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# Effects of Plant Ash Fortification on *okpa* the Ethnic and Traditional Snack of Southeast Nigeria

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## To cite this article:

Okwunodulu Nwazulu Innocent, Ogu Ukamaka Rosemary, Nwachukwu Chinyere Ann, Ukom Nwankwo Anthony. Effects of Plant Ash Fortification on *okpa* the Ethnic and Traditional Snack of Southeast Nigeria. *World Journal of Food Science and Technology*. Vol. 5, No. 4, 2021, pp. 55-63. doi: 10.11648/j.wjfst.20210504.11

**Received:** June 21, 2021; **Accepted:** July 2, 2021; **Published:** October 30, 2021

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**Abstract:** *Okpa* is a popular traditional snack widely relished by both rich and poor including the elderly people of south eastern part of Nigeria and therefore could be a good vehicle for nutrient intervention programmes. It is rich in protein but not a good source of minerals which fortification with empty palm bunch ash will enhance to prevent osteoporosis and other related diseases among the elderly people. Bambara groundnut paste was prepared, mixed with water and seasonings, and divided into four batches. Three out of the four batches were fortified each with 1, 5 and 10% ash as samples B, C and D respectively. Each batch was separately wrapped (250 ml) in plantain leaves and steamed. The remaining unfortified batch served as control (sample A). Proximate and mineral contents were evaluated with standard analytical methods. Sensory evaluation was determined subjectively with 20 semi-trained panelists. With increase in ash fortification levels, there was increase in moisture (58.40-59.50%), fibre (1.20-1.30%), ash (1.35-1.55%), calcium (72.50-85.38 mg/100g), magnesium (114.45-126.46 mg/100g), zinc (5.70-6.33 mg/100g), iron (1.45-2.36 mg/100g), phosphorous (206.32-219.40 mg/100g) and sodium (12.27-14.92 mg/100g). Only protein (8.63-8.43%), fat (4.15-4.00%), carbohydrate (25.83-25.23%), energy (164.63-160.31 Kcal), and acceptability (7.05-4.10) decreased. The control sample had the highest acceptability score which was not statistically different from samples with 1 and 5% ash. Ash concentrations of 1 and 5% enhanced the taste, appearance, aroma and texture of the *okpa* more than the control. There was significant increase in most nutrients most especially the minerals more than the control.

**Keywords:** *Okpu*, Bambara Groundnut, Empty Palm Bunch Ash

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## 1. Introduction

The *okpa* is a semi-solid pudding prepared from steamed Bambara groundnut paste [1] after mixing with desired ingredients. It is a popular and widely cherished snack by both the rich and poor in the eastern part of Nigeria. The *okpa* can be termed a thermogenic food as it helps in weight loss [2]. *Okpa* is prepared after the mature dried Bambara groundnut seeds have been dehulled, milled, sieved and thoroughly mixed with water and seasonings like palm oil or crude palm fruit extract, salt, pepper and other spices as

desired. The paste after mixing is traditionally wrapped with banana leaves in small wraps of 250 ml or more before steaming for 30-50 min to form the semi-solid *okpa*. Today, low density transparent polythene, tin plates and plastic or aluminium containers are being used [1]. The use of palm oil and crude palm fruit extract in the preparation is a common practice. Their effect on the sensory properties of *okpa* has not been documented and they also boost the flavour and aesthetic appeal.

Bambara groundnut (*Vigna subterranean*) is an indigenous African leguminous crop and one of the most important pulses grown on the continent [3]. It originated from West

African countries like Nigeria, Cameroon Chad, and has been cultivated throughout drier tropical Africa. Bambara groundnut has high yield, resistance to diseases and adaptability to poor soils and rainfall [4]. It is the third eaten legume in Africa after groundnut (*Arachis hypogea*) and cowpea (*Vigna unguiculata*) as an important protein source in the diets by mostly the poor who cannot afford expensive animal protein [5].

Bambara groundnut makes a balanced food, as it contains sufficient quantities of beneficial nutrients such as carbohydrate (65%), protein (18%), fat (6.5%), water (10%), fibre (15-20%), potassium, calcium, phosphorous, iron, sodium and cholesterol [6]. Furthermore, Brough and Azam-Ali [7] reported 65% carbohydrates, 16.25% protein and 6.3% fat with relatively high proportions of lysine and methionine. It is richer than peanuts in such essential amino acids as isoleucine, leucine lysine, methionine, phenylalanine, threonine and valine [8, 5]. The fatty acid content is predominately linoleic, palmitic and linolenic acids. The gross energy value is greater than other common pulses such as cowpea, lentil and pigeon pea [9].

The seeds are consumed at different developmental stages, either immature or fully ripe. The immature seeds can be consumed fresh, boiled, grilled as a meal or mixed with immature groundnuts or green maize. Mature dried Bambara groundnut seeds are very hard; hence boiling becomes a prerequisite before any further preparation. They are milled to produce flour which can be used to bake biscuits or mixed with cereals and boiled to make porridge. They are also roasted, broken into pieces, boiled, crushed and eaten as a relish or eaten whole as snack like in peanut when boiled [10, 5]. Bambara groundnut can also be used to provide a balanced amino-acid profile of cereal grains [11] or to fortify garri to improve the protein content.

Bambara ground nut is underutilized in Nigeria as human foods because of such constraints as hard to cook phenomenon, strong beany flavour, anti-nutrient contents, poor dehulling and milling characteristic [12]. Anti-nutrients inhibit protein digestibility and absorption of amino acids [13] and calcium availability [14]. Bambara groundnut contains such anti-nutrient as cyanogens, saponins, trypsin inhibitor [15, 13], tannins, phytate and oligosaccharide (Raffinose and starchyose which causes flatulence). Bambara groundnut may lead to allergic reactions to people who are allergic to legumes. However, low levels of tannins have beneficial effects in human nutrition which projected Bambara groundnut as beneficial to human diets [16].

Heat treatment such as boiling, roasting, autoclaving [17], soaking, milling, dehulling, germination and fermentation [18]. Have been reported to eliminate some or most of the anti-nutritional factor activities in legumes. Traditional methods of cooking Bambara groundnut which involved overnight or few hours soaking before boiling also eliminate anti-nutrients.

Plant ash from palm husk is the inorganic residue after open air incineration of palm husk. Its content and composition depend on the types of plant materials used [19].

Historically, plant ashes have been traditionally incorporated into human diet in Africa in various levels and for various purposes [13]. It has been applied as a leavening agent, tenderizer and emulsifying agents, as well as a flavour enhancer. Plant ashes have been reported as good source of minerals which addition to foods could enhance its mineral content [19]. When the ash is mixed with water, the filtrate normally turns to brown colour and forms slippery emulsion with oil indicating alkalinity. The filtrate had been used to prepare *ngu* used in preparing traditional delicacies like *nsisa* (Africa salad), *ugba*, *nkwobi*, *isiewu* and as a tenderizer in cooking hard to cook foods like African breadfruit (*ukwa*) and meat [20]. Plant ash is also used to leaven baked products, as a culinary food additive, emulsifying agents and flavour enhancers [21, 22]. The filtrate is also used to prepare *otong* for eating meat, drinking palm wine and spicing soup in Annag, Akwalbom state of Nigeria [23]. Plant ash affects the sensory properties of food products such as taste because the emulsified oil coats the tongue, impacts good mouth feel and enhances desired flavour of the food [18]. This work therefore aimed at evaluating the effects of plant ash on the proximate, mineral and acceptability of *okpa*.

## 2. Materials and Methods

### 2.1. Sources of Raw Materials

Bambara groundnut (Figure 1) and ingredients used were purchased from Ubani market in Umuahia, Empty palm husk (Figure 2) was procured from NgodoIsuochi in Umunneochi Local Government Area, all in Abia State.



Figure 1. Bambara groundnut.



Figure 2. Empty palm bunch.

### 2.2. Preparation of Ash from Empty Palm Husk

The husk was sun-dried to remove moisture and incinerated under hygienic condition to obtain raw ash. The raw ash was milled after cooling and sieved to remove larger particles. The ash filtrate obtained was weighed, mixed with distilled water according to concentrations and filtered with double layer muslin cloth (Figure 3) to obtain 1, 5 and 10%

concentrations of plant ash filtrates which were boiled and used in the mixing of the Bambara groundnut flour.

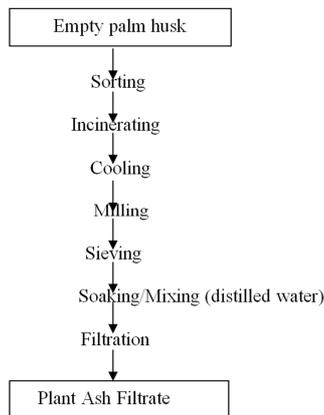


Figure 3. Flow chart for the production of plant ash filtrates.

### 2.3. Preparation of okpa with Bambara Groundnut Flour

Dried mature Bambara groundnut was sundried, milled with local attrition hammer mill and sieved with 250-micron mesh sieve to obtain fine Bambara groundnut flour. The flour was divided into four parts and three parts were respectively mixed with 1, 2 and 3% warm water plant ash extract, seasoned according to proportions (Table 1) and manually blended thoroughly in a stainless steel basin to form a consistent paste. The same process was repeated on the remaining part with same quantities of seasonings and warm water without plant ash to serve as control. Each part was packaged in plantain leaves and transparent polyethylene (250 ml) tied and steamed separately for 45 min to obtain the semisolid *okpa* (Figure 4). The wraps (Figures 5 and 6) were allowed to cool at room temperature before unwrapping. The slices (Figure 7) were used for the analysis.

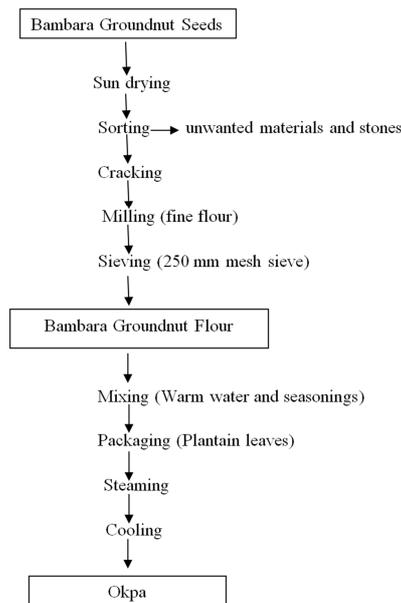


Figure 4. Production of okpa with Bambara groundnut flour.



Figure 5. Okpa wrapped in banana leaves.



Figure 6. Okpa wrapped in transparent polyethylene.



Figure 7. Sliced okpa.

Table 1. Seasonings and quantities used for the formulation.

| Ingredients       | Quantity |
|-------------------|----------|
| Bambara groundnut | 1000g    |
| Red pepper        | 80 g     |
| Onion             | 100 g    |
| Salt              | 100 g    |
| Water             | 1500 ml  |
| Oil               | 200 ml   |

### 2.4. Proximate Analysis

#### 2.4.1. Proximate Composition

Moisture, fat and protein contents were determined using AOAC [24] methods. Carbohydrate content was determined by difference while energy was calculated using energy substrates as described by Mullan [25].

#### 2.4.2. Determination of Minerals

##### (i) Calcium and Magnesium

These were determined using Versenate EDTA complexometric titration method of Carpenter and Hendricks [26]. Magnesium was determined by adjusting the pH of the solution to 10 with 20 ml of ammonia buffer. Then a pinch of the indicator Eric Rome black was added, thoroughly shaken and titrated against 0.02N EDTA solution until the color changed from mauve to permanent deep blue. Calcium was determined by adjusting the pH to 12 with 10% NaOH solution and then titrated with 0.02N EDTA using seleochrome dark blue (calcon) as indicator in place of Eric Rome black. A reagent blank was titrated to serve as control. Calcium and magnesium contents were calculated according to the formula:

$$\% \text{ calcium or magnesium} = \frac{100}{w} \times EW \times N \times \frac{Vf}{Va} \times T - B$$

Where W=weight of sample analyzed, EW=equivalent weight, N=normality of EDTA, Vf=total volume of extract, Va=volume of extract titrated, T=titre value of the sample, B=titre value of blank

### (ii) Determination of zinc

Zinc content was determined with the method of AOAC [24]. Two drops of Eric Rome Black was added into 25 ml of digest as an indicator and the mixture was titrated against 0.02N EDTA until the red solution turns blue. The concentration of zinc was calculated as presented in the formula:

$$\text{Zn (mg)} = M_{\text{EDTA}} \times (\text{V in ml of EDTA}) \times (\text{molar mass of Zn}) \times \frac{1}{10}$$

### (iii) Iron

Spectrophotometric method of James [27] was used on 1 g of each sample digested with 20 ml of acid mixture (650 ml concentrated HNO<sub>3</sub>, 80 ml perchloric acid and 20 ml concentrated H<sub>2</sub>SO<sub>4</sub>). The iron standard was prepared at different concentrations of 2 to 10 ppm and absorbance readings were taken at 520 nm which were used to plot a standard iron curve for extrapolation.

### (iv) Phosphorous

Vanadomolybdate (yellow) spectrometry method described by James [27] was used with 1 g of each sample was dispensed into a test tube. Standard phosphorous solution and blank were prepared and their absorbance readings were taken with Jenway electronic spectrophotometer at a wavelength of 420 nm. The phosphorous content was determined with the formula:

$$P = \frac{g}{100g} = \frac{100}{W} \times \frac{Au}{As} \times \frac{Vf}{Va}$$

Where: W=weight of sample analyzed, Au=absorbance of a test sample, As=absorbance of standard solution, Vf=total volume of filtrate, Va=Volume of filtrate analyzed.

### (v) Sodium

Flame photometry method described by Carpenter and

Hendricks [26] was used with Digital Flame Photometer ME-881. Appropriate filter for sodium was chosen; standard solution was prepared and diluted to concentrations of 2, 4, 6, 8 and 10 ppm. The 10 ppm concentration was first aspirated and its emission intensity adjusted to a hundred units. Similarly, the rest were aspirated starting with the least concentration (2 ppm). The emission intensity of the standard solution was plotted against the concentration to obtain a standard curve (calibration graph) for sodium. The optical density emissions recorded from sodium was matched with the curve to obtain by extrapolation the quantity of sodium ions in the samples. The experiment was repeated three more times and the mean concentration was used for the calculation of sodium content:

$$\text{Na (mg/100g)} = \frac{100}{W} \times \frac{1}{1000} \times X \times \frac{Vf}{Va} \times D$$

Where: - W=weight of sample used, X=concentration (in ppm) from curve, Vf=total volume of the extract (digest) flamed and D=dilution factor where applicable.

### (vi) Sensory Evaluation

Sensory evaluation was conducted as described by Iwe [28] on both fortified and unfortified *okpa* samples with 20 semi-trained panelists. They were randomly selected from male and female staff and students of Michael Okpara University of Agriculture Umudike, Abia State Nigeria. They aged between 17 to 35 y. The samples were coded and randomly presented to each panelist in a well lighted room with same type of plate and a bottle of water to rinse their mouths before and after each test. They were instructed to taste each sample presented before them, evaluate their taste, appearance, aroma, texture, overall acceptability, and rank the attributes according to 9-point Hedonic scale where 1 represents "dislike extremely" and 9 'like extremely'.

### (vii) Statistical Analysis

Data obtained were statistically analyzed using one way ANOVA and the means were separated with Duncan's New Multiple Range Test (DNMRT). Statistical Package for Social Sciences (SPSS) version 16 at 5% (p<0.05) acceptable level was used.

## 3. Result and Discussion

### 3.1. Proximate Composition

The results are shown in Table 2.

Table 2. Proximate composition of *okpa*.

| S/N | Moisture                 | Protein                 | Fat                     | Fibre                   | Ash                      | Carbohydrate             | Energy                    |
|-----|--------------------------|-------------------------|-------------------------|-------------------------|--------------------------|--------------------------|---------------------------|
| A   | 59.10 <sup>a</sup> ±0.14 | 8.75 <sup>a</sup> ±0.00 | 4.20 <sup>a</sup> ±0.00 | 1.20 <sup>a</sup> ±0.28 | 1.20 <sup>c</sup> ±0.00  | 25.55 <sup>a</sup> ±0.14 | 164.21 <sup>a</sup> ±0.3  |
| B   | 58.40 <sup>a</sup> ±0.04 | 8.63 <sup>a</sup> ±0.17 | 4.10 <sup>a</sup> ±0.14 | 1.20 <sup>a</sup> ±0.00 | 1.35 <sup>bc</sup> ±0.07 | 25.83 <sup>a</sup> ±0.24 | 163.91 <sup>a</sup> ±1.29 |
| C   | 58.65 <sup>a</sup> ±0.07 | 8.63 <sup>a</sup> ±0.18 | 4.15 <sup>a</sup> ±0.07 | 1.25 <sup>a</sup> ±0.07 | 1.45 <sup>ab</sup> ±0.07 | 25.88 <sup>a</sup> ±0.46 | 164.63 <sup>a</sup> ±0.89 |
| D   | 59.50 <sup>a</sup> ±0.99 | 8.43 <sup>a</sup> ±0.11 | 4.00 <sup>a</sup> ±0.00 | 1.30 <sup>a</sup> ±0.07 | 1.55 <sup>a</sup> ±0.07  | 25.23 <sup>a</sup> ±0.95 | 160.31 <sup>b</sup> ±0.44 |
| LSD | 1.16                     | 0.33                    | 0.21                    | 0.11                    | 0.21                     | 0.66                     | 0.30                      |

Values mean of triplicate determinations± SD. Values on the same column with different superscript are significantly different (p<0.05). A=sample without ash (control), B=sample fortified with 1% ash, C=sample fortified with 5% ash and D=sample fortified with 10% ash.

### 3.1.1. Moisture Content (MC)

There was no significant ( $p < 0.05$ ) moisture variation between all the samples including the control. This notwithstanding, the MC of the fortified samples increased slightly (58.40-59.50%) with increase in ash content concentration but lower than the control (59.10%) except sample D (59.50%) with 10% ash content. This may mean that the ash concentrations used had no significant ( $p < 0.05$ ) increase on MC. Higher concentration may have significant ( $p < 0.05$ ) effect on MC, but may decrease the acceptability. The slight MC increase may mean no significant ( $p < 0.05$ ) variations in texture, taste, mastication and swallowing any of the sample as MC affects them.

### 3.1.2. Protein

Though protein decreased with increase in ash content, there was no significant ( $p < 0.05$ ) variation between the fortified samples (8.63-8.43%) and the control (8.75%). The slight decrease could be attributed to insignificant ( $p > 0.05$ ) protein-calcium interaction [29] which never had any significant variations. Protein values of fortified and control samples in this study were lower than 19% reported by (Okonkwo and Opara [6]. The differences could be attributed to the variety of the Bambara groundnut used, processing method like water ratios used and plant ash fortification. Protein is essentially responsible for proper growth, muscle tissues repairs and a component of child's blood, organs, skin and glands [30].

### 3.1.3. Fat

Fat content of the fortified samples (4.10-4.00%) decreased without significant ( $p < 0.05$ ) variation as ash concentration increased. The decrease could be due to interaction of fat with calcium [31] as palm bunch is rich in calcium [19]. Protein values of all the fortified samples were lower than the control (4.20%), but higher than 3.04–3.21% reported by Emelike and Barber [34] for *okpa*. The variation could be due to variety of Bambara groundnut used, water ratio, types of ingredients used and levels of interaction of fat with calcium content of the ash [31]. Fat has been reported as a very important nutrient in food because of its flavor enhancement properties [33], swallowing, energy and a source of fat-soluble vitamins [34].

### 3.1.4. Fiber

Without significant ( $p < 0.05$ ) variation, the fiber content of the fortified samples (1.20 to 1.30%) increased with increase in ash content higher than the control (1.20%). The fiber increase could probably be due to the ash which tenderized and liquefy some of the carbohydrate content of the Bambara groundnut. Fiber values obtained in this study were lower but within 1.35 to 2.75% reported by Emelike and Barber [32] for *okpa* probably the ash may have liquefy some of the digestible fibre. Crude fiber is the amount of indigestible sugars present in a food sample which has the physiological

role of adding bulk to stool, enhances peristalsis movement and thus contribute to the maintenance of internal health [35]. By facilitating peristalsis movement, dietary fibre helps to reduce many intestinal diseases, colon cancer and hypertension [36].

### 3.1.5. Ash

The ash content of the fortified samples (1.35-1.55 mg/100g) increased significantly ( $p < 0.05$ ) with increase in ash content concentration more than the control (1.20 mg/100g). The increase which could be credited to the mineral packed palm bunch ash justified the essence of the fortification. Ash content reflects the mineral composition of a food which is high in palm bunch ash [19]. Least ash value of the control justified the ash increasing effect of the fortificant ash.

### 3.1.6. Carbohydrate

Although there was no significant carbohydrate content variation between the control and the fortified samples, there was slight decrease (25.88-25.23%) with increase in ash concentration. The decrease could be as a result of tenderization and liquefaction of carbohydrate by the ash which is a tenderizer [19]. Despite the carbohydrate content decrease, all the fortified samples except sample D with 10% ash inclusion were higher than the control (25.55%). The least carbohydrate content of sample D therefore justified the tenderizing effect of the fortificant ash. The carbohydrate content of all the samples was lower than 31.95% reported by Okwunodulu *et al* [37] for *okpa*. The difference could be attributed to the Bambara groundnut variety, ingredients used and fortificant ash [17, 19]. Carbohydrate is one of the major energy substrate and therefore may not affect significantly ( $p < 0.05$ ) the energy, texture, taste and colour of the control and fortified samples which carbohydrate influences.

### 3.1.7. Dietary Energy

Plant ash fortification did not significantly ( $p < 0.05$ ) affected the energy content of the *okpa* except in sample D with 10% ash. This implied that significant effect could be possible as from 10% ash inclusion. The ash inclusion decreased the energy content of all the fortified samples (164.63-160.31%) slightly lower than the control (164.21 mg/100g) except in sample C (164.63%) as the fortificant ash increased. This implied that significant ( $p < 0.05$ ) energy reduction could be as from 10% ash level of fortification and above. Therefore, the levels of 1 to 5% are desirable in this regard. The energy levels of fortified *okpa* decreased from 164.63 mg/100g in sample C with 5% ash to 160.31 mg/100g in sample D with 10% ash.

## 3.2. Mineral Composition of *okpa*

The results are presented in Table 3.

Table 3. Mineral composition of plant ash fortified *okpa* (mg/100g).

| Sample | Calcium                  | Magnesium                 | Zinc                    | Iron                    | Phosphorus                | Sodium                   |
|--------|--------------------------|---------------------------|-------------------------|-------------------------|---------------------------|--------------------------|
| A      | 69.00 <sup>d</sup> ±0.00 | 108.30 <sup>d</sup> ±0.00 | 4.60 <sup>d</sup> ±0.42 | 0.80 <sup>d</sup> ±0.00 | 201.17 <sup>d</sup> ±0.45 | 7.65 <sup>d</sup> ±0.35  |
| B      | 72.50 <sup>c</sup> ±0.00 | 114.45 <sup>c</sup> ±0.00 | 5.70 <sup>b</sup> ±0.35 | 1.45 <sup>c</sup> ±0.00 | 206.32 <sup>c</sup> ±0.18 | 12.27 <sup>c</sup> ±0.26 |
| C      | 79.6 <sup>b</sup> ±0.60  | 119.56 <sup>b</sup> ±0.41 | 6.05 <sup>b</sup> ±0.00 | 1.98 <sup>b</sup> ±0.11 | 211.35 <sup>b</sup> ±0.00 | 14.03 <sup>b</sup> ±0.32 |
| D      | 85.38 <sup>a</sup> ±0.00 | 126.46 <sup>a</sup> ±0.00 | 6.33 <sup>a</sup> ±0.17 | 2.36 <sup>a</sup> ±0.00 | 219.40 <sup>a</sup> ±0.00 | 14.92 <sup>a</sup> ±0.00 |
| LSD    | 3.50                     | 4.15                      | 2.35                    | 0.38                    | 5.02                      | 0.89                     |

Values are mean of triplicate determinations ± SD. Values on the same column with different superscript are significantly different ( $p < 0.05$ ). A=sample without ash (control), B=sample fortified with 1% ash, C=sample fortified with 5% ash and D=sample fortified with 10% ash.

### 3.2.1. Calcium

There were significant ( $p < 0.05$ ) calcium improvement in the fortified *okpa* samples compared to the control. Calcium increased from 72.50 mg/100g in sample B with 1% ash to 85.38 mg/100g in sample D with 10% ash more than the control (69.00 mg/100g). These significant ( $p < 0.05$ ) increases could be attributed to the fortificant ash. Palm bunch had been reported as a very good calcium source [19]. These increases were higher than 0.95% to 1.10 mg/100 reported by Emelike and Barber [32] from *okpa* probably due to ash inclusion. But slightly lower than 78.82 to 85.50 reported by Odeghe *et al* [38] from *okpa* prepared with pumpkin and scent leaves may be because of variety, inclusion of pumpkin and scent leaves which may have been richer in calcium content. The fortified *okpa* may help to reduce the risk of osteoporosis, cardiovascular diseases and cancer [39] among the elder people. Calcium also helps to build strong bones and teeth, vital for nerve transmission and muscle function, necessary for blood clotting, aids in conversion of food into energy among others [40, 41].

### 3.2.2. Magnesium

Magnesium content of the fortified samples also improved significantly ( $p < 0.05$ ) with increase in ash fortification levels more than the control (108.30 mg/100g). The increment was from 114.45 to 126.46 mg/100g respectively in samples B with 1% ash and D with 10% ash. The increase was higher than the ranges 11.20 to 16.00 and 0.40 mg/100g 0.50% reported respectively by Odeghe *et al* [38] and (Emelike and Barber [32] from *okpa*, may be because of variety and ingredients used. Interestingly, magnesium content of the fortified *okpa* is the highest mineral increment in this study as a result of the added plant ash. The magnesium improvement could also improve the health benefits of the fortified samples. Magnesium helps maintain normal muscle and nerve function, keeps heart rhythm steady and support a healthy immune system [42].

### 3.2.3. Zinc

Like other minerals, zinc content of the fortified *okpa* samples improved significantly ( $p < 0.05$ ) with plant ash fortification levels more than the control (4.60 mg/100g) thereby implicated the ash as a major source of the increment. They improved from 5.70 mg/100g in sample B with 1% ash to 6.33 mg/100g from D with 10% ash. None significant ( $p > 0.05$ ) variation between samples B (1% ash) and C (5%) fortified *okpa* may mean higher improvement as from 5% ash

fortification level but may affect the acceptability. The values obtained from this study were lower than 11.20 to 16.00 mg/100g reported by Odeghe *et al* [38] from *okpa* prepared with fluted pumpkin and scent leaves. This may be due to variety, ingredients, water to flour ratio, scent leaves and pumpkin used. Zinc is important in cell division, cell growth, wound healing, immune function and the breakdown of carbohydrates [43].

### 3.2.4. Iron

Iron is important for haemoglobin formation which carries oxygen to the body tissues. Iron deficiency (anemia) is characterized by poor oxygen-carrying capacity, a condition that causes fatigue in athletes [44]. Significant ( $p < 0.05$ ) iron increase of the fortified samples with ash fortification levels is a welcome development because of the health benefits. The increment which was from 1.45 mg/100g in sample B (1% ash) to 2.36 mg/100g in sample D (10% ash) more than the control (0.80 mg/100g) is an indication that the ash was the major source.

### 3.2.5. Phosphorus

Phosphorous content of the fortified samples also increased significantly ( $p < 0.05$ ) with increase in ash inclusion levels. Ash was therefore the major cause of the increment from 206.32 mg/100g in sample B (1% ash) to 219.40 mg/100g in sample D (10% ash). Phosphorous is the highest mineral among all the minerals in all the fortified samples. With 1:3 calcium-phosphorus ratios of all fortified samples including the control, they will make better strong bone. Calcium and phosphorus forms deposit of calcium phosphate that maintain strong bones, balances the body's pH level and improves digestion [45, 42].

### 3.2.6. Sodium

Sodium content of the fortified samples improved significantly ( $p < 0.05$ ) as the ash fortification levels increased. The improvement which was from 12.27 mg/100g in sample B (1% ash) to 14.92 mg/100g in D (10% ash) more than the control (7.65 mg/100g) substantiated the effect of ash. Plant ash fortification must have been the major contributor as empty palm bunch is a good source of sodium [19]. This increase is mineral improvement and the associated health benefits. Sodium helps among others to maintain body fluid balance, blood pressure, muscle contraction and nerve transmission [46].

## 3.3. Sensory scores of the Fortified *okpa*

The result is presented in Table 4.

**Table 4.** Sensory properties of fortified the okpa samples.

| Samples | Taste                   | Appearance              | Aroma                   | Texture                 | Acceptability           |
|---------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| A       | 6.23 <sup>a</sup> ±1.97 | 4.19 <sup>a</sup> ±1.36 | 6.48 <sup>a</sup> ±1.08 | 6.38 <sup>a</sup> ±1.32 | 7.14 <sup>a</sup> ±0.9  |
| B       | 6.38 <sup>a</sup> ±2.16 | 4.62 <sup>c</sup> ±1.94 | 6.10 <sup>a</sup> ±2.29 | 7.14 <sup>a</sup> ±1.39 | 6.90 <sup>a</sup> ±1.87 |
| C       | 6.24 <sup>a</sup> ±1.55 | 7.52 <sup>a</sup> ±1.60 | 6.71 <sup>a</sup> ±1.19 | 6.90 <sup>a</sup> ±1.33 | 7.05 <sup>a</sup> ±1.20 |
| D       | 3.38 <sup>b</sup> ±1.60 | 5.62 <sup>b</sup> ±2.06 | 3.90 <sup>b</sup> ±2.21 | 4.22 <sup>b</sup> ±2.34 | 4.10 <sup>b</sup> ±1.70 |
| LSD     | 0.15                    | 1.67                    | 2.20                    | 2.14                    | 2.80                    |

Values are mean of triplicate determinations ± SD. Values on the same column with different superscript are significantly different ( $p < 0.05$ ). A=sample without ash (control), B=sample fortified with 1% ash, C=sample fortified with 5% ash and D=sample fortified with 10% ash.

### 3.3.1. Taste

The taste of the fortified *okpa* samples decreased as the ash content increased in the formulation. Despite the decrease (6.38-6.24), taste scores of all the fortified samples were slightly higher than the control (6.23) except sample D (10% ash) with 3.38 which is significantly ( $p < 0.05$ ) lower than the rest samples. This implied that ash fortification beyond 5% may significantly ( $p < 0.05$ ) lower the taste beyond acceptability. Slight taste score variations between samples B (1% ash) and C (5% ash) and their significant ( $p < 0.05$ ) variation with sample D (10%) justified that. Their higher taste scores than the control samples confirmed flavour enhancement of ash [18]. Slight taste score variations obtained in this study may be due to familiarity of the panelists with the control than the fortified *okpa*.

### 3.3.2. Appearance

The scores increased significantly ( $p < 0.05$ ) as ash fortification levels increased from 4.62 in sample B (1% ash) and peaked (7.52) in sample C (5% ash) signifying appearance decrease beyond 5% ash inclusion probably due to the brown colour of the ash filtrate. The appearance scores of all the fortified samples were more than the control (4.19) which is enhancement of the aesthetic appeal by the ash. The increase could be due to hydrolysis of the carbohydrate to simple sugar which caramelized during steaming to give the *okpa* a desirable colour more than the control.

### 3.3.3. Aroma

Despite the increase in aroma scores due to increase in ash fortification levels, there was no significant ( $p < 0.05$ ) variation between all the samples including the control except in D (10% ash). Higher aroma score (6.71) of sample C (5% ash) than all the other samples justified 5% ash as the peak level. The scores obtained for aroma increased from 3.90 in sample D (10% ash) through 6.10 in sample B (1% ash) to 6.71 in sample C (5% ash).

### 3.3.4. Texture

There were no significant texture scores between all the samples including the control except in D (10% ash) with significant ( $p < 0.05$ ) variation compared to the rest samples. With increase in ash fortification levels, texture scores decreased from 7.14 in sample B (1% ash) to 4.22 in sample D (10% ash). The decrease could be due to hydrolysis of Bambara groundnut carbohydrate into simple sugars thereby decreased their texture. Slight texture score variations between samples B (1% ash) and C (5% ash) which are

maximum implicated 5% ash as the maximum fortification level for maximum texture.

### 3.3.5. General acceptability

Control (0% ash) had the maximum acceptability level (7.14) which was not significant ( $p > 0.05$ ) from samples B (1% ash) and C (5% ash). The panelists may have been familiar with the control. This also testified that maximum acceptability was at 5% ash fortification level. However, sample D (10% ash) had the lowest score (4.10) which was significantly different from the other samples ( $p < 0.05$ ). All the samples were liked moderately except D (10% ash) which was dislike slightly.

## 4. Conclusion

Plant ash fortification of *okpa* prepared with Bambara groundnut to enhance the nutrient and energy content is feasible. The fortification improved moisture, fat, fibre, ash, carbohydrate, energy, calcium, magnesium, zinc, iron, phosphorous and sodium maximally at 5% level of ash fortification. Protein and acceptability were decreased without significant difference. Therefore, 1-5% plant ash levels maximally justified the aim of fortification of *okpa*. Beyond 5%, there may be nutrient improvement more than what was obtained, but acceptability may be compromised to the point of total rejection.

## Conflict of Interest

The authors declare no conflict of interest.

## Acknowledgements

Authors are grateful to the Department of Food Science and Technology of Michael Okpara University of Agriculture Umudike, Abia State Nigeria for their provision of reagents used and the analytical space.

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