RESEARCH ARTICLE

Quality attributes of *abari* (maize pudding) produced from maize and bambara groundnut flour blends

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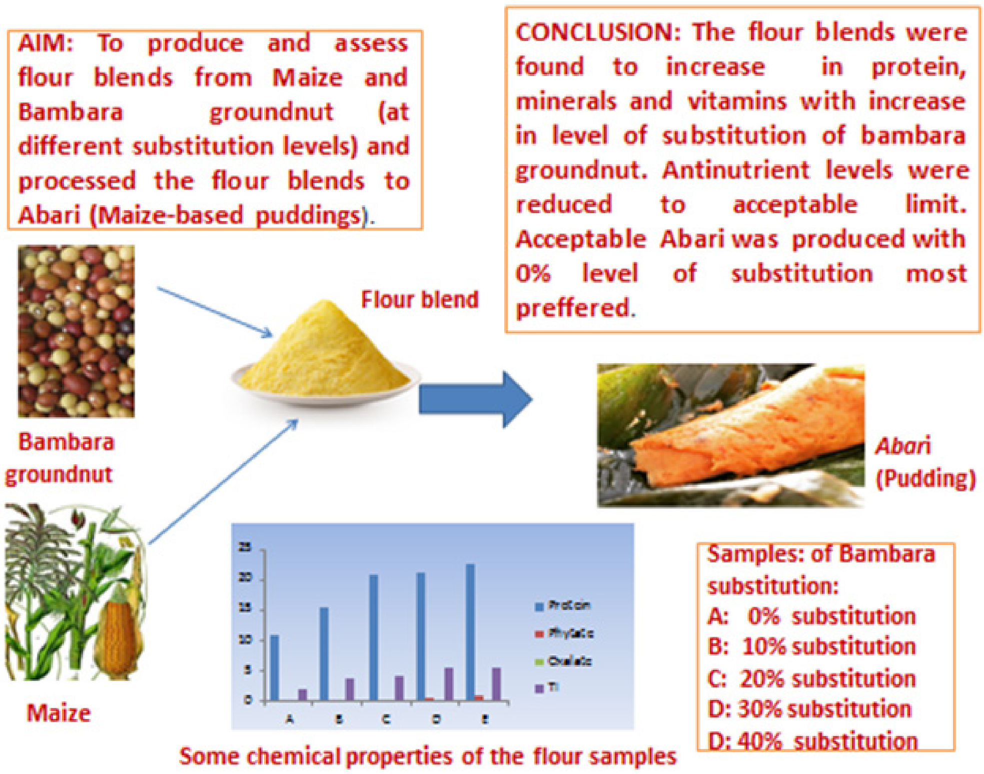

Highlights

- Functional flour blends can be processed from maize and bambara groundnut.
- The flour blends were high in protein, mineral and vitamin.
- The antinutrients in the flours were within the acceptable limit.
- *Abari* (maize pudding) with acceptable sensory attributes was developed.

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Quality attributes of *abari* (maize pudding) produced from maize and bambara groundnut flour blends

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Abstract: This study assessed the chemical and functional properties of maize and bambara flour blends and the sensory qualities of *Abari* made from the blends (100:00, 90:10, 80:20, 70:30, and 60:40 of bambara nut:maize). The blends were analysed for proximate composition, vitamins, minerals, functional and anti-nutritional properties. *Abari* samples were subjected to sensory evaluation. The results indicated a range from 13.20 to 11.73%, 1.67 to 3.50%, 10.74 to 22.42%, 1.07 to 4.48%, 2.15 to 5.27%, and 71.17 to 52.59%, for moisture, ash, protein, fibre, fat and carbohydrate contents respectively. The functional properties ranged from 74.00 to 78.33 mg/100 g, 7.88 to 6.73 mg/100 g, 75.00 to 94.67 mg/100 g, and 0.67 to 0.72 mg/100 g for water absorption capacity, swelling capacity, oil absorption capacity, and bulk density respectively. The vitamins ranged from 0.150 to 0.159 mg/100 g, 0.055 to 0.071 mg/100 g, and 0.112 to 0.063 mg/100g for vitamin B_1, vitamin B_2 and vitamin B_3 respectively. The mineral composition ranged from 13.34 to 15.88 mg/g, 6.45 to 7.46 mg/100 g, 14.10 to 13.76 mg/100 g, 9.86 to 10.42 mg/100 g and 363.00 to 912.00 mg/100 g for iron, magnesium, calcium, potassium, and phosphorus respectively. The *Abari* samples prepared from the blends compared favourably in terms of acceptability with control from 100% maize.

Keywords: Maize; bambara groundnut; *Abari*; composite flour; sensory evaluation.

INTRODUCTION

Maize (*Zea mays*) is a staple food for about 50% of the Sub-Saharan African population (Olaniyan, 2015). It is recognized as the most widely grown cereal in the world and ranks third among major cereal crops after wheat and rice (Farnia *et al*., 2014). It is predominantly composed of starch (60-75%) and is an excellent source of vitamins (including fat soluble vitamin E) and minerals. However, the protein content of maize is very low, constituting only about 9-12%, when compared with other grains (Otunola, *et al*., 2012). It is an important food crop and also one of the most abundant cereals in Nigeria. Its kernels vary in colour (white, yellow, orange, red and black) depending on the environmental conditions and genetic makeup (Bello and Oluwalana, 2017). It can be processed into relatively large number of intermediary products such as maize grist for brewing industry, maize meal and maize flour for food and chemical industries among others. Maize and its food products in the developing countries are known to have a low nutritive value characterized by low protein content, high energy, and bulk density. The protein contents of cereal such as maize are low in relevant amino acids like lysine and tryptophan which are indispensable for growth especially in children. Maize has a multitude of uses and ranks second to wheat among the world's cereal crops in terms of production (Abdulrahman, and Kolawole, 2008).

Maize could be cooked or ground in a process called Nixtamalization. It is a major source of corn starch (maize flour), which is a major ingredient in home cooking and in many industrialized food products. Maize is also a major source of cooking oil and gluten. Maize starch can be hydrolyzed and enzymatically treated to produce syrups, a sweetener, which is also fermented and distilled in order to produce grain alcohol. Starch from maize can also be processed into plastics, fabrics, adhesives, and many other chemical products (Karl, 2008). Maize flour, one of the end-products of dry-milling of maize grains, and the food products derivable from the flour have been observedto exhibit variations in their physical, chemical and/or rheological properties due to such factors as maize variety, particle size differential of flour (Bolade *et al*., 2009). However, there are limited research work on the effect of flour production methods, with variation in the unit operations, on the flour properties and textural characteristics of food products prepared from such flour. Mestres *et al.* (2009) investigated the influence of maize flour, produced through the use of disc and hammer mills, on the quality attributes of thick pastes commonly consumed in Benin, a West African country. As a major source of cheap carbohydrate, maize is also a very valuable food crop in the Mediterranean region, the Middle East, and parts of Asia [9]. In Nigeria, maize is further processed into local beverages such as *Burukutu*, *Kunnu* and *Pito*. Snacks such as popcorn, roasted corn, and cooked corn as well as numerous dishes which include Tuwo, Masa, Waina, Ibier, Choko, Mumu, Couscous, Gwate and Ekoki are products from maize. Maize, like other cereals has both domestic and industrial uses. Maize grain can be consumed fresh by

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boiling or roasting. It may also be traditionally processed by wet or dry milling into a variety of food products (Olaniyan, 2015). In the southwestern part of Nigeria, maize is taken as pap (*Ogi*), solid gel (*Eko*), and mashed maize (*Egbo*). It is also processed into snacks like *Donkwa*, Popcorn, *Aadun*, *Kokoro*, and *Elebute* (Olanipekun *et al.,* 2015). Another maize product popularly consumed in the southern part of Nigeria is *Abari*.

Abari is a maize-based pudding consumed mostly in the south-western part of Nigeria (Olanipekun *et al*., 2015). It is known with this name in Ekiti state, but also as *Sapala* in Abeokuta of Ogun State and *Ekpanakpapa* in Efik-speaking part of Nigeria (Olanipekun *et al*., 2015). In the traditional preparation of *Abari*, maize slurry is made and seasoned with pepper, onion, and palm oil. The seasoned slurry is then wrapped in leaves and steamed for about 40–60 min, forming a gel that, in shape, looks like *moimoi* beans pudding (a bean-based pudding). *Abari* is consumed by both adults and children. But just as with other mainly maize based food products, prolonged consumption of *Abari* is associated with protein deficient nutritional status like protein-energy malnutrition (PEM) and kwashiorkor in children. Fortification of *Abari* with a cheap protein-rich food material like bambara groundnut (*Vigna subterranean*) can be a way out. Also, *Abari* is mainly produced from maize paste, this makes its production difficult when maize is not in season.

Bambara groundnut **(***Vigna subterranea***)** is an under-utilized legume mostly grown by the female gender in tropical and sub-tropical areas where it serves as a means of livelihood **(**Adeleke *et al*., 2018**)**. It belongs to *Fabaceae* family under the genus *Vigna***.** Bambara groundnuts varieties are of two types: *V. subterranea var. spontanea* (the wild type) and *V. subterranea var. subterranean* (the domesticated type). The crop takes its name from the bambara tribe in Mali and in the Sahelian provinces of West Africa (Alhassan *et al***.,** 2018). It has been rated as the third most significant pea in West Africa, in terms of its versatility (Alkaya *et al*., 2017). The crop is said to be tolerant to drought, and local research on bambara nut has also confirmed that local varieties of bambara nut are drought tolerant (Berchie *et al*., 2012). The authors went on to suggest that bambara nut may be a suitable crop for cultivation in marginal areas with low rainfall. In addition to its reported drought tolerance, bambara nut seed also makes a complete feed for both humans and animals. The above ground material and by-products of bambara nut can be used as feed ingredients and incorporated in the formulation of animal feeds. Bambara nut can be easily converted to meat which may meet human needs for animal-protein. Bambara nut has nutritional benefits which could improve the level of malnutrition and boost food security. The bambara nut seed is comprised of 63% carbohydrate, 19% protein and 6.5% fat (Chazovachii *et al*., 2013). Other works on the nutritional benefits of bambara nuts obtained from various geographical location revealed similar trends. Adewumi *et al*, (2014) reported bambara nut from the Southeast Nigeria to comprise 2.86% moisture, 32% protein, 7.4% fat, 5.78% ash, 2.68% crude fibre and 53% carbohydrates. In Northern Nigeria, Cutting, (2011) revealed that bambara nut from Kano contained approximately moisture content 13%, ash 3.52%, protein 19%, fat 7%, fibre 6% and carbohydrate 63%. In the North central (Benue State), Didari *et al.,* (2014) reported that bambara nut seeds contain approximately 6% moisture content, 4% ash content, 6% crude fibre, 20% protein content, 6% lipid composition and 56% carbohydrate. Also, commercial bambara nut collected from South-West Nigeria by Doron and Snydman, (2015) revealed to possess moisture content of (7%) protein (18%) fat (6%), ash (4%), crude fiber (4%) and carbohydrate (60%). Bambara seeds are highly proteinous, with malted seeds consisting of ten dissimilar proteins and dry seeds consisting of twelve different proteins (Adewumi et al, 2014). Also, its seeds contain about 15-27% protein, which is high in lysine (6.5–6.8%) and a reasonable amount of methionine (1.8%) normally found limiting in legumes (Arise *et al.*, 2017). Bambara groundnut varieties provide up to 25% protein when compared to other legumes. These sought-after protein levels can be valuable in improving animal feed diets with low protein contents. Bambara groundnut by-products such as bambara groundnut sievate, which is a result of processing bambara groundnut into flour for human use, has undergone adequate research and it was suggested that it can be used in poultry diets and also suitable for human diets (Ijarotimi and Keshinro, 2012). This study therefore assessed the chemical, functional and nutritional properties of maize and bambara nut composite flour, and the sensory qualities of improved *Abari* made from the composite of maize-bambara nut flour blends.

MATERIALS AND METHODS

Maize (*Zea mays*) of the yellow variety and bambara groundnut were sourced from Institute of Agricultural Research and Training (IART), Moor Plantation, Ibadan, Oyo State, Nigeria, and stored in a cool dry place for subsequent use.

Preparation of maize flour

Whole maize grains were dehusked and shelled from the cob. The grains were sorted out from plant debris, stones, and other foreign materials, and washed in water to remove other tiny dirt particles that are present on the grains. The grains were drained and dried at 60 ^{o}C in a hot air oven. The dried maize grains were then milled into flour using a hammer mill.

Bambara groundnut flour preparation

Bambara groundnut were sorted out from plant debris, stones and other foreign materials and then washed to remove other particles from its surface, and soaked in cold water for 12 h, drained, and oven dried at 37 ^{o}C in a hot air oven. The dried bambara groundnut were milled into flour using a hammer mill.

Experimental design for the preparation of *Abari* from maize-bambara flour blends

Formulations of composite flour for production of *Abari* from different combination levels of maize (60-90%) and bambara (10-40%) were generated using Central Composite Design (CCD) of Design Expert.

Production of *Abari* from maize-bambara composite flour

Abari samples were made using the method of Abdulrahaman and Kolawole (2008), with slight modifications. The flour blends (300 g) were mixed and stirred in clean warm water (550 mL) to form a slurry. Groundnut oil (100 mL), onion (15 g) and ground pepper (10 g) were added to the slurry as well as smoked fish (10 g), salt (½ teaspoon) and seasoning (a teaspoon). The slurry was thoroughly stirred to have a homogenized mixture. This was then portioned in small quantities in leaves, wrapped and steamed in a covered pot on a hot plate for 30 min until well cooked.

Proximate, vitamin and mineral compositions of the flour blends

Proximate composition (moisture, protein, ash, fat, crude fibre and carbohydrate) was determined by difference according to the standard methods of Association of Official Analytical Chemists (2005). Selected vitamins (vitamins B_1, B_2 and B_3) and minerals (iron, magnesium, calcium, potassium, and phosphorus) were also determined using the method of AOAC, (2005).

Functional properties of maize-bambara nut composite flours

Water absorption capacity was determined using the method of Mbofung *et al.,* (2006). Swelling capacity was determined according to the method of Onwuka, (2005). Oil absorption capacity was determined by method described by Abulude, (2001), while bulk density was determined using the method described by AOAC (2012).

Anti-nutritional factors of maize-bambara flour blends

Oxalate and phytate were carried out using the method of Leyva *et al*. (1990). Trypsin inhibitor was determined according to the method of AOAC (2005). Cyanide was determined according to the method of Price and Bulter, (1977) with some modifications.

Sensory evaluation

The samples of *Abari* made from maize-bambara nut composite flours were subjected to sensory evaluation for the attributes of crust colour, aroma, appearance, internal texture, taste, and general acceptability. A 20-semi-trained member panel carried out this evaluation, and scores were allocated by the panelists based on a 9-point hedonic scale, ranging from 1 (dislike extremely) to 9 (like extremely).

Statistical analysis

All determinations reported in this study were carried out in triplicates. In each case, a mean value and standard deviation were calculated. Data were subjected to analysis of variance (ANOVA) to determine the statistical significance of the results, and mean values separated using Duncan's New Multiple Range Test at $p<0.05$ significant level using Statistical Package for Social Scientists (SPSS) software version 25.0.

RESULTS

Proximate composition of maize-bambara nut composite flours

The proximate composition of the flour blends of maize and bambara nut is presented in Table 1. Result revealed that moisture content of the flours was within the range of 11.70-13.73% which decreased as level of substitution increased. M90:B10 has the highest moisture content of 13.73% while the lowest (11.70%) was recorded for M60:B40. Ash content ranged from 1.67-4.00%. The result showed that ash content was highest (4.00%) in the M90:B10 sample, while the lowest value of 1.67% was recorded for the whole maize flour. The result for crude protein ranged from 10.74 - 22.42%. M60:B40 sample had the highest crude protein content of 22.42% while whole maize flour had the lowest value of crude protein of 10.7%. The result further revealed that crude protein increased with increased substitution of bambara nut flour for maize flour (from 10-40%) progressively. Crude fibre ranged from 1.01-4.48%. Sample M60:B40 had the highest crude fibre of 4.48% while whole maize flour had the lowest value of crude fibre of 1.01%. The result for crude fat had ranges of 2.15-5.27%. Carbohydrate content ranged of

Table 1: Proximate composition of Maize-Bambara nut composite flours.

Samples	Moisture (%)	Ash (%)	Protein (%)	Fibre (%)	Fat (%)	CHO (%)
M100	$13.20^{b}\pm0.67$	$1.67^{a}\pm0.02$	$10.74^{a}\pm0.02$	$1.07^{a}\pm0.02$	$2.15^{a}\pm0.17$	$71.17^{d}\pm0.60$
M90:B10	$13.70^{d}\pm0.34$	$4.00^{d}\pm0.67$	$15.41^{b}\pm0.13$	$3.08^{b}\pm0.01$	$3.63^{b}\pm0.07$	$60.18^{c}\pm0.07$
M80:B20	$13.60^{c}\pm0.21$	$3.00^{b}\pm0.08$	$20.88^{c}\pm0.11$	$4.18^{c}\pm0.05$	$4.91^{c}\pm0.12$	$53.37^{a}\pm0.22$
M70:B30	$11.93^{a}\pm0.01$	$3.67^{c}\pm0.20$	$20.98^{c}\pm0.09$	$4.20^{cd}\pm0.17$	$4.94^{c}\pm0.15$	$54.29^{b}\pm0.14$
M60:B40	$11.73^{a}\pm0.02$	$3.50^{c}\pm0.31$	$22.42^{d}\pm0.60$	$4.48^{d}\pm0.21$	$5.27^{d}\pm0.30$	$52.59^{a}\pm0.19$

*Values are means ± standard deviations of three replicates of samples.

*Means within the same column with different superscripts are significantly different (p < 0.05).

M100 = 100% whole maize flour; **M90:B10** = 90% Maize flour and 10% Bambara nut flour; **M80:B20** = 80% maize flour and 20% Bambara nut flour; **M70:B30** = 70% maize flour and 30% Bambara nut flour; **M60:B40** = 60% wheat flour and 40% Bambara nut flour.

52.59 - 71.17%. Whole maize had the highest carbohydrate content of 71.17%, while M60:B40 had the lowest value of carbohydrate of 52.59%. The result further revealed that carbohydrate values decreased progressively with increasing substitution of bambara nut flour. The trends could obviously be due to higher content of carbohydrate recorded in whole maize flour compared to whole bambara nut flour. Similar result of carbohydrate content of wheat-bambara nut flour has been reported according to Yusufu and Ejeh, (2018).

Anti-nutritional factors of maize-bambara nut composite flours

The results of anti-nutritional factors of maize-bambara flour blends are presented in Table 2. Phytate content ranged from 0.16 - 0.87%. Sample M60:B40 had the highest value of 0.87%, while the lowest value of 0.16% was recorded for whole maize flour. Similar result of phytate content of wheat-bambara nut flour was reported by Olaoye *et al.,* (2018). Oxalate content was observed to be highest 0.26% in M60:B40 sample, while the lowest value of 0.15% was recorded for whole maize flour. Hence, the concentration of oxalates increased with progressive increase in the percentage substitution of bambara flour in the flour samples. However, a decrease occurred when the percentage substitution of bambara nut flour was 20% for whole maize flour. Similar result of oxalates content of wheat-bambara nut flour has been reported according to Olaoye *et al.,* (2018). Trypsin Inhibitor was highest in M60:B40 having the value of 5.48%, while the lowest value of 1.95% was recorded for whole maize flour. Also, trypsin inhibitor increased with progressive increase in the percentage substitution of bambara flour in the flour samples. Olaoye *et al.,* (2018) observed similar result of trypsin inhibitor of wheat-bambara nut flour. Cyanide content ranged from 0.11 - 0.50%. Highest value 0.50% was recorded for M60:B40 sample, while the lowest value of 0.11% was recorded for whole maize flour. As a result of this, the concentration of cyanide had unstable trend with progressive increase in the percentage substitution of bambara flour in the flour samples.

Mineral composition of maize and bambara groundnut flour blends

The mineral contents of the composite flour samples are presented in Table 3. Iron content ranged from 11.53 - 16.22 mg/100 g, with sample M90:B10 having the highest value (16.22 mg/L), and M80:B20 with the lowest value (11.53 mg/100 g). Magnesium had the highest value of 7.66 mg/100 g for sample M90:B10, while sample M70:B30 had the lowest value of 6.12 mg/L. Calcium ranged between 13.11 - 19.34 mg/l00 g with sample M80:B20 having the highest value of 19.34 mg/100 g, and M70:B30 with the lowest value 13.11 mg/100 g. For Potassium, the

Table 2: Anti-nutritional Factors of Maize-Bambara nut Composite Flours mg/100 g.

Samples	Phytate	Oxalate	Trypsin Inhibitor	Cyanide
M100:0	$0.17^{b}\pm0.01$	$0.15^{a}\pm0.00$	$1.95^{a}\pm0.02$	$0.11^{a}\pm0.00$
M90:B10	$0.16^{a}\pm0.00$	$0.23^{c}\pm0.01$	$3.70^{b}\pm0.01$	$0.40^{c}\pm0.01$
M80:B20	$0.21^{b}\pm0.01$	$0.21^{b}\pm0.00$	$4.02^{c}\pm0.10$	$0.36^{b}\pm0.01$
M70:B30	$0.44^{c}\pm0.01$	$0.24^{c}\pm0.01$	$5.41^{d}\pm0.08$	$0.38^{b}\pm0.01$
M60:B40	$0.87^{d}\pm0.02$	$0.26^{d}\pm0.01$	$5.48^{d}\pm0.11$	$0.50^{d}\pm0.02$

*Values are means ± standard deviations of three replicates of samples.

*Means within the same column with different superscripts are significantly different (p<0.05).

M100 = 100% whole maize flour; **M90:B10** = 90% Maize flour and 10% Bambara nut flour; **M80:B20** = 80% maize flour and 20% Bambara nut flour; **M70:B30** = 70% maize flour and 30% Bambara nut flour; **M60:B40** = 60% wheat flour and 40% Bambara nut flour.

Table 3: Mineral Composition of Maize-Bambara nut Composite Flours.

Samples	Fe (mg/100 g)	Mg (mg/100 g)	Ca (mg/100 g)	K (mg/100 g)	P (mg/100 g)
M100	$13.34^{b}\pm0.67$	$6.45^{ab}\pm0.21$	$14.10^{b}\pm0.20$	$9.86^{b}\pm0.60$	$363.00^{a}\pm1.61$
M90:B10	$16.22^{c}\pm0.34$	$7.66^{d}\pm0.54$	$18.56^{c}\pm1.17$	$11.56^{d}\pm0.43$	$426.67^{b}\pm2.37$
M80:B20	$11.53^{a}\pm0.28$	$6.32^{ab}\pm0.26$	$19.34^{d}\pm1.09$	$9.22^{b}\pm0.87$	$493.33^{bc}\pm1.12$
M70:B30	$14.54^{bc}\pm0.90$	$6.12^{a}\pm0.19$	$13.11^{a}\pm0.87$	$6.79^{a}\pm0.22$	$816.33^{c}\pm2.54$
M60:B40	$15.88^{bc}\pm0.78$	$7.46^{c}\pm0.71$	$13.76^{a}\pm0.36$	$10.42^{c}\pm1.00$	$912.00^{d}\pm2.23$

*Values are means ± standard deviations of three replicates of samples.

*Means within the same column with different superscripts are significantly different (p<0.05).

M100 = 100% whole maize flour; **M90:B10** = 90% Maize flour and 10% Bambara nut flour; **M80:B20** = 80% maize flour and 20% Bambara nut flour; **M70:B30** = 70% maize flour and 30% Bambara nut flour; **M60:B40** = 60% wheat flour and 40% Bambara nut flour.

trend was similar to what was recorded for magnesium. Potassium had the highest value of 11.56 mg/100 g for sample M90:B10. This was followed by M60:B40 with the value of 10.42 mg/l00 g, and M70:B30 having the lowest value of 6.79 mg/100 g. Phosphorus value ranged from 363.00 - 912.00 mg/100 g. Sample M60:B40 was observed to be the highest (912.00 mg/L), while whole maize flour sample had the lowest phosphorus value of 363mg/L There was significant increase of phosphorus with increase substitution of bambara nut flour.

Vitamin composition of maize and bambara groundnut flour sample

The vitamins composition of the flour samples is presented in Table 4 below. For vitamin $B_{1,}$ the highest value (0.170 mg/100 g) was found in M70:B30 samples, while whole maize flour had the lowest value (0.150 mg/100 g). There was increase in vitamin B_1 content with increased level of bambara nut substitution but decreased at 40% bambara nut substitution. Vitamin B_2 showed unstable increasing trend with increase incorporation of bambara nut flour. The result showed that sample M60:B40 had the highest value of (0.071 mg/100 g), while M80:B20 sample had the lowest (0.051 mg/100 g). For Vitamin B_3, the result showed that sample M80:B20 had the highest result (0.171 mg/100 g), while M60:B40 sample had the lowest (0.063mg/100 g).

Functional properties of maize-bambara nut composite flours

The results of functional properties of maize and bambara nut flour blends are shown in Table 5. The result revealed that M60:B40 sample had the highest value of water absorption capacity (78.33%), followed by whole maize flour sample which had a value of (74%), and the lowest value (70%) was recorded for sample M90:B10. Generally, there was reduction in the water absorption capacity of the flour samples as percentage substitution of bambara nut flour increased. The result correlated with the findings of Yusufu and Ejeh, (2018) on functional properties of wheat-bambara nut flour where it was reported that 60% wheat flour with 40% Substituted bambara nut has the highest water absorption capacity. Swelling capacity was highest in M80:B20 sample having a value of 8.09%, while the lowest value of 6.73% was obtained for M60:B40 sample. The result negates the findings of Olaoye *et al.,* (2018) on functional properties of wheat-bambara nut flour where it was reported that 95% wheat flour with 5% Substituted bambara nut has the highest swelling capacity. The result indicated that there was progressive increase in the oil absorption capacity of the flour samples as percentage substitutions of bambara nut flour were increased. However, M80:B20 had the highest value of 118.33%, while whole maize flour had the lowest value (75%). The result

Table 4: Vitamin composition of maize-bambara nut composite flours.

Samples	Vitamin B_1 (mg/100 g)	Vitamin B_2 (mg/100 g)	Vitamin B_3 (mg/100 g)
M100	$0.150^{a}\pm0.01$	$0.055^{a}\pm0.00$	$0.112^{b}\pm0.00$
M90:B10	$0.154^{a}\pm0.00$	$0.059^{a}\pm0.00$	$0.097^{ab}\pm0.00$
M80:B20	$0.162^{b}\pm0.01$	$0.051^{a}\pm0.00$	$0.171^{c}\pm0.01$
M70:B30	$0.170^{c}\pm0.01$	$0.060^{b}\pm0.00$	$0.066^{a}\pm0.00$
M60:B40	$0.159^{a}\pm0.01$	$0.071^{c}\pm0.00$	$0.063^{a}\pm0.00$

*Values are means ± standard deviations of three replicates of samples.

*Means within the same column with different superscripts are significantly different ($p<0.05$).

M100 = 100% whole maize flour; **M90:B10** = 90% Maize flour and 10% Bambara nut flour; **M80:B20** = 80% maize flour and 20% Bambara nut flour; **M70:B30** = 70% maize flour and 30% Bambara nut flour; **M60:B40** = 60% wheat flour and 40% Bambara nut flour.

Table 5: Functional Properties of Maize-Bambara nut Composite Flours (%).

Samples	Water absorption Capacity	Swelling Capacity	Oil Absorption Capacity	Bulk Density
M 100	$74.00^{b}\pm1.37$	$7.88^{b}\pm0.57$	$75.00^{a}\pm1.67$	$0.67^{b}\pm0.17$
M90:B10	$70.00^{a}\pm1.21$	$7.88^{b}\pm0.48$	$101.67^{b}\pm2.01$	$0.64^{a}\pm0.07$
M80:B20	$71.67^{b}\pm1.34$	$8.09^{c}\pm0.52$	$118.33^{c}\pm2.31$	$0.68^{b}\pm0.02$
M70:B30	$70.33^{a}\pm0.67$	$7.41^{ab}\pm0.31$	$101.00^{b}\pm1.22$	$0.73^{c}\pm0.13$
M60:B40	$78.33^{c}\pm1.28$	$6.73^{a}\pm0.40$	$94.67^{a}\pm1.00$	$0.72^{c}\pm0.21$

*Values are means ± standard deviations of three replicates of samples.

*Means within the same column with different superscripts are significantly different ($p<0.05$).

M100 = 100% whole maize flour; **M90:B10** = 90% Maize flour and 10% Bambara nut flour; **M80:B20** = 80% maize flour and 20% Bambara nut flour; **M70:B30** = 70% maize flour and 30% Bambara nut flour; **M60:B40** = 60% wheat flour and 40% Bambara nut flour.

negates the findings of Olaoye *et al.,* (2018) on functional properties of wheat-bambara nut flour where it was reported that whole wheat flour sample has the highest oil absorption capacity. There was also progressive increase in the bulk density contents of the flour samples as percentage substitution of bambara nut flour was increased except when the percentage substitution of bambara groundnut was 10%. Hence, the result indicated that M70:B30 had the highest bulk density value of 0.73%, while M90:B10 had the lowest value of 0.64%. The results negate the findings of Olaoye *et al.,* (2018) on functional properties of wheat-bambara nut flour where it was reported that whole wheat flour sample has the highest bulk capacity.

Sensory evaluation of *Abari* made from maize-bambara nut composite flours

The results of sensory scores of *Abari* made from maize-bambara nut flour blends are presented in Table 6. The mean colour scores ranged from 4.83 - 7.24. The control sample (Whole maize sample) was rated highest (7.24), followed by M90:B10 sample with (6.79), while M60:B40 (maize sample substituted with 40% bambara nuts sample) was significantly lower and rated the lowest (4.83).

Aroma means scores ranged from 4.34 - 7.03. The M80:B20 sample was rated highest (7.03) followed by the control sample (whole maize sample) (6.62), while M60:B40 was rated lowest (4.34) by the panelists. The high aroma score in M80:B20 as chosen by the panelists implies that the addition of the bambara nut flour in the production of *Abari* improved the aroma of the sample. Similar aroma result has been reported by Onihi *et al.,* (2019). Taste scores of the *Abari* samples ranged from 5.00 - 6.24, with sample M90:B10 sample having the highest (6.24) followed by M80:B20 sample with (5.90) mean score, the control sample (whole maize sample) with 5.69 mean score, while M60:B40 was significantly lower and rated the lowest aroma (5.00). Flavour scores varied from 4.97 - 6.83 respectively. The control sample that is, the whole maize flour sample was rated the highest flavour with (6.83), while M60:B40 was significantly lower and rated the lowest flavour (4.97). The flavour scores decreased with percentage increase in substitution of the control sample with bambara nut flour in the production of *Abari*. A similar result on sensory analysis (flavour) has been reported according to Olanipekun *et al.,* (2015). For the Samples texture, the mean scores varied from 4.79-7.55 respectively. The control sample that is, the whole maize flour sample was rated the highest flavour with (7.55) mean score followed by M90:B10 sample with (5.97), while M60:B40 was significantly lower and rated the lowest texture (4.79). Similar to flavour, texture scores also reduced with percentage increase in substitution of the control sample with bambara nut flour in the production of *Abari*. Similar findings were reported by Ohini *et al.,* (2019).

DISCUSSION

Moisture plays very important role in the keeping quality of foods and high moisture content can have adverse effect on their storage stability. Hence, the reduced moisture recorded in the flour samples (below 14%) could be advantageous in ensuring storage stability and prolonged shelf life. Similar result on moisture content of wheat-bambara nut flour has been reported according to Olaoye, *et al.,* (2018). The higher value in M90:B10 indicated that a bit of addition bambara nut flour to maize flour would increase the ash content of the sample. The result negates the findings of Olaoye *et al.,* (2018) on ash content of wheat-bambara nut flour with bambara nut had the highest ash content. Similarly, sample M60:B40 had the highest value of 5.27% while whole maize flour had the lowest value of 2.15%. A trend similar to that of crude protein was recorded for each of crude fiber and crude fat; their values increased progressively with increased substitution of bambara nut flour. The trends could obviously be due to higher contents of ash, crude fibre, crude protein, and crude fat recorded in whole bambara flour than whole maize Flour. Similar results on crude protein, fibre and fat contents of wheat-bambara nut flour was reported according to Yusufu and Ejeh (2018). As a result of this, the concentration of phytates increased with progressive increase in the percentage substitution of bambara flour in the flour samples. However, a decrease occurred when the percentage substitution of bambara nut flour was 10% for whole maize flour. The results of

Table 6: Sensory Scores of *Abari* made from maize-bambara nut composite flours.

Samples	Colour	Appearance	Aroma	Taste	Flavour	Texture
M 100	7.24^{c}±0.67	6.59^{b}±0.45	6.62^{ab}±0.17	5.69^{ab}±0.11	6.83^{c}±0.08	7.55^{c}±0.67
M90:B10	6.79^{b}±0.12	6.41^{b}±0.18	6.55^{ab}±0.61	6.24^{c}±0.23	6.45^{b}±0.12	5.97^{b}±0.54
M80:B20	6.66^{b}±0.34	6.45^{b}±0.65	7.03^{b}±0.34	5.90^{b}±1.21	6.28^{b}±0.32	5.48^{ab}±1.60
M70:B30	6.10^{b}±0.11	5.76^{ab}±0.67	5.93^{a}±1.07	5.38^{ab}±0.44	5.66^{ab}±0.27	5.31^{ab}±1.25
M60:B40	4.83^{a}±0.23	4.28^{a}±0.21	4.34^{a} ±1.43	5.00^{a}±1.37	4.97^{a}±0.89	4.79^{a}±0.31

*Values are means ± standard deviations of 20-member panel scores.

*Means within the same column with different superscripts are significantly different ($p < 0.05$).

M100 = *Abari* made from whole maize flour; **M90:B10** = *Abari* made from 90% maize flour and 10% bambara nut flour; **M80:B20** = *Abari* made from 80% maize flour and 20% Bambara nut flour; **M70:B30** = *Abari* made from 70% maize flour and 30% bambara nut flour; **M60:B40** = *Abari* made from 60% wheat flour and 40% bambara nut flour.

the mineral content correlated with the findings of Yusufu and Ejeh, (2018) on mineral content of wheat-bambara nut flour where it was reported that 60% wheat flour with 40% Substituted bambara nut has the highest presence of iron, calcium, potassium, and phosphorus. Generally, there was reduction in the water absorption capacity of the flour samples as percentage substitution of bambara nut flour increased. The result correlated with the findings of Yusufu and Ejeh, (2018) on functional properties of wheat-bambara nut flour where it was reported that 60% wheat flour with 40% Substituted bambara nut has the highest water absorption capacity.

Similar result on sensory analysis (colour) has been reported according to Olanipekun *et al.,* (2015). The mean appearance scores ranged from 4.28 - 6.59. There was no significant difference at ($P<0.05$) among the samples (M100, M90:B10, and M80:B20) respectively. The control sample was rated highest (6.59), followed by M80:B20 sample (6.45), while M60:B40 sample was rated lowest with the value (4.28). The panelists' preference for the control sample over other samples made from the composite flours may be due to the alteration in the physical properties of the *abari* as a result of the inclusion of bambara nut flour. Similar result on appearance was reported by Olanipekun *et al.,* (2015).

CONCLUSION

The study concluded that the proximate composition of the flour blends of maize and bambara nut were significantly different among samples in all the parameters determined. The reduced moisture content recorded in the flour samples (below 14%) could be advantageous in ensuring storage stability and prolonged shelf life. Meanwhile, crude protein increased as bambara nut flour was substituted for the maize flour (from 10 - 40%) progressively. The trends could obviously be due to higher contents of ash, crude fibre, crude protein, and crude fat recorded in whole bambara Flour than whole maize Flour. Carbohydrate content decreased as more bambara nut flour were substituted for the maize flour (from 10 - 40%) progressively. There was significant increase in anti-nutrients, vitamins, minerals, and functional properties of the maize-bambara nut composite flour with increased substitution of bambara nut flour. Based on the nutritional assessment of the maize-bambara composite flour, and the sensory scores obtained from *Abari* made from the flour blends, the composite flour has been found as high quality food considering the nutritional component therefore could be very suitable for the production of *Abari* that would be richer in protein, vitamins and minerals than the traditional *Abari* made from whole maize flour, and this could impose a lot of nutritional benefits to the populace as the *Abari* is fortified with bambara nut flour.

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STATEMENT OF CONFLICT OF INTEREST

The authors declare no competing interest in this work.

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