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CHEMICAL, FUNCTIONAL AND SENSORY QUALITIES OF ABARI (MAIZE-BASED PUDDING) NUTRITIONALLY IMPROVED WITH BAMBARA GROUNDNUT (Vigna subterranea)

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ABSTRACT

Abari (a maize-based pudding) was prepared from five selected formulations of maize-bambara groundnut composite flours generated using central rotatable design of Response Surface Method. A control was also prepared from 100% maize flour. Standard methods were used to determine the functional properties of the various flours as well as the proximate compositions and sensory attributes of abari made from them. Inclusion of bambara groundnut flour caused a significant difference in the swelling index (1.65-2.69 g/g) of the various flours but bulk density (0.76-0.92 g/cm^3), oil absorption capacity (0.66-0.88 g/g) and water absorption capacity (1.44-1.59 g/g) were not significantly affected. Protein and ash contents of abari significantly increased with inclusion of bambara groundnut flour. The value of the protein content ranges from 6.21-31.69%. Supplementation of maize with bambara groundnut for abari production generally resulted in improved sensory qualities. Based on the findings, the application of bambara groundnut in the fortification of maize-based African traditional foods can help improve the nutritional status of the African populace without causing adversely impaired rheological and cooking qualities of the products.

Keywords: Abari, Bambara groundnut, Sensory, Protein-energy-malnutrition

INTRODUCTION

Maize (Zea mays) is a staple food for about 50% of the sub-saharan African population (Olaniyan, 2015). It is 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). Maize grain can be consumed fresh by 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), 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). But unlike moimoi, abari becomes hard and brittle when cooled (Omueti and Morton, 1996). 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

The protein content of bambara groundnut is comparable to that of other legumes, making it a good complement for cereal-based diets (Kaptso et al., 2013). Its seeds contain about 15 - 27%

protein (Arise et al., 2015), 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., 2017a, Ijarotimi and Esho, 2009). Bamshaiye et al. (2011) and Arise et al. (2015) noted that this legume grain has the potential to improve malnutrition and boost food availability as it contains sufficient quantities of protein, carbohydrate and fat. In addition to this, bambara groundnut is highly drought tolerant and gives better yield under harsh agronomic condition than other legume grains such as groundnut and soybean (Mazahib et al., Arise et al., 2016).

In spite of these aforementioned nutritional and agronomic advantages, bambara groundnut is less investigated in Nigeria, and, in fact, ranks third after groundnut (Arachis hypogeal) and cowpea (Vigna unguiculata) in terms of importance in Africa (Arise et al., 2015). This is unconnected with certain identified constraints, ranging from "hard--to-cook" phenomenon, strong beany flavor, poor dehulling and milling characteristics, to presence of some anti-nutrients (Falade et al., 2015) However, there are now various processing techniques that reduce these challenges to the barest minimum. It was therefore the aim of this study to investigate some of the important functional properties of maize-bambara groundnut composite flours as well as the nutrient contents and consumer acceptability of its pudding (abari) which is normally produced from maize paste.

MATERIALS AND METHOD

Maize (Zea mays) of the yellow variety was sourced from Ganmo, Kwara State and bambara groundnut was purchased from Oja-Oba market in Ilorin, Kwara State, both in Nigeria. These were stored in cool dry place for subsequent use.

Production of Maize Flour

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

Production of Bambara Groundnut Flour

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

Experimental Design for the Preparation of Abari from Maize-Bambara Flour Blends

Formulations of abari from different combination levels of maize (60 - 90%) and bambara (10 - 40%) were generated using Central Composite Design (CCD) of Design Expert (Version 7.0). There were 13 runs (treatments) in all, out of which 5 were central points (Table 1). However, five treatments: formulations marked "**" 95.19-4.81, 90-10, 75-25, 79.37-20.63, 69.23-30.77 were selected for analyses as well as control (100% maize abari).

Table 1. Central Composite Design of Maize-Bambara Flour Combinations for the Preparation of Abari

CCD generated runs		Percentage equivalents of generated runs	
Maize	Bambara	Maize (%)	Bambara (%)
60.00	10.00	85.71	14.29
75.00	46.21	61.88	38.12
90.00	10.00	90.00**	10.00
60.00	40.00	60.00	40.00
90.00	40.00	69.23**	30.77
96.21	25.00	79.37**	20.63
75.00*	25.00	75.00**	25.00
75.00*	25.00	75.00	25.00
75.00*	25.00	75.00	25.00
75.00	3.79	95.19**	4.81
75.00*	25.00*	75.00	25.00
53.79	25.00	68.27	31.73
75.00*	25.00*	75.00	25.00

Keys: * : central points, ** : selected runs

Abari Preparation

Abari was made using the method of Abdulrahaman and Kolawole (2006), with slight modifications. Briefly, maize and Bambara flour blends (100 g each) were prepared using the selected combination ratios. Each of the blends was mixed and stirred in clean warm water (140 ml) to form slurry. Groundnut oil (40 ml), onion (4 g) and ground pepper (10 g) were added to the slurry as well as smoked fish, salt and seasoning (maggi). The ingredients were thoroughly stirred with the slurry so as to have a homogeneous mixture. This was then portioned in small quantity in leaves (eweran), wrapped and steamed in a covered pot until well cooked. Cooking period lasted 30 min on a hot plate. The food product looked exactly like moin-moin (steamed cowpea paste) when done.

Functional Properties of Maize-Bambara Flour Blends

Swelling Capacity

The method described by Oluwole and Karim (2005) was used. Ten gram of the flour was measured into a 300 ml measuring cylinder, and the volume occupied was noted. Then 150 ml of distilled water was added to the flour and allowed to stand for 4 hrs. The final volume after swelling was recorded. The percentage swelling was calculated as

$$\text{Swelling capacity } \% = \frac{\textit{final volume} - \textit{initial volume}}{\textit{initial volume}} \times 100$$

Oil Absorption

This was determined using the method of Oyeyinka et al. (2013). One gram of the sample was dispensed into a weighed centrifuge tube with10 ml of sunflower oil and mixed thoroughly. The mixture was allowed to stand for 1 hr before being centrifuged at 3500 rpm for 30 min. The excess oil (unabsorbed) was decanted and the tube inverted over an adsorbent paper to drain dry. The weight of oil absorbed was determined by difference. The oil absorption capacity was calculated as:

$$\text{OAC } \% = \frac{\textit{volume of oil used} - \textit{volume of free oil}}{\textit{weight of sample used}} \times 100$$

Water Absorption

This was determined using the method of Arise et al., (2015) with slight modification. Briefly, One gram of the sample was dispensed into a weighed centrifuge tube with 10 ml of distilled water and mixed thoroughly. The mixture was allowed to stand for 1 hr before being centrifuged at 3500 rpm for 30 min. The excess water (unabsorbed) was decanted and the tube inverted over an adsorbent paper to drain dry. The weight of water adsorbed was determined by difference. The water absorption capacity was calculated as:

$$\text{WAC } \% = \frac{\textit{volume of water used} - \textit{volume of free water}}{\textit{weight of sample used}} \times 100$$

Bulk Density

The method described by AOAC (2012), was adopted for determining the bulk density of the sample. Sample (20 g) was weighed into a 100 ml graduated measuring cylinder, the bottom of which was tapped with the palm. The cylinder was placed on a table and final volume was read. The final volume was used to calculate bulk density as g/ml.

$$\text{Bulk density} = \frac{\textit{weight of sample}}{\textit{volume of sample}}$$

Proximate Analysis of Maize-Bambara Abari

Proximate composition of maize-bamababara abari was determined according to the standard methods of Association of Official Analytical Chemists (AOAC 2012). These included moisture, protein, ash, fat, crude fibre. Carbohydrate contents were determined by difference.

Sensory Evaluation of Maize-Bambara Abari

The various maize-bambara groundnut abari samples were presented to 50 semi-trained panelists comprising of staff and students from the Department of Home Economics and Food Science, who were asked to rate them on appearance, aroma, taste, texture and overall acceptability using a 9 point Hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely).

Microbial Analyses of Maize-Bambara Abari

The methods described by Fawole and Oso (2007) were used for the bacterial and fungal counts. Each of the samples, 1 g (w/v) was pipetted aseptically into 9 ml of sterile distilled water in a separate test-tube and serially diluted by pipetting 1 ml of the diluted samples into another 9 ml of sterile distilled water. This was prepared up to 10^{-4} dilutions. The 10^{-4} dilution was then plated by transferring 1 ml into a separate petri-dish (in duplicates). For bacterial count, sterile molten nutrient agar was added and mixed by swirling the plate before allowing it to solidify. The plates were incubated at 37 °C for 24 hrs and were examined for growth and colonies, counted and recorded as total bacteria count.

The same procedure was followed for fungi count except that the nutrient medium used was potato dextrose agar and incubation was done at 25 °C and for 72 hrs.

Statistical Analysis

Results obtained from the analyses above were subjected to analysis of variance (ANOVA) and the means were separated by Multiple Paired Comparison test (Duncan 1955) using SPSS (version 16.0)

RESULT AND DISCUSSION

There were significant differences ($p < 0.05$) in the functional properties of the maize and maize-bambara groundnut flour blends (Figures 1 and 2). The swelling index, bulk density and water absorption capacity (WAC) values increased with increasing levels of bambara groundnut flour in the flour blends. However, there was an inconsistency in oil absorption capacity (OAC) values as the level of bambara groundnut increased. Swelling index values ranged from 2.56-2.69 g/g with sample A0 (100:0) which is the control having the least value, while sample A5 (69.23% maize and 30.77% bambara flour) had the highest. Mustapha (2012), reported a similar result for abari made from whole maize flour. The increase in the swelling capacity could be due to the conformational properties of protein and the particle size of the flour. In addition, Arise et al. (2017b) reported that bambara protein contain more of hydrophilic amino acids. These amino acids which are water loving could be responsible for the increase in the swelling index. The bulk density values ranged from 0.84-0.99 g/cm^3 with control having lowest and A5 having highest values. A similar result was reported for kokoro made from maize-groundnut fortified with defatted groundnut flour. The bulk density values (0.645-0.767) increased with increasing levels of defatted groundnut flour (Otunola et al., 2012). In the same vein the increase in WAC with increase in level of bambara groundnut could be attributed to the type of the water loving amino acids present in the bambara groundnut thereby making the water absorption capacity high (Arise et al., 2017b). Oil absorption capacity of the maize-bambara flour blends appears not to follow a particular trend. There was an increase initially but a decrease occurs as the quantity of bambara groundnut flour increased. Oil absorption capacity is an important functional property that enhances the mouth feel and retains the flavor of food products and also plays a role in their shelf life (Aremu et al., 2007).

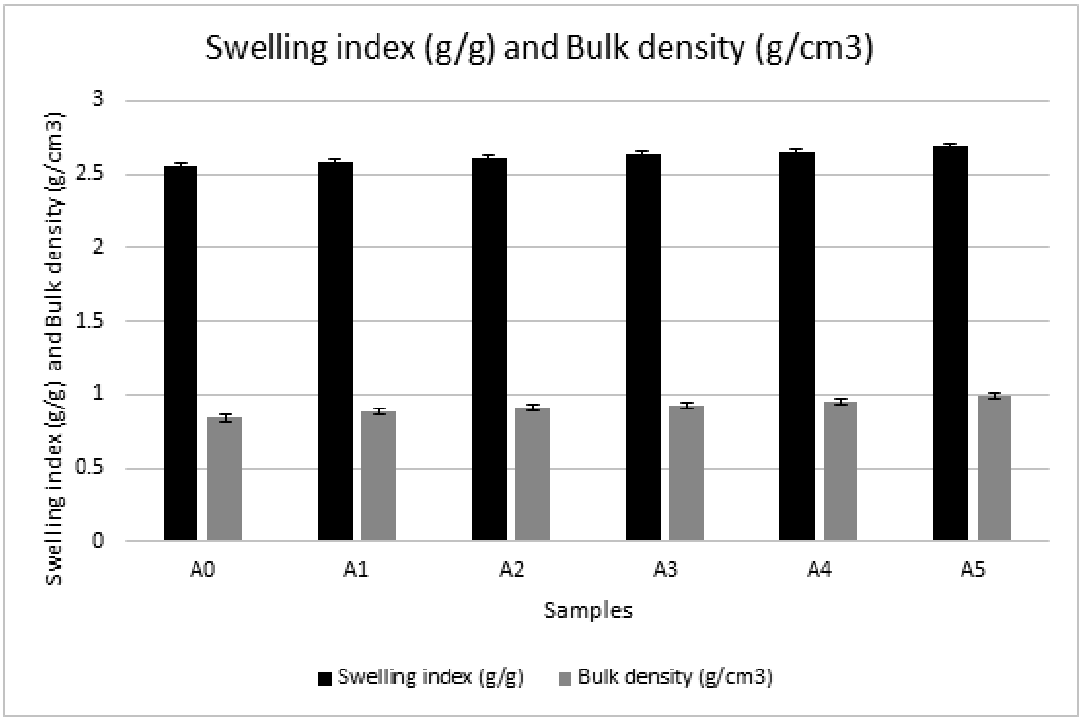

Figure 1: Bulk Density and Swelling Capacity of Maize-Bambara Flour Blends
A0= 100% maize (control), A1= 95.19% maize flour + 4.81% Bambara groundnut flour, A2= 90% maize flour + 10% Bambara groundnut flour, A3 = 79.37% maize flour + 20.63% Bambara groundnut flour, A4 = 75% maize flour + 25% Bambara groundnut flour, A5= 69.23% maize flour + 30.77% Bambara groundnut flour

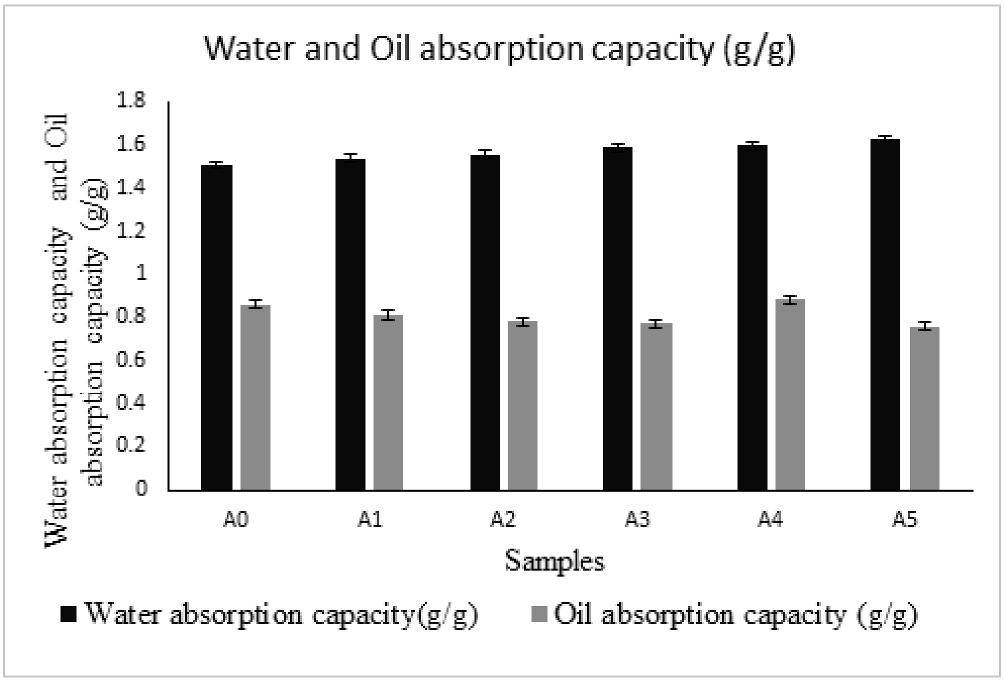

Figure 2: Water Absorption and Oil Absorption Capacity of Maize-Bambara Flour Blends
A0= 100% maize (control), A1= 95.19% maize flour + 4.81% Bambara groundnut flour, A2= 90% maize flour + 10% Bambara groundnut flour, A3 = 79.37% maize flour + 20.63% Bambara groundnut flour, A4 = 75% maize flour + 25% Bambara groundnut flour, A5= 69.23% maize flour + 30.77% Bambara groundnut flour

Proximate Composition of Maize and Maize-Bambara Abari

The major components in the abari made from 100% maize are moisture (44.22%) and carbohydrate (33.54%). In contrast, for the abari produced from maize-bambara blend flours, moisture (45.55-48.52%) and protein (24.50 - 31.69%) were the major components (Table 2). Fibre (1.76-1.79%) and fat (7.46-11.07%) contents were generally low. In general, protein, moisture and ash contents increased, while fat, fibre and carbohydrate content decreased with increasing levels of bambara groundnut flour. Previous research suggested that protein contents of cereals can be enhanced by adding legumes such as groundnut, soya bean, cowpea and bambara groundnut which are better sources of protein (Arise et al., 2018, Otunola et al., 2012). The various abari samples made from maize-bambara groundnut composite flours had higher protein contents than whole maize abari (sapala) which had 8.7 - 10.01% (Mustapha, 2012). The increase in protein content of the maize-bambara abari is expected since bambara groundnut is a rich source of protein. The protein content varies from 15-27% (Arise et al., 2015, Arise et al., 2017a, Arise et al., 2018). However, Olanipekun et al. (2015), reported a lower protein range of values (5.90 - 7.81%) for abari produced from whole maize and kidney bean flour blends. The high protein contents reported for the various maize-bambara groundnut abari samples indicate that supplementation of abari traditionally made from 100% maize with bambara groundnut flour can be a good nutritional intervention in a bid to preventing protein deficiencies among populace whose diet is largely based on this indigenous maize product.

Table 2: Proximate Composition of Abari Samples

Sample	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Fibre (%)	Carbohydrate (%)
A0	44.22±0.5^{s}	3.17±0.1^{a}	11.07±0.1^{d}	6.21±0.0^{a}	1.79±0.1^{a}	33.54±0.2^{f}
A1	45.55±6.8^{b}	5.78±0.5^{b}	7.46±0.0^{a}	24.50±0.4^{b}	1.77±0.6^{a}	14.94±4.4^{e}
A2	46.52±6.8^{c}	5.78±0.6^{b}	8.12±1.6^{b}	25.40±0.7^{c}	1.78±0.5^{a}	12.40±7.9^{d}
A3	46.80 ±1.5^{c}	5.78±0.2^{b}	10.78±0.4^{c}	27.66^{c}±0.1^{d}	1.76±0.4^{a}	7.22±2.9^{c}
A4	47.00± 1.0^{d}	5.78±0.3^{b}	8.94±0.6^{b}	29.70±0.3^{e}	1.77±0.5^{a}	6.81±0.1^{b}
A5	48.52± 2.7^{e}	5.82±0.4^{b}	8.10±1.5^{b}	31.69±0.7^{f}	1.78±0.1^{a}	4.09±1.2^{a}

Values are means ± standard deviation of duplicate determinations Values not followed by the same superscript in the same row are significantly different ($p<0.05$).A0= 100% maize (control), A1= 95.19 % maize flour + 4.81% Bambara groundnut flour, A2= 90% maize flour + 10% Bambara groundnut flour, A3 = 79.37% maize flour + 20.63% Bambara groundnut flour, A4 = 75% maize flour + 25% Bambara groundnut flour, A5= 69.23% maize flour + 30.77% Bambara groundnut flour.

Sensory Properties of Maize-Bambara Abari

There was a noticeable improvement on each of the sensory parameters at different levels of bambara groundnut inclusions (Table 3). Taste was noticeably improved at 10% bambara groundnut inclusion level while appearance and aroma, then texture, in that order, were improved at > 20%. This suggests that taste is the most responsive sensory parameter to bambara supplementation of maize in abari production. The results obtained in this study are similar to the findings of Olanipekun et al. (2015), except for appearance. These authors reported that abari produced from blends of maize and kidney bean flours all had higher mean scores than abari made from 100% maize in terms of flavor, mouth feel and overall acceptability. However, on the contrary, they found that the appearance was impaired. This may be due to the different physical characteristics of the types of legume used. Previous studies carried out by Otunola et al. (2012) and Olanipekun et al. (2015), suggest that consumers prefer products made from composite flours containing maize and legume to products from 100% maize flour .

Table 3. Sensory Quality of Maize-Bambara Groundnut Abari

Sample	Aroma	Appearance	Taste	Texture	Overall acceptability
A0	7.00±0.0[a]	7.00 ±0.0[a]	7.00±0.0[a]	6.50±0.7[a]	7.50±0.7[a]
A1	7.00±0.0[a]	7.00±0.0[a]	7.50±0.7[a]	6.50±0.7[a]	7.50±0.7[a]
A2	7.50±0.7[a]	7.50±0.7[a]	7.50±0.7[a]	6.50±0.7[a]	8.50±0.7[b]
A3	8.00±0.0[b]	7.50±0.7[a]	7.50±0.7[a]	7.50±0.7[b]	8.50±0.7[b]
A4	8.50±1.4[b]	8.00±0.7[b]	9.00±0.7[b]	7.50±0.5[b]	9.00±0.0[c]
A5	8.50±0.7[b]	8.00±0.7[b]	9.00±0.5[b]	7.50±0.5[b]	9.00±0.7[c]

Values are mean ± standard deviation of duplicate determinations

Values not followed by the same superscript in the same row are significantly ($p<0.05$) different. A0= 100% maize (control) A1= 95.19 % maize flour + 4.81% Bambara groundnut flour A2= 90% maize flour + 10% Bambara groundnut flour, A3 = 79.37% maize flour + 20.63% Bambara groundnut flour, A4 = 75% maize flour + 25% Bambara groundnut flour, A5= 69.23% maize flour + 30.77% Bambara groundnut flour

Microbial Analysis of Maize-Bambara Groundnut Abari

The bacterial loads of the various abari samples after 24 hrs of storage ranged from 8.0 x 10^1 in sample A0 to 1.6 x 10^2 cfu/g in sample A5. The recorded bacterial loads may be attributed to contamination during production (Karim et al., 2017). There was a steady increase in the bacterial loads of the samples with increased levels of bambara groundnut flour inclusion. This may be associated with the richer nutrients of the bambara supplemented abari samples, most especially in protein (Table 2). After 48 hrs, the bacterial loads had increased by approximately 19-folds. There was no fungal growth until after 48 hrs of storage and this ranged between 1.0 x 10^3 and 2.0 x 10^4 cfu/g. This implies that the various abari samples may not be guaranteed of being free from mycotoxins after 48 hrs of storage. There was however no presence of Escherichia coli or any other Coliform and Staphylococus aureus throughout the storage period indicating there was no faecal contamination.

Table 4: Total Plate Count of Maize-Bambara Abari after 24 hrs of Storage at 28±2 °C and 70% RH

Samples	Mesophillic bacteria count (cfu/g)	Escherichia coli. count (cfu/g)	Staphylococus aureus count (cfu/g)	Coliform count (cfu/g)	Fungi count (sfu/g)
A0	$8.0X10^1$	ND	ND	ND	ND
A1	$1.1X10^2$	ND	ND	ND	ND
A2	$1.2X10^2$	ND	ND	ND	ND
A3	$1.3X10^2$	ND	ND	ND	ND
A4	$1.4X10^2$	ND	ND	ND	ND
A5	$1.6X10^2$	ND	ND	ND	ND

Key: ND= Not Detected, A= 100% maize (control), A1= 95.19 % maize flour + 4.81% Bambara groundnut flour, A2= 90% maize flour + 10% Bambara groundnut flour, A3 = 79.37% maize flour + 20.63% Bambara groundnut flour, A4 = 75% maize flour + 25% Bambara groundnut flour, A5= 69.23% maize flour + 30.77% Bambara groundnut flour.

Table 5: Total Plate Count of Abari Prepared from Maize and Bambara Flour Blends after 48 Hrs of Storage at 28±2 °C and 70% RH

Samples	Mesophillic bacteria count (cfu/g)	Escherichia coli count (cfu/g)	Staphylococus aureus count (cfu/g)	Coliform count (cfu/g)	Fungi count (sfu/g)
A0	$1.5X10^3$	ND	ND	ND	$1.0X10^3$
A1	$1.8X10^3$	ND	ND	ND	$1.0X10^3$
A2	$2.0X10^3$	ND	ND	ND	$1.0X10^3$
A3	$2.5X10^3$	ND	ND	ND	$2.0X10^4$
A4	$2.7X10^3$	ND	ND	ND	$2.0X10^4$
A5	$3.0X10^3$	ND	ND	ND	$2.0X10^4$

Keys: RH= Relative Humidity, ND= Not Detected, A0= 100% maize (control), A1= 95% maize flour + 5% Bambara groundnut flour, A2= 90% maize flour + 10% Bambara groundnut flour, A3= 75% maize flour +25% Bambara groundnut flour, A4= 79.37% maize flour + 20.62% Bambara groundnut flour, A5= 69.23% maize flour + 38.12% Bambara groundnut flour

CONCLUSION

The study showed that maize and bambara groundnut composite formulations can be used in the production of abari. Abari produced from blends of maize and bambara groundnut had improved protein and ash contents and improved sensory qualities. The study has further resolved the difficulty associated with abari production when fresh maize is out of season, as both dry maize and bambara groundnut have proven to be suitable substitutes.

REFERENCES

Abdulrahaman, A. and Kolawole, O. M. 2006. Traditional preparations and uses of maize in Nigeria. Enthnobot. Leaflet, 10: 219-227

AOAC 2012. Official methods of analysis of AOAC International (19th ed.), Gaithersburg, M.D USA.

Aremu, M., Olaofe, O., Akintayo, E. 2007. Functional properties of some Nigerian varieties of legume seed flours and flour concentration effect on foaming and gelation properties. Journal of Food Technology, 5: 109-115.

Arise, A. K., Alashi, A. M., Nwachukwu, I. D., Ijabadeniyi, O. A., Aluko, R. E., Amonsou, E. O. 2016. Antioxidant activities of Bambara groundnut (Vigna subterranea) protein hydrolysates and their membrane ultrafiltration fractions. Food and Function, 7: 2431-2437.

Arise, A. K., Alashi, A. M., Nwachukwu, I. D., Malomo, S. A., Aluko, R. E., Amonsou, E. O. 2017a. Inhibitory properties of bambara groundnut protein hydrolysate and peptide fractions against angiotensin?converting enzymes, renin and free radicals. Journal of the Science of Food and Agriculture, 97: 2834-2841.

Arise, A. K., Amonsou, E. O.and Ijabadeniyi, O. A. 2015. Influence of extraction methods on functional properties of protein concentrates prepared from South African bambara groundnut landraces. International Journal of Food Science and Technology, 50: 1095-1101.

Arise, A. K., Nwachukwu, I. D., Aluko, R. E., Amonsou, E. O. 2017b. Structure, composition and functional properties of storage proteins extracted from Bambara groundnut (Vigna subterranea) landraces. International Journal of Food Science and Technology, 52: 1211-1220.

Arise, A. K., Oyeyinka, S. A., Dauda, A. O., Malomo, S. A., Allen, B. O. 2018. Quality evaluation of maize snacks fortified with Bambara groundnut flour. Annals. Food Science and Technology, 19: 283-291.

Bamshaiye, O., Adegbola, J., Bamishaiye, E. 2011. Bambara groundnut: An under-utilized nut in Africa. Advances in Agricultural Biotechnology, 1:60-72.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics, 11: 1-42.

Falade, K. O., Ogundele, O. M., Ogunshe, A. O., Fayemi, O. E., Ocloo, F. C. 2015. Physico-chemical, sensory and microbiological characteristics of plain yoghurt from Bambara groundnut (Vigna subterranea) and soybeans (Glycine max). Journal of

Food Science and Technology, 52: 5858-5865.

Farnia, A., Mansouri, M., Farnia, A., Branch, B. 2014. Study on morphological characteristics of maize (Zea mays L.) cultivars under different plant densities. India Journal of Natural Sciences, 5: 8391-8397.

Fawole, M. O. and Oso, B. A. 2007. Laboratory Manuals of Microbiology, Ibadan, Nigeria, Spectrum Publishers.

Ijarotimi, O. S. and Esho, T. R. 2009. Comparison of nutritional composition and anti-nutrient status of fermented, germinated and roasted Bambara groundnut seeds (Vigna subterranea). British Food Journal, 111: 376-386.

Kaptso, K., Njintang, N., Nguemtchouin, M., Scher, J., Hounhouigan, J., Mbofung, C. 2013. Drying kinetics of two varieties of Bambara groundnuts (Vigna subterranea) seeds. Journal of Food Technology, 11: 30-37.

Mazahib, A., Nuha, M., Salawa, I., Babiker, E. 2013. Some nutritional attributes of bambara groundnut as influenced by domestic processing. International Food Research Journal, 20:1165- 1171.

Mustapha, M. A. 2012. Evaluation of Some quality attributes of Sapala made from dried maize (Zea Mays L). Journal of Food Science and Technology, 8(6):86-90.

Karim, O.R., Aruna, H. E., Ojulari, O.V., Akintayo, O.A., Olawuyi, I.F. 2017. Quality and safety properties of street vended beske (fried soy cake) in Ilorin metropolis. FUTA Journal of Research in Sciences, 13: 453-563.

Olanipekun, O., Olapade, O., Suleiman, P., Ojo, S. 2015. Nutrient and sensory analysis of abari made from composite mixture of kidney bean flour and maize flour. Sky Journal of Food Science, 4 (2): 019- 023.

Olaniyan, A. B. 2015. Maize: Panacea for hunger in Nigeria. African Journal of Plant Science, 9: 155-174.

Oluwole, O., Karim, O. 2005. Production of biscuits from Bambara, cassava and wheat flour blends. Journal of Raw Material Research, 2: 34-38.

Omueti, O., Morton, I. O. 1996. Development, acceptability, nutritional and physical characteristics of protein improved Nigerian abari (maize meal) prepared from soya and maize flours. International Journal of Food Sciences and Nutrition, 47: 369-375.

Otunola, E., Sunny-Roberts, E., Adejuyitan, J., Famakinwa, A. 2012. Effects of addition of partially defatted groundnut paste on some Properties of 'kokoro'(a popular snack made from maize paste). Agriculture and Biology Journal of North America, 3: 280-286.

Oyeyinka, S., Oyeyinka, A., Karim, O., Kayode, R., Balogun, M., Balogun, O. 2013. Quality attributes of weevils (Callosobruchus maculatus) infested cowpea (Vigna unguiculata) products. Nigeria Journal of Agriculture Food and Environment, 9: 16-22.