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QUALITY EVALUATION OF MAIZE SNACKS FORTIFIED WITH BAMBARA GROUNDNUT FLOUR

Abimbola Kemisola Arise[1]* Samson Adeoye Oyeyinka[1], Adegbola Oladele Dauda[1], Sunday A. Malomo[2], and Barakat Olabanke Allen[1]
[1]Department of Home Economics and Food Science, University of Ilorin, Kwara State, Nigeria.
[2]Department of Food Science and Technology, Federal University of Technology, Akure, Nigeria.
*Corresponding author: abimbolatemi@gmail.com/arise.ak@unilorin edu.ng; Phone no +2348033605881

Abstract
Kokoro is a popular maize-based snack in Nigeria, which is consumed by adults and children but characterized by low protein content. The snacks were produced from blends of maize flour substituted with Bambara groundnut flour. Maize and Bambara groundnut flours were mixed in various proportions using central composite rotatable design. Flour blends were evaluated for functional and pasting properties, while snacks were analyzed for proximate composition and sensory qualities. The water absorption capacity value decreased with increased Bambara flour in the blends ranging from 1.68-1.90. There were significant changes ($p < 0.05$) in the pasting properties of the resulting flour blends where sample containing highest amount of Bambara (30%) had the highest value of 366.0 RVU and 90°C for final viscosity and pasting temperature respectively. Proximate analysis results revealed significant ($p < 0.05$) increase in protein (13.0-32.3%) while carbohydrate content (73.12–51.27%) decreased with inclusion of Bambara flour. No significant difference ($p < 0.05$) occurred in the sensory qualities of products from 100% maize and 82.5:17.5% (maize: Bambara) flour blend. Hence, acceptable Kokoro snacks from an 82.5:17.5(maize: Bambara flour) blend have been formulated, which could enhance the nutritional wellness of the target consumers.

Keywords: Bambara groundnut flour; Maize flour; kokoro; Pasting properties; sensory properties

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1. INTRODUCTION

Protein energy malnutrition (PEM) is rampant, predominantly among rural women and children in developing countries where maize serves as a staple food and could be reduced by the availability of cheap, nutritious foods based on simple processes such as supplementation (Awoyale, Maziya-Dixon, Sanni, & Shittu, 2011). *Kokoro* is a popular Nigerian snack made from maize (*Zea mays*) paste mixed with onion and salt. The snack is commonly produced in Imashayi, Joga and Iboro villages of Yewa North Local Government of Ogun state, Nigeria(Oranusi & Dahunsi, 2015). *Kokoro* is a finger like maize-based snack food that is consumed alone or with roasted groundnuts (Awoyale *et al.*, 2011). The major nutrient in *kokoro* is carbohydrate with limited amounts of protein. For instance, Osidipe (2012) reported low protein content (5.8%) and relatively high carbohydrate of 68.8% for kokoro made from maize. According to these authors,the low protein content in *kokoro* is very evident, with a shortage of tryptophan and lysine (Osidipe, 2012). The nutritional value of *kokoro* can be improved by complementing the main ingredient (maize) with legumes which are better sources of amino acids (Arise, Alashi, Nwachukwu, Malomo, Aluko, & Amonsou, 2016). Improving the nutritional value of snacks including *kokoro* is important because snacks are mostly eaten between meals. Furthermore, several people are now dependent on snack foods as part of their daily diet (Chávez-Jáuregui, Cardoso-Santiago, Silva, & Arêas, 2003). Consequently, it is important to produce a highly acceptable snack with improved nutritional quality as a means of reducing PEM and other nutrient deficiencies (Chávez-Jáuregui *et al.*, 2003). The use of protein-rich grain such as Bambara groundnut (*Vigna subterranea*) is highly promising in the improvement of cereal-based snacks. Previous studies reported a higher protein content for *kokoro* supplemented with soya bean flour, the protein content increased from 12.27% to 26.97% on substitution with soya bean flour (Adelakun, Adejuyitan, Olajide, & Alabi, 2005). Due to the high fat content of soya bean, pulses appear to be a better alternative in enriching cereal-based snacks, since pulses such as Bambara are generally low in fat with moderate amounts of protein.

Bambara groundnut (*Vigna subterranea*) is a leguminous crop of African origin. It is rich in protein (15 and 27%) and carbohydrate (56-68%)(Arise *et al.*, 2015; Onimawo, Momoh, & Usman, 1998; Oyeyinka, Singh, Adebola, Gerrano, & Amonsou, 2015). Bambara protein contains high levels of lysine (6.5–6.8%) and a reasonable amount of methionine (1.8 g per 100 g) which is normally limiting in legumes (Arise, Alashi, Nwachukwu, Ijabadeniyi, Aluko, & Amonsou, 2016; Ijarotimi & Esho, 2009).Hence, it can be potentially used in food products as a protein supplement. Mbata, Ikenebomeh, and Alaneme (2009), fortified Bambara groundnut flour with fermented maize and reported that the product obtained had better quality than the control (fermented maize only). In this study, the functional properties of maize and Bambara flour and the quality of resulting snack was investigated. The objective of this study is to produce *kokoro* with increased nutritional value and also increase the utilization of underutilized Bambara groundnut which is cheap and readily available.

2. MATERIALS AND METHODS

2.1. Materials

Yellow maize and cream coat Bambara were purchased from a local market Oja-Oba in Ilorin, Kwara state, Nigeria. They were all transported to the laboratory in clean polyethylene bags for later use. Refined vegetable oil, salt, and onions were obtained from a local market in Ilorin, Kwara state.

2.2. Methods

Preparation of unfortified fermented maize flour

Dried yellow maize was cleaned, winnowed and rinsed with water. The grains were washed and boiled for 1hr. The water used for boiling was decanted and the grains steeped overnight to ferment at room temperature. The fermented grains were sieved from steeped water and sun dried for 2-3 days. The dried maize grains were then milled using a disc attrition mill. The milled grains were then sieved through a fine mesh sieve (sieve size) to obtain maize flour.

Preparation of Bambara groundnut flour

Bambara was cleaned and winnowed to be free from stone, debris or other foreign materials. The cleaned Bambara was soaked in water for 72 hr and allowed to ferment at room temperature. It was then dehulled by hands to remove the seed coat. The dehulled seeds were oven dried for 2-3 days at 50^{o}C.The dried seeds were milled into flour using a disc attrition mill, sieved (sieve size) to obtain the Bambara flour. The flour was stored in a hermetically sealed container in refrigerator until needed.

Formulation and production of kokoro fortified with bambara flour

Central composite rotatable design of Design-expert (Version 7.0 Design-Expert 2005) was used to determine the experimental design and the ingredients combination levels for the *kokoro* formulation. The two basic ingredients incorporated in the *kokoro* were maize and Bambara groundnut flour. This gave rise to 13 runs with five central points (Table 1). The *kokoro* was produced according to the method of Awoyale et al. (2011), with some modifications. Briefly, 100 ml of water was boiled and 50 gram of blend was poured and stirred to form a paste in each case. Onion was wet milled separately. The remaining 50g was mixed with salt and onion and added to the paste with continuous stirring for about 3 mins to form homogenous dough. The dough was allowed to cool to a temperature of 40℃ and kneaded by hand on a chopping board. The kneaded dough was cut into pieces, rolled into ring shapes and deep fried in hot groundnut oil for 3 mins, drained and left to cool.

Table 1 Central composite design of the maize and Bambara groundnut flour combinations for the production of *kokoro*

Ratio of maize to Bambara before conversion		Ratio of maize to Bambara after conversion to percentage	
82.50	17.50*	82.5	17.5
70.00	30.00	70	30
82.50	17.50*	82.5	17.5
82.50	17.50*	82.5	17.5
95.00	5.00	76	24
70.00	30.00	93	6.7
82.50	17.50*	70.1	29.9
82.50	17.50*	95	5
95.00	5.00	78.7	21.3
64.82	17.50	100.0	0.2
82.50	-0.18	99.7	0.3
82.50	17.50	82.5	17.5
100.18	17.50	85.1	14.9

*represents centre point

The *kokoro* pieces were packed in low density polythene bags and stored at ambient temperature.

Functional properties of maize-bambara blend flours

The functional properties of maize flour and maize-bambara flour such as water absorption capacity (WAC), oil absorption capacity (OAC), bulk density and swelling capacity were determined. WAC and OAC were determined according to the method of Arise et al. (2015), with slight modifications. One gram of each sample was dispersed in 10 mL of distilled water (or sunflower oil) in a 50-mL pre-weighed centrifuge tube. The dispersion was vortexed for 1 min, allowed to stand for 30 min and then centrifuged at 4000 g for 30 min at room temperature. The supernatant was decanted, excess water (or oil) in the upper phase was drained for 15 min, and the tube containing the residue was weighed again to determine the amount of water or oil retained per gram of the sample.

The Bulk Density of the flour sample was determined as previously described (Oyeyinka, Oyeyinka, Karim, Toyeeb, Olatunde, & Arise, 2014). The swelling power of flour was determined based on a modified method of Julianti, Rusmarilin, and Yusraini (2015). Briefly, approximately 0.1 g of sample was transferred into a weighed graduated 50 ml centrifuge tube. Distilled water was added to give a total volume of 10 ml. The sample in the tube was stirred gently by hand for 30 s at room temperature, and then heated at 60^{o}C for 30 min. After cooling to room temperature, the samples were centrifuged for 30 min at 3000 rpm. The weight of sediment was recorded.

Pasting properties of maize-bambara groundnut flour blends

The pasting properties include pasting temperature, peak viscosity, time to peak, temperature at peak, hot and cold viscosity breakdown, set back and final viscosity. 3.5 g of sample was weighed and 25 mL of water was dispensed into the canister. Paddle was placed inside the canister, this was placed centrally onto the paddle coupling and then inserted into the rapid visco analyzer (RVA) machine. The measurement cycle was initiated by pressing the motor tower of the instrument. The profile can be seen as it is running on the monitor of a computer connected to the instrument. The 13 minutes profile was used, the time-temperature regime used was; idle temperature 50℃ for 1min, heated from 50℃ to 95℃ in 3 mins 45 secs, then held at 95℃ for 2 mins 30 secs, the sample was subsequently cooled to 50℃ over a 3 min 45 secs period followed by a period of 2 minutes where the temperature was controlled at 50℃.

Proximate composition

Moisture, ash, fibre and fat contents were determined using standard laboratory procedures (AOAC, 2000). Protein content was determined by the Kjeldahl method (6.25×N) and total carbohydrate was calculated by difference.

Sensory evaluation

The *kokoro* samples were evaluated by a panel of fifty untrained judges drawn from the University of Ilorin, Nigeria for attributes of colour, texture, flavor, crispness and general acceptability on a hedonic scale of 1-9, where 1 = dislike extremely and 9 = like extremely.

Statistical analysis

All data readings were done in triplicates and subjected to analysis of variance using statistical package for social science (SPSS)

3. RESULTS AND DISCUSSION

3.1. Functional properties of maize-Bambara groundnut flour blends

There were significant differences ($p < 0.05$) in the functional properties of the maize and Bambara groundnut flour blends (Figure 1 and 2). The bulk density values increased with increasing levels of Bambara groundnut flour in the flour blends. However, there was a decrease in water absorption capacity (WAC), oil absorption capacity (OAC) and swelling capacity (SC) as the level of Bambara groundnut increased. Bulk density values ranged from 0.38g/mL- 0.97g/mL with sample WMF (100:0) which is the control having the least value, while sample MBC (82.5% maize and17.5% Bambara flour) had the highest value.

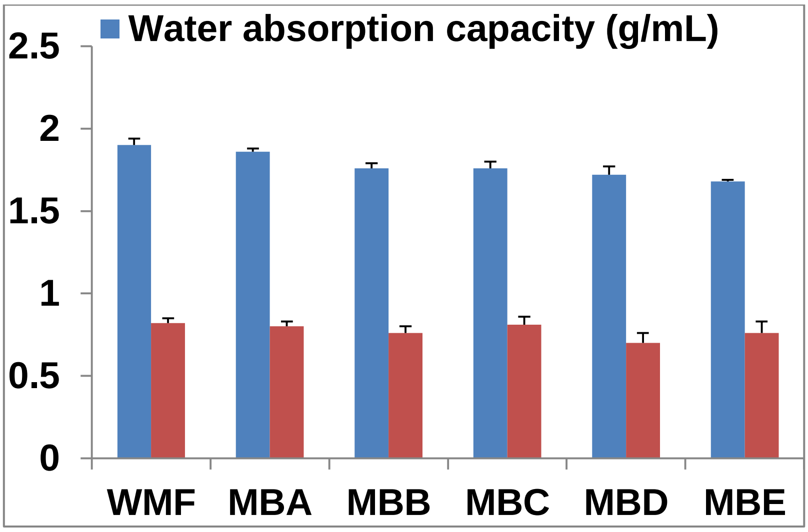

Figure 1. Water absorption and oil absorption capacity of maize-Bambara flour blends

WMF: 100% whole maize flour; MBA: 95% maize flour, 5% Bambara groundnut flour; MBB: 85% maize flour, 15% Bambara groundnut flour; MBC: 82.5% maize flour, 17.5% Bambara groundnut flour; MBD: 76% maize flour, 24% Bambara groundnut flour; MBE: 70% maize flour, 30% Bambara groundnut flour.

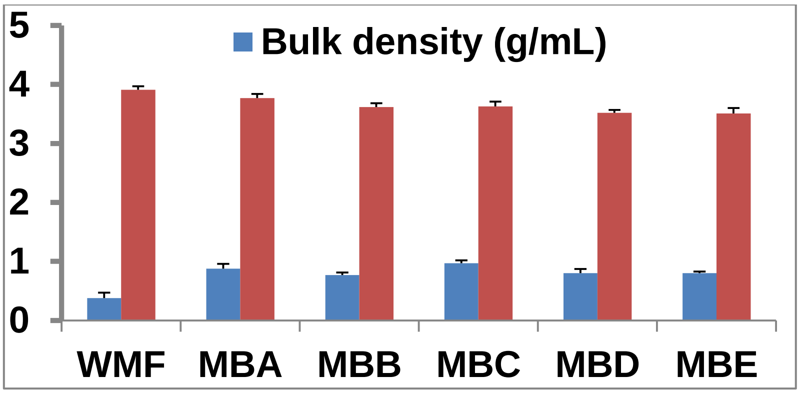

Figure 2. Bulk density and swelling capacity of maize-Bambara flour blends

WMF: 100% whole maize flour; MBA: 95% maize flour, 5% Bambara groundnut flour; MBB: 85% maize flour, 15% Bambara groundnut flour; MBC: 82.5% maize flour, 17.5% Bambara groundnut flour; MBD: 76% maize flour, 24% Bambara groundnut flour; MBE: 70% maize flour, 30% Bambara groundnut flour.

The increase in bulk density with increase in level of substitution of Bambara is similar to report of Akoja, Adebowale, Makanjuola, and Salaam (2016) who supplemented maize with protein hydrolysate prepared from pigeon pea seed to produce *kokoro*. Bulk density is an index of the heaviness of the flour materials and expresses the relative volume of packaging material needed. The bulk density is generally affected by the particle size. It has relevant application in packaging, transportation, and raw material handling (Adebowale, Adegunwa, Okunbolurin, & Bakare, 2016).
The WAC and OAC values ranged from 1.68-1.90 g/mL: 0.82-0.76 g/mL respectively with sample MBE (70% maize: 30% Bambara flour) having the least value while sample WMF (control) had the highest value. The decrease in WAC of the flour with increasing inclusion of Bambara groundnut flour may be attributed to the reduction in the amount of maize in the flour blends. Maize is richer in starch and may absorb more water when compared with Bambara groundnut flour. The result in the current study is different from the trend reported by Osidipe (2012). The author reported an increase in WAC and OAC with increase in beni-seed inclusion in maize flour. Conversely, Akoja *et al.* (2016), reported similar trend of decrease in WAC and OAC with increase in level of inclusion of protein hydrolysate in corn flour which is similar to our result. OAC is the ability of a food or food ingredient to absorb oil or fat. It is an indicator for flavor retention.
The values of swelling capacity ranged from 3.51-3.91 g/mL. The values of the swelling capacity obtained in this study is greater than 0.95-1.4 g/mL reported for corn flour partially substituted by defatted groundnut (Otunola, Sunny-Roberts, Adejuyitan, & Famakinwa, 2012). The swelling capacity is a function of the product to rise when having interaction with water.

3.2. Pasting properties of maize-Bambara flour blends

The pasting property is an essential factor in predicting the cooking and baking qualities of flour. Usually, starch when heated increases in viscosity as a result of the swelling of the starch granules and the quantity of water absorbed depends on the duration of cooking and starch content (Yadav, Anand, Kaur, & Singh, 2012). Table 2 shows the pasting characteristics of the maize–Bambara groundnut flour blends.

Table 2 Pasting properties of maize- Bambara groundnut flour blends

Samples	Pv (RVU)	Trough (RVU)	BD (RVU)	Fv (RVU)	Setback	P_T (min)	Pasting temp. (°C)
WMF	124.5 ± 2.99^{b}	104.5 ± 0.99^{c}	20.0 ± 0.01^{c}	183.5 ± 0.12^{a}	79.00 ± 0.11^{a}	6.8 ± 0.28^{b}	83.5 ± 0.12^{ab}
MBA	113.0 ± 0.00^{a}	91.5 ± 0.71^{bc}	21.5 ± 0.71^{d}	209.5 ± 0.36^{c}	118.0 ± 0.07^{c}	7.0 ± 0.00^{a}	81.0 ± 1.41^{a}
MBB	108.0 ± 2.83^{a}	90.0 ± 1.41^{bc}	18.0 ± 1.41^{b}	199.5 ± 0.78^{b}	112.5 ± 0.36^{b}	7.0 ± 0.00^{a}	85.0 ± 0.00^{b}
MBC	105.5 ± 2.36^{a}	89.0 ± 0.83^{b}	16.5 ± 0.53^{b}	199.5 ± 0.71^{ab}	110.5 ± 0.12^{b}	7.0 ± 0.00^{a}	80.0 ± 0.07^{a}
MBD	103.0 ± 2.70^{a}	88.5 ± 0.12^{b}	14.5 ± 0.71^{a}	209.0 ± 1.41^{c}	119.5 ± 0.71^{ab}	7.0 ± 0.00^{a}	79.5 ± 0.36^{a}
MBE	102.0 ± 1.40^{a}	80.0 ± 1.20^{a}	22.0 ± 0.19^{d}	366.0 ± 0.63^{d}	194.0 ± 0.44^{d}	7.0 ± 0.05^{a}	90.0 ± 0.66^{c}

In each of the column, samples whose means are not followed by the same superscripts are significantly different (at $p < 0.05$).
WMF: 100% whole maize flour; MBA: 95% maize flour, 5% Bambara groundnut flour; MBB: 85% maize flour, 15% Bambara groundnut flour; MBC: 82.5% maize flour, 17.5% Bambara groundnut flour; MBD: 76% maize flour, 24% Bambara groundnut flour; MBE: 70% maize flour, 30% Bambara groundnut flour.
Pv=peak viscosity, BD= breakdown viscosity, Fv= final viscosity, P_T= pasting time

Peak viscosity ranged between 102.0 to 124.5 RVU (Rapid viscosity unit), where the 100% maize had the highest value and sample with the highest substitution of Bambara groundnut flour (70:30) had the least value of 102.0 RVU. This is in agreement with the findings of Akoja *et al.* (2016) and Abegunde, Bolaji, and Adeyemo (2014) when maize flour was substituted with protein hydrolysate from pigeon pea and cowpea flour respectively. The peak viscosity is the highest viscosity attained during the gelatinization which decreased with the increasing level of Bambara groundnut flour inclusion. This reduction may be as a result of higher protein content present in Bambara groundnut flour, which has been reported to lower paste viscosity (Adebowale, Adeyemi, & Oshodi, 2005). Trough viscosity is the maximum viscosity at the constant temperature phase of the RVA profile and the ability of the phase to withstand breakdown during cooling. Similarly, 100% maize had the highest value of 104.5 RVU. The addition of Bambaragroundnut flour in general lowers the trough of maize flour, which implies that the blends may not find good applications in the food system, where high paste stability during cooking is required (Adegunwa, Adeniyi, Adebowale, & Bakare, 2015). The breakdown, which is the difference in the peak viscosity and trough, is an indication of the rate of gelling stability, which is dependent on the nature of the product. Sample MBE had the highest value of breakdown. This showed that the gelling stability reduced with increase in Bambara flour substitution. It is however noteworthy that sample MBE (70:30) had a higher value than the control. This is in agreement with the findings of Abegunde *et al.* (2014), when maize was substituted with cowpea. The setback value does not follow a particular pattern. However, MBE (70:30) had highest setback value (194 RVU) among the samples. The peak time ranged between 6.80 and 7.00 minutes. There was no significant difference ($p < 0.05$) between the samples. The peak time gives an indication of ease of cooking. More so, the shorter the peak time, the better the ease of cooking (Adegunwa *et al.*, 2015). The pasting temperatures of all the samples were low when compared to pasting temperature obtained for *kokoro* of maize-beni seed blends (Osidipe, 2012). However, the result is similar to that of *kokoro* of maize-cowpea (Abegunde *et al.*, 2014). The final viscosity do not follow a particular pattern. However, sample MBE had the highest final viscosity of 366RVU. The final viscosity obtained is lower than that obtained for *kokoro* from maize-cowpea and maize- pigeon pea protein (Abegunde *et al.*, 2014; Akoja *et al.*, 2016).

3.3. Proximate composition of *kokoro* produced from maize-bambara flour blends

The major components in the kokoro samples were carbohydrate (51.27-73.12%) and protein (13.00-32.30%) (Table 3).

Table 3 Proximate composition of *kokoro* produced from maize- Bambara flour blends

Samples	Protein (%)	Moisture (%)	Ash (%)	Crude fat (%)	Crude fiber (%)	Carbohydrate (%)
WMF	13.00±0.27[a]	7.03±0.53[a]	1.85±0.00[a]	5.00±0.44[b]	2.97±.0.03[b]	73.12±0.90[e]
MBA	15.04±0.56[b]	8.28±1.71[b]	1.90±0.01[a]	4.50±0.10[ab]	2.80±0.02[ab]	67.48±0.37[d]
MBB	17.42±0.13[c]	7.38±1.02[ab]	2.10±0.01[b]	4.40±0.66[ab]	2.50±0.04[ab]	66.2±1.43[d]
MBC	21.44±0.45[d]	6.86±0.52[a]	2.34±01[b]	4.25±1.04[ab]	2.45±0.01[a]	62.66±0.90[c]
MBD	27.60±1.05[e]	7.30±0.40[ab]	2.45±0.11[bc]	3.98±1.10[a]	2.40±0.03[a]	56.27±0.20[b]
MBE	32.30±1.66[f]	7.88±1.10[ab]	2.50±0.01[c]	3.70±0.30[a]	2.35±0.06[a]	51.27±1.73[a]

In each of the column, samples whose means are not followed by the same superscripts are significantly different (at $p< 0.05$).

WMF: 100% whole maize flour; MBA: 95% maize flour, 5% Bambara groundnut flour; MBB: 85% maize flour, 15% Bambara groundnut flour; MBC: 82.5% maize flour, 17.5% Bambara groundnut flour; MBD: 76% maize flour, 24% Bambara groundnut flour; MBE: 70% maize flour, 30% Bambara groundnut flour.

Ash (1.85-2.50%), fats (3.70-5.00%) and fibre (2.35-2.97%) contents were generally low. In general, protein 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 improved by adding legumes such as groundnut, soya bean, cowpea and Bambara groundnut which are better sources of protein (Arise *et al.*, 2015). The increase in protein contents of the kokoro samples is expected since Bambara groundnut is known to be a good source of protein. According to the literature, the protein content of Bambara groundnut may vary between15 and 27% (Arise et al., 2015; Onimawo, Momoh, & Usman, 1998; Oyeyinka, Singh, Adebola, Gerrano, & Amonsou, 2015).Thus, the enriched kokoro samples can be potentially used to increase the protein intakes of community where the snacks is commonly consumed.

3.4. Sensory properties of *kokoro*

The results for taste showed that increase in Bambara flour resulted in a decrease in the sensory score except for sample MBC (82.5:17.5) that has equal score as the control (Table 4).

Table 4 Mean sensory scores of *kokoro* samples

Sample	Aroma	Color	Crunchiness	Taste	Texture	Overall acceptability
WMF	7.5±0.61^{b}	7.5±0.71^{a}	8.0±0.41^{c}	7.0±1.41^{b}	7.5±0.71^{c}	7.5±0.50^{c}
MBA	6.5±0.60^{ab}	7.5±0.71^{a}	6.5±0.71^{b}	6.0±1.41^{b}	6.0±0.45^{bc}	6.5±0.45^{b}
MBB	6.5±0.38^{ab}	7.5±0.71^{a}	6.5±0.71^{b}	5.5±0.71^{b}	5.50±.071^{b}	5.5±0.40^{a}
MBC	6.5±0.74^{ab}	7.5±0.71^{a}	6.0±1.41^{a}	7.0±1.41^{b}	7.50±0.71^{c}	7.5±0.62^{c}
MBD	5.5±0.73^{a}	7.5±0.71^{a}	6.0±0.71^{a}	4.5±2.12^{a}	4.0±0.41^{a}	5.5±0.51^{a}
MBE	7.5±0.71^{b}	7.5±0.71^{a}	6.0±1.41^{a}	6.5±0.71^{bc}	6.5±0.71^{ab}	6.5±0.71^{b}

In each of the column, samples whose means are not followed by the same superscripts are significantly different (at p< 0.05).
WMF: 100% whole maize flour; MBA: 95% maize flour, 5% Bambara groundnut flour; MBB: 85% maize flour, 15% Bambara groundnut flour; MBC: 82.5% maize flour, 17.5% Bambara groundnut flour; MBD: 76% maize flour, 24% Bambara groundnut flour; MBE: 70% maize flour, 30% Bambara groundnut flour.

The Bambara inclusion was actually new to *kokoro* consumers. For crunchiness, there was significant difference (p < 0.05) between samples MBE (70:30) and WMF (100:0) in which sample WMF had the highest score while sample MBE had the least score. There was no significant difference in all samples in terms of colour. This is in agreement with the report of Abegunde *et al.* (2014) who reported no difference in color for *kokoro* prepared from maize-cowpea. The result showed that score for overall acceptability decreased with increase in Bambara flour except for sample MBC (82.5:17.5) that has equal score as the control. In all, the samples were highly rated by the panelists.

4. CONCLUSION

The study showed that low nutritional quality of *kokoro* can be improved through supplementation with Bambara flour. This is reflected particularly in the improved protein (13-32%) which increased with increase in Bambara flour. *Kokoro* from maize-Bambara blend can serve as a nutritious food or snack and help redress the problem of protein-energy malnutrition especially in children. Sensory evaluation showed that *kokoro* produced from 82.5% maize: 17.5% Bambara flour was rated same as *kokoro* produced from 100% maize. *Kokoro* with a higher nutritional content can be made with composite blends of maize flour and Bambara groundnut flour.

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