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Quality evaluation and storage properties of traditional maize-based snacks: *Ipekere Agbado* enriched with Bambara groundnut

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Abstract

Background: *Ipekere agbado* is a traditional maize-based snack consumed in South Western part of Nigeria, but low in protein content and deteriorate within few days. Hence, this study aimed at evaluating the chemical compositions, functional properties, softness index and storage properties as influence by Bambara groundnut (BG) enrichment. Maize and Bambara groundnut flours were well mixed to generate the following blends: MB10 (Maize 90%, Bambara groundnut 10%), MB20 (Maize 80%, Bambara groundnut 20%), MB30 (Maize 70%, Bambara groundnut 30%) and CTRL (Maize 100%) which served as control.

Results: Protein value increased with increase in Bambara groundnut flour inclusion. The value obtained for Na/K and Ca/P ratio of *ipekere agbado* samples including CTRL were all significantly ($p < 0.05$) lower than 1.00 and greater than 2.00 respectively. Low bulk density was observed in the enriched products compared with CTRL. Storage properties (TBA, PV and FFA) resulted in noticeable increase with increasing storage periods. The maize-snack stored at 37 °C had significantly ($p < 0.05$) shorter storage shelf life compared to those stored at 18 °C and 25 °C.

Conclusion: The overall result showed that 20% Bambara substitution was the most adequate to produce an acceptable and nutritious snack ("ipekere agbado"). Hence, consumption may improve nutrient intake and reduce protein energy malnutrition menace.

Keywords: Maize, *Ipekere agbado*, Functional properties and storage stability

Background

Maize (*Zea mays*) is a stable food widely consume as a cheap sources of calories and used as the main grain diet for school feeding via the Home Grown School Feeding Program in Nigeria (WFP 2017; Rapando et al. 2020). It is can be consumed boiled, roasted or use in production of verities of traditional snacks such as *ipekere agbado, dankwa, robo, aadun, kokoro* (Olaniyi and Oluwamukomi 2017; Dauda et al. 2020).

Among these traditional maize-based snacks *ipekere agbado* is more popular and widely consumed by the *Yoruba's* in the Southern part of Nigeria. It is cheap, easy to eat and known for its nutritious taste, crispiness and appealing creamy colour. *Ipekere agbado* is readily available on the streets, markets, schools, among others (Ugwuanyi et al. 2020). However, like other traditional maize-based snacks, *ipekere agbado* is low in protein (Akoja 2016). Hence, the needs for enrichment using legumes such as Bambara groundnut which may help in reduction of the prevalence of protein-energy malnutrition (PEM) (Adegbanke et al. 2019; Ijarotimi and Keshinro 2020).

Bambara groundnut (*Vigna subterranea*) belongs to the plant family *Fabaceae* and originated from the West Africa (Burkina Faso, Guinea, Mali, Nigeria and Senegal) (FAOSTAT 2015; USDA 2017). In Nigeria, it is used for local snacks such as *okpa*, *Sagidi*, and *Kulikuli*

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and beverage due to its high protein (18–22%) content (Kouassi and Zoro-Bi 2010).

PEM is a common childhood disorder among rural dwellers and is primarily caused by consumption of food low in protein and calories (Ahmed et al. 2020). PEM is responsible for the deaths of over 6 million out of 12 million under children between 1 and 5 years of age and Africa account 26% globally (Yigit and Tezcan 2004; Patil and Divyarani 2015). Several government policies have been implemented in order to reduce the menace caused by PEM such as different as dietary modifications, food enrichment and supplementation (Onis et al. 2012; Saadat et al. 2020). Enrichment of carbohydrate based diet using legume (such as Bambara groundnut and soy cake) have been reported to significantly improve protein and calories content of local diet (Adegbanke et al. 2019; Oluwajuyitan and Ijarotimi 2019; Aderinola et al. 2020; Akinyede et al. 2020). Nevertheless, must traditional maize-based snacks experience short shelf-life and deteriorates faster despite enrichment. Hence, the present study aimed at evaluating the proximate, functional and storage stability of traditional maize-based snacks (*ipekere agbado*) enriched with Bambara groundnut flour.

Materials

Sources of food materials

Yellow maize (*Zea mays*), Bambara groundnut (*Vigna subterraenea* L.) and other ingredients; onion, fresh pepper and vegetable oil used for this research were obtained within the tropics raining season in the month of June, from Oja-Oba market, Akure, Nigeria. Yellow maize (*Zea mays*), Bambara groundnut (*Vigna subterraenea* L.) were authenticated at the Department of Crop Production and Pest Management of Federal University of Technology, Akure. All the chemicals used were of analytical grades.

Processing of the food materials

Yellow maize flour production

Olaniyi and Oluwamukomi (2017) method was used in production of yellow maize grains flour. Grains were sorted to remove extraneous matter, washed with clean water, boiled for 1 h (Instant Pot Pressure Cooker, UK) and dried (Memmert 854, Gallenkamp, UK) at 65 °C for 8 h. The dried maize was milled (Laboratory blender (Model KM 901D; Kenwood Electronic, Hertfordshire, UK) and sieved through no 200 mesh sieve and packaged in airtight polyethylene bag until further use.

Bambara groundnut flour production

Bambara groundnut were processed into flour using the method described by Adegbanke et al. (2019). Bambara groundnuts were cleaned, sorted to remove defective ones, stones and other extraneous matters. The cleaned seeds were soaked in potable water for 1 h and boiled at a temperature of 100 °C for 45 min to soften the seed coat for easy dehulling. The seeds were then dehulled manually. The dehulled Bambara groundnut were dried (Memmert 854, Gallenkamp, UK) at 65 °C for 24 h and milled (Laboratory blender (Model KM 901D; Kenwood Electronic, Hertfordshire, UK) and sieved through no 200 mesh sieve. The flour samples were packaged in airtight polyethylene bag and stored at room temperature (27 ± 2 °C) until ready for analysis.

Formulation of flour blends

Maize and Bambara groundnut flours were blended to generate the following: MB10 (Maize 90%, Bambara groundnut 10%), MB20 (Maize 80%, Bambara groundnut 20%), MB30 (Maize 70%, Bambara groundnut 30%) and CTRL (Maize 100%) which served as control. They were individually mixed with other ingredients at constant weight (Table 1). The functional properties of the composite blends were then determined.

Production of ipekere agbado samples

Generated flour blends were mixed individually together to form a stiff dough which was molded manually and deep-fried in palm oil until well fried and crispy to produce maize-based snack called *ipekere agbado* according to the methods of Olaniyi and Oluwamukomi (2017). Constant turning was ensured to avoid being burnt and palm oil was changed intermittently to avoid undesirable crust colour. The resulting *ipekere agbado* samples were cooled and divided into three portions. One portion was immediately used for sensory evaluation (Fig. 1), the second portion was packaged in HDPE film with 100 mm thickness and kept under room temperature (27 ± 2 °C) until ready for other analyses such as proximate and mineral compositions and softness index. The other portion was stored at three different temperatures of 18, 25 and

Table 1 Food formulation of *ipekere agbado samples*

Samples	CTRL	MB10	MB20	MB30
Maize (g)	100.00	90.00	80.00	70.00
Bambara groundnut (g)	0.00	10.00	20.00	30.00
Palm oil (ml)	10.00	10.00	10.00	10.00
Salt (g)	4.00	4.00	4.00	4.00
Pepper (g)	25.00	25.00	25.00	25.00
Onion (g)	70.00	70.00	70.00	70.00
Water (ml)	150.00	150.00	150.00	150.00

CTRL: Commercial *ipekere agbado* (Maize 100%); MB10: (Maize 90% + Bambara groundnut flour 10%) *ipekere agbado*; MB20: (Maize 80% + Bambara groundnut flour 20%) *ipekere agbado*; and MB30: (Maize 70% + Bambara groundnut flour 30%) *ipekere Agbado*

Fig. 1 Bambara Groundnut Enriched "Ipekere Agbado" in the formulated rate. CTRL: Commercial *ipekere agbado* (Maize 100%); MB10: (Maize 90% + Bambara groundnut flour 10%) *ipekere agbado*; MB20: (Maize 80% + Bambara groundnut flour 20%) *ipekere agbado*; and MB30: (Maize 70% + Bambara groundnut flour 30%) *ipekere agbado*

37 °C for 8 days while being removed at 2 days interval for storage stability tests.

Analyses

Sensory evaluation of ipekere agbado

Thirty (30) semi-trained panelists were selected randomly from staff and students of Federal University of Technology, Akure. Nigeria. The panelists were screened with respect to their interest and ability to differentiate food sensory properties as described by (Iwe 2002). The study was carried out in a well illuminated sensory evaluation room of the Department of Food Science and Technology in the mid-morning hours (10.00 am) and the exercise was well monitored to avoid interference of other panelists. Each panelist was provided with a glass of clean water to rinse their mouths between the four evaluation sessions of 3 min interval. The *ipekere agbado* samples were presented in three digit coded plates and were evaluated for taste, crunchiness, aroma, appearance and overall acceptability using a 9-point hedonic scale in which 1 represents the least score (dislike extremely) and 9 the most desirable score (like extremely) for all attributes (Iwe 2002).

Determination of functional properties of ipekere Agbado flour blends

Bulk density (BD): A 50 g of *ipekere agbado* flour sample was put into a 100 mL measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density (g/cm^3) was calculated as weight of flour (g) divided by flour volume (cm^3) according to the method described by Oluwajuyitan and Ijarotimi (2019).

$$\text{Bulk density} = \frac{\text{weight of sample}}{\text{volume of sample after tapping}} \times 100 \tag{1}$$

Water absorption capacity (WAC): The method described by Onwuka (2005) was used. One gram of the *ipekere agbado* flour sample was weighed into a 15 mL centrifuge tube and suspended in 10 mL of water. It was shaken on a platform tube rocker for 1 min at room temperature. The *ipekere agbado* sample was allowed to stand for 30 min and centrifuged at 1200 × g for 30 min. The volume of free water was read directly from the centrifuge tube.

$$\text{WAC} = \frac{\text{amount of water added} - \text{free water}}{\text{weight of sample}} \times \text{density of water} \times 100 \tag{2}$$

Oil absorption capacity (OAC): The method described by Onwuka (2005) was used for evaluating *ipekere agbado* OAC. One gram of the *ipekere agbado* flour sample was weighed into a 15 mL centrifuge tube and suspended in 10 mL of oil. It was shaken on a platform tube rocker for 1 min at room temperature. The sample was allowed to stand for 30 min and centrifuged at 1200 × g for 30 min. The volume of free oil was read directly from the centrifuge tube.

$$\text{OAC} = \frac{\text{amount of oil added} - \text{free oil}}{\text{oil of sample}} \times \text{density of oil} \times 100 \quad (3)$$

Determination of proximate composition of Ipekere agbado

The proximate compositions (moisture, crude fat, crude protein, total ash and crude fibre) of the i*pekere agbado* samples were analyzed according to the standard methods described in AOAC (2012). Total carbohydrate (CHO) content was calculated by the difference, as follows:

$$\text{CHO}(\%) = 100 - (\%\text{Moisture} + \%\text{Crude fat} + \%\text{Total ash} + \text{Crude fibre} + \text{Crude protein}) \quad (4)$$

Determination of mineral composition of ipekere agbado

The mineral composition: calcium, magnesium, iron, copper and zinc were determined using Atomic Absorption Spectrophotometer (AAS Model SP9). Sodium and potassium were determined using flame emission photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK) with NaCl and KCl as the standards (AOAC 2012). Phosphorus was determined using Vanado-molybdate method.

Determination of the Softness Index of "Ipekere Agbado"

The softness indices of "ipekere agbado" were determined using Precision Cone Penetrometer (Benchtop model, Pioden Controls Ltd., UK) (Bolade 2010). Freshly prepared "ipekere agbado" were placed on top of the closed end of the clean cylindrical tin container of a dimension 6 cm (diameter) by 6 cm (height). The ipekere agbado on top of the container was subjected to penetrometer evaluation by positioning its center perpendicularly to the falling probe of the penetrometer. The probe was finally released to fall freely from a standard distance to penetrate into the product on the cylindrical tin container. The total depth of penetration of the probe was then read on the penetrometer scale and the reading, expressed in millimeter (mm), was taken as an index of the product softness.

Determination of storage stability of Ipekere agbado

Thiobarbituric acid value (TBA) TBA was determined at 2, 4, 6 and 8 days' storage period using the method of Darwish et al. (2012). Briefly, 20 g of the *ipekere agbado* samples and 40 mL of 7.5% trichloroacetic acid were homogenized with a spatula for 1 min and left to stand for 30 min. Thereafter it was filtered using Whatman NO. 1 filter paper. About 5 mL of the filtrate were prepared with 5 mL of thiobarbituric acid (TBA) solution (0.2883 g TBA/100 mL water) in a test tube. Blank was carried out using 5 mL distilled water and 5 mL TBA solution. The tubes were covered and heated in a boiling water bath for 40 min, then, cooled in an ice bath. Absorbance at 538 nm was measured using ultraviolet–visible scanner spectrophotometer (LKB 4045 Cambridge, England). The TBA value was calculated by multiplying the absorbance by the factor of 7.8 and the result expressed in mg of malonaldehyde per 1 kg sample.

Peroxide value (PV) The peroxide value (PV) of *ipekere agbado* samples was determined at 2, 4, 6 and 8 days' storage period by following the method described in AOAC (2012). The powdered samples of the *ipekere agbado* (5 g) were soaked in 30 mL chloroform for 12 h in an air tight flask. The chloroform extract was filtered through Whatman's filter paper No. 1 to a test tube and 1 g of potassium iodide and 10 ml of acetic acid were added. The tube was kept in a boiling water bath until boiling. After boiling, the tubes were immediately cooled by dipping in a tap water. In a conical flask, 20 ml of 5% (w/v) potassium iodide solution was taken to which the contents of the above tube were transferred with washing with 20 ml distilled water. The contents of the conical flask were then titrated against 0.002 N sodium thiosulphate using starch as an indicator. Peroxide value was expressed as ml of 0.002 N sodium thiosulphate solution per g of the extract *ipekere agbado*.

Free fatty acids (FFA) The Free fatty acids (FFA) value of *ipekere agbado* samples was determined using the method of Pearson and Jones (1978) described by Anyasor et al. (2009). About 1 g of the sample was weighed into a conical flask and 50 ml of hot neutral alcohol will be added with a few drops of phenolphthalein. The mixture was shaken vigorously and titrated with 0.1 M sodium hydroxide solution with constant shaking until the pink colour persisted for 15 s.

$$\text{FFA}(\%\text{oleic acid}) = \frac{\text{Titre value} \times \text{molarity}(0.1N\ \text{NaOH}) \times 28.2}{\text{weight of sample}} \times \text{density of oil} \times 100 \quad (5)$$

Statistical analysis

Data were subjected to analysis of variance using SPSS (IBM version. 20.0, SPSS Inc., Quarry Bay, Hong Kong) and presented as means ± standard deviation. Comparisons between different groups was done using Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT).

Table 2 Proximate composition (g/100 g) of fresh *ipekere agbado samples*

Samples	Moisture	Crude protein	Crude fat	Crude fiber	Total ash	Carbohydrate
CTRL	10.29 ± 1.51[a]	5.79 ± 0.05[d]	8.62 ± 0.15[c]	3.56 ± 0.23[a]	2.32 ± 0.19[b]	69.42 ± 1.58[a]
MB10	8.38 ± 0.44[c]	8.08 ± 0.04[c]	11.72 ± 0.45[b]	2.87 ± 0.06[b]	2.43 ± 0.11[b]	66.52 ± 0.60[b]
MB20	9.24 ± 1.73[ab]	10.34 ± 0.02[b]	17.51 ± 0.19[b]	2.57 ± 0.23[b]	2.87 ± 0.29[b]	67.47 ± 1.45[b]
MB30	9.68 ± 1.12[a]	12.21 ± 0.04[a]	21.63 ± 0.41[a]	1.39 ± 0.11[c]	3.64 ± 0.18[a]	51.47 ± 1.45[c]
*NIS Ref	< 10.00	> 10.00	10.00–25.00	< 5.00	< 3.00	> 64.00

Values are mean ± standard deviation. Values with the same superscript in the same column are not significantly different ($p < 0.05$)

CTRL: Commercial *ipekere agbado* (Maize 100%); MB10: (Maize 90% + Bambara groundnut flour 10%) *ipekere agbado*; MB20: (Maize 80% + Bambara groundnut flour 20%) *ipekere agbado*; and MB30: (Maize 70% + Bambara groundnut flour 30%) *ipekere agbado*

* NIS Ref. (NIS 2004)

Table 3 Mineral composition (mg/100 g) of fresh *ipekere agbado* samples

Elements	CTRL	MB10	MB20	MB30
Na	183.5 ± 2.50[b]	157.00 ± 1.00[a]	136.00 ± 2.00[c]	182.50 ± 1.50[b]
K	204.50 ± 0.50[a]	203.00 ± 1.00[c]	195.00 ± 3.00[b]	194.50 ± 0.50[b]
Ca	2.60 ± 0.10[a]	1.51 ± 0.01[b]	1.50 ± 0.01[b]	1.49 ± 0.01[b]
Mg	1.21 ± 0.01[a]	0.82 ± 0.02[d]	0.91 ± 0.01[c]	1.11 ± 0.01[b]
Zn	0.32 ± 0.01[a]	0.25 ± 0.01[b]	0.20 ± 0.01[c]	0.24 ± 0.02[bc]
Cu	0.15 ± 0.01[b]	0.18 ± 0.00[a]	0.12 ± 0.01[c]	0.10 ± 0.0[c]
P	0.32 ± 0.00[b]	0.26 ± 0.00[d]	0.33 ± 0.00[a]	0.28 ± 0.00[c]
Fe	0.21 ± 0.02[c]	0.30 ± 0.01[a]	0.20 ± 0.01[c]	0.25 ± 0.01[b]
Na/K	0.90[b]	0.77[c]	0.70[d]	0.94[a]
Ca/P	8.13[a]	5.81[b]	4.55[d]	5.32[c]

Values are mean ± standard deviation. Values with the same superscript in the same column are not significantly different ($p < 0.05$)

CTRL: Commercial *ipekere agbado* (Maize 100%); MB10: (Maize 90% + Bambara groundnut flour 10%) *ipekere agbado*; MB20: (Maize 80% + Bambara groundnut flour 20%) *ipekere agbado*; and MB30: (Maize 70% + Bambara groundnut flour 30%) *ipekere agbado*

Values of $p < 0.05$ were considered as statistically significant.

Results

Proximate composition of *ipekere agbado*

Table 2 present the proximate composition of *ipekere agbado* samples. The moisture, crude protein, crude fat, crude fibre, total ash and carbohydrate ranged as follow; 8.38 g/100 g in MB10—10.29 g/100 g in CTRL; 5.79 g/100 g in CTRL—12.21 g/100 g in MB30; 8.62 g/100 g in CTRL—21.63 g/100 g; 1/39 g/100 g in MB30—3.56 g/100 g; 2.32 g/100 g in CTRL—3.64 g/100 g in MB30 and 51.47 g/100 g in MB30—69.42 g/100 g in CTRL respectively. It was observed that the moisture content of the *ipekere agbado* samples were significantly ($p < 0.05$) lower compared with CTRL (10.29 g/100 g).

Table 4 Functional properties of the *ipekere agbado* composite flour

Samples	Bulk density (g/mL)	WAC (mL/g)	OAC (mL/g)
CTRL	0.93 ± 0.01[a]	229.54 ± 6.96[a]	145.70 ± 6.42[c]
MB10	0.90 ± 0.02[b]	215.05 ± 8.72[ab]	174.34 ± 12.21[b]
MB20	0.88 ± 0.00[b]	211.13 ± 12.57[ab]	186.52 ± 6.74[ab]
MB30	0.86 ± 0.01[b]	189.54 ± 6.54[b]	204.55 ± 5.65[a]

Values are mean ± standard deviation. Values with the same superscript in the same column are not significantly different ($p < 0.05$)

CTRL: Commercial *ipekere agbado* (Maize 100%); MB10: (Maize 90% + Bambara groundnut flour 10%) *ipekere agbado*; MB20: (Maize 80% + Bambara groundnut flour 20%) *ipekere agbado*; and MB30: (Maize 70% + Bambara groundnut flour 30%) *ipekere agbado*

Mineral composition of *ipekere agbado* samples

Mineral composition of *ipekere agbado* samples is presented in Table 3. Sodium and potassium were the most abundant elements in the samples. There was a significant difference ($p < 0.05$) between CTRL among other samples. The values obtained for sodium and potassium ranged between 136.00 mg/100 g in MB20—183.50 mg/100 g in CTRL and 194.50 mg/100 g in MB30—204.50 mg/100 g in CTRL respectively.

Functional Properties of the Enriched 'Ipekere Agbado' Composite Flour

Table 4 present the functional properties *ipekere agbado* samples. The BD, WAC and OAC ranged as follow: 0.86 g/mL in MB30—0.93 g/mL in CTRL; 189.54 mL/g in MB30—229.54 mL/g in CTRL and 145.70 mL/g in CTRL—204.55 mL/g in MB30 respectively. Low BD observed in *ipekere agbado* samples (MB10-30) compared with CTRL is advantageous, the lower the BD, the more economical the packaging materials. The results obtained from the present study showed that the inclusion Bambara groundnut results in a simultaneous decreased in WAC of *ipekere agbado* samples. Meanwhile, a significant

Table 5 Thiobarbituric acid (mg malonaldehyde/kg) of stored *ipekere agbado* samples at different temperature (°C)

Temperature (°C)	Sample	Storage period (days)			
		2	4	6	8
18	CTRL	0.05 ± 0.01^{ab}	0.13 ± 0.00^{b}	0.38 ± 0.06^{ab}	0.44 ± 0.03^{b}
	MB10	0.03 ± 0.01^{b}	0.08 ± 0.01^{c}	0.29 ± 0.01^{b}	0.47 ± 0.02^{b}
	MB20	0.07 ± 0.01^{a}	0.18 ± 0.01^{a}	0.42 ± 0.01^{a}	0.55 ± 0.03^{ab}
	MB30	0.05 ± 0.01^{ab}	0.08 ± 0.00^{c}	0.48 ± 0.01^{a}	0.65 ± 0.04^{a}
25	CTRL	0.72 ± 0.03^{a}	0.36 ± 0.04^{a}	0.73 ± 0.03^{b}	1.01 ± 0.01^{b}
	MB10	0.72 ± 0.01^{a}	0.31 ± 0.07^{a}	0.67 ± 0.02^{b}	1.01 ± 0.02^{b}
	MB20	0.12 ± 0.04^{a}	0.35 ± 0.02^{a}	0.78 ± 0.04^{ab}	1.04 ± 0.02^{ab}
	MB30	0.06 ± 0.01^{a}	0.22 ± 0.01^{a}	0.86 ± 0.01^{a}	1.09 ± 0.01^{a}
37	CTRL	0.08 ± 0.01^{a}	0.36 ± 0.09^{a}	0.80 ± 0.08^{b}	1.05 ± 0.02^{b}
	MB10	0.10 ± 0.60^{a}	0.42 ± 0.06^{a}	0.74 ± 0.02^{b}	1.07 ± 0.01^{b}
	MB20	0.08 ± 0.01^{a}	0.27 ± 0.05^{a}	0.87 ± 0.02^{a}	1.04 ± 0.01^{b}
	MB30	0.18 ± 0.01^{a}	0.34 ± 0.03^{a}	0.98 ± 0.01^{a}	1.16 ± 0.01^{a}

Values are mean ± standard deviation. Values with the same superscript in the same column are not significantly different ($p < 0.05$)

CTRL: Commercial *ipekere agbado* (Maize 100%); MB10: (Maize 90% + Bambara groundnut flour 10%) *ipekere agbado*; MB20: (Maize 80% + Bambara groundnut flour 20%) *ipekere agbado*; and MB30: (Maize 70% + Bambara groundnut flour 30%) *ipekere agbado*

($p > 0.05$) increase was obtained for OAC and increased with increase in Bambara groundnut substitution.

Storage properties of *ipekere agbado* samples

Table 5 present the TBA result of *ipekere agbado* samples at three different temperatures (18, 25 and 37) °C under storage for 7 days respectively. The TBA value of the sample significantly ($p > 0.05$) increased with increasing level of Bambara groundnut flour substitution among *ipekere agbado* samples and with increasing period of storage days within the sample.

The PV results (Table 6) follows a similar trend with TBA (Table 5) result. The PV of *ipekere agbado* samples significantly ($p > 0.05$) increased with increasing level of Bambara groundnut flour substitution with increasing period of storage time within the sample. Comparatively, the values obtained for *ipekere agbado* samples stored at 35 °C were significantly ($p > 0.05$) higher than *ipekere agbado* samples stored at 18 °C and 25 °C respectively.

Table 7 present the FFA values of *ipekere agbado* samples stored at different temperatures under storage for

Table 6 Peroxide value (mEq/kg) of oil extract from stored *ipekere agbado* samples at different temperature (°C)

Temperature (°C)	Sample	Storage period (days)			
		2	4	6	8
18	CTRL	0.50 ± 0.10^{a}	0.50 ± 0.10^{b}	1.39 ± 0.60^{a}	1.69 ± 0.30^{c}
	MB10	0.30 ± 0.10^{a}	0.70 ± 0.10^{b}	2.09 ± 0.70^{a}	1.89 ± 0.10^{c}
	MB20	1.20 ± 0.40^{a}	1.10 ± 1.00^{ab}	2.29 ± 0.10^{a}	2.89 ± 0.10^{b}
	MB30	0.90 ± 0.30^{a}	1.49 ± 0.30^{a}	2.49 ± 0.50^{a}	4.18 ± 0.20^{a}
25	CTRL	0.10 ± 0.20^{a}	1.79 ± 0.20^{b}	3.09 ± 0.50^{b}	4.08 ± 0.30^{b}
	MB10	1.20 ± 0.40^{a}	2.09 ± 0.10^{b}	3.88 ± 0.30^{ab}	4.68 ± 0.50^{b}
	MB20	1.79 ± 0.20^{a}	1.10 ± 0.10^{c}	5.38 ± 0.60^{ab}	6.37 ± 0.40^{a}
	MB30	1.99 ± 0.20^{a}	2.89 ± 0.10^{a}	6.37 ± 1.00^{a}	7.07 ± 0.30^{a}
37	CTRL	0.10 ± 0.20^{b}	2.89 ± 0.70^{a}	4.18 ± 0.20^{c}	4.78 ± 0.40^{b}
	MB10	1.39 ± 0.20^{ab}	3.69 ± 0.70^{a}	5.33 ± 0.15^{bc}	6.08 ± 0.10^{ab}
	MB20	1.69 ± 0.30^{ab}	4.28 ± 0.90^{a}	6.47 ± 0.30^{ab}	7.27 ± 0.70^{a}
	MB30	2.39 ± 0.40^{a}	4.58 ± 1.40^{a}	7.37 ± 0.80^{a}	7.77 ± 0.80^{a}

Values are mean ± standard deviation. Values with the same superscript in the same column are not significantly different ($p < 0.05$)

CTRL: Commercial *ipekere agbado* (Maize 100%); MB10: (Maize 90% + Bambara groundnut flour 10%) *ipekere agbado*; MB20: (Maize 80% + Bambara groundnut flour 20%) *ipekere agbado*; and MB30: (Maize 70% + Bambara groundnut flour 30%) *ipekere agbado*

Table 7 Free fatty acid (%) of stored *ipekere agbado* samples at different temperature (°C)

Temperature (°C)	Sample	Storage period (days)			
		2	4	6	8
18	CTRL	0.24 ± 0.02^{b}	0.45 ± 0.06^{a}	0.64 ± 0.13^{a}	0.64 ± 0.13^{ab}
	MB10	0.39 ± 0.00^{a}	0.38 ± 0.13^{a}	0.45 ± 0.06^{a}	0.58 ± 0.06^{b}
	MB20	0.27 ± 0.01^{b}	0.45 ± 0.06^{a}	0.90 ± 0.38^{a}	0.83 ± 0.06^{ab}
	MB30	0.24 ± 0.02^{b}	0.45 ± 0.06^{a}	0.77 ± 0.13^{a}	1.09 ± 0.19^{a}
25	CTRL	0.32 ± 0.06^{a}	0.64 ± 0.13^{b}	1.47 ± 0.32^{a}	1.65 ± 0.12^{b}
	MB10	0.38 ± 0.13^{a}	0.70 ± 0.19^{b}	1.28 ± 0.00^{a}	1.69 ± 0.11^{b}
	MB20	0.64 ± 0.13^{a}	1.09 ± 0.19^{ab}	1.76 ± 0.00^{a}	1.86 ± 0.06^{ab}
	MB30	0.70 ± 0.19^{a}	1.54 ± 0.26^{a}	1.78 ± 0.02^{a}	2.05 ± 0.00^{a}
37	CTRL	0.32 ± 0.06^{b}	0.83 ± 0.06^{c}	1.41 ± 0.13^{b}	1.47 ± 0.18^{b}
	MB10	0.64 ± 0.13^{ab}	1.15 ± 0.13^{b}	1.65 ± 0.12^{b}	1.98 ± 0.06^{ab}
	MB20	0.58 ± 0.06^{ab}	1.62 ± 0.04^{a}	1.92 ± 0.13^{ab}	2.24 ± 0.19^{a}
	MB30	0.77 ± 0.13^{a}	1.56 ± 0.02^{a}	2.24 ± 0.19^{a}	2.56 ± 0.13^{a}

Values are mean ± standard deviation. Values with the same superscript in the same column are not significantly different ($p < 0.05$)

CTRL: Commercial *ipekere agbado* (Maize 100%); MB10: (Maize 90% + Bambara groundnut flour 10%) *ipekere agbado*; MB20: (Maize 80% + Bambara groundnut flour 20%) *ipekere agbado*; and MB30: (Maize 70% + Bambara groundnut flour 30%) *ipekere agbado*

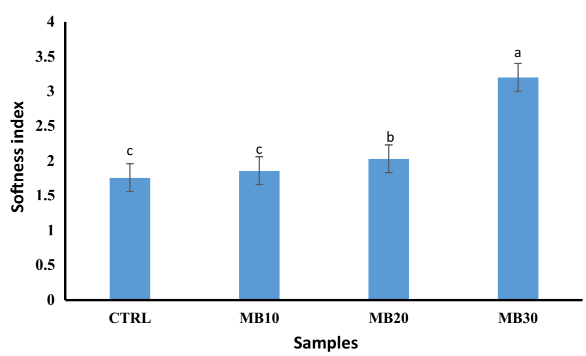

Fig. 2 Softness index of *ipekere agbado* samples. Bar with the same superscript are not significantly different ($p < 0.05$). CTRL: Commercial *ipekere agbado* (Maize 100%); MB10: (Maize 90% + Bambara groundnut flour 10%) *ipekere agbado*; MB20: (Maize 80% + Bambara groundnut flour 20%) *ipekere agbado*; and MB30: (Maize 70% + Bambara groundnut flour 30%) *ipekere agbado*

period of 7 days. The values obtained were significantly ($p < 0.05$) influenced by increasing level of Bambara flour substitution and duration of storage. The FFA of the samples increased with the level of Bambara flour substitution among *ipekere agbado* samples and with increasing period of storage time within the sample. This observation could be attributed to the high crude fat content (Table 2) observed with inclusion of Bambara flour which increase the hydrolytic degradation of oily components of Bambara enriched *ipekere agbado* under storage.

Softness index of *ipekere agbado* samples

Figure 2 present the softness index of *ipekere agbado* samples. It was observed that the softness index of MB30 was significantly ($p > 0.05$) higher compared with other samples. This finding may be attributed to the degree of inherent associative forces within the starch molecules in the *ipekere agbado* samples which may be responsible by genetic factors such as amylose/amylopectin ratio and the level of chemical transformation during *ipekere agbado* samples preparation.

Table 8 Sensory attributes of fresh *ipekere agbado* samples

Sample	Appearance	Crispiness	Taste	Aroma	Overall acceptability
CTRL	6.47 ± 0.18^{a}	6.73 ± 0.22^{ab}	6.50 ± 0.32^{b}	6.50 ± 0.27^{ab}	7.13 ± 0.25^{ab}
MB10	6.00 ± 0.39^{a}	6.00 ± 0.42^{bc}	6.03 ± 0.50^{b}	6.03 ± 0.45^{b}	6.27 ± 0.50^{b}
MB20	7.00 ± 0.34^{a}	7.03 ± 0.31^{a}	7.53 ± 0.20^{a}	7.33 ± 0.26^{a}	7.63 ± 0.33^{a}
MB30	6.07 ± 0.43^{a}	5.53 ± 0.38^{c}	5.53 ± 0.40^{b}	6.00 ± 0.38^{b}	6.10 ± 0.36^{b}

Values are mean ± standard deviation. Values with the same superscript in the same column are not significantly different ($p < 0.05$)

CTRL: Commercial *ipekere agbado* (Maize 100%); MB10: (Maize 90% + Bambara groundnut flour 10%) *ipekere agbado*; MB20: (Maize 80% + Bambara groundnut flour 20%) *ipekere agbado*; and MB30: (Maize 70% + Bambara groundnut flour 30%) *ipekere Agbado*

Sensory quality attributes of *ipekere agbado* samples

Table 8 present the sensory quality attributes of *ipekere agbado* samples. It was observed that the sensory panelist ranked CTRL significantly ($p > 0.05$) higher compared with MB10 and MB30 in terms of appearance, crispiness, taste, aroma and overall acceptability.

Discussion

This finding indicates that the developed *ipekere agbado* samples may have extended shelf-life as microbial activities reduced with moisture content less than the recommended value (< 10.00 g/100 g) (NIS 2004; Leser 2013) for food samples.

The protein content of *ipekere agbado* samples were lower compared with (> 10.00 g/100 g) recommended value (NIS 2004) but were significantly ($p > 0.05$) higher than CTRL (5.79 g/100 g). Observed protein value increase with increase in Bambara groundnut flour inclusion and this may be attributed to the fact that leguminous plant seeds (such as Bambara groundnut) are rich in protein with good arrays of amino acids and minerals (Fagbemi et al. 2004; Adegbanke et al. 2019). Hence, *ipekere agbado* may be use in management of protein-energy malnutrition. As this may help increase the protein content (from plant based—legumes) and reduced the consumption of high carbohydrate/ starchy foods (Oluwajuyitan et al. 2020, 2021; Ijarotimi et al. 2021).

A significant ($p > 0.05$) increase was also observed in the fat and ash content of *ipekere agbado* samples with Bambara substitution and these value were significantly ($p > 0.05$) higher compared with CTRL (8.62 g/100 g). However, these value were within the recommended value for food products (NIS 2004). Hence, low fat content could observe may help in establishing longer shelf life of due to reduced oxidative activities (Awolu et al. 2015). Increased ash content observed in *ipekere agbado* samples is an indication of mineral contents of *ipekere agbado* samples and this may be attribute to the effect of legume-supplementation (Alabi and Anuonye 2007). Similar trend was also reported by Etsey et al. (2007) for snacks fortified with legume.

Potassium protects against arterial hypertension and is also required to; maintain osmotic balance of the body fluids, pH, regulate muscle and nerve irritability, control glucose absorption, and enhance normal retention of protein during growth (Wardlaw 2004; Omoba et al. 2013). However, no ($p < 0.05$) significant difference was observed MB20 and MB30 in term of potassium and calcium content.

The calcium content which ranged from 1.49 mg/100 g in MB30—2.60 mg/100 g in CTRL decreased with increase in Bambara groundnut substitution and this is in agreement with the findings of Chikwendu (2007) in the study of chemical composition of *Akara* a maize-based snacks developed from fermented and germinated ground bean and maize. Calcium constitutes a large proportion of the bone: human blood and extracellular fluid. It is necessary for the normal functioning of cardiac muscles, milk coagulation and blood clotting, and the regulation of cell permeability (Lopez-Martinez et al. 2009). Comparatively, the value obtained for Na/K and Ca/P ratio of *ipekere agbado* samples including CTRL were all significantly ($p < 0.05$) within the recommended value (< 1.00) for management of high blood pressure and (> 2.00) for the development of strong bone and teeth formation respectively (Olapade et al. 2006; Lopez-Martinez et al. 2009; Oluwajuyitan and Ijarotimi 2019).

The BD is an index for measuring packaging material and is influenced by particle size and density of the flour product (Amadinkwa 2012). It has been shown that high BD is desirable for greater ease of dispersibility and reduction of paste thickness (Amadinkwa 2012). Low BD had been found to be an advantage in formulating complementary foods as it enhances nutrient and calorie density per feed of child (Akpata and Akubor 1999).

The lower WAC of the inclusion Bambara groundnut in the flour compared to the 100% maize may be advantageous as it may result in food products with lower viscosity which results in higher digestibility of the snack. (WHO 2003). This finding indicate that MB10-30 may result in food products with lower viscosity which results in higher digestibility of the snack compared with CTRL with low digestibility (WHO 2003).

The value for OAC increased with increase in Bambara groundnut substitution (145.70 ml/g–204.55 ml/g). The implication of this is that the major proteins in flours are predominantly hydrophilic compared with CTRL (Deshpande 1983).

Result observed in TBA could be attributed to high crude fat content observed in *ipekere agbado* samples and this is in agreement with the findings of Ronald and Ronald (1991) who report a progressive oxidation of oily portion Bambara groundnut sample under storage at different storage temperatures which was attributed to the reaction between oxygen and light (Jambunathan and Reddy 1991). Comparatively, it was observed that TBA value obtained in the present study were significantly ($p > 0.05$) higher than 1.50 mg malonaldehyde/kg reported by Sahar et al. (2012) for fried meat. Disparity in values may be attributed to the onset of rancidity in fried meat reported by Sahar et al. (2012). TBA values greater than 2.00 mg malonaldehyde/kg are considered to be rancid (Suman et al. 2010). This affirm that the values obtained in the present study were safe for consumption as values reported are all less than 1.00 mg malonaldehyde/kg up to day 8 for *ipekere agbado* samples stored at

18 °C. However, for *ipekere agbado* samples stored at 25 and 37 °C TBA values were less than 1.00 mg malonaldehyde/kg up to day 6. Meanwhile, at day 8 values obtained were significantly higher than 1.00 mg malonaldehyde/kg. Hence, deterioration must have set in via rancidity.

However, the PV values were significantly (< 0.05) lower than 10.00 meq/kg, a value at which oil or fried food is considered to be rancid but the values obtained from the present study were significantly ($p > 0.05$) higher than 1.00 meq/kg which is the PV value for freshly refined oil or freshly fried food products reported by Gunstone (2008). The implication of this, is that the *ipekere agbado* samples stored at three different temperatures are relatively safe for consumption, non-deteriorated, free of rancidity and may have extended shelf-life.

This FFA results is in agreement with the report of Gupta (2005) and Nkafamiya et al. (2010) who reported that the high FFA values are due to triacylglycerol hydrolysis that takes place upon release of water from the food being fried as well as crude fat present in oily food may be more liable to rancidity compared to refined oil which is in agreement with the findings of the present study.

According to Chen et al. (2013), FFA is a measuring indices widely use in determining the safety or quality of frying oil or fried food products. The values obtained from the present study shows that the *ipekere agbado* samples stored at 37 °C were significantly ($p \leq 0.05$) higher compared to those stored at 18 °C and 25 °C respectively. And these may be attributed to more exposure of *ipekere agbado* samples to high temperature and this is in agreement with the findings Ullah et al. (2003) and Njobeh et al. (2006) who reported that accumulation of FFA is normally accelerated by storage at high temperatures and in the presence of light or water, which release lipolytic enzyme which are responsible for the degeneration of triacylglycerol in oily foods.

The result observed in softness index is similar to the report of Moorthy et al. (1996) who observed that the flour preparation methods could affect the inherent associative forces within the starch molecules of flour. Mua and Jackson (1997) also report that higher amylose content and longer amylopectin chains could contribute to the hardness of a food gel or dumpling from maize, thus affecting its softness index. Hence, *ipekere agbado* softness index observed in this study may simulate the force required to compress the food product, thereby increasing the product crispiness.

The result obtained in the sensory score may be attributed to the familiarity of sensory panelist to the commercial product compared to the developed *ipekere agbado* samples enriched with Bambara groundnut flour. However, sample MB20 was ranked significantly ($p > 0.05$) higher than CTRL in term all access parameters. Hence, sample MB20 is more preferred and acceptable by sensory panelist compared with CTRL, MB10 and MB30 respectively.

Conclusions

This study has shown that increasing the percentage of Bambara groundnut flour in maize and Bambara groundnut flour blends for "ipekere agbado" production up to 30% resulted in significant increase in protein content, protein quality of the Bambara groundnut enriched samples with increasing level of Bambara groundnut flour substitution. The sensory attributes for 30% Bambara groundnut enriched "ipekere agbado" were least preferred probably because of the strong beany flavour while that of 20% was most preferred. This shows that up to 20% Bambara groundnut flour can be added to "ipekere agbado" to improve its nutritional value and eating quality. Enriching "ipekere agbado" with 20% Bambara groundnut resulted in very acceptable products, it can therefore be concluded that to obtain an acceptable Bambara groundnut enriched "ipekere agbado", the Bambara groundnut substitution level should not be more than 20%. The storage stability parameters: TBA, PV and FFA resulted in noticeable increase in values of these parameters with increase in the storage period. This may be due to the increase in the level of crude fat present in the Bambara groundnut. Therefore, the products may not be storable for longer period of time. Inclusion of Bambara groundnut in *ipekere agbado* resulted in significant increase in protein and mineral content with improved functional properties. Nevertheless, *ipekere agbado* with up to 20% inclusion of Bambara groundnut (MB20) was ranked to be comparable to the control sample without Bambara ground nut samples. Hence, its consumption will improve nutrient intake and thus have the potential of reducing the prevalence of Protein Energy Malnutrition (PEM).

Abbreviations

BG: Bambara groundnut; MB10: Maize 90% + Bambara groundnut 10%; MB20: Maize 80% + Bambara groundnut 20%; MB30: Maize 70% + Bambara groundnut 30%; CTRL: (Maize 100%)—Control sample; TBA: Thiobarbituric acid value; PV: Peroxide value; FFA: Free Fatty Acids; PEM: Protein energy malnutrition; BD: Bulk density; WAC: Water absorption capacity; OAC: Oil absorption capacity; WHO: World Health Organization.

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Authors' contributions

MOT carried out the laboratory analysis and wrote the first draft of the manuscript while OTD carried out the statistical analysis and proof read the first draft. OMO supervised the research work and corrected the final draft of the manuscript. All authors read and approved the manuscript.

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Availability of data and materials

Data are available on request.

Declarations

Ethical approval and consent to participate

The study protocol was approved by the Ethical Committee School of Agriculture and Agricultural Technology, Federal University of Technology, Akure, Nigeria (FUTA/SAAT/2020/016). Verbal consent to participate was obtained from the sensory panelist who participate in sensory evaluation.

Consent for publication

Not applicable.

Competing interests

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