by the sensory panels, but the optimum level for the composite flour is 56.25% HQCF and 43.75% BNF resulting in chinchin of lower moisture and fat content.

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 writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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