Applied Tropical Agriculture
Volume 22, No. 2, 188-196, 2017.

Physicochemical and Sensory Qualities of "Aadun" a Maize based Snack Supplemented with Defatted African Oil Bean Seed Flour

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ABSTRACT

The effect of substituting roasted whole maize (Zea may) flour with African oil bean seed (Pentaclethra macrophylla Benth) flour and acceptability of the product was investigated. Composite flour was developed from roasted maize and African oil bean seed flour at ratios 90:10 (MAO1), 80:20 (MAO2), 70:30 (MAO3) and 100% (MAF) as control sample. Maize based snack (aadun) was produced from resulting composite blends. Proximate, chemical, functional, minerals and sensory properties of samples were determined using standard procedures. The protein, fat and mineral content increased with increasing African oil seed flour substitution. Protein (14.55±0.02) and fat (10.45±0.45) was highest in MAO3. Tannins and oxalates increased with increasing African oil bean seed substitution. Phytate contents in samples were significantly ($P<0.05$) higher in MAO2 and MAO3 than other samples. At 30% substitution level the taste, appearance and overall acceptability of maize based snack were significantly affected and unacceptable. Production of enriched maize-based snack could be best achieved at 10-20% substitution of maize flour with African oil bean seed flour.

Key words: Maize, snacks, roasting, African oil bean, substitution

INTRODUCTION

Maize (*zea mays*), is among the most important and most widely grown cereal grain in the world. Maize is a grain of importance as typified in its global high rate of production. In 2007, the global maize grain production stood at 766 million tonnes with United State of America being the largest producer with 40% of the total global production (Radosavljević *et al*., 2010). Almost half of the world production of maize is produced from the developing countries including Nigeria (Samapundo *et al.,* 2007). Its applications include but not limited to human consumption, feeds for livestock, bio-fuel production and as raw material for many industrial applications (FAO, 2012).

African oil bean (P*entaclethra macrophylla Benth)* is a tropical tree belonging to the leguminosae family. The oil bean tree is typical of the southern rain forest zone of west Africa. African oil bean seeds have a flat shape, hard, smooth in texture, brown coloured and about 6 cm long (Nwokolo and Smartt, 1996). The African oil bean tree soil improving properties makes it of importance in the south east of Nigeria (Akindahunsi, 2004). Common uses of African oil bean include; food, edible oil, seed craft, dye, fencing and palings, charcoal, carving bowls, medicine (anti-convulsion, anti-itching and anti-diarrhea), wood and ornamental (Enujiugha and Agbede, 2000; Asoegwu *et al*., 2006).

Protein energy malnutrition is a problem affecting a larger proportion of the global population with severe cases found in rural areas of Africa. Therefore, developing inexpensive, practicable and nutritionally rich food products is germane, serving as vehicle in managing malnutrition in rural areas. *Aadun* is a savoury maize-based snack typical of Yoruba ethnic group in Nigeria. It is prepared from roasted whole maize (*Zea mays*) meal and table salt thoroughly mixed in palm oil to obtain uniformity. It is served as traditional snack to people of different economic, age and social status at social functions (Adedokun, 2006). *Aadun* is a rich source of energy, phosphorus and magnesium but low in protein thus necessitating the substitution of whole maize flour with African oil bean seed flour (rich in protein) for its production. This study investigated the effect of substituting roasted whole maize flour with African oil bean seed flour on physicochemical, functional, antinutrient and sensory properties of produced maize based snack (*aadun*).

MATERIALS AND METHODS

Materials

Sources of Materials: Maize grains (*Zea mays* L.) and African oil bean seeds (*Pentaclethra macrophylla* Benth), Salt, palm oil and leaves used in the study were purchased from Oba market in Akure, Ondo state, Nigeria. All chemicals used were of analytical grade and obtained from Sigma-Aldrich Chemical Co., St. Louis, USA.

Methods

Production of roasted maize flour: Maize grains were cleaned, roasted in an oven (Laboratory oven, DHG 9101.1SA) at 70˚C for 15 min and dry milled to a particle size of 230 µm to obtain roasted maize flour (Fig. 1).

Production of African oilseed flour: African oil bean seeds were parboiled for about 6 h, dehulled and the cotyledons were sliced manually into two. It was then cooked for about 5 h and soaked in water for about 6 h at ambient temperature (25 ^{o}C). Sliced African oil bean seed was wet milled, defatted with n-hexane in a soxhlet extractor for 6 h and dried at 60 ^{o}C until moisture content is approximately 5%. Defatted African oil bean seed meal was dried milled into flour as shown in Fig. 2.

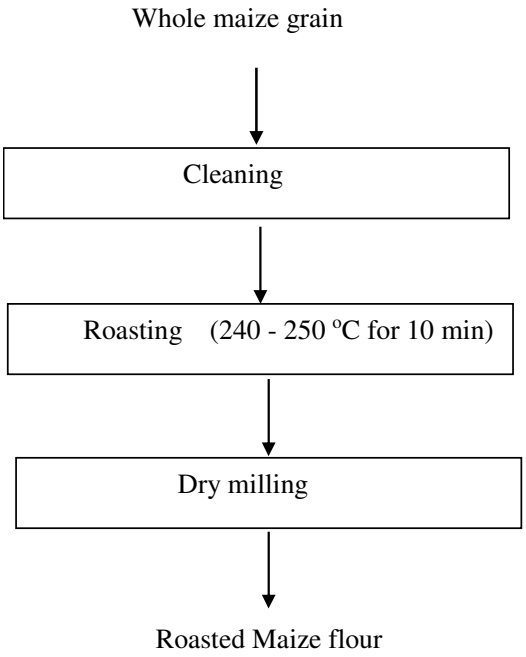

Figure 1: Production of roasted maize flour

Production of aadun: Composite flours (90:10 (MAO_1), 80:20 (MAO_2), 70:30 (MAO_3) and 100% (MAF) 100:0) were produced from the ratios of roasted maize flour and defatted African oil bean seed flour. *Aadun* was produced by mixing resulting composite flours with palm oil (27%), Pepper (1.6%) and salt (0.3%). The mixture was cooled and wrapped in leaves as described in Fig 3.

Analyses

Determination of the physicochemical properties of flour blends

Proximate composition of flour blends

Moisture, crude fat, ash, crude fibre and protein content of samples were determined using standard methods (AOAC, 2005) while the carbohydrate content was determined by difference.

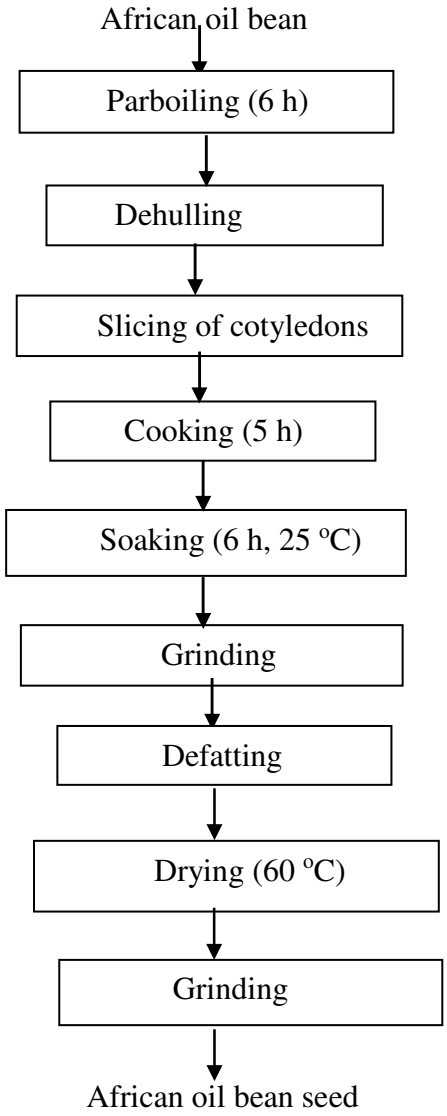

Figure 2: Production of defatted African oil bean seed flour

Mineral content of flour blends

Microelements (Fe and Zn) and macro elements (Na, K, Ca and Mg) content of samples were determined according to AOAC, (2000). About two gramme of samples were weighed and heated at 550 ºC for 8 h in a Muffle furnace. Ashed samples were dissolved with 100 ml 1M HCl and digest was used for the determination. Flame photometre (Model GT. 240) was used for Na, Ca, Mn and K (AOAC, 1990) and Atomic Absorption Spectrophotometre (Perkin Elmer, Model 3300, USA) was used for Fe, K, Zn and Mg while phosphorus was determined using Bush-Lamb Spectronic 20 (Gallenkamp and Co. Ltd. England).

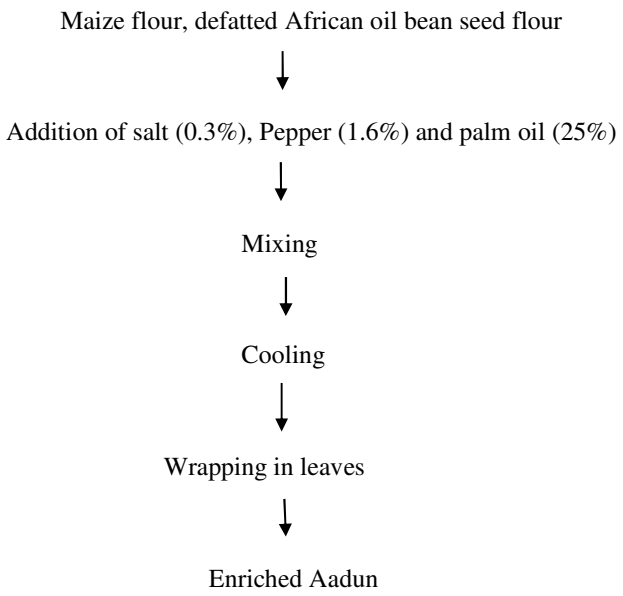

Figure 3: Production of maize based snack (*aadun*)

Determination of Functional properties of flour blends

Water absorption capacity and oil absorption capacity

The water absorption capacity was determined as described by Sathe *et al*., (1982). About 10 ml of water was added to 1 g of each sample blend, the suspension was stirred using magnetic stirrer for about 5 mins. The suspension was transferred into centrifuge tubes and centrifuged at 3,500 x g for 30 min. The supernatant obtained was measured in a measuring cylinder. The water/oil absorbed was calculated as the difference between the initial water/oil added to sample and the volume of supernatant obtained after centrifuging. Result was expressed as percentage g/g of water/oil absorbed by the blends (Eq. 1 and 2).

$$Water\ Absorption\ Capacity\ (\%g/g) = \frac{Volume\ of\ water\ absorbed}{Weight\ of\ sample} \quad Eq.\ 1$$

$$Oil\ Absorption\ Capacity\ (\%g/g) = (Volume\ of\ Oil\ absorbed\ \times density)/(Weight\ of\ Sample) \quad Eq.\ 2$$

Emulsion capacity and stability

The emulsion capacity and stability were determined as described by Yasumatsu *et al.* (1972). About 2 g of sample and 100 ml distilled water were homogenised for 30 min at high speed (100 x g) in a Moulinex blender. After complete dispersion, peanut oil was added, mixed and left to separate into two layers. The emulsion capacity was expressed as gramme of oil emulsified per gramme of flour while the volumetric changes in foam, oil and aqueous layers were recorded after 3 h and expressed as emulsion stability.

Least gelation concentration

Sample suspension of 2%, 4%, 6%, 8%, 12%,14%,16%,18% and 20% (m/v) were prepared in 10 ml distilled water in test tubes. The tubes containing the suspension were heated for an hour in water bath, rapidly cooled in water for 2 h and was inverted. The least gelation concentration was taken as the concentration at which the sample in the inverted test tube did not fall or slip (Coffman and Garcia, 1977).

Bulk density

The bulk density of samples was determined as described by Oladele and Aina (2007). About 5 g of the sample was poured into a graduated measuring cylinder and was tapped constantly until there was no further change in volume. Bulk density was expressed as g/cm^3 (Eq. 3).

$$\text{Bulk density (g/ml)} = (\text{Weight of the sample})/(\text{Volume occupied}) \quad Eq.\ 3$$

Determination of anti-nutrients in samples

Determination of tannin

The tannin content of the samples were determined as described by Pearson (1976). Tannin was extracted from samples by dissolving 5 g sample in 50 ml distilled water. Mixture in the conical flask was made to stand for 30 min with shaking at intervals of 10 min then centrifuged at 5000 x g to obtain a supernatant (tannin extract). The tannin extract was made up to 100 ml in a standard flask with distilled water. About 5 ml of diluted extract and 5 ml of standard tannic acid (0.01 g/l tannic acid) were measured into different 50 ml volumetric flasks. Exactly 1 ml of Folin–Denis reagent was added to each flask followed by 2.5 ml of saturated sodium carbonate solution. The solutions were made up to 50 ml mark with distilled water

and incubated at room temperature (20–30 °C) for 90 min. The absorbance of solutions were measured against the reagent blank (standard tannic acid solution) in a Beckmann spectrophotometer at 760 nm wavelength. The tannin content was deduced from the standard tannin curve. Tannin content (mg/100 ml in cell) was calculated as described in Equation 4.

$$Tannin\ content\ (mg/100ml) = \frac{Sample\ reading - \ blank}{standard\ reading - blank} \quad Eq.\ 4$$

Determination of phytate content

Phytate content of the samples were determined as described by Reddy and Love (1999). Four (4) gramme of sample was soaked in 100 ml 2% HCl for 5 h and filtered. Five (5) ml of 3% ammonium thiocyanate solution was added to 25 ml of filtrate. The resulting mixture was titrated against iron (III) chloride solution until an end point (brownish- yellow colour which persisted for 5 min) was reached. The phytate content was calculated as described in Equation 5;

$$Phytate\ content(mg/g) = Titre\ value\ x\ 2.32 \quad Eq.\ 5$$

Determination of oxalate

Oxalate content was determined as described by A.O.A.C (2000). One (1) g sample was weighed into 100 ml conical flask, to which 75 ml of 1.5 N H_2SO_4 was added. The solution was stirred intermittently with the aid of a magnetic stirrer for about an hour and then filtered using Whatman No 1 filter paper. Twenty-five (25) ml filtrate was titrated against 0.1 N $KMNO_4$ solution till an end point (faint pink colour persists for at least 30 sec) was reached. The oxalate concentration was calculated as described in Equation 6.

$$Oxalate\ concentration\ (mg/g) = Titre\ value\ x\ 0.09004 \quad Eq.\ 6$$

Determination of the oxidation properties

Determination of peroxide value

Peroxide value (PV) of samples was determined using the method of (AOAC, 1990). About 1 g of sample was weighed into a clean dried boiling tube containing a 20ml solvent mixture of acetic acid and diethyl ether and boiled for 60 sec. The content was placed in 250ml volumetric flask containing 20 ml of 5% potassium iodide. The solution was titrated against 0.002 M sodium thiosulphate using starch as indicator. The peroxide value was calculated as described in the equation 7

$$\text{P V} = \frac{\text{(Volume of the blank used} - \text{Titre value) ml x Molarity of sodium thiosulphate}}{\text{Weight of sample}} x\ 1000 \quad Eq.\ 7$$

Determination of acid value and free fatty acid (FFA)

About 1 g of the sample was weighed into a conical flask, 2.5 ml of 95% (v/v) alcohol was added and 1 ml of phenolphthalein indicator. The solution was titrated with 0.1 M potassium hydroxide (KOH) (AOAC, 1990). The acid value and FFA was calculated as described in Equation 8 and 9.

$$\text{Acid value} = \frac{\text{Titre value x Molarity of KOH x 56}}{\text{Weight of sample}} \quad Eq.\ 8$$

$$\text{Free fatty acid} = \frac{\text{Titre value x Normality of KOH x 282}}{\text{weight of sample (g) x 10}} \quad Eq.\ 9$$

Sensory evaluation of product samples

A twenty-man panelist comprising of staff and student of the Federal University of Technology, Akure was used and selection was made on the basis of familiarity with "aadun". The samples were presented to panelists in a randomised order and were evaluated for appearance, taste, aroma, texture, mouthfeel and overall acceptability on a 7-point hedonic scale (Larmond, 1977).

Statistical analysis

Data was generated in triplicate and analysis was done using one-way Analysis of Variance (ANOVA) of the Statistical Package for Social Sciences (SPSS version 10.0 for windows) and the means were separated using Duncan's Multiple Range test.

RESULTS

The proximate composition of substituted maize based snack and 100% maize based snack (aadun) is shown in Table 1. Protein content of samples increased with increasing substitution with African oil bean seed flour. The protein content of the snack was significantly different in all samples with MAO_3 having the highest (14.55±0.02) compared to control (7.26±0.09). The total ash content ranges from 1.85 ± 0.01 to 2.24 ± 0.02. Ash content was highest in MAO_3 (2.44 ± 0.03) and least in the MAF (Control). The fat content increased with increasing substitution with African oil bean seed flour. The carbohydrate content reduced with increasing African oil bean seed flour while the moisture content of the samples ranged from 3.49 ± 0.03% to 4.32 ± 1.13%.

Functional properties of maize-african oil bean flour blends

Table 2 shows the functional properties of the maize-African oil bean seed flour blends. The oil absorption capacity and water absorption capacity (WAC) increased (2.0±0.05-3.15±0.05) with increasing substitution of African oil bean seed flour. The oil and water absorption capacity was highest in MAO_3 and least in MAO_2. Least gelation capacity (LGC) properties of flour blends increased with increasing substitution with african oil bean seed flour. LGC was ranged from 0.40 to 1.95 and was highest in MAO_3 while the control had the least value. Samples were significantly different from others including the control at P≥0.05. Foaming capacity (FC) was highest in the control sample 10.95±0.05 while MAO_2 and MAO_3 was not significantly different from each other. The emulsion capacity of the flour blends ranged from 2.15±0.05 - 5.05±0.00 and was highest in MAO_2. The bulk density of the blends ranged from 0.7±0.00-0.85±0.04. There was no significant difference in control, MAO_2, MAO_3. The peroxide value (PV), acid value (AV) and free fatty acids (FFA) are presented in Table 3.

Table 1: Proximate chemical composition of maize-oil bean seed flours

Samples	Moisture (%)	Fibre (%)	Fat (%)	Ash (%)	Protein (%)	Carbohydrate (%)
MAF	4.24 ^{a} ±0.50	2.12 ^{d} ±0.25	3.81 ^{d} ±0.04	1.85 ^{d} ±0.01	7.26 ^{d} ±0.09	80.70 ^{a} ±0.61
MAO_1	3.68 ^{a} ±0.29	2.22 ^{c} ±0.02	5.32 ^{c} ±0.07	2.06 ^{c} ±0.02	9.36 ^{c} ±0.09	76.97 ^{b} ±0.09
MAO_2	3.40 ^{a} ±0.03	2.32 ^{b} ±0.02	8.45 ^{b} ±0.09	2.26 ^{b} ±0.05	12.37 ^{b} ±0.26	71.13 ^{c} ±0.40
MAO_3	4.32 ^{a} ±1.13	2.42 ^{a} ±0.02	10.45 ^{a} ±0.45	2.44 ^{a} ±0.03	14.55 ^{a} ±0.02	65.81 ^{d} ±0.60

Values represent mean ± standard error of triplicate determinations and values with same superscript along the column are not significantly different (p≤0.05). **Keys:** MAF= 100 % Maize flour (Control); MAO_1 = 90% maize + 10% African oil been flour; MAO_2 = 80% maize flour + 20% African oil bean flour; MAO_3 = 70% maize flour + 30% African oil bean flour.

Table 2: Functional properties of maize-oil bean seed flour blends

Samples	OAC (g/g)	WAC (g/g)	FC (%)	EC (%)	LGC (g/cm3)	Bulk Density (%)
MAF	2.25^{c} ±0.50	3.75^{b}±0.05	10.95^{a}±0.05	2.15^{c}±0.05	0.40^{d} ±0.00	0.73^{c}±0.01
MAO_1	2.45^{b}±0.05	3.45^{c}±0.05	6.05^{c}±0.05	4.00^{b}±0.01	1.15^{c} ±0.05	0.85^{a}±0.04
MAO_2	2.00^{d}±0.00	3.40^{c}±0.00	7.00^{b}±0.00	5.05^{a}±0.00	1.60^{b} ±0.00	0.70^{b}±0.00
MAO_3	3.15^{a} ±0.05	4.00^{a}±0.00	7.05^{b}±0.05	4.10^{b}±0.01	1.95^{a}±0.05	0.70^{b}±0.00

Values represent mean ± standard error of triplicate determinations and values with same superscript along the column are not significantly different (p≤0.05). **Keys:** OAC= Oil Absorption Capacity, WAC = Water Absorption Capacity, FC = Foaming Capacity, EC = Emulsion Capacity, LGC = Least Gelation Capacity. MAF= 100 % Maize flour (Control); MAO_1 = 90% maize + 10% African oil been flour; MAO_2 = 80% maize flour + 20% African oil bean flour; MAO_3 = 70% maize flour + 30% African oil bean flour; MAO_3 = 70% maize flour + 30% African oil bean flour.

Table 3: Acid value, free fatty acids and peroxide values of Maize-African oil bean flour

Samples	Acid value (mgKOH/g)	Free fatty acid (%)	Peroxide value (mgKOH/g)
MAF	9.39 ^{d}±0.14	4.70^{d}±0.08	0.001^{c}±0.00
MAO_1	20.63^{c}±0.49	10.45^{c}±0.07	0.004^{b}±0.00
MAO_2	24.96^{b}±0.00	12.48^{b}±0.00	0.0037^{b}±0.00
MAO_3	26.22^{a}±0.14	13.12^{a}±0.07	0.014^{a}±0.00

Values represent mean ± standard error of triplicate determinations and values with same superscript along the column are not significantly different (p≤0.05). **Keys:** MAF= 100 % Maize flour (Control); MAO_1 = 90% maize + 10% African oil been flour; MAO_2 = 80% maize flour + 20% African oil bean flour; MAO_3 = 70% maize flour + 30% African oil bean flour.

The acid value of produced maize based snack ranged from 9.39±0.14 mgKOH/g to 26.22±0.14 mgKOH/g, free fatty acid (4.70±0.08 - 13.12±0.07%) and peroxide value (0.001±0.00 - 0.014±0.00 mgKOH/g). Acid value, free fatty acid and peroxide concentrations increased significantly with increasing substitution with African oil bean and its content was highest in MAO_3.

Table 4 shows the mineral composition of the samples. Result showed that manganese, sodium and zinc contents increased with increasing substitution of african oil bean seed flour in produced snack while phosphorus and calcium concentration decreased with increasing substitution. Manganese ranged from 0.09 to 0.21 g/100 g, sodium (36.78 - 40.31) g/100 g, zinc (0.21 - 0.61) g/100 g, phosphorus (0.67 - 0.21) g/100 g, calcium (2.21 - 1.88) g/100 g. Sodium, potassium, manganese, zinc, iron and copper was significantly higher in MAO_3 compared to other samples and control. The Ca/k ratio of samples were not significantly different P≥0.05 ranging from 0.02 to 0.03

Table 4: Mineral composition of maize based snack (*aadun*)

Samples (g/100g)	MAF	MAO_1	MAO_2	MAO_3
Na	36.78^{d}±0.02	38.07^{c}±0.05	39.61^{b}±0.01	40.31^{a}±0.01
K	74.68^{b}±0.55	75.31^{b}±0.01	74.68^{b}±0.55	99.8^{a}±0.00
Mn	0.13^{c}±0.00	0.09^{d}±0.01	0.18^{b}±0.01	0.21^{a}±0.01
Zn	0.30^{c}±0.00	0.21^{d}±0.01	0.53^{b}±0.01	0.61^{a}±0.01
Mg	0.91^{a}±0.01	0.61^{d}±0.01	0.80^{b}±0.00	0.71^{c}±0.01
Fe	1.00^{c}±0.00	0.75^{d}±0.01	2.06^{b}±0.01	2.26^{a}±0.00
Ca	2.21^{a}±0.01	1.95^{c}±0.01	2.12^{b}±0.01	1.88^{d}±0.01
Cu	0.08^{c} ±0.01	0.05^{d}±0.00	0.27^{b}±0.01	0.31^{a}±0.01
P	0.67^{a}±0.01	0.54^{b}±0.01	0.53^{c}±0.00	0.27^{d}±0.00
Ca/K	0.03^{a}±0.01	0.03^{a}±0.03	0.03^{a}±0.00	0.02^{a}±0.01
Na/K	0.49^{a}±0.02	0.51^{a}±0.02	0.53^{a}±0.05	0.40^{b}±0.03
Ca/P	3.29^{c}±0.02	3.61^{c}±0.03	4.0^{b}±0.02	6.96^{a}±0.01

Values represent mean ± standard error of triplicate determinations and values with same superscript along the column are not significantly different ($p \leq 0.05$). **Keys:** MAF= 100 % Maize flour (Control); MAO_1 = 90% maize + 10% African oil been flour; MAO_2 = 80% maize flour + 20% African oil bean flour; MAO_3 = 70% maize flour + 30% African oil bean flour.

g/100g, Na/K (0.40 – 0.53 g/100 g) and Ca/P (3.29 – 6.96 g/100g). Table 5 shows the levels of some anti-nutrients in the maize-african oil bean flour blends. Oxalate, tannins and phytates increased with increasing african oil bean flour substitution. The Control sample had the lowest tannin, oxalate and phytate content.

Table 5: Anti-nutrient of maize-african oil bean flour blend

Samples	Oxalate (mg/g)	Tannin (mg/100g)	Phytate (mg/100g)
MAF	0.40±0.04^{d}	2.65±0.02^{d}	3.67±0.28^{c}
MAO1	1.04±0.04^{c}	5.45±0.07^{c}	8.46±0.57^{b}
MAO2	2.79±0.09^{b}	5.83±0.02^{b}	9.58±0.01^{a}
MAO3	3.42±0.01^{a}	6.97±0.07^{a}	9.87±0.28^{a}

Values represent mean ± standard error of triplicate determinations and values with same superscript along the column are not significantly different ($p \geq 0.05$). **Keys:** MAF= 100 % Maize flour (Control); MAO_1 = 90% maize + 10% African oil been flour; MAO_2 = 80% maize flour + 20% African oil bean flour; MAO_3 = 70% maize flour + 30% African oil bean flour.

Table 6 shows the sensory evaluation results of maize-based snack (enriched aadun) produced from composite flour of maize and african oil bean seed flour. Sensory quality attributes of *aadun* were negatively affected by substitution with african oil bean seed flour at different levels studied. The appearance of aadun ranged from neither like nor dislike to slightly like with the control sample having the highest score. There was no significant difference in appearance and texture of the snack. The taste characteristics of samples ranged from moderately dislike to extremely dislike and samples were significantly different ($P \geq 0.05$). The texture ranged from neither like nor dislike to slightly dislike. Aroma of samples ranged from slightly dislike to moderately like. Values of aroma in MAO_3 and MAO_2 were significant compared MAO_1 and control. The mouth feel of the samples reduced with increasing substitution and its rating ranged from slightly dislike (MAO_3) to moderately like in the control.

DISCUSSION

The improved protein content in the sample could find promising application in the developing food product that will have higher protein content especially in areas where the starchy staples are localised. This finding agrees with that of Olaoye *et al*. (2006) who produced *Agidi*-a fermented cereal product from maize flour substituted with soyflour. The ash content of produced snack increased with increasing substitution with African oil bean seed flours. The ash content is indicative of minerals present in the snack. High fat content could reduce the shelf stability of food products due to possible development of off flavours and rancidity especially in samples containing more than 90% unsaturated fatty acids (Enujiugha and Ayodele-Oni, 2003). Reduce moisture content will enhance product shelf-stability indicating *aadun* could have a good shelf stability. The crude fibre was relatively low, increasing with increasing substitution with African oil bean seed flour.

Oil absorption capacity (OAC) is an indication of the rate at which protein binds to fat in food formulations (Onimawo and Akubor, 2012). Fat acts as a flavour retainer and helps improve the mouthfeel of products (Balogun and Olatidoye, 2010). The high OAC suggested the presence of apolar amino acids in the flour blends. WAC is an index of the amount of water retained in protein matrix of food material. The removal of fat from the samples exposes the water binding sites on the side chain groups of protein units previously blocked in a lipophilic environment thereby leading to an increase in WAC values in defatted flours

Table 6: Sensory analysis of maize based snack (*aadun*)

Samples	Appearance	Taste	Texture	Aroma	Mouth feel	Overall acceptability
MAF	5.4^{a}±1.95	6.7^{a}±0.67	5.1^{a}±2.02	5.2^{ab}±0.78	5.6^{a}±1.42	5.6^{a}±1.26
MAO_1	5.6^{a}±1.07	5.1^{b}±1.73	5.0^{a}±1.25	4.2^{bc}±1.75	4.3^{ab}±1.05	4.6^{b}±1.26
MAO_2	5.3^{a}±1.63	3.4^{c}±2.17	3.7^{c}±2.16	3.8^{c}±1.48	4.2^{ab}±1.31	3.9^{c}±1.28
MAO_3	4.3^{a}±2.35	2.5^{d}±1.84	4.5^{b}±1.35	5.5^{a}±0.97	3.0^{b}±2.21	2.3^{d}±1.25

Values represent mean ± standard error of triplicate determinations and values with same superscript along the column are not significantly different ($p \leq 0.05$). **Keys:** MAF= 100 % Maize flour (Control); MAO_1 = 90% maize + 10% African oil been flour; MAO_2 = 80% maize flour + 20% African oil bean flour; MAO_3 = 70% maize flour + 30% African oil bean flour.

(Adebowale *et al.,* 2005). Gelling ability is influenced by the nature of proteins, starch and gums in samples, as well as the interaction during heat treatment (Enujiugha and Ayodele-Oni, 2003). The low level of least gelation concentration could be attributed to the possible formation of intermolecular hydrogen bonds between amylose molecules and other proteins present in the cooled gel samples (Mbaeyi, 2005). Foaming capacity (FC) is a property of protein in samples. Foamability of a food material varies with the type of protein, solubility and other factors (Akubor and Eze, 2012). Good foamability has been linked to the flexible protein molecule that could reduce surface tension while poor foamabilty is due to highly ordered globular protein which is relatively difficult to denature by heat (Onimawo and Akubor, 2012). The higher FC observed in control sample could be due to the protein (zein) reported in maize. High emulsion capacity denotes better flavour retainment, mouth feel and taste of food (Oyarekua and Adeyeye, 2009). Bulk density is a function of particle size and is inversely proportional to bulk density (Akubor and Eze, 2012).

PV, AV and FFA are good shelf life quality indices in oily food products. FFA, Acid values and Peroxide values are within acceptable limit of edible oilseeds. FFA is formed due to hydrolysis of triglycerides and may be promoted by reaction of oil with moisture (Frega *et al*., 1999). FFA values of less than 5% obtained are within the acceptable limit for edible products (Eckey, 1954). Acid value is indicative of edibility while peroxide value is a measure of peroxides and hydro-peroxides formed during initial stage of lipid oxidation. Peroxide reduces oil digestibility and cause destruction of fat soluble vitamins. The acid value and peroxide values obtained in this study were higher than those reported by Al-Fatlawi and Abbas (2010) in Alkhair, Birzce and Sandy vegetable oil.

In general, substitution of maize with african oil bean seed flour influence the mineral content of a maize based snack (aadun). This finding corroborate that of previous authors on the appreciable amount of important minerals present in african oil bean flour (Enujiugha and Agbede, 2000). Calcium is an essential micronutrient that ensures good health and wellbeing (Weaver and Heaney, 2006). Calcium serves in diverse biological function of the body such as growth and bone formation. According to the Food and Nutrition Board a dietary allowance of 360 mg and 1200 mg of calcium is recommended for infants and adults respectively (FNB, 1980). Phosphorus and calcium are stored as calcium phosphate in the body while aiding body and growth formation. Calcium phosphorus ratio was highest in MAO3 (6.96 g/100 g) Magnesium is essential for normal nerve and heart function. Potassium is an essential nutrient that has an important role in the synthesis of protein in man (Malik and Scivastava, 1982). Magnessium contents increased with increasing african oil bean substitution in aadun and its values were significantly different ($P \geq 0.05$) from the control. The produced samples may be able to aid the further absorption of copper in view of concerns that suboptimal copper status could predispose the development of inflammatory and degenerative diseases (Roberts-Nkrumah and Badrie, 2008). The values of sodium, iron, potassium and zinc in the products were lower than that reported in diabetic snacks made from *Afzelia africana* and *Detarium microcarpium* seed flour (Onyechi *et al.,* 2013) and Ogunmodimu *et al.* (2015) in high protein fibre snack made from wheat-soybean concentrate –cassava fibre flour. Iron is essential for heamoglobin formation, cognitive development and oxidation of macro nutrients (Adeyeye and Otokiti, 1999). The sodium to potassium (Na/K) ratio of the samples were less than one (≤ 1.00) implying that the snack has less sodium relative to potassium which could be suitable for people suffering from cardiovascular diseases (Ogbuagu *et al*., 2011).

There was a successive increase in the level of oxalates and tannins due to the increased substitution of African oil bean in the flour blends. Tannins have ability to form insoluble complexes with proteins which can impair digestibility of food proteins (Ogunlade *et al.,* 2011). Presence of tannins in large quantities in foods can lead to intestinal tract damage, and carcinogenesis (Anuonye *et al.,* 2012). Phytate is a complex class of naturally occurring phosphorus compounds that can influence the functional and nutritional properties of foods.

The sensory properties of produced aadun were rated low with increasing substitution with African oil bean seed.

MAO_3 was adjudged unacceptable by the panelist in comparison with other samples and the control. This could be due to the fact that many of the panelist used are not familiar with African oil bean seed.

CONCLUSION

Substitution of the African oil bean seed flour with roasted maize flour to produce *aadun* is achievable within 10-20% substitution levels. However, oil bean seed flour substitution above 20% for *aadun* production is unacceptable. African oil bean seed flour could serve as a source of dietary protein and mineral supplement in traditional maize based snack (aadun) eaten especially in areas where staple foods are majorly roots or tubers and cereals. However, the relatively high oxalate, phytates and tannin content is still a treat to the utilisation of African oil bean seed flour and therefore requires further study to ensure the delivery of nutrients.

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