

Amino acid profile, pasting, and sensory properties of croissant snacks produced from wheat-fermented Bambara flour

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Abstract

Croissants are wheat flour-based delicious bakery products that are usually consumed as part of breakfast or lunch meals. In this study, fermented bambara groundnut was used to supplement wheat flour in the following ratios (5:95%; 10:90%; 15:85%; 20:80%, and 25:75%, respectively) to produce croissant snacks. The results of the functional properties of the flour blends revealed an increase in water absorption capacity (81–92%) and bulk densities (0.81–1.20 g/cm³) with an increased added ratio of fermented Bambara flour. Contrarily, increasing the Bambara groundnut in the blend resulted in the decreased oil absorption capacity (70–63%) and the swelling capacity (0.75–0.4%). The pasting characteristics data revealed an increase in pasting temperature and setback viscosity and a decrease in peak, breakdown, and final viscosities, as well as trough and peak time with an increase in the addition of fermented Bambara flour. Proximate composition of the croissant showed an increase in protein, fiber, ash, moisture, and fat content and a decrease in carbohydrate content. Physical properties data showed an increase in loaf weight but a decrease in loaf volume and specific volume of the snacks. The amino acid profile showed an increase in the amount of essential amino acids in the enriched croissants (28.66/100 g protein) compared with the control sample (24.05/100 g protein). The sensory attributes obtained for the croissants showed that the products were highly acceptable by the panelists. Hence, the affirmation that the acceptable quality and high nutritional croissants could be produced from wheat-fermented Bambara groundnut flour blends.

KEYWORDS

amino acid, Bambara groundnut, croissant, pasting properties, sensory properties

1 | INTRODUCTION

Croissant is a delicious bakery product, which is formed by enveloping a sheet of butter or margarine in yeast dough, and is usually consumed for breakfast, lunch, or as snack by children (Slavica, Božana, Jašić, & Blagojević, 2008). The croissant (a French cake),

which was characterized by half-moon shape, was majorly produced from wheat flour, sugar, salt, yeast, eggs, and margarine for lamination (Slavica et al., 2008). Croissants are commonly prepared from the high-cost major raw material wheat, which invariably led to an increasing rate of wheat import in developing countries, like Nigeria, that do not produce it. Besides, recurrent ingestion of wheat has been

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proven to result in certain health effects such as autoimmune responses and gluten sensitivity (Adebayo, Ogunsina, & Taiwo, 2018). Wheat is also a major source of complex carbohydrate of 71%, fat about 2.10%, minerals about 2.10%, and a considerable amount of vitamins (Kumar et al., 2011). Despite being a good source of calories and some other nutrients like vitamins and minerals, wheat flour is still considered to be nutritionally poor because of the fact that proteins found in cereal are deficient in certain amino acids such as lysine and methionine (Kumar et al., 2011). In addition, protein-energy malnutrition (PEM) accounts for more than 50% of deaths in children; it is therefore quickly necessary to find a solution to this problem (Grover & Ee, 2009). Consequently, as a result of these, several attempts have been made to eliminate the problems associated with the consumption of wheat through the use of locally available plant products such as legumes. Legumes seed are protein-rich crop that has abundance of the essential amino acid (EAA) especially lysine. Therefore, supplementation of wheat with legume protein may bring a solution to PEM especially in snacks like a croissant that are majorly consumed by children.

Bambara groundnut (*Vigna subterranea*) is an indigenous legume of Africa whose usage is low. It ranks the third legume after groundnut (*Arachis hypogea*) and cowpea (*Vigna unguiculata*) in Africa (Arise, 2016; Arise, Amonsou, & Ijabadeniyi, 2015). The crop is drought tolerant, and it can withstand both hot temperatures and low rainfall. In addition, the crop has a very high resistance to pests and diseases (Arise, 2016; Bamshaiye, Adebola, & Bamshaiye, 2011). Studies have shown that on average, the seeds contain majorly carbohydrates (56–68%) and protein (15–27%) (Arise et al., 2015; Oyeyinka, Singh, Adebola, Gerrano, & Amonsou, 2015). It also contains high levels of lysine (6.5–6.8%), and interestingly, methionine that is limiting amino acid in legume has been reported to be found abundant in Bambara groundnut (1.8 per 100 g), which is normally limiting in cereals (Arise, 2016; Arise, Nwachukwu, Aluko, & Amonsou, 2017). In spite of its drought-tolerant abilities and high nutritional value, Bambara groundnut is still underutilized as the crop that is not widely marketed (Adebowale, Schwarzenbolz, & Henle, 2011; Arise et al., 2016). Researches had shown the possibility of using Bambara in various food products such as biscuits, cake, maize snacks, and maize pudding (Arise, Akintayo, Dauda, & Adeleke, 2019; Arise, Oyeyinka, Dauda, Malomo, & Allen, 2018; Okafor, Okafor, Leelavathi, Bhagya, & Elemo, 2015). In the same vein, past works had proven that fermentation processing method helps in reducing or eliminating antinutritional and toxic contents present in legumes, thereby improving the seed utilization (Arinola & Adesina, 2014; Devappa & Swamylingappa, 2008). Fermentation has also been reported to cause an increase in nutritional composition especially the protein contents of legumes. For instance, Iyenagbe, Malomo, Idowu, Badejo, and Fagbemi (2017) reported an increase in protein content of fermented conophor nut when compared with the unfermented conophor nut. Thus, the aim of this study was to evaluate the effect of fermented Bambara ground nut flour on the functional, nutritional, and sensory acceptability of croissant.

2 | MATERIALS AND METHODS

2.1 | Materials

White wheat flour and cream coat Bambara groundnut were purchased from a local market at Oja-Oba in Ilorin, Kwara State, Nigeria (8.4799°N longitude, 4.5418°E latitude).

2.2 | Methods

2.2.1 | Preparation of Bambara groundnut flour

Bambara groundnut flour was produced using the method of Arise et al. (2019), with slight modifications. Briefly, Bambara groundnut was sorted and cleaned to be free from foreign materials. The cleaned Bambara was soaked in water for 72 h and allowed to ferment at room temperature ($32 \pm 2^\circ\text{C}$). It was then dehulled by hands to remove the seed coat. The dehulled seeds were oven dried for 3 days at 35°C . The dried seeds were then ground in a Warring laboratory mill blender (HGBTWTS3, Torrington, CT, USA) and sieved through a screen mesh of 355 μm to obtain fine Bambara flour.

2.2.2 | Preparation of flour blends

The flour blends were prepared by mixing wheat flour and fermented Bambara groundnut flour in the following ratio: 5:95% Bambara wheat (BW), 10:90% (BW), 15:85% (BW), 20:80% (BW), and 25:75% (BW), respectively, while 100% wheat flour served as control according to the method described by Arise et al. (2018). The mixing was done for 10 min using a Kenwood laboratory mixer (Kenwood BLX52 model, UK).

2.2.3 | Production of croissants

The croissants were produced using the method of Slavica et al. (2008) with slight alterations. Flour (500 g), sugar (50 g), unsalted butter (60 g), salt (0.6 g), yeast (5 g), and milk (360 ml) were mixed together for 5 min using a mixer to get dough of 800 g. Then, the dough was rolled into a ball and allowed to rest in the freezer for 30 min. The dough was brought out from the freezer and shaped into a rectangular shape, then put into a bowl, covered with aluminum foil, and allowed to rest in the freezer for 4 h. The dough was brought out and laminated to get multiple layers, then brushed lightly with egg wash (milk and egg) and baked in a preheated oven for 15 min at 220°C , and cooled and packaged in a white hermetically sealed transparent polythene bag for further analysis.

2.3 | Determination of the functional properties of wheat-fermented Bambara flour blends

Water absorption capacity (WAC) was determined using the method of Adebowale et al., (2011). A 10 ml of distilled water was added to 1.0 g of the sample in a beaker. The suspension was stirred using a

magnetic stirrer for 5 min. The suspension obtained was thereafter centrifuged at 4,000× *g* for 30 min, and the supernatant was measured in a 10-ml graduated cylinder. The density of water was taken as 1.0 g/cm³. Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant. The same method is used for oil absorption capacity (OAC) is just that the water used for water absorption capacity was replaced with oil for oil absorption capacity.

$$\text{WAC}\% = \frac{\text{Volume of water used} - \text{volume of free water}}{\text{weight of sample used}} \times 100. \quad (1)$$

Swelling capacity was determined using the method described by Adebawale, Adegoke, Sanni, Adegunwa, and Fetuga (2012) with slight modifications. Briefly, 2 g of the sample was weighed and poured into a measuring cylinder, and the initial value was noted, 25 ml of distilled water was added, and the solution was vigorously shaken and left for 30 min, 1 h, and 2 h for the samples to absorb water and swell up. Then the weight of the swelled sample was taken. The percentage of the swelling index was calculated as

$$\% \text{swelling} = \frac{\text{weight of swelled sample} \times 100}{\text{initial weight sample}}. \quad (2)$$

Bulk density of the flour sample was determined by the method of Arise et al. (2019). Briefly, previously weighed measuring cylinder was filled to the 10-ml mark with the sample. The bottom of the cylinder was tapped gently but repeatedly on a laboratory bench until there was no further absorption of the sample level at the 10-ml mark. The cylinder with the sample was weighed. The bulk density of the samples was determined by

$$\text{Bulk density} \left(\frac{\text{g}}{\text{cm}^3} \right) = \frac{W2 - W1}{V}, \quad (3)$$

where

W1 = Weight of empty cylinder (g)

W2 = Weight of cylinder + sample (g)

V = Volume of cylinder occupied by the sample (cm³).

2.4 | Pasting properties of the flour blends of wheat flour and Bambara groundnut flour

The pasting properties of flour samples were determined using RVA (Starch master 2, Newport Scientific Pvt. Ltd., Warriewood, Australia) according to the previously described method by Arise et al. (2018). Briefly, 65 g of the substituted flours were homogeneously dispersed in 450-ml distilled water. The suspension was heated from 30°C to 95°C (at 1.5°C/min), kept at 95°C for 15 min, and cooled to 50°C (at 1.5°C/min). Finally, the paste was held at 50°C for 15 min. Gelatinization and peak temperatures, peak, and final viscosities were determined by the RVA. Ease of cooking, gelatinization index, setback, and stability of the starch were calculated from peak, breakdown, and final viscosities.

2.5 | Proximate analysis of the croissant samples

Ash, fat, and moisture content were determined using AOAC methods (AOAC, 2000). The protein content was determined by Kjeldahl method ($N \times 6.25$). Total carbohydrate was calculated by difference as expressed below:

$$\text{Carbohydrate} = 100 - (\text{Moisture} + \text{Ash} + \text{Fat} + \text{Fibre} + \text{Protein}). \quad (4)$$

2.6 | Physical characteristics of the croissant sample

The physical characteristics of croissant samples such as loaf weight, loaf volume, specific loaf volume, and color were determined using the method of Makinde and Akinoso (2014). Loaf weight was measured 30 min after the loaves were removed from the oven using a laboratory scale (CE-410I, Camry Emperors, China), and the readings were recorded in grams. Loaf volume was measured using the rapeseed displacement method (however, sorghum was used to replace rapeseed here). A box of fixed dimensions (23.00 × 14.30 × 17.00 cm) of internal volume 5,591.30 cm³ was put in a tray, half filled with sorghum grains, shaken vigorously four times, then filled till slightly overfilled so that overfilled fell into the tray. The box was shaken again twice, and a straight edge was used to press across the top of the box once to give a level surface. The seeds were decanted from the box into a receptacle and weighed. The procedure was repeated three times, and the mean value for seed weight was noted (*Cg*). A weighed loaf was placed in the box, and weighed seeds (3,500 g) were used to fill the box and leveled off as before. The overspill was weighed, and from the weight obtained, the weight of seeds around the loaf and volume of seed displaced by the loaf were calculated using the following equations:

$$\text{Seeds displaced by loaf (L)} = Cg + \text{overspill weight} - 3,500 \text{ g} \dots \dots \dots (5)$$

The specific loaf volume was determined by dividing the loaf volume by its corresponding loaf weight (cm³/g).

2.7 | Color measurement

Color measurement of the crust and crumbs was carried out using color flex (A60-1014-593; Hunter Associates Laboratory, Reston, VA, USA) on the basis of lightness (*L**), red-green (*a**), and yellow-blue (*b**) values. Wheat flour was used as reference. The instrument was calibrated against white and black color tiles before color measurement.

2.8 | Determination of the amino acid content

Amino acid content was determined using Pico-Tag method (Bidlingmeyer, Cohen, & Tarvin, 1984). Briefly, the known (2.0 g) sample was hydrolysed, evaporated in a rotary evaporator, and loaded into Technicon Sequential Multi-Sample Amino Acid Analyser (TSM-1) (Technicon Instruments Corporation, New York, USA). A 10 µl of each

hydrolysate was dispensed into the cartridge of the analyzer. The analyzer was separated and analyzed free acidic, neutral, and basic amines, which will last for 76 h. Norleucine was employed as the internal standard. A 10 µl of the standard solution mixture of the amino acid was also loaded into the analyzer. Values of both the standard and samples were recorded and printed out as chromatogram peaks by the chart recorder.

Calculation from the peaks: The net height of each peak produced on the chromatogram (each representing amino acid) was measured. The half-height of each peak was located, and the width of the peak at half-height will accurately be measured. Approximate area of each peak was then obtained by multiplying the height with the width of the half height. All measurement was in millimeter (mm). The norleucine equivalent (NE) for each amino acid in the standard mixture was calculated as

$$NE = \frac{\text{Area of neulocine peak}}{\text{Area of each amino acid in the standard mixture}} \quad (6)$$

2.9 | Sensory evaluation

Sensory evaluation of croissant was conducted. A 50-member panel of semi-trained judges (average age of 30 years comprising of 25 female and 25 male) consisting of students and lecturers from the University of Ilorin was employed for this sensory exercise (Gargi Ghoshal & Mehta, 2019; Ghoshal, Shivhare, & Banerjee, 2016). A 9-point hedonic scale was used. The scale ranged from like *extremely* (9) to *dislike extremely* (1). Each of the samples was rated for appearance, color, texture, aroma, flavor, and general acceptability.

2.10 | Statistical analysis

Triplicate values were obtained for all the analyses. The means and standard deviations of all the analyses were thus calculated. The results were subjected to analysis of variance using statistical package for social science (SPSS), whereas means were separated using Duncan Multiple Range Test (DMRT) at $p < .05$.

3 | RESULTS AND DISCUSSION

3.1 | Proximate composition of croissant produced from wheat Bambara flour

Protein, carbohydrate, and fat are the major components of croissant (Table 1). The results revealed that there was an increase in moisture content from 6.08–6.15%, ash 3.08–3.42%, crude fiber 0.38–0.45%, fat content 12.15–14.69%, crude protein 13.10–16.00%, and a decrease in carbohydrate content 65.12–59.09%. These results are similar to the findings of Makinde and Akinoso (2014) in which the authors reported an increase in moisture, ash, fiber, fat, and protein contents when sesame seed flour was added to wheat flour for bread production. The increase in protein content is expected because Bambara groundnut is a good source of protein whose protein ranges from 16% to 27%. Also, fermentation has been reported to lead to an increase in protein content (Arise, 2016). The low carbohydrate is also expected because carbohydrate is calculated by difference; therefore, the increase in protein content would cause a decrease in the carbohydrate content. The increase in fat content could be due to the butter that was added to the croissant during production. The final product is thus expected to reduce the issues of PEM and found recommended during dietary intervention of PEM reduction, because their protein contents are higher than the 10% globally recommended (FAO/WHO, 2003) for the young infant and children.

3.2 | Functional properties of wheat-fermented Bambara groundnut flour blends

The WAC and bulk density increased with an increased addition of Bambara flour (Table 2). On the contrary, a decrease in OAC and swelling capacity was observed with an increase in fermented Bambara groundnut inclusion. The increase in WAC and decrease in OAC of the flour blends can be attributed to the presence of higher amount of hydrophilic amino acid in Bambara groundnut (Table 5), thereby absorbing more water (Arise, Dauda, Awolola, & Akinlolu-ojo, 2017; Arise et al., 2018). This result agreed with the findings of Ajatta, Akinola, and Osundahunsi (2016). The authors reported an increase in WAC and bulk density (240–275% and 0.82–0.85 g/ml, respectively)

TABLE 1 Proximate composition of the croissants produced from wheat-fermented Bambara flour blends

Sample	Moisture (%)	Ash (%)	Crude fiber (%)	Crude fat (%)	Crude protein (%)	Carbohydrate (%)
Control (W-100)	9.08 ^b ± 0.12	3.09 ^a ± 0.51	0.37 ^b ± 0.34	12.14 ^c ± 0.13	11.09 ^e ± 0.50	64.23 ^a ± 0.24
W-95/FB-5	9.15 ^b ± 0.51	3.21 ^a ± 0.44	0.38 ^b ± 0.41	12.66 ^c ± 0.41	11.95 ^e ± 0.64	62.65 ^b ± 0.20
W-90/FB-10	9.32 ^b ± 0.42	3.29 ^a ± 0.12	0.39 ^b ± 0.23	13.93 ^b ± 0.14	12.71 ^d ± 0.41	60.36 ^c ± 0.61
W-85/FB-15	9.50 ^b ± 0.10	3.35 ^a ± 0.21	0.41 ^a ± 0.31	14.04 ^a ± 0.10	13.10 ^c ± 0.33	59.60 ^c ± 1.00
W-80/FB-20	10.35 ^a ± 0.21	3.43 ^a ± 0.31	0.41 ^a ± 0.21	14.53 ^a ± 0.13	14.35 ^b ± 0.12	56.93 ^d ± 0.11
W-75/FB-25	10.95 ^a ± 0.33	3.65 ^a ± 0.40	0.44 ^a ± 0.10	14.69 ^a ± 0.11	15.07 ^a ± 0.51	55.20 ^d ± 0.40

Note: Sample codes represent percent (%) levels of wheat (W) and fermented Bambara (FB) in flour blends, with control as 100% wheat. Mean ± SD. Means with the same superscript within the same column are not significantly different (DMR test, $p < .05$). Mean ± SD. Means with the same superscript within the same column are not significantly different (DMR test, $p < 0.05$)

TABLE 2 Functional properties of wheat-fermented Bambara groundnut flour blends

Sample	Water absorption capacity (%)	Oil absorption capacity (%)	Bulk density (g/cm ³)	Swelling capacity (%)
Control (W-100)	81.23 ^c ± 0.61	70.56 ^a ± 0.60	0.81 ^e ± 0.10	0.75 ^a ± 0.71
W-95/FB-5	86.12 ^b ± 0.34	65.77 ^b ± 0.31	0.83 ^d ± 0.11	0.65 ^b ± 0.83
W-90/FB-10	86.67 ^b ± 1.02	65.19 ^b ± 0.54	0.93 ^d ± 0.22	0.55 ^c ± 0.62
W-85/FB-15	87.86 ^b ± 0.63	64.58 ^b ± 0.63	1.05 ^c ± 0.31	0.50 ^c ± 0.11
W-80/FB-20	91.51 ^a ± 0.21	64.53 ^b ± 0.52	1.07 ^b ± 0.41	0.45 ^d ± 0.32
W-75/FB-25	92.69 ^a ± 0.21	63.40 ^b ± 0.51	1.20 ^a ± 0.13	0.40 ^d ± 0.71

Note: Sample codes represent percent (%) levels of wheat (W) and fermented Bambara (FB) in flour blends, with control as 100% wheat. Mean ± SD. Means with the same superscript within the same column are not significantly different (DMR test, $p < 0.05$).

when bread fruit was incorporated into wheat for composite flour production. Also when Bambara groundnut flour was added to maize for abari production, an increase in water absorption (1.6–1.8 g/ml) and bulk density (0.84–0.99 g/ml) was observed (Arise et al., 2019).

3.3 | Pasting properties of the flour blends

Pasting properties of a food can be defined as the changes that occur in the food (especially starch) due to the application of heat in the presence of water; such changes affect texture, digestibility, and end use of the food product (Ocheme, Adedeji, Chinma, Yakubu, & Ajibo, 2018). In this study, there was a decrease in peak viscosity, breakdown viscosity, final viscosity (FV), trough, and peak time with an increase in addition of Bambara groundnut flour (Table 3). On the contrary, there was an increase in setback viscosity and pasting temperature with an increase in addition of Bambara groundnut flour.

Peak viscosity reduced significantly ($p < .05$) from 3,287 to 3,209 RVU with an increase in Bambara groundnut flour addition. The peak viscosity indicates the viscous load likely to be encountered during mixing; however, past study had reported higher peak viscosity to result in higher swelling index (Olapade, Babalola, & Aworh, 2014). Reduction in peak viscosity could be due to the reduction in starch

content, because wheat flour has more starch than Bambara groundnut flour. It could also be due to the interactions between the starch, fat, and protein contents of the blends. More so, peak viscosity has correlation with water binding ability of starch, which takes place at equilibrium point between swelling leading to an increase in viscosity, while reduction is caused by rupturing and realignment (Ocheme et al., 2018).

The break down viscosities and the indicators of paste stability (Akanbi, Nazamid, & Adebawale, 2009) of the flour blends ranged from 1,139 Control (W-100) to 1,081 RVU (sample W-75/FB-25). The low breakdown viscosity of the flour blends indicates their ability to withstand breakdown during heating and shearing. High breakdown viscosity of flour may reduce its ability to withstand heating and shear stress during cooking (Ocheme et al., 2018).

The setback values of the flour blends ranged from 1,234 ± 5.66 RVU to 1380.50 ± 10.61. Setback viscosity indicates gel stability and potential for retrogradation. This probably suggests that the dough would have higher resistance to retrogradation while the syneresis effect may be reduced (Akinwale, Shittu, Adebawale, Adewuyi, & Abass, 2017).

The FV indicates the re-association of starch granules especially amylose during cooling time after gelatinization. The lower FV observed with the increase in the addition of Bambara flour to the

TABLE 3 Pasting characteristics of wheat-fermented Bambara flour blends

Sample	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak time (min)	Pasting temperature (°C)
Control (W-100)	3287 ^a ± 0.31	2189 ^a ± 0.71	1139 ^a ± 0.51	3570 ^a ± 0.51	1380 ^a ± 0.61	6.23 ^a ± 0.11	68.40 ^c ± 0.10
W-95/FB-5	3216 ^a ± 0.53	2100 ^b ± 0.12	1156 ^a ± 0.71	3462 ^b ± 0.20	1362 ^a ± 0.31	6.17 ^{ab} ± 0.12	68.74 ^{bc} ± 0.14
W-90/FB-10	3205 ^a ± 0.20	2116 ^a ± 0.41	1078 ^a ± 0.50	3400 ^b ± 0.31	1346 ^a ± 0.62	6.12 ^b ± 0.21	69.28 ^b ± 0.13
W-85/FB-15	3209 ^a ± 0.34	2067 ^b ± 1.00	1086 ^a ± 0.54	3373 ^c ± 0.31	1295 ^b ± 0.31	6.07 ^{bc} ± 0.21	69.30 ^b ± 0.51
W-80/FB-20	3204 ^a ± 0.43	2054 ^b ± 0.61	1071 ^a ± 0.42	3368 ^c ± 0.60	1225 ^b ± 0.80	5.97 ^{cd} ± 0.11	69.34 ^b ± 0.73
W-75/FB-25	3209 ^a ± 0.52	2006 ^b ± 0.81	1081 ^a ± 0.41	3115 ^d ± 0.81	1234 ^b ± 0.61	5.90 ^d ± 0.14	71.38 ^a ± 0.62

Note: Sample codes represent percent (%) levels of wheat (W) and fermented Bambara (FB) in flour blends, with control as 100% wheat. Mean ± SD. Means with the same superscript within the same column are not significantly different (DMR test, $p < .05$).

TABLE 5 Amino acid (g/100 g protein) composition of croissants

Amino acid (g/100 g protein)	Control (W-100)	W-90/FB-10
Essential amino acids		
Leucine	6.19 ± 0.08	7.59 ± 0.01
Lysine	3.45 ± 1.02	4.56 ± 0.09
Isoleucine	3.61 ± 1.03	4.22 ± 0.04
Histidine	1.85 ± 0.01	2.01 ± 1.04
Tryptophan	0.84 ± 1.04	0.97 ± 0.08
Valine	3.63 ± 0.06	4.03 ± 0.03
Methionine	1.26 ± 0.02	1.28 ± 1.18
Phenylalanine	4.01 ± 1.0	3.90 ± 0.06
Threonine	3.22 ± 1.02	4.00 ± 0.06
TEAA	24.05 (g/100 g protein)	28.66 (g/100 g protein)
Nonessential amino acids		
Tyrosine	2.93 ± 1.01	3.44 ± 1.05
Cysteine	0.97 ± 1.12	1.21 ± 1.21
Alanine	0.83 ± 0.04	1.76 ± 0.01
Glutamic acid	9.92 ± 1.12	10.60 ± 1.03
Glycine	3.80 ± 0.14	4.00 ± 0.06
Arginine	5.16 ± 0.06	6.02 ± 1.05
Aspartic acid	6.64 ± 0.01	8.03 ± 0.01
Serine	3.67 ± 0.01	3.21 ± 0.02
Proline	3.05 ± 0.74	3.25 ± 0.23
TNEA	36.97 (g/100 g protein)	41.52 (g/100 g protein)
Hydrophilic amino acids	14.59	15.86
Hydrophobic amino acids	22.58	26.03
Acidic amino acids	16.56	18.63
Basic amino acids	10.46	12.59

Note: Sample codes represent percent (%) levels of wheat (W) and fermented Bambara (FB) in flour blends, with control as 100% wheat.

Abbreviations: TEAA, total essential amino acids = Leucine + Lysine + Isoleucine + Phenylalanine + Tryptophan + Valine + Methionine + Histidine + Threonine; TNEA, total non-essential amino acids = Tyrosine + Cysteine + Alanine + Glutamic acid + Glycine + Aspartic acid + Serine + Proline + Arginine. Hydrophobic amino acids = Methionine + Alanine + Valine + Leucine + Isoleucine + Proline + Phenylalanine. Hydrophilic amino acids = Glycine + Tyrosine + Serine + Threonine + cysteine. Basic amino acids = Lysine + Histidine + Arginine. Acidic amino acids = Glutamic acid + Aspartic acid.

flour blends indicates the ability of the flour to form a viscous paste or gel after cooking and cooling, as well as the resistance of the paste to shear stress during stirring (Arise et al., 2018).

Trough viscosity is the maximum viscosity at the constant temperature of the RVA profile and the ability of the paste to withstand breakdown during cooling (Arise et al., 2018). The increase in inclusion of Bambara groundnut flour to cause a decrease in the trough viscosity implied that the blends might not maintain high paste stability during cooking.

TABLE 4 Physical characteristics of croissant produced from wheat-fermented Bambara flour blends

Sample	Loaf weight (g)	Loaf volume (cm ³)	Specific volume (cm ³ /kg)
Control (W-100)	57.50 ^d ± 0.71	250.50 ^a ± 0.70	4.40 ^a ± 0.11
W-95/FB-5	60.50 ^c ± 0.74	225.50 ^b ± 0.64	3.76 ^b ± 0.20
W-90/FB-10	64.50 ^c ± 0.91	220.50 ^b ± 0.72	3.45 ^b ± 0.33
W-85/FB-15	67.50 ^c ± 0.62	217.50 ^c ± 0.50	3.25 ^b ± 0.44
W-80/FB-20	71.50 ^b ± 0.50	215.50 ^c ± 0.63	3.04 ^b ± 0.11
W-75/FB-25	75.50 ^a ± 0.10	210.50 ^c ± 0.71	2.77 ^a ± 0.20

Note: Sample codes represent percent (%) levels of wheat (W) and fermented Bambara (FB) in flour blends, with control as 100% wheat. Mean ± SD. Means with the same superscript within the same column are not significantly different (DMR test, $p < .05$).

The time it takes for peak viscosity to occur in minutes is referred to as peak time (Adebowale, Sanni, & Awonorin, 2005). The peak time of the flour blends in this study ranged from 5.90 to 6.23 min. The peak time was highest in the control sample (6.2 min) when compared with the blends. Low peak time observed in the flour blends may be attributed to the reduced starch content as a result of Bambara groundnut flour substitution. Ajatta et al. (2016) reported a decrease in peak time (6.04–5.45 min) upon the substitution of breadfruit flour with wheat flour. However, low peak time is indicative of its ability to cook fast, which is an added advantage (Ajatta et al., 2016).

The pasting temperature of flour samples ranged from 68.40°C to 71.38°C. The ability of starch to imbibe water and swell is primarily dependent on the pasting temperature. Previous work affirmed that the higher the pasting temperature, the faster the tendency for a paste to be formed (Adebowale, Sanni, & Fadahunsi, 2011). The pasting temperature also indicates the minimum temperature required to cook or gelatinize the flour (Arise, Dauda, et al., 2017; Arise et al., 2018).

The inclusion of fermented Bambara groundnut flour to wheat flour affected some pasting properties of the flour blends. The onset of gelatinization occurred faster for flours with a high inclusion level of fermented Bambara, and retrogradation decreased as levels of Bambara groundnut flour increased. The behavior in pasting characteristics among starches could be due to differences in amylose content, crystallinity, and the presence or absence of amylose–lipid interaction (Mune Mune & Sogi, 2015). The results obtained in this study are similar to the findings of other authors. For instance, when Bambara flour was incorporated to wheat and plantain flour for cookies production, the peak and FV decreased (from 2,606 to 2,226 RVU and from 3,026 to 2,290 RVU, respectively) with an increased level of Bambara flour in wheat Bambara flour blend (Arise, Dauda, et al., 2017). In the same vein, when Bambara flour was added to

maize to produce maize flour, final and peak viscosity also decreased (Arise et al., 2018).

3.4 | Physical characteristics of the croissant

Loaf weight was observed to increase with an increase in the level of wheat Bambara flour blends as shown in Table 4. On the contrary, there was a decrease in loaf volume and specific volume. This result is similar to the increase in loaf weight and decrease in loaf volume and specific volume upon the addition of plantain and Bambara groundnut flour (Kiin-Kabari, Eke-Ejiofor, and Giami, 2015), sesame seed flour (Makinde and Akinoso, 2014), and African oil bean flour (Nwosu, Elochukwu, and Onwurah, 2014) to wheat flour, respectively. They observed the increase in the weight of the croissant samples could be attributed to increased moisture absorption (Table 1) and less retention of carbon dioxide gas in the blended dough, resulting in heavy dough and loaves (Yusufu, Abu, Igyor, Chinma, & Onuh, 2017; Yusufu & Ejeh, 2018). Meanwhile, the decrease in loaf volume and specific volume is probably due to the reduction in wheat gluten protein of the various samples. The flour with higher gluten content would possess higher ability to extend and retain the carbon dioxide produced during fermentation thereby yielding a higher loaf volume (Kiin-Kabari et al., 2015).

3.5 | Color attributes of croissant samples produced from wheat-fermented Bambara flour blends

There was an increase in whiteness (L^*) and a decrease in redness (a^*) and yellowness (b^*) of the croissant samples with increased addition in the level of Bambara groundnut flour (data not shown). The color became darker as the level of Bambara groundnut flour increased because of the Maillard browning and caramelization reactions between wheat proteins and the added sugar, which are influenced by the distribution of water (Makinde & Akinoso, 2014). Color of products is one of the factors that determine the acceptability of products. Previous work (Makinde and Akinoso, 2014) had shown that surface color depends both on the physico-chemical characteristics of the raw dough (i.e., water content, pH, reducing sugars, and amino acid content) and on the operating conditions

applied during baking (i.e., temperature, air speed, relative humidity, and modes of heat transfer). The Maillard or caramelized browns are also found to be a good source of antioxidants (phenols), which have been attributed with good physiological needs in managing diverse chronic diseases.

This result is similar to that of Eissa, Hussein, and Mostafa (2007), who produced biscuit and bread from wheat flour and un-germinated and germinated legume seeds of mushroom, and in the same vein, Makinde and Akinoso (2014) also reported similar result when bread was produced from wheat flour and black sesame flours.

3.6 | Amino acid composition of the croissant

Nutritional quality of protein depends on its EAA. The amino acid composition of two samples of the croissant is shown in Table 5. The result revealed that there was an increase in almost all of the amino acid composition in sample W-90/FB-10 (90% wheat and 10% Bambara) than control (W-100). There was a significant increase in EAAs (such as lysine, leucine, isoleucine, tryptophan, arginine, threonine, valine, histidine, phenylalanine, tyrosine, and methionine) found in sample W-90/FB-10 (90% wheat and 10% Bambara) than the control sample (100% wheat). Although glutamic acid and aspartic acid also increased, there was a decrease in serine. The increase in the amino acid profile of wheat Bambara flour blends is due to the high quality of protein present in Bambara flour, because legumes are protein-rich crops and have higher amino-acid composition than cereals. The high lysine content of the Bambara groundnut protein is a very important nutritional attribute that makes the legume a good supplementary protein to cereals with known deficiency in lysine (Adebawale et al., 2011; Arise, 2016; Arise, Dauda, et al., 2017). In addition, the hydrophobic amino acids are higher in sample that contained 10% Bambara (W-90/FB-10) than in sample that contained 100% wheat (W-100). This could be an added advantage as this croissant sample could be eaten as a functional food. Arise et al. (2016) reported that the hydrophobic amino acids act as antioxidants by increasing the solubility of peptides in lipids, which then facilitates better interaction with free radicals. It is also worthwhile knowing that other parameters such as hydrophilic, acidic, and basic amino acids also increased with inclusion of Bambara flour. Therefore, incorporation of fermented Bambara flour into wheat improved the protein quality of croissant snacks as

TABLE 6 Sensory evaluation of the croissant

Sample	Appearance	Color	Taste	Texture	Aroma	Overall acceptability
Control (W-100)	7.21 ^a ± 0.20	7.23 ^a 1.04	6.03 ^c ± 1.39	6.38 ^b ± 1.27	6.38 ^{ab} ± 1.18	6.67 ^b ± 1.34
W-95/FB-5	7.38 ^a ± 1.04	6.97 ^a ± 0.78	7.10 ^a ± 1.17	7.21 ^a ± 1.08	6.82 ^a ± 0.94	7.38 ^a ± 1.14
W-90/FB-10	7.03 ^a ± 0.17	6.85 ^a ± 1.01	6.77 ^{ab} ± 1.14	6.92 ^{ab} ± 1.04	6.51 ^{ab} ± 1.07	7.45 ^a ± 0.90
W-85/FB-15	6.95 ^a ± 0.97	6.92 ^a ± 1.11	6.21 ^{bc} ± 1.45	6.67 ^{ab} ± 1.42	6.26 ^{ab} ± 1.23	6.85 ^b ± 1.20
W-80/FB-20	7.03 ^a ± 1.11	6.79 ^a ± 1.08	5.90 ^c ± 1.52	6.33 ^b ± 1.22	6.0 ^b ± 1.56	6.41 ^b ± 1.33
W-75/FB-25	7.26 ^a ± 1.02	7.23 ^a 1.04	6.41 ^{bc} ± 1.31	6.90 ^{ab} ± 1.17	6.74 ^a ± 1.3	7.10 ^a ± 1.07

Note: Sample codes represent percent (%) levels of wheat (W) and fermented Bambara (FB) in flour blends, with control as 100% wheat. Mean ± SD. Means with the same superscript within the same column are not significantly different (DMR test, $p < .05$).

well as producing a potential functional food that could found applicable in human health (like high BP and diabetic) management.

3.7 | Sensory evaluation of the croissant

Interestingly, the sensory evaluation results revealed that the panelists generally accepted all the samples with fermented Bambara groundnut inclusion (Table 6) even more than the control (W-100) except for sample W-80/FB-20 (80% wheat and 20% fermented Bambara). The addition of fermented Bambara groundnut makes the croissant to be more appealing and attractive. This current result is in line with the report on other food products like maize pudding (Arise et al., 2019) and maize snacks (Arise et al., 2018) that had substituted Bambara groundnut in their composition.

4 | CONCLUSION

The study showed that croissant of acceptable quality and higher nutritional value could be produced from blends of wheat and fermented Bambara groundnut flours. The inclusion of fermented Bambara groundnut in production of croissant snack will help in combating the problem of PEM commonly associated with growing children. Besides, value addition to the underutilized Bambara groundnut is greatly achieved in this study as well as enhancing its utilization. Based on the sensory evaluation conducted, sample W-90/FB-10 (90% wheat and 10% fermented Bambara) was found to be the most generally acceptable. Therefore, preparation in agreement with sample W-90/Fb-10 could be recommended as a viable and fortified formulation for croissant snack production.

DATA AVAILABILITY STATEMENT

Data will be made available on request.

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CONFLICT OF INTEREST

None declared.

AUTHOR CONTRIBUTIONS

Arise K. Abimbola designed the experiment, supervised the study, prepared the draft of the manuscript, and served as the corresponding author of the manuscript. Taiwo O. Ganiyat collected and analyzed the data. Malomo A. Sunday thoroughly read and edited the manuscript.

ETHICS STATEMENT

The study proposal was presented within the Departmental Research and Ethical committee and was approved by the Ethical

committee of the Department of Home Economics and Food Science, University of Ilorin, Nigeria. All the panelists were briefly screened for their ability to discern differences in the organoleptic parameters of food substances participant, and they are regular consumers of croissant snacks.

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