Effect of Bambara Groundnut Flour (*Vignasubterranea*) Inclusion on the Functional, Pasting,Physical and Proximate Properties of Composite Cassava-bambara Flour

ABSTRACT

This study evaluated the effect of Bambara groundnut flour inclusion on the functional, pasting, physicalproperties and proximatecompositionsof composite flour (CF) from cassava and Bambara groundnut. Cassava variety (IITA-TMS-IBA011368)and Bambara groundnut were processed into flour and blended together based on D-Optimal mixture design with an outcome of eight experimental samples using Design Expert Software (Version 12.0). The flour blends were analyzed for functional,pasting, physical properties (color), baking strength and proximate composition. Data obtained were analyzed using analysis of variance and means were separated using Ducan's Multiple Range Test.Range of resultsfor bulk density, water absorption capacity, swelling index, solubility index and oil absorption capacity of the composite flour are 0.64-0.80g/mL,0.38-1.37%,0.77-0.91%, 6.00-8.65,1.58-2.97, respectively. The peak viscosity, trough, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature ranged from162.84±2.09to426.50±1.83RVU,77.96±2.71to195.59±8.91RVU,84.88±0.63to234.75±5.58RVU, 158.92±4.34 to 293.17±1.34RVU,76.88±18.04to101.42±5.08RVU,4.10±0.03to5.93±0.00 min and 75.05±0.05to94.78±0.38^{o}C, respectively. The baking strength characteristics of the flour blends such as moisture, ash, color, wet gluten, zenleny dry protein and wet protein ranged from11.55 to12.55%,0.50 to1.25%,88.65 to90.55, 8.35 to13.80, -2.35 to41.25, 4.92to 13.85% and 4.53 to 11.99%, respectively.Moisture, ash, fibre, fat,protein and carbohydrate of the composite flour ranged from7.57 to 11.87%, 0.42 to2.40 %,1.78 to3.00%,2.81 to5.62%, 8.42 to12.68% and 67.61 to75.99%, respectively. Flour lightness, redness and yellowness ranged from 33.22 to54.10, -2.89 to-1.14, 5.94 to9.35, respectively.The inclusion of Bambara groundnut flour had a significant effect on the functional (swelling index, water and oil absorption capacity), pasting (peak, trough and final viscosity) and proximate (ash, fat and carbohydrate) properties of the flour blends.

Keywords: Baking strength;Bambara groundnut;composite flour;functional properties;proximate composition.

1. INTRODUCTION

"The importance of flour in the food industry cannot be overemphasized asit is the major raw material use in the production of an array of food products and it equallyserves as staple raw material across the globe"[1]. "Composite flours are a blend of different flours rich in starch or protein, with or without wheat flour, which has found application in bakery products"[2]. Prospecting floursfrom underutilized, low cost and abundant leguminous crops for baking purposes in food industry is key considering the high cost of wheat importation in relation to food production cost.

“Cassava is drought-tolerant and mature roots maintain their nutritional value for up to three years”[3]. “It is a multiple year crop and its roots can be kept in the ground until needed, thus increasing food security”[4]. Cassava roots are very rich in starch and contain significant amount of calcium (50 mg/100g), phosphorus (40 mg/100g) and vitamin C (25 mg/100g), however they are poor in protein and other nutrients.

“High Quality Cassava Flour (HQCF) is one of the major products from cassava roots traded in the world food market and its popularity in the sub-region is on the increase due to high cost of wheat importation and characteristic celiac related diseases, HQCF can replace wheat flour to at least 30 %”. [5]Characteristically, HQCF is unfermented, smooth, odorless, white and sometimes creamy in color depending on the variety from which it is produced and of course requiresa rapidprocessing to avoid fermentation of the roots[6]. Starch from HQCF produced with low postharvest physiologically deteriorated cassava varieties has capacity to form strong gelsand could be composited with wheat and other flours because of its strong binding capacity and good aesthetic (creamy color) [6]. Relatively, HQCF from low postharvest physiologically deteriorated cassava has relatively low protein content and therefore could be blended with flour from a crop rich in protein for the supply of lysine which is an essential amino acid instrumental in the synthesis of protein and mineral absorption.

“Bambara groundnut is a leguminous crop that is rich in protein (15 – 27%) and carbohydrate (57–67%)”[7]. “It is often referred to as a complete food because of its reasonably high protein contentand a good balance of the essential amino acids”[8-10]. “The high levels of lysine (6.5 – 6.8%) in Bambara groundnut and the considerable amount of methionine (1.8 - 2.84%), which is normally limiting in most legumes, further confirm the grain as a balanced diet”[11]. Therefore, the study assessed theeffect of Bambara groundnut flour inclusion on the functional, pasting, physical and proximate properties of composite cassava-bambara flour.

2. MATERIALS AND METHOD

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.

2.1 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 Iweet al. [12] and Alimiet al.[13]. 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.

2.2 Processing of Bambara Groundnut Seeds into Flour

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, 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[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 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.

2.3 Preparation of the Flour Blends

One hundred grams (100g) of each of High Quality Cassava Flour, and Bambara groundnut flour was prepared according to each formulation using a D-Optimal mixture design with an outcome of eight experimental samples (runs) generated with Design Expert Software (Version 12.0).

Table 1: Composition of flour blends

Sample /Run	High quality cassava flour (HQCF)	Bambaranut flour (BNF)	WF
1	62.50	37.50	0.00
2	50.00	50.00	0.00
3	50.00	50.00	0.00
4	62.50	37.50	0.00
5	68.75	31.25	0.00
6	56.25	43.75	0.00
7	75.00	25.00	0.00
8	75.00	25.00	0.00

WF: Wheat flour

2.4 Functional Properties of the Flour Blends

The bulk density of each of the flour was determined according to the method of Nwosuet al. [16]. “Flour sample (10 g) was put in a calibrated 50 mL measuring cylinder. Then the bottom of the cylinder was tapped repeatedly unto a firm pad on a laboratory bench until a constant volume was observed. The packed volume was recorded”. [16] The bulk density was calculated as the ratio of the flour weight to the volume occupied by the flour after tapping in equation 1.

$$\textit{Bulk Density (g/mL)} = \frac{Weight\ of\ sample\ (g)}{Volume\ of\ sample\ (mL)} \qquad (1)$$

2.4.1 Water Absorption Capacity of the Flour Blends

Water absorption capacity was determined following the methods of Onwuka and Onwuka[17]. One (1) gram ofeachflour was weighed into a clean conical graduated centrifuge tube and mixed thoroughly with 10 mL distilled water using a platform tube rocker for 30 s. The flour was then allowed to stand for 30 min at room temperature, after which it was centrifuged at 3500 rpm for 30 min. After centrifugation, the volume of the free water (supernatant) was read directly from the graduated centrifuge tube. The absorbed water was converted to weight (in grams) by multiplying by the density of water (1 g/mL). The water absorption capacity was expressed in grams of water absorbed per gram of flour as indicated in equation 2.

Absorbed water = total water - free water (2)

2.4.2 Swelling Index

The swelling index was determined using the method described by Okaka and Potter [18]. “Ten grams (10g) of the flour was dispensed in a calibrated 100 mL measuring cylinder, 10mls of distilled water was added and the volume was noted. This cylinder was left to stand undisturbed for 1h. The volume which the sample then occupied was recorded”. [18] The swelling index was determined by calculation as indicated in equation 3:

Swelling index = v2/v1 (3)

Where v1= initial volume occupied by the sample, V2=volume occupied by the sample after swelling

2.4.3 Water Solubility Index

Water solubility index determines the number of polysaccharides or polysaccharide released from the granule on the addition of excess of water.WSI was the weight of drysolids in the supernatant from the water absorption index testexpressed as percentage of the original weight of thesample

$$WSI\ (\%) = \frac{\text{Weight of dissolved solid in supernatant}}{\text{Weight of dry solids}} \times 100 \quad (4)$$

2.4.4 Oil Absorption Capacity of the Flour Blends

Oil absorption capacity was determined by the method of Onwuka and Onwuka[17]. One gram each of the flour was measured and 10 mL refined corn oil was weighed into a dry, clean centrifuge tube and both weights were noted. Refined corn oil of 10mL was poured into the tube and properly mixed with the flour. The suspension was then centrifuged at a speed of 3500 rpm for 15 min. The supernatant was thereafter discarded and the tube content was re-weighed. The gain in mass was recorded as the oil absorption capacity of the flour

2.5 Pasting Properties of the Flour Blends

The pasting profile of the flour blendswere determined using a Rapid ViscoAnalyser (Model RVA 3D+, Newport Scientific, Australia). A known quantity of 3.5 g of flour sample was weighed into the test canister. Then 2.5 g of flour blends flour weighed into a dried empty canister; 25 ml of distilled water was added into the canister containing the flour. The solution of flour sample and distilled water were thoroughly mix and the canister was well fitted into the RVA. The slurry was heated from 50 to 95 ^{o}C with a holding time of 2 min followed by cooling to 50 ^{o}C with 2 min holding time. A constant rate of heating was applied and the cooling at a rate of 11.25 ^{o}C/min. Peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperature were read from the pasting profile with the aid of Thermocline for Windows Software connected to a computer.

2.6 Chemical Analysis on the Flour Blends

2.6.1 Baking Strength of the Flour Blends

Baking strength of the flour blends was determined instrumentally using Perten IM9520. Briefly, 3 g of the composite flour was weighed into a cuvette and placed into the holder in the machine connected to a display. Parameters such as moisture, ash, color, wet gluten, zenleny, protein (wet) and protein (dry) measured were displayed on the monitor attached to the instrument.

2.6.2 Proximate Analysis of the Composite Flour

All proximate components of the composite flours were determined following standard analytical procedures of AOAC [19].

2.7 Color Attributes of the Composite Flour

Color properties of the flour blends were measured instrumentally using Minolta colorimeter. The color was expressed as the average of three L^*, a^* and b^* readings, where L^* stands for brightness, + a^* redness, - a^* greenness, +b^* yellowness, - b^* blueness [20].

2.8 Statistical Analysis

Data obtained from functional, pasting, physical and chemical composition was statistically analyzed for significant effect of independent variable on the responses at 5% level using analysis of variance (ANOVA) of SPSS version 25 while the meanswere separated using Duncan's Multiple Range Test (DMRT) at 95% confidence level.

3.0 RESULTS AND DISCUSSION

3.1 Functional Properties of Flour Blends

The functional properties of the flour blends are presented in Table 2. The flour blends were significantly ($p<0.05$) different in terms of bulk density,which ranged from 0.64to 0.80g/cm^3, with 100% wheat flour (control)having the highest while sample $HQCF_{75.00}BNF_{25.00}WH_{0.00}$ had the least value. The weight of a given food material is referred to as the "bulk density"[21]. The observed increase in bulk density could be attributed to several factors such as increased particle size, change in particle shape, and improved packing arrangement of the constituent flours[22].

Water absorption capacity (WAC) of flour blends differed significantly ($p<0.05$). The percentage water absorption capacity ranged from 0.64±0.00to0.80±0.00 %. At increasing content of the Bambara groundnut flour, the water absorption capacity of the flour blends increased. This trend of increased water absorption capacity in composite flours containing legumes observed in this present study had been reported by Alimi et al. [2] andOmoniyi et al.[23]. This observation could be attributed to the loosened structure of starch polymers of the composite flour as the starch of the constituent flours increased due to the additive effect and also there was increased capacity to absorb water due to increased protein network created as the quantity of Bambara groundnut flour increased.

The flour blends were significantly different ($p<0.05$) with respect to their swelling index and had range of mean value 0.77±0.00 to 0.91±0.00%. It was observed that inclusion of Bambara groundnut flour had additive effect on the swelling power of the composite flours. Swelling capacity is used as an index to assess the extent of interaction between the swollen starch granules and water. The higher the swelling capacity, the shorter the cooking time of such a flour blend, was indicating the extent to which the starch granules have swollen and softened [24]. This is particularly interesting due to the fact that consumers do take the volume of a food material as an index to measure value for their money spent especially with regard to baked food products.

The existence of strong bonding forces influenced by protein and fat quantity with propensity to form complexes with amylose as measured by solubility index of the flour blends were significantly different ($p<0.05$) and ranged from 6.00±0.00to 8.65±0.00, with flour blend $HQCF_{75.00}BNF_{25.00}WF_{0.00}$ having the lowest while sample $HQCF_{62.50}BNF_{37.50}WF_{0.00}$ had the highest.

Blending HQCF withBambara groundnut flour had significant ($p<0.05$) effects on the resulting composite flour. Wheat flour was observed to be significantly ($p<0.05$) different from the composite flours. As the levelsofBambara groundnut flour increased in the blends, solubility index increased, this could be as a result of starch degradation in the flour blends [25]. Report has it that highsolubility indexcould be due to high amount of amylose which leaches out easily during the swelling process[26]. A higher value of solubility of flour indicates an improved digestibility. Thehighsolubility indexobtained with these flour blends is of prime importance and could be explored inthe food preparations especiallyfor infants and the aged who needs more readily digestible food.

The flour blends were significantly ($p<0.05$) different with respect to oil absorption capacity, which ranged from 1.58±0. 00to 2.97±0.00, with flour blend $HQCF_{68.75}BNF_{31.25}WF_{0.00}$ having the least value while sample $HQCF_{50.00}BNF_{50.00}WF_{0.00}$had the highest. Blending HQCF withBambara groundnut flour significantly ($p<0.05$) improved the oil absorption capacity of the flour blends. Increase in the quantity of Bambara groundnut flour was observed to increase the oil absorption capacity of the flour blends. The relative increase in oil absorption capacity of the flour blends could be attributed to the high hydrophobic nature of the protein which showed superior binding affinity for lipids. The oil absorption capacity observed in this study especially incomposite flour involving high quality cassava and Bambara nut flour is an indication that the flours can bind fat physically by capillary attraction, therefore can enhance the flavor, increase mouthfeel and act as flavor retainer, as well as improvingthe textural propertiesof food. Flour blends $HQCF_{50.00}BNF_{50.00}WF_{0.00,}$ $HQCF_{62.50}BNF_{37.50}WF_{0.00,}$ $HQCF_{50.00}BNF_{50.00}WF_{0.00}$ and$HQCF_{56.25}BNF_{43.75}WF_{0.00}$ could find application in the production of pastry and baked food products due to relative improved capacities toabsorb oil and retain flavor.

3.2 Pasting Properties of the Composite Flours

The pasting profile of the flour blends is presented in Table 3. There were significant ($p<0.05$) differences in the pasting properties of the flour blends except in trough, final and setback viscosities. Peak viscosity ranged in mean values from 62.84±2.09 to 426.50±1.83 RVU,high peak viscosity is an index of high starch content. This explains why sample $HQCF_{68.75}BNF_{31.25}WF_{0.00}$ had the highest value indicating high starch content as compared to the other blends. The peak viscosity is the ability of starch to swell freely before physical breakdown as noted by Sanniet al.[27]. The relative decrease in peak viscosity at increased quantity of Bambara groundnut flour in the flour blends may not be unconnected with the fact that legume starches had been noted to have a resistant pattern to swelling[28]and the high fat content at increased Bambara groundnut flour inclusion could also be adduced as a factor for the observed relative decreased peak viscosity.

Stability of starch granules to heating is referred to as the holding strength or trough. Worth pointing out is the fact that the composite flowers were significantly ($p<0.05$) different from wheat flour with regards to trough.The result indicated a decrease in holding strength with increase in the quantity ofBambara groundnut flour in the composite. The range of mean values obtained in this study were higher than range (39.60-59.19 RVU) reported for wheat and walnut by Ofia-olua[29] but are in agreement with Kiin-kabari[30] on functional and pasting properties of wheat and plantain flours enriched with Bambara groundnut protein concentrate.

The hot paste stability of the starch as measured by breakdown viscosity which reveals the degree of starch disintegration [31, 32, 6]. Breakdown viscosity of the flour blends were significantly different ($p<0.05$) and ranged from84.88±0.63 to234.75±5.58 RVU,100% wheat flour (control) had the lowest while sample $HQCF_{68.75}BNF_{31.25}WF_{0.00}$ had the highest. The higher the breakdown viscosity, the lower the ability of starch in the flour samples to withstand heating and shear stress [33]. Relatively, increased quantity of Bambara groundnut flour in the composite flours tends to reduce the breakdown viscosity of the flour blends and this trend has been reported by previous studies on composite flours [34].

The final viscosity (FV) is a major pasting parameter that determines the final product quality of starch-based food; the higher the FV, the better. The final viscosity of the flour blends were statistically not different ($p>0.05$) butworth pointing out is the fact that the composite flours were significantly ($p<0.05$) different from wheat flour with regards to final viscosity. It depicts the ability of food material to form gel during processing. The range (158.92±4.34 to 293.17±1.34 RVU) of value in this study obtained in this present studyis relatively higher than (95.51-252 RVU) reported by Ofia-olua[29] for wheat and walnut blends.

The retrogradation tendency of starch or starch-based food product as measured by setback viscosity has been used successfully to study the behavior of food materials. The lower the setback viscosity value, the better for flour meant for baking purposes [6]. Setback viscosity values are reported to correlate with ability of starches to gel into semi solid pastes. The range(76.88±18.04 to 101.42±5.08 RVU) in this study is relatively lower than (56.09 – 153.88 RVU) for sweet potato starch-based tapioca grits reported by Awoyale et al. [35]; relatively lower than (80 – 124 RVU) reported by Alimi et al. [6], slightly higher than range reported by Eke et al. [34].This could be attributed to the differences in the genetic make-up of the crops from which the constituent flours used in the studies were produced.

Time to attain maximum (peak) viscosity is referred to as the peak time. The requisite time for starch portion of food material to cook is referred to as the peak time. The requisite time for the starch portion of the flour blends to cook were significantly ($p<0.05$) different and ranged from4.10±0.03 to 5.93±0.00 min, with wheat flour having the highest while flour sample $HQCF_{62.50}BNF_{37.50}WF_{0.00}$ had the lowest. This trend of reduced peak time when wheat flour is replaced by flours from other crops is similar to what was earlier reported [6]. The range (4.10±0.03 to 5.93±0.00 min) for composite cassava-bambara flour is relative lower than (4.10 – 5.93 min) reported by Awoyale et al. [35] for sweet potato starch-based tapioca grits.

A point at which a notable increase in viscosity of starch with observable simultaneous swelling occurs is referred to as the "pasting temperature". It gives a clear picture of energy costs involved in such a production process [6]. The pasting temperature of the flour blends ranged from 75.05±0.05 to 94.78±0.38 ^{o}C,with flour sample $HQCF_{62.50}BNF_{37.50}WF_{0.00}$having the lowest while wheat flour had the highest. This result indicates an increase in peak time and pasting temperature as substitution of high-quality cassava flour and Bambara nut flour increased.The lower the pasting temperature, the better from energy conservationprinciple as it relates directly to cost of energy involved in production process. This trend of results in this present study is similar to what was reported by Alimi et al. [6] and Eke et al.[34].

3.3 Baking Strength of the Flour Blends

The baking strength of the flour blends characterized by parameters such as moisture, ash, color properties, wet gluten, zenleny, protein (dry basis) and protein (wet basis) contents is presented in Table 4. The flour blends were significantly (p<0.05) different in terms of moisture,whichrangedfrom11.55 to 12.55%, with 100 % wheat flour having the lowest, while sample $HQCF_{75.00}BNF_{25.00}WF_{0.00}$ had the highest. Notably, all the composite flours had moisture content relatively higher than wheat flour. The moisture content of a food material depicts its shelf stability, usually the lower the moisture content, the better for a flour material to be stored prior usage. The range of moisture (11.55 to 12.55%) contents of the flour blends are within the range (12.45 to 13.10 %) reported by Alimi et al. [6].

Mineral element present in food as measured by ash content is an essential parameter in milling industries as it is instrumental in estimating the yield of flour and equally important in assessing milling functionality of flour [28]. The ash content of the flour blends ranged from 0.50 to 1.25%, wheat flour having the least while sample $HQCF_{75.00}BNF_{25.00}WF_{0.00}$ had the highest. The ash contents of the flour blends were significantly higher than that of wheat flour due to additive effect.

The flour blends were significantly (p<0.05) different in terms of color, and rangedfrom 88.65to 90.55, with sample $HQCF_{62.50}BNF_{37.50}WF_{0.00}$ having the lowest while sample $HQCF_{75.00}BNF_{25.00}WF_{0.00}$ had the highest. It was observed that HQCF exerted a masking effect over Bambara groundnut flour in terms of color.The flour blends were significantly (p<0.05) different in terms of wet gluten content and ranged from8.35 to 13.80, with wheat flour having the highest while sample $HQCF_{68.75}BNF_{31.25}WF_{0.00}$ had the lowest. This result is expected simply because gluten content in the composite flour would be relatively reduced due to dilution effect brought about by the partial replacement of wheat with Bambara groundnut flour.

Zenleny value depicts the suitabilityof flour for baking purpose. The composite flours were significantly ($p<0.05$) different in terms zeleny value, with range of value-2.35 to 41.25, with wheat flour having the highest while sample $HQCF_{68.75}BNF_{31.25}WF_{0.00}$had the lowest.The composite flours were significantly ($p<0.05$) different in terms of protein contents on wet and dry basis, with ranges 13.85% and 4.53 to 11.99 %, respectively.Expectedly, wheat flour had the highest value while samples $HQCF_{75.00}BNF_{25.00}WF_{0.00}$ and $HQCF_{68.75}BNF_{31.25}WF_{0.00}$ had the lowest. The protein contents of the flour blends were improved.

3.4 Proximate Composition of the Flour Blends

The proximate compositions of composite flours were significantly ($p<0.05$) different and are presented in Table 5. The moisture content of the flour blends ranged from 7.57-11.87%; the moisture content of a food material determine how shelf stable the food is. The moisture contents of the flour blends were within the safe moisture (10-14 %) limit for flour. The composite flours with respect to safe moisture limit are expected to be shelf- stable if packaged in air-tight container. Relatively low moisture contents recorded in this study will not support the growth and proliferation of microorganisms[6, 36].

The ash content of the flour blendswere significantly ($p<0.05$) different and ranged from 0.42- 2.40 %, with 100% wheat flour having the lowest while sample $HQCF_{62.50}BNF_{37.50}WF_{0.00}$had the highest content.BlendingBambara groundnut flour with HQCFhad significant ($p<0.05$) effect on the ash content of the composite flours. Ash content is an indication of mineral content of food as it was evident with the presence of calcium and phosphorus [37]. The improved ash content of the composite flours when compared with wheat flour indicated the additive effect of composite flour technology, giving rise to composite flours richin minerals.The ash (0.42-2.40 %) content recorded for the composite flour in this study is relatively lower than range (1.28 – 2.63 %) reported by Oklo et al. [38]. This can be connected with the fact that maize in the flour blend reported by Oklo et al. [38] had mineral content that is relatively higher than that of cassava from which HQCF was prepared, consequently the observed relatively higher ash content.

The crude fibre content of the flour blends were significantly ($p<0.05$) different and ranged from 1.78-3.00%, blending Bambara groundnut flour and HQCF improved the fibrecontent of the composite flour but were relatively lower to that of wheat flour.The range (1.78-3.00 %) of value for crude fibre recorded in this study was relatively higher than (0.93 – 1.86 %) for composite maize-soybean flour [38].

The composite flours were significantly ($p<0.05$) different with respect to fat content,which ranged from 2.81 - 5.62 %, with wheat flour having the least while sample $HQCF_{62.50}BNF_{37.50}WF_{0.00}$ had the highest.The observed improvement in fat content of the resulting composite flour could be attributed to additive effect brought about by blending HQCF with Bambara groundnut flour (composite flour technology). These composite flours if applied in the preparation of food products has propensity to improve palatability and enhance the flavor of food [37, 28]. The range (2.81 - 5.62 %) of fat content recorded in this present study is relatively higher than (2.05 – 5.63 %) reported by Oklo et al. [38] for composite maize-soybean flour and higher than (0.40 – 3.71 %) for composite wheat-cassava flour reported by Alimi et al. [6]. Diallo et al. [39] reported that the use of Bambara groundnut in composite flours improves the protein, ash, fibre and fat content of the derived products.

The flour blends were significantly ($p<0.05$) different with respect to protein content and had values rangingfrom8.42-14.50%, with sample $HQCF_{75.00}BNF_{25.00}WF_{0.00}$ having the lowest while sample $HQCF_{50.00}BNF_{50.00}WF_{0.00}$ had the highest.Interestingly, blending HQCF with Bambara groundnut flour resulted in appreciable increase in protein contents of the composite flours, attesting to the fact that the composite flours have the potential to contribute to the daily human protein requirement [40].Synthesis of new protein from hydrolyzed free amino acids during fermentation by microflora enzymes could be adduced as one of the reasons for the observed increase in the protein contents of the flour blends. Worthy of note is the fact that when legumes such as Bambara groundnut, soybeans and cowpea supplement cereals and tubers, they provide a protein quality comparable to or higher than that of animal protein [41].

Blendinghigh-quality cassava flour and Bambara groundnut flour had a significant ($p<0.05$) effect on the carbohydrate content of the flour blends. The mean value ranged from 67.61 - 75.99 %, with sample $HQCF_{50.00}BNF_{50.00}WF_{0.00}$ having the least while sample $HQCF_{75.00}BNF_{25.00}WF_{0.00}$ had the highest. It is important to point out that at increasing content of Bambara groundnut flour, there was observed relative decrease in carbohydrate contents of the flour blends indicating that starch granules of HQCF exert a masking effect on the starch content of Bambara groundnut flour. Also, it is well known that HQCF has comparatively higher carbohydrate content than Bambara groundnut flour. Generally, the carbohydrate content of the flour blends were relatively higher than that of 100 % wheat flour which could be attributed to the additive effect of blending HQCF with flour from a leguminous crop. These energy thresholds of the composite flours suggests that they could find application in managing protein-energy malnutrition since there is enough quantity of carbohydrate to derive energy from in order to reserve protein for its primary function of building the body and repairing the worn-out tissues rather than use as a source of energy. The range (67.61 - 75.99 %) of carbohydrate contents for these composite flours in this study is in the same range (72.71 – 76.15%) for composite wheat-cassava flour reported by Alimi et al. [6] and relatively lower than (64.33 - 79.91 %)reported by Oklo et al. [38].

3.5 Color Attribute of the Flour Blends

The color characteristics of the flour blends are presented in Table 6. Color is known to play a significant role in the acceptance of products and flour products by theconsumer [42]. When accurately measured, it givesinformation on the pigment degradation that takes place during the production process [43]. The color of the flour blends were significantly ($p<0.05$) affected by the additive effectthat Bambara groundnut flour exerted, especially on the flour lightness (L^*) and yellowness (b^*). Theflour lightness(L^*) values indicating whiteness of the flour blendsranged from 33.22 to 54.10, with 100%wheat flour(control) having the least while sample $HQCF_{62.50}BNF_{37.50}WF_{0.00}$ had the highest lightness. An increase in (L^*) value was observed as inclusion of Bambara groundnut flour increased, but reverse was the caseat increasing level ofHQCF. The same trend in (L*) was observed for red-greenness (-a*) value and flour yellowness (b*).

The values with all measurements above zero, suggesting that the red zone is dominating over the green in all the flour blends.The flourred-greenness (-a*) value ranged from -2.89 to -1.14,with 100% wheat flour having the lowest while $HQCF_{62.50}BNF_{37.50}WH_{0.00}$ had the highest value.The (b*) values, with all measurements more than zero, which also imply that the yellow zone is in greater expression that the blue in all the flour blends. The composite flours varied in terms of flour yellowness (b*),and had mean valueranging from 5.94 to 9.35,with 100% wheat flour having the lowest while flour sample $HQCF_{62.50}BNF_{37.50}WF_{0.00}$ had the highest. The L*, a* and b* values of a flour sample is strongly influenced by the genetic composition of the constituent flours[24, 28]. The results in this study is in consonance with the report of Ramliet al. [44], with a clear indication that an attempt to enhance the nutrient base of food powders may affect the color parameter and that the higher the percentage substitution, the greater the tendency of impact on the color of the resulting flour blends.

4. CONCLUSION

The study revealed that the inclusion of Bambara groundnut flour had a significant effect on the functional, pasting and physical properties of the flour blends. Blending Bambara groundnut flour with HQCF improved the proximate composition of the resulting composite flours, especially, the protein, fat and ash contents which are critical factors to be considered when selecting flours for use in the food (baking) industry. Considering the baking strength, the order of suitability of the flour blends for baking purpose is: $HQCF_{75.00}BNF_{25.00}WF_{0.00}$ > $HQCF_{50.00}BNF_{50.00}WF_{0.00}$> $HQCF_{62.50}BNF_{37.50}WF_{0.00.}$

COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS’ CONTRIBUTIONS

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

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Table 2: Functional properties of the flour blends

Sample blends	Bulk density (g/ml)	Water absorption capacity (%)	Swelling index (%)	Solubility index	Oil absorption capacity (%)
$HQCF_{62.50}BNF_{37.50}WF_{0.00}$	0.69 ± 0.00^{g}	0.80 ± 0.00^{d}	0.77 ± 0.00^{a}	7.21 ± 0.00^{d}	2.58 ± 0.00^{h}
$HQCF_{50.00}BNF_{50.00}WF_{0.00}$	0.65 ± 0.00^{c}	0.99 ± 0.00^{f}	0.91 ± 0.00^{d}	7.73 ± 0.00^{f}	2.97 ± 0.00^{i}
$HQCF_{50.00}BNF_{50.00}WF_{0.00}$	0.67 ± 0.00^{e}	0.78 ± 0.00^{c}	0.91 ± 0.00^{d}	8.46 ± 0.00^{g}	2.38 ± 0.01^{f}
$HQCF_{62,50}BNF_{37.50}WF_{0.00}$	0.66 ± 0.00^{c}	0.59 ± 0.00^{b}	0.83 ± 0.00^{c}	8.65 ± 0.00^{i}	1.78 ± 0.01^{b}
$HQCF_{68.75}BNF_{31.25}WF_{0.00}$	0.69 ± 0.00^{f}	0.38 ± 0.01^{a}	0.83 ± 0.00^{c}	7.23 ± 0.00^{e}	1.58 ± 0.00^{a}
$HQCF_{56.25}BNF_{43.75}WF_{0.00}$	0.67 ± 0.00^{d}	1.37 ± 0.00^{h}	0.91 ± 0.00^{f}	7.19 ± 0.00^{b}	2.20 ± 0.00^{e}
$HQCF_{75.00}BNF_{25.00}WF_{0.00}$	0.65 ± 0.00^{b}	1.19 ± 0.00^{g}	0.83 ± 0.00^{c}	6.00 ± 0.00^{g}	2.00 ± 0.00^{d}
$HQCF_{75.00}BNF_{25.00}WF_{0.00}$	0.64 ± 0.00^{a}	0.98 ± 0.00^{e}	0.83 ± 0.00^{c}	7.20 ± 0.00^{c}	1.80 ± 0.00^{c}
$HQCF_{0.00}BNF_{0.00}WF_{100}$	0.80 ± 0.00^{h}	0.98 ± 0.00^{ef}	0.78 ± 0.00^{b}	8.57 ± 0.00^{h}	2.39 ± 0.00^{g}

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 3: Pasting properties of the flour blends

Sample Blends	Peak viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Set back (RVU)	Peak time (min)	Pasting temperature (°C)
$HQCF_{62.50}BNF_{37.50}WF_{0.00}$	323.09 ± 12.34^{bc}	170.21 ± 2.88^{b}	152.88 ± 9.46^{bcd}	267.04 ± 10.46^{b}	96.84 ± 7.59^{a}	4.70 ± 0.10^{cd}	76.28 ± 0.43^{ab}
$HQCF_{50.00}BNF_{50.00}WF_{0.00}$	326.79 ± 14.21^{bc}	177.63 ± 1.38^{b}	149.17 ± 15.59^{bc}	268.59 ± 5.59^{b}	90.96 ± 6.96^{a}	4.84 ± 0.17^{d}	77.48 ± 0.73^{b}
$HQCF_{50.00}BNF_{50.00}WF_{0.00}$	284.92 ± 26.67^{b}	152.38 ± 17.55^{b}	132.55 ± 9.13^{ab}	230.67 ± 33.25^{b}	78.29 ± 15.71^{a}	4.87 ± 0.00^{d}	77.15 ± 0.40^{b}
$HQCF_{62.50}BNF_{37.50}WF_{0.00}$	362.38 ± 66.71^{a}	180.58 ± 32.75^{b}	181.79 ± 33.96^{bcd}	257.46 ± 50.79^{b}	76.88 ± 18.04^{a}	4.10 ± 0.03^{a}	75.05 ± 0.05^{a}
$HQCF_{68.75}BNF_{31.25}WF_{0.00}$	426.50 ± 1.83^{d}	191.75 ± 3.75^{b}	234.75 ± 5.58^{e}	293.17 ± 1.34^{b}	101.42 ± 5.08^{a}	4.20 ± 0.00^{a}	75.45 ± 0.40^{a}
$HQCF_{56.25}BNF_{43.75}WF_{0.00}$	339.54 ± 7.96^{bcd}	171.42 ± 2.34^{b}	168.13 ± 5.62^{bcd}	272.54 ± 4.2^{b}	101.13 ± 1.88^{a}	4.50 ± 0.03^{bc}	75.85 ± 0.05^{a}
$HQCF_{75.00}BNF_{25.00}WF_{0.00}$	399.96 ± 6.63^{cd}	195.59 ± 8.91^{b}	204.37 ± 15.54^{de}	290.88 ± 2.80^{b}	95.30 ± 6.13^{a}	4.30 ± 0.03^{ab}	75.48 ± 0.33^{a}
$HQCF_{75.00}BNF_{25.00}WF_{0.00}$	384.21 ± 20.13^{cd}	184.29 ± 6.97^{b}	199.92 ± 13.34^{cde}	273.17 ± 11.00^{b}	88.88 ± 4.21^{a}	4.34 ± 0.07^{ab}	75.83 ± 0.08^{a}
$HQCF_{0.00}BNF_{0.00}WF_{100}$	162.84 ± 2.09^{a}	77.96 ± 2.71^{a}	84.88 ± 0.63^{a}	158.92 ± 4.34^{a}	80.96 ± 1.63^{a}	5.93 ± 0.00^{e}	94.78 ± 0.38^{c}

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

HQCF=High Quality cassava Flour, BNF=Bambara Nut Flour, WF=Wheat Flour

Table 4: Baking strength of the flour blends

Sample blends	Moisture (%)	Ash (%)	Colour	Wet gluten	Zenleny	Protein (dry) (%)	Protein (wet) (%)
$HQCF_{62.50}BNF_{37.50}WF_{0.00}$	12.35±0.05^{ef}	0.83±0.01^{d}	89.55±0.05^{c}	10.75±005^{c}	8.65±0.05^{c}	6.12±0.01^{c}	8.36±0.01^{h}
$HQCF_{50.00}BNF_{50.00}WF_{0.00}$	12.05±0.05^{c}	0.76±0.0^{c}	88.85±0. 05^{b}	11.45±0. 05^{e}	12.65±0. 05^{e}	7.36±0.0 ^{e}	6.47±0. 01^{e}
$HQCF_{50.00}BNF_{50.00}WF_{0.00}$	12.25±0. 05de	0.84±0.0^{d}	88.75±0. 05^{a}	11.55±0. 05^{e}	4.35±0. 05^{b}	7.55±0. 01^{f}	6.61±0. 01^{f}
$HQCF_{62.50}BNF_{37.50}WF_{0.00}$	12.35±0. 05^{ef}	0.71±0.0^{b}	88.65±0. 05^{a}	10.20±0.00^{b}	11.90±0.10^{d}	6.12±0.01^{c}	5.35±0. 01^{c}
$HQCF_{68.75}BNF_{31.25}WF_{0.00}$	12.45±0. 05^{fg}	0.84±0.0^{d}	89.95±0. 05^{d}	8.35±0. 05^{a}	-2.35±0. 05^{a}	5.18±0.01^{b}	4.53±0.O1^{b}
$HQCF_{56.25}BNF_{43.75}WF_{0.00}$	12.10±0.01^{cd}	0.90±0.0^{e}	89.85±0. 05^{d}	11.15±0. 05^{d}	-2.45±0. 05^{a}	7.65±0.01^{g}	6.76±0. 01^{g}
$HQCF_{75.00}BNF_{25.00}WF_{0.00}$	12.55±0.05^{g}	1.25±0.01^{f}	90.55±0. 05^{e}	8.50±0.00 ^{a}	21.40±0.00^{g}	4.92±0.00^{a}	4.29±0.02^{a}
$HQCF_{75.00}BNF_{25.00}WF_{0.00}$	11.75±0. 05^{b}	0.76±0.01^{c}	89.45±0. 05^{c}	11.75±0. 05^{f}	15.65±0. 05^{f}	6.88±0.01^{d}	6.06±0. 01^{d}
$HQCF_{0.00}BNF_{0.00}WF_{100}$	11.55±0. 05^{a}	0.50±0.01^{a}	89.85±0.05^{d}	13.80±0.10^{g}	41.25±0.25^{i}	13.85±0.0^{h}	11.99±0.02^{i}

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 5: Proximate compositions of the flour blends

Sample blends	Moisture (%)	Ash (%)	Fibre (%)	Fat (%)	Protein (%)	Carbohydrate (%)
$\mathbf{HQCF_{62.50}BNF_{37.50}WF_{0.00}}$	7.76 ± 0.10^{bc}	1.89 ± 0.03^{c}	2.17 ± 0.12^{c}	3.57 ± 0.01^{c}	9.61 ± 0.11^{b}	75.03 ± 0.31^{e}
$\mathbf{HQCF_{50.00}BNF_{50.00}WF_{0.00}}$	10.55 ± 0.13^{e}	1.93 ± 0.13^{c}	1.78 ± 0.05^{a}	5.21 ± 0.00^{g}	11.30 ± 0.12^{c}	69.23 ± 0.21^{b}
$\mathbf{HQCF_{50.00}BNF_{50.00}WF_{0.00}}$	8.67 ± 0.07^{d}	1.89 ± 0.06^{c}	1.94 ± 0.02^{ab}	5.39 ± 0.00^{h}	14.50 ± 0.19^{e}	67.61 ± 0.25^{d}
$\mathbf{HQCF_{62.50}BNF_{37.50}WF_{0.00}}$	8.18 ± 0.09^{c}	2.40 ± 0.06^{a}	2.27 ± 0.08^{cd}	5.62 ± 0.01^{i}	11.31 ± 0.27^{c}	70.22 ± 0.35^{c}
$\mathbf{HQCF_{68.75}BNF_{31.25}WF_{0.00}}$	7.57 ± 0.04^{ab}	1.99 ± 0.01^{e}	2.64 ± 0.26^{d}	3.61 ± 0.00^{d}	12.22 ± 0.14^{d}	71.97 ± 0.13^{d}
$\mathbf{HQCF_{56.25}BNF_{43.75}WF_{0.00}}$	8.01 ± 0.03^{bc}	2.00 ± 0.00^{c}	2.15 ± 0.03^{c}	4.47 ± 0.01^{f}	10.75 ± 0.10^{c}	72.63 ± 0.89^{d}
$\mathbf{HQCF_{75.00}BNF_{25.00}WF_{0.00}}$	8.01 ± 0.37^{bc}	1.58 ± 0.07^{b}	2.58 ± 0.10^{cd}	3.41 ± 0.01^{b}	8.42 ± 0.25^{a}	75.99 ± 0.25^{f}
$\mathbf{HQCF_{75.00}BNF_{25.00}WF_{0.00}}$	7.16 ± 0.09^{a}	2.20 ± 0.04^{d}	1.97 ± 0.03^{ab}	3.81 ± 0.01^{e}	9.54 ± 0.13^{b}	75.34 ± 0.21^{ef}
$\mathbf{HQCF_{0.00}BNF_{0.00}WF_{100}}$	11.87 ± 0.01^{f}	0.42 ± 0.04^{a}	3.00 ± 0.08^{bcd}	2.81 ± 0.01^{a}	12.68 ± 0.23^{d}	69.92 ± 0.14^{c}

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

HQCF=High Quality cassava Flour, BNF=Bambara Nut Flour, WF=Wheat Flour

Table 6: Color properties of the flour blends

Sample Blends	Lightness	Greenness	Yellowness
$HQCF_{62.50}BNF_{37.50}WF_{0.00}$	54.10±8.43^{b}	-1.14±0.28^{c}	9.35±1.23^{b}
$HQCF_{50.00}BNF_{50.00}WF_{0.00}$	39.14±4.50^{ab}	-2.27±0.60^{abc}	6.31±0.54^{a}
$HQCF_{50.00}BNF_{50.00}WF_{0.00}$	44.05±6.54^{a}	-1.93±0.53^{abc}	7.04±1.14^{ab}
$HQCF_{62,50}BNF_{37.50}WF_{0.00}$	47.87±5.64^{a}	-1.65±0.46^{abc}	6.79±1.10^{a}
$HQCF_{68.75}BNF_{31.25}WF_{0.00}$	46.25±0.21^{a}	-1.55±0.12^{bc}	7.61±0.05^{ab}
$HQCF_{56.25}BNF_{43.75}WF_{0.00}$	39.41±1.30^{a}	-2.07±0.18^{abc}	6.53±0.18^{a}
$HQCF_{75.00}BNF_{25.00}WF_{0.00}$	39.26±1.11^{a}	-2.32±0.17^{abc}	6.10±0.23^{a}
$HQCF_{75.00}BNF_{25.00}WF_{0.00}$	37.31±2.52^{a}	-2.48±0.43^{ab}	6.22±0.55^{a}
$HQCF_{0.00}BNF_{0.00}WF_{100}$	33.22±1.16^{a}	-2.89±0.13^{a}	5.94±0.09^{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