

# Evaluation of Bread made from Various Blends of Arrowroot Starch and Wheat Flour

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## Abstract

There is proliferation of strategic researches on increasing partial or total replacement of wheat flour in bread-making due to the spiking prices of wheat, globally. Bread samples A (control), B, C, D, E, F, G and H, made from flour blends of wheat flour and arrowroot starch in the percentage ratios of 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60 and 0:100 respectively were evaluated for their baking potentials to replace the conventional 100% wheat flour bread. Further studies were done on bread sample D (bread sample of comparable baking properties with 100% wheat flour bread), to determine its mineral composition, anti-nutrient composition, and storage stability. Samples B-H, had higher weights (625 – 745 g) and densities (0.222 – 0.6183 g/cm<sup>3</sup>) than control sample; Samples B-D did not significantly ( $P < 0.05$ ) differ in height with control sample and the same was with samples C and D in terms of bread volume. Samples B-E and H were significantly ( $P < 0.05$ ) better in appearance, taste, flavor; while samples B-D and H had better texture and overall acceptability. Sample D was significantly ( $P < 0.05$ ) higher in Zn, Na, K, Ca, Mg, P and oxalates; but lower in Cu, Fe, HCN and tannins. Sample D exhibited good storage stability and even better keeping quality than control (sample A) within 6 days. The results of this investigative study revealed that bread sample D was as good as bread sample A, or even better, and thus could serve as an alternative to 100% wheat flour bread.

## Keywords

Arrowroot starch, Wheat flour, Bread, Sensory properties, Physical properties, Nutrient and Anti-nutrient composition, Storage studies, Microbial quality

## Abbreviations

**A:** Flour blend of 100% wheat flour; **B:** Flour blend of 90% wheat flour and 10% arrowroot starch; **C:** Flour blend of 80% wheat flour and 20% arrowroot starch; **D:** Flour blend of 70% wheat flour and 30% arrowroot starch; **E:** Flour blend of 60% wheat flour and 40% arrowroot starch; **F:** Flour blend of 50% wheat flour and 50% arrowroot starch; **G:** Flour blend of 40% wheat flour and 60% arrowroot starch; **H:** Flour blend of 100% arrowroot starch

## Introduction

Bread, a food with awesome variety of flavors and nutrients is becoming

the basis of our daily diet worldwide and particularly in developing countries like Nigeria and Kenya. For example, in Nigeria, bread consumption cuts across class barriers of both the rich and poor as breakfast, snacks and in between meals. It is a fermented confectionary product produced mainly from wheat flour, water, yeast and salt by a series of operations including mixing, kneading, proofing, shaping and baking [1, 2]. Wheat flour is the main ingredient in making bread because of its exclusive ability to form dough when mixed with water due to the presence of gluten in it. Unfortunately, wheat is exorbitantly imported into Nigeria since its climate does not support the growth and this really places severe burden on the country's resources, thus hugely depleting the nation's foreign exchange reserve. For instance, Nigeria only produces about 1% of the 5-6 million metric tons of the wheat consumed annually in Nigeria [3].

Many studies have investigated the potentials of substituting wheat flour with other flours from breadfruit, cassava, cocoyam, plantain, sweet potato, malted sorghum, pigeon pea, cowpea, taro and yams for production of bread and other bakery products [2, 4, 5]. Interestingly, formulations of composite flours with starches have shown better baking responses than those with flours [2, 5]. Besides, researchers have revealed that starch is an important component of bakery products, functionally and nutritionally since it constitutes about 65 - 85% of grain based flour [6, 7].

Starch (a polymer of glucose molecules) is the most important human diet and it is contained in such staple foods as potatoes, sweet potatoes, wheat, cocoyam, yam, maize, rice, cassava and arrowroots [2, 6, 7]. Shockingly, among all these starch sources mentioned, arrowroots (*Tacca leontopetaloides*), a tropical edible rhizomes, have received the poorest research attention irrespective of their rich potentials and popularity in Northern part of Nigeria. Arrowroots are widely distributed in Nigeria and eaten as food in many states, but have not been domesticated as in East Africa and Asia [8, 9]. Arrowroots have potentials for utilizations in food, pharmaceutical and other industrial purposes but there is very little information on its uses other than energy sources among communities that cultivate them. Thus continuous studies are being promoted to find out other potentials of these lesser-known crops [7, 10] for efficient utilization and application in the industrial sector. There is no doubt that the use of arrowroot starch for the production of baked products would help reduce Nigeria's dependence on wheat flour importation, thereby advancing its utilizations in Nigeria. Furthermore, celiac disease have been implicated in excessive consumption of wheat flour based products [11] due to the presence of gluten (protein in wheat flour) which is allergic to some people. For instance, gluten free bread is a trending choice in Europe and America. Thus, identifying and developing starches with good physico-chemical and baking potentials will help to realize the vision of expendable utilization of under-utilized crops in Nigeria, thereby promoting food security, increasing employment and contributing to economic growth. Equally important is the need to undertake strategic research to identify, develop and promote some lesser-known and non-conventional crops whose starches can meet the standards of starch-based industries for high quality starches at affordable prices [10].

The objectives of this study were to evaluate the physical properties, mineral composition, anti-nutrient properties, storage stability and overall acceptability of the bread samples produced from composite flour of wheat flour and arrowroot starch in the percentage ratios of 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60 and 0:100 respectively.

## Materials and Methods

### Materials

Fresh tubers of arrowroot were harvested from a farm in the Faculty of Agriculture, Kogi State University, Anyigba, Kogi State, Nigeria. Wheat flour, butter, calcium propionate, salt, granulated sugar, milk and improver were purchased from Anyigba market in Anyigba town, Kogi state, Nigeria.

### Methods

#### Starch production

The method of [12] was used in the production of arrowroot starch as shown in figure 1. Two kilograms of hand-peeled arrowroot tubers were washed thoroughly, chopped into approximately 1.0 cm cubes and grated for 10 min using double barrel grater (Stainless Steel Model). The resultant pulp was suspended in ten times its volume with distilled water, stirred for 5 min and subsequently sieved through a 0.075 mm mesh screen. The filtrate (starch slurry) was allowed to stand for 8 h and the supernatant decanted off after sedimentation in order to remove impurities. The starch slurry (sediment) was re-suspended in distilled water and stirred for 5 min. Filtration was repeated as before and the filtrate was allowed to sediment for 8 h before decanting off the supernatant. The starch (i.e., sediment) obtained from arrowroot tubers was oven dried in a cabinet dryer (RXH-5-C model) at  $55 \pm 2^\circ\text{C}$  for 1 h. The oven dried starch was cooled, packaged in polyethylene bags and stored at room temperature ( $27^\circ\text{C}$ ) prior to analyses.

#### Formulation of the flour blends

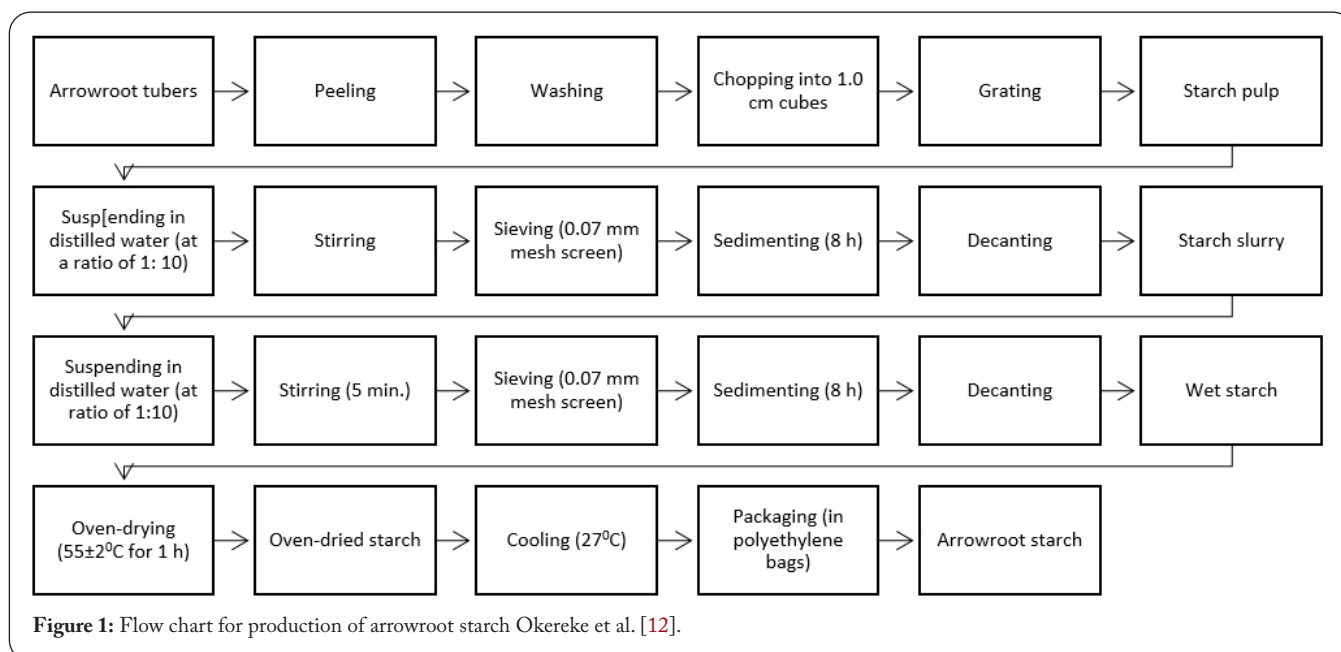
The arrowroot starch was used to substitute 0, 10, 20, 30, 40, 50, 60 and 100% of wheat flour in Philip blender (HR2811 model) operated at full speed for 10 min. The flour blends were packaged in high density polyethylene bags prior to use.

#### Production of the bread samples

The recipe used for the production of the bread samples is shown in table 1. The straight dough method was used to produce the eight bread samples labeled A, B, C, D, E, F, G and H. All the ingredients (flour blend, calcium propionate, butter, sugar, yeast, salt, milk and water) were added, thoroughly mixed and kneaded to obtain the dough [2]. The different dough samples were placed in baking pans, smeared with vegetable oil, covered with baking pan cover and allowed to stay for one hour for fermentation to take place. The dough samples were then baked in the oven at  $230^\circ\text{C}$  for 30 minutes. The baked loaves were carefully removed from the pans and allowed to cool and then packaged in polyethylene bags for analyses. The procedure is shown in figure 2.

#### Evaluation of the physical properties of the bread samples:

Bread samples were evaluated for loaf weight (g) using an



electronic balance. The height, length and breadth of the bread samples were measured with digital vernier caliper. Then the volume of each bread sample was obtained by multiplying its length with its breadth and height as stated below:

Volume of bread( $cm^3$ ):  $Length \times Breadth \times Height$

Then density of each bread sample was obtained by dividing its weight by its corresponding loaf volume.

Thus, Density of bread sample ( $g/cm^3$ ):  $\left(\frac{\text{Weight of bread}}{\text{Volume of bread}}\right)$

### Sensory evaluation of the bread samples

The bread samples were sliced into pieces of uniform thickness and served to ten trained panelists randomly selected from students and staff of the Department of Food, Nutrition and Home Sciences, Kogi State University, Anyigba. The panelists evaluated the bread samples on a 5-point Hedonic scale where one represented disliked extremely and five liked extremely [13]. The samples were evaluated for appearance, texture, flavour and overall acceptability. The samples were presented in 3-digit coded white plastic plates. The sensory evaluation was carried out in

the sensory evaluation laboratory under white color lighting. The order of presentation of the samples to the panelists was randomized. Portable water was provided for the panelists to rinse their mouths in between evaluations.

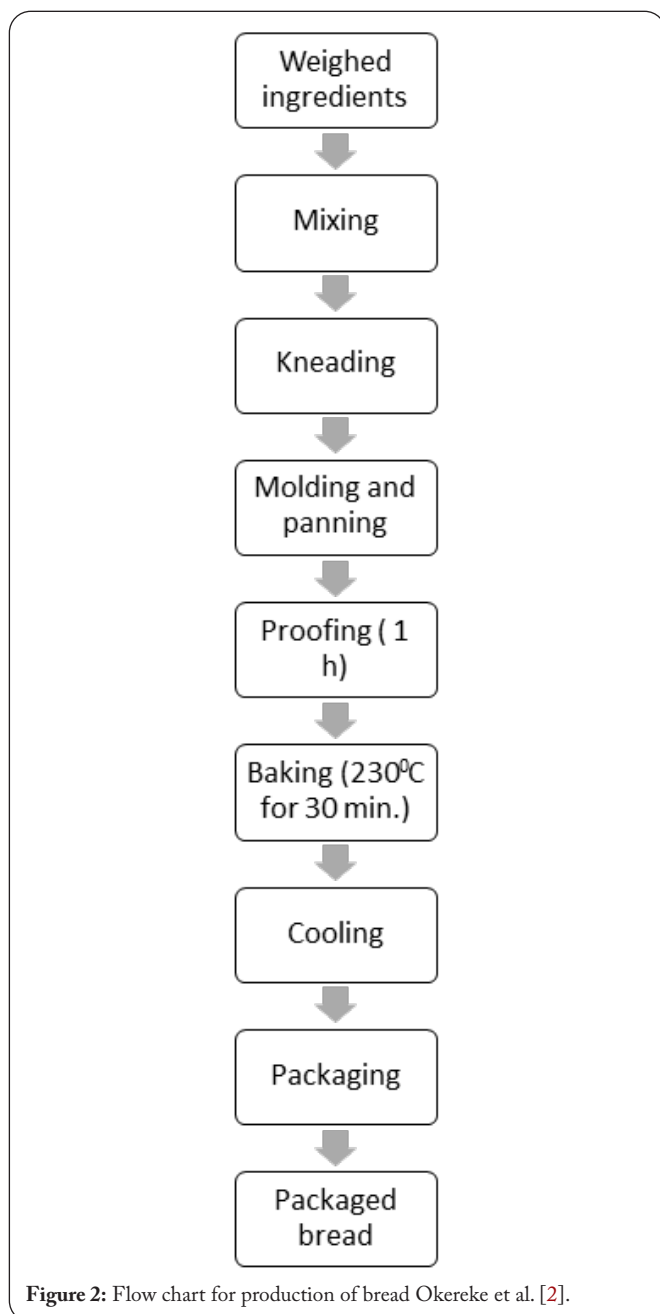
**Determination of minerals (zinc, iron, copper, potassium, calcium, magnesium, and phosphorous) contents of the bread samples A and D:**

**Iron content:** The iron content of the sample was determined using the method described by AOAC [14]. The ash (2 g) obtained from the ash analysis earlier was boiled in a beaker with 10 ml of 20% HCl and then filtered into 100 ml standard flask. This was made up to the mark with de-ionized water. The iron content was determined by using the Unicam Solar Spectrophotometer (Model 969 Mk 11, Unicam Ltd, Cambridge, UK) to measure the absorbance at 248.3 nm wavelength.

**Calcium content:** The calcium content of the sample was determined using the method described by AOAC [14]. The ash (2 g) obtained from the ash analysis earlier was boiled in a beaker with 10 ml of 20% HCl and then filtered into 100 ml standard flask. This was made up to the mark with de-

**Table 1:** Recipe for bread production from the various flour blends of wheat flour and arrowroot flour.

Bread sample code	Flour Blend (Wheat Flour: Arrowroot starch) (g)	Calcium propionate (g)	Butter (g)	Sugar (g)	Yeast (g)	Salt (g)	Milk (g)	Water (mL)
A	100.00 : 0.00	0.15	9	20	6	2	20	100
B	90.00 : 10.00	0.15	9	20	6	2	20	100
C	80.00 : 20.00	0.15	9	20	6	2	20	100
D	70.00 : 30.00	0.15	9	20	6	2	20	100
E	60.00 : 40.00	0.15	9	20	6	2	20	100
F	50.00 : 50.00	0.15	9	20	6	2	20	100
G	40.00 : 60.00	0.15	9	20	6	2	20	100
H	0.00 : 100.00	0.15	9	20	6	2	20	100



ionized water. The calcium content was determined by using the Unicam Solar Spectrophotometer (Model 969 Mk 11, Unicam Ltd, Cambridge, UK) to measure the absorbance at 422.7 nm wavelength.

**Magnesium content:** The magnesium content of the sample was determined using the method described by AOAC [14]. The ash (2 g) obtained from the ash analysis earlier was boiled in a beaker with 10 ml of 20% HCl and then filtered into 100 ml standard flask. This was made up to the mark with de-ionized water. The magnesium content was determined by using the Unicam Solar Spectrophotometer (Model 969 Mk 11, Unicam Ltd, Cambridge, UK) to measure the absorbance at 285.2 nm wavelength.

**Phosphorus content:** The phosphorus content of the sample was determined using the method described by AOAC [14]. The ash (2 g) obtained from the ash analyses earlier was boiled

in a beaker with 10 ml of 20% HCl and then filtered into 100 ml standard flask. This was made up to the mark with de-ionized water. The total phosphorus content was obtained using ascorbic blue colour procedure of Okalebo et al. [15] by reading the absorbance at a wavelength of 880 nm on a Helia Gamma Spectrophotometer (Helios Gamma UV-vis Spectrophotometer, thermo Spectronic, Cambridge, UK).

**Sodium and potassium contents:** The method as described by Onwuka [16] was followed to determine the sodium and potassium contents. Sample (1.0 g) was digested with 20.0 ml of acid mixture (650 ml of concentrated HNO<sub>3</sub>; 80 ml PCA; 20 ml concentrated H<sub>2</sub>SO<sub>4</sub>). The aliquots of the diluted clear digest were taken for photometry using flame analyzer. Absorbance for sodium was read at 767nm while that for potassium was read at 589nm. The concentrations of sodium and potassium were obtained from the calibration curves obtained from the standards.

**Zinc and copper contents:** The method as described by Onwuka [16] was followed to determine the sodium and potassium contents. Sample (1.0 g) was digested with 20.0 ml of acid mixture (650 ml of concentrated HNO<sub>3</sub>; 80 ml PCA; 20 ml concentrated H<sub>2</sub>SO<sub>4</sub>). The digest was diluted with distilled water to 500 ml mark. The aliquots of the diluted clear digest were taken for photometry using Atomic Absorption Spectrophotometer. Absorbance for zinc was read at 435nm while that for copper was read at 485nm. The concentrations of zinc and copper were obtained from the calibration curves obtained from the standards.

#### Evaluation of the anti-nutrient (food toxicants) composition of bread samples A and D:

**Oxalate content:** It was determined by titration method as described by Onwuka [16]. Milled bread sample (2 g) was suspended in 190 mL of distilled water in a 250 mL volumetric flask. Ten milliliters (10 mL) of 6M HCl was added and the suspension digested at 100 °C for 1h. The suspension was cooled and then made up to 250 mL mark before filtering it. Duplicate portions of 125 mL of the filtrate were measured into beakers and four drops of methyl red indicator added. This was followed by the addition of concentrated NH<sub>4</sub>OH solution (drop wise) until the test solution changed from salmon pink colour to yellow colour at pH of 4.0 – 4.5. Each portion was then heated to 90 °C, cooled and filtered to remove precipitate containing ferrous iron. The filtrate was again heated to 90 °C, and 10 mL of 5% CaCl<sub>2</sub> solution was added while being stirred constantly. After heating, it was cooled and left overnight at 5°C. The solution was then centrifuged at 2500 rpm for 5 min. The supernatant was decanted and the precipitate completely dissolved in 10 mL of 20% (V/V) H<sub>2</sub>SO<sub>4</sub> solution. At this point, the total filtrate resulting from digestion of 2 g of milled bread sample was up to 300 mL with distilled water. Aliquots of 125 mL of the filtrate was heated until near boiling, and then titrated against 0.05 M standardized KMnO<sub>3</sub> solution to a faint pink color which persisted for 30 seconds. The calcium oxalate content was calculated using the formula:

$$\text{Oxalate content (mg/100g)}: \left( \frac{T}{ME} \times \frac{V_{me}}{Mf} \times \frac{Df \times 100000}{1} \right)$$

Where:

T: Titre value of  $\text{KMnO}_4$  (mL)

Vme: Volume: mass equivalent (i.e 1cm of 0.05M  $\text{KMnO}_4$ ; 0.00225g anhydrous oxalic acid)

ME: Molar mass of  $\text{KMnO}_4$  in oxalate ( $\text{KMnO}_4$  redox reaction)

Mf: Mass of bread sample: 2 g

Df: Dilution of factor:  $\left(\frac{V_t}{A}\right) \times \left(\frac{300}{125}\right)$ : 2.4

Vt: Total volume of filtrate: 300 mL

A: Aliquot used for titration : 125 mL

Tannins content: It was determined by the Folin-Dennis spectrophotometric method as described by Onwuka [16]. Milled bread sample (2 g) was dispersed in 10 mL distilled water and agitated. This was left to stand for 30 min at room temperature (27 °C), being shaken at 5 min interval. It was then centrifuged and the extract (supernatant) obtained. The extract (2.5 mL) was dispersed into 50 mL volumetric flask. Similarly 2.5 mL of standard tannic acid solution was dispersed into a separate 50 mL flask. Folin-Denis reagent (1.0 mL) was measured into each flask, followed by 2.5 mL of saturated  $\text{Na}_2\text{CO}_3$  solution. The mixture was diluted to mark in the 50 mL flask, and incubated for 90 min at room temperature (27 °C). The absorbance was measured at 250 nm in an electronic spectrophotometer (Genway model 6000). Readings were taken with the reagent blank at zero. The tannin content was calculated as stated below:

$$\text{Tannin content (\%)} = \left(\frac{A_n}{A_s} \times \frac{C}{M} \times \frac{V_f}{V_a} \times 100\right)$$

Where:

An: Absorbance of the bread sample

As: Absorbance of standard solution

C: Concentration of standard solution

M: Mass of bread sample

Vf: Total volume of extract

Va: Volume of extract analyzed

Hydrogen cyanide (HCN) content: Hydrogen cyanide content was determined by acid titration method as described by Onwuka [16]. Bread sample (15 g), milled to pass No. 20 sieve, was placed into 800 mL Kjeldahl flask and then added 100 mL distilled water. It was macerated at room temperature (27 °C) for 2 h. Distilled water (100 mL) was added and steamed to distill. The tip of condenser was adjusted appropriately to dip below surface of liquid in receiver before distillation. The distillate was collected in 20 mL 0.02N  $\text{AgNO}_3$  acidified with 1.0 mL  $\text{HNO}_3$ . When 150 mL has passed over, the distillate was filtered through gooch wash receiver and gooched with little water. Then excess  $\text{AgNO}_3$  combined with filtrate and washings, was titrated with 0.02N KCN, using Fe alum indicator. Then, the Hydrogen cyanide (HCN) content was determined as follows:

Hydrogen cyanide (mg): Titre value  $\times$  0.54 (i.e 1.0 mL 0.02 N KCN : 0.54 mg of HCN)

Storage studies on bread sample A (100% wheat flour: 0% arrowroot flour) and sample D (70% wheat flour: 30% arrowroot flour) for six days

Microbiological analysis (total aerobic viable bacteria count, and mold count): The bread samples were stored at ambient temperature ( $30 \pm 2$  °C) for a period of six days, and monitored every two days for bacterial and mold growth. The method of viable plate count or colony count described by American Public Health Association [17] was used to enumerate the aerobic viable bacterial cell numbers and mold count in the bread samples. Mashed bread sample (1 g) was mixed in 9 mL peptone water. Sub-samples were diluted decimally and 0.1 mL aliquots were spread plated on nutrient agar (NA) and potato dextrose (PDA) for enumeration of aerobic viable bacteria and molds respectively. The nutrient agar (NA) plates were incubated at 37 °C for 24 - 144 hours while potato dextrose (PDA) plates were incubated at room temperature (27 °C) for 24 - 144 hours. The colonies were then counted and expressed as colony forming units per gram (cfu/g) of samples. All counts were done in duplicate using the Stuart scientific colony counter. Observed colonies were sub-cultured repeatedly on media used for primary isolation to obtain pure cultures. Microbial quality evaluation of the bread samples were done in triplicates for every 2 days from 0 day, within the storage period of 6 days.

Evaluation the pH of the bread samples A and D during storage

The method described by Bartkiene et al. [18] was used to study the pH of the bread samples for six days. Bread sample (5 g) was homogenized with 50 mL of distilled water and the pH was measured using a pH Meter (HANNA HI 221, Europe, Romania). Determination of pH of the bread samples were done in triplicates for every 2 days from 0 day, within the storage period of 6 days.

Determination of peroxide values of the bread samples A and D during storage

The method of AOAC [19] was used in determination of the peroxide values of the lipid fractions of the bread samples for six days. Lipids were extracted from milled bread samples with chloroform. Ten milliliters (10 mL) of the extracted lipids were dissolved in 15.0 mL glacial acetic acid and 1.0 mL of saturated KI aqueous solution. The sample was stirred and left for 5.0 min in darkness, followed by the addition of 75 mL of water and 1.0 mL of a starch solution. Formed iodine was titrated with 0.01 N sodium thiosulphate. The Peroxide Value (PV) was expressed as mili-equivalents of active oxygen per kilogram of lipids (meq  $\text{O}_2$ /kg of lipids). All samples were analyzed in triplicates for every 2 days from 0 day, within the storage period of 6 days.

Sensory evaluation of the bread samples A and D during storage

The bread samples were sliced into pieces of uniform thickness and served to ten trained panelists randomly selected from students and staff of the Department of Food, Nutrition and Home Sciences, Kogi State University, Anyigba. The

panelists evaluated the bread samples on a 5-point Hedonic scale where 1 represented disliked extremely and 5 represented liked extremely [13, 20]. The samples were evaluated for appearance, texture, flavor and overall acceptability. The samples were presented in 3-digit coded white plastic plates. The sensory evaluation was carried out in the Sensory Evaluation Laboratory under white color lighting. The order of presentation of the samples to the panelists was randomized. Portable water was provided for the panelists to rinse their mouths and palates in between evaluations. The sensory evaluation of the bread samples were done for every 2 days from 0 day, within the storage period of 6 days.

### Experimental design

The experiments were fit into a one way Analysis of variance (ANOVA). Eight bread samples (i.e from bread samples A, B, C, D, E, F, G and H) were generated in triplicates for each experiment on their sensory and physical properties yielding a total of twenty-four samples/experiment analyzed. Then, two bread samples (i.e from bread samples A and D) were generated in triplicates for each experiment on their mineral composition, anti-nutrient (food toxicants) composition, microbiological analysis, pH values, peroxide values and sensory properties during the storage studies, yielding a total of six (6) samples/experiment analyzed.

### Statistical analysis

Results of all determinations were expressed as means of triplicate values. Data were subjected to one-way Analysis of Variance (ANOVA), and the means were separated using Duncan's multiple range test to determine the significant differences at 5% probability ( $p < 0.05$ ). An IBM SPSS Statistical package (version 20.0) was used for all statistical analyses.

## Results and Discussion

### Physical properties of the bread samples

Results of the physical properties of composite bread samples made from various blends of wheat flour and arrowroot starch (A, B, C, D, E, F, G and H) are presented in table 2.

The heights of the bread samples significantly ( $p < 0.05$ ) decreased from 10.90 cm (bread sample A) to 4.20 cm (bread sample G). All composite breads significantly ( $p < 0.05$ ) had reduced heights compared to the control bread sample A (100% wheat flour bread) due to their reduced gluten contents as a result of substitution effects on the flour blends [21, 22]. Many researchers have reported that partial replacements of wheat flour with non-glutinous flours lead to lower bread heights [2, 21, 23]. However, the increased proportions of arrowroot starch in flour blends of bread samples B, C and D did not significantly  $p < 0.05$  affect their heights and shapes. The weight of the bread samples ranged significantly ( $p < 0.05$ ) from 550 g (control bread sample A) to 745 g (bread sample H). Weight of bread is an indicator of the amount of moisture and carbon dioxide diffused out of the bread loaf during baking [2]. The increased weights of the bread samples could be attributed to substitution effects of the wheat flour in their flour blends as the arrowroot starch might have high water absorbing capacity, resulting in heavier dough due to poor air entrapment [22]. The loaf volume of the bread samples varied significantly ( $P < 0.05$ ) between 1205.00 cm<sup>3</sup> (bread sample H) and 3134.00 cm<sup>3</sup> (bread sample A). The loaf volumes of the composite bread samples linearly decreased with increased substitution of wheat flour with arrowroot starch due to their declining gluten content [24]. The higher the gluten content of flour, the better the ability of the flour to extend and retain the carbon dioxide produced during fermentation (proofing) thereby yielding a higher loaf volume. However, bread samples C and D did not significantly ( $P < 0.05$ ) differ from bread sample A, indicating it could favourably compete with bread sample A in terms of loaf volume. Loaf volume is very important bread characteristic providing a quantitative measurement of baking performance [21] and thus most consumers prefer breads with high volume. These results are in agreement with the reports

**Table 2:** Physical properties of bread samples made from the various flour blends of wheat flour and arrowroot starch.

Bread sample code	Flour Blend (Wheat Flour: Arrowroot starch) (%)	Weight (g)	Breadth (cm)	Height (cm)	Length (cm)	Volume (cm <sup>3</sup> )	Density (g/cm <sup>3</sup> )
A	100.00 : 0.00	550.00 ± 0.05 <sup>d</sup>	11.50 ± 0.10 <sup>a</sup>	10.90 ± 0.41 <sup>a</sup>	25.00 ± 0.06 <sup>a</sup>	3134.00 ± 0.00 <sup>a</sup>	0.175 ± 0.03 <sup>a</sup>
B	90.00 : 10.00	625.00 ± 0.10 <sup>c</sup>	11.10 ± 0.03 <sup>a</sup>	10.50 ± 0.06 <sup>a</sup>	24.20 ± 0.02 <sup>a</sup>	2821.00 ± 0.40 <sup>b</sup>	0.222 ± 0.18 <sup>a</sup>
C	80.00 : 20.00	650.00 ± 0.04 <sup>c</sup>	11.00 ± 0.00 <sup>a</sup>	10.40 ± 0.17 <sup>a</sup>	24.80 ± 0.07 <sup>a</sup>	2837.00 ± 0.09 <sup>a</sup>	0.229 ± 0.00 <sup>a</sup>
D	70.00 : 30.00	725.00 ± 0.08 <sup>a</sup>	10.70 ± 0.09 <sup>a</sup>	10.20 ± 0.05 <sup>a</sup>	25.90 ± 0.09 <sup>a</sup>	2826.72 ± 0.11 <sup>a</sup>	0.261 ± 0.01 <sup>a</sup>
E	60.00 : 40.00	726.00 ± 0.18 <sup>a</sup>	10.90 ± 0.00 <sup>a</sup>	7.00 ± 0.02 <sup>b</sup>	25.00 ± 0.00 <sup>a</sup>	1908.00 ± 0.50 <sup>c</sup>	0.381 ± 0.00 <sup>a</sup>
F	50.00 : 50.00	728.00 ± 0.26 <sup>a</sup>	11.30 ± 0.01 <sup>a</sup>	6.00 ± 0.08 <sup>b</sup>	25.70 ± 0.33 <sup>a</sup>	1742.00 ± 0.03 <sup>c</sup>	0.418 ± 0.22 <sup>a</sup>
G	40.00 : 60.00	730.00 ± 0.46 <sup>a</sup>	11.90 ± 0.32 <sup>a</sup>	4.20 ± 0.00 <sup>c</sup>	25.90 ± 0.20 <sup>a</sup>	1262.00 ± 0.00 <sup>c</sup>	0.578 ± 0.03 <sup>a</sup>
H	0.00 : 100.00	745.00 ± 0.02 <sup>a</sup>	10.80 ± 0.04 <sup>a</sup>	4.50 ± 0.05 <sup>c</sup>	24.80 <sup>a</sup> ± 0.01	1205.00 ± 0.07 <sup>c</sup>	0.6183 ± 0.04 <sup>a</sup>

Values are mean ± standard deviation of triplicate determinations.

Values with different superscripts within the same column are significantly different at ( $P < 0.05$ ).

of Lagnika et al. [25], Nasir et al. [22], Mudau et al. [26] and Alabi et al. [24] who observed similar trends for weight and volume of bread samples made from composite wheat-cassava flour blends, wheat-amaranth flour blends, wheat-finger millet flour blends and wheat-fermented finger millet flour blends respectively. The densities of the bread samples were not significantly ( $P < 0.05$ ) different, but there was increase in densities of the bread samples as the substitution levels of wheat flour increased. Appearance, weight and volume are common indices for bread acceptability by consumers in Nigeria.

### Sensory properties of the bread samples

Results of the sensory properties of composite bread samples (A, B, C, D, E, F, G and H) made from various blends of wheat flour and arrowroot starch are presented in table 3.

The bread sample H, received the highest scores in the general acceptability evaluated. However, the bread sample D (containing up to 30% arrowroot starch) was not significantly different ( $p < 0.05$ ) from control sample (100% wheat bread) in the scores for appearance, taste, flavor, texture and overall acceptability. Then, above 30% level of arrowroot starch addition (bread samples E, F, G and H), sensory scores decreased steadily in all the sensory attributes studied. Therefore, bread sample D (with 30% arrowroot starch inclusion) was with the best sensory properties and therefore could be recommended to replace bread made from 100% wheat flour. This bread formulation will definitely reduce huge depletion of the nation's foreign exchange reserve through wheat importation. The

bread samples A and D, were further subjected to storage-stability studies.

**Note:** From the results obtained, bread sample D (70% wheat flour and 30% arrowroot starch) had comparatively best physical and sensory properties inter alia the composite bread samples and could compete favourably with bread sample A (100% wheat flour). So further research was carried out on the mineral composition, antinutrient composition and storage studies of bread sample D in comparison with bread sample A.

### Mineral composition of bread samples A and D

Results of the mineral composition of the bread samples A and D are shown in table 4. Zinc (Zn), sodium (Na), Potassium (K), calcium (Ca), magnesium (Mg) and phosphorus (P) contents of bread sample D were significantly ( $P < 0.05$ ) higher than those of bread sample A. These results are in agreement with the results of Barber et al. [27] who observed increments in Ca, Mg, K, Na and Zn contents of wheat flour bread supplemented with defatted/undefatted cashew kernel flour. The increase in mineral content of sample D could be from arrowroot [7]. Similarly, Odunlade et al. [28] reported significant ( $P < 0.05$ ) increase in Zn, Ca and Mg contents of wheat bread incorporated with leafy vegetable powders. Results of Akubo et al. [29] that evaluated the chemical composition of wheat bread incorporated with raw and boiled African palm root flours, aligned with the results on Zn and Na contents but contradicted with the reports on Fe, K, Mg and P contents. Malomo et al. [30] observed significant ( $P < 0.05$ )

**Table 3:** Sensory properties of bread samples produced from the various flour blends of wheat flour and arrowroot starch.

Bread sample	Flour Blend (Wheat Flour: Arrowroot flour) (%)	Appearance	Taste	Flavor	Texture	Overall Acceptability
A	100.00 : 0.00	1.6 ± 0.00 <sup>i</sup>	3.4 ± 0.06 <sup>b</sup>	2.9 ± 0.00 <sup>b</sup>	2.0 ± 0.04 <sup>b</sup>	2.3 ± 0.01 <sup>b</sup>
B	90.00 : 10.00	4.5 ± 0.12 <sup>a</sup>	4.5 ± 0.13 <sup>a</sup>	4.8 ± 0.31 <sup>a</sup>	4.7 ± 0.09 <sup>a</sup>	4.7 ± 0.00 <sup>a</sup>
C	80.00 : 20.00	4.5 ± 0.05 <sup>a</sup>	4.5 ± 0.17 <sup>a</sup>	4.2 ± 0.04 <sup>a</sup>	4.7 ± 0.36 <sup>a</sup>	4.1 ± 0.45 <sup>a</sup>
D	70.00 : 30.00	4.4 ± 0.39 <sup>a</sup>	4.5 ± 0.06 <sup>a</sup>	4.6 ± 0.08 <sup>a</sup>	4.4 ± 0.21 <sup>a</sup>	4.1 ± 0.12 <sup>a</sup>
E	60.00 : 40.00	3.7 ± 0.07 <sup>a</sup>	4.2 ± 0.09 <sup>a</sup>	4.0 ± 0.00 <sup>a</sup>	3.8 ± 0.01 <sup>b</sup>	3.1 ± 0.07 <sup>b</sup>
F	50.00 : 50.00	2.6 ± 0.02 <sup>b</sup>	3.8 ± 0.11 <sup>b</sup>	3.5 ± 0.20 <sup>b</sup>	3.0 ± 0.04 <sup>b</sup>	2.6 ± 0.08 <sup>b</sup>
G	40.00 : 60.00	2.1 ± 0.10 <sup>b</sup>	3.5 ± 0.05 <sup>b</sup>	2.8 ± 0.16 <sup>b</sup>	2.5 ± 0.08 <sup>b</sup>	2.5 ± 0.02 <sup>b</sup>
H	0.00 : 100.00	4.9 ± 0.00 <sup>a</sup>	4.9 ± 0.07 <sup>a</sup>	4.5 ± 0.01 <sup>a</sup>	4.8 ± 0.17 <sup>a</sup>	4.5 ± 0.05 <sup>a</sup>

Values are mean ± standard deviation of triplicate determinations.

Values with different superscripts within the same column are significantly different at ( $P < 0.05$ ).

**Table 4:** Mineral composition (mg/100g) of bread samples A and D.

Bread sample code	Flour Blend (Wheat Flour: Arrowroot starch) (%)	Zinc (Zn)	Iron (Fe)	Copper (Cu)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Phosphorus (P)
A	100.00 : 0.00	2.6 ± 0.00 <sup>b</sup>	1.5 ± 0.07 <sup>a</sup>	5.2 ± 0.03 <sup>a</sup>	95.6 ± 0.00 <sup>b</sup>	30.8 ± 0.02 <sup>b</sup>	39 ± 0.02 <sup>b</sup>	14.2 ± 0.05 <sup>b</sup>	562.5 ± 0.12 <sup>b</sup>
D	70.00 : 30.00	3.9 ± 0.06 <sup>a</sup>	0.9 ± 0.19 <sup>b</sup>	3.00 ± 0.08 <sup>b</sup>	103.6 ± 0.01 <sup>a</sup>	42.8 ± 0.06 <sup>a</sup>	50.8 ± 0.08 <sup>a</sup>	20.6 ± 0.00 <sup>a</sup>	650.3 ± 0.03 <sup>a</sup>

Values are mean ± standard deviation of triplicate determinations.

Values with different superscripts within the same column are significantly different at ( $P < 0.05$ ).

reduction in Zn and Fe contents (i.e., contradictory results) of bread samples formulated with wheat, breadfruit and breadnut flours, but aligned on the results of Cu, Na and Ca. Minerals are of great significant importance in human nutrition: they give structural, regulatory and catalytic functions in the body and should form part of human diet [6, 27, 31, 32]. Obviously, availability of bread sample D, will help mitigate malnutrition (hidden hunger) prevalent in developing and developed countries.

### Anti-nutrient composition of bread samples A and D

Results of the anti-nutrient composition of the bread samples A and D are presented in table 5. The oxalate content of the bread sample D (3.9 mg/100g) was significantly ( $P < 0.05$ ) higher than in bread sample A (2.60 mg/100g). Oxalates (in large amount) form insoluble complexes with calcium (Ca), Magnesium (Mg) and Iron (Fe), thereby reducing their bioavailability for utilizations in the human body. However, the level of the toxicant (oxalate) in bread sample D, was not high enough to cause health concern as studies have revealed the detrimental level to be 80 mg/g diet [33, 34]. Kidney stones, bitter/astringent taste and scratches (in the mouth and throat) making food unpalatable, have been traced to ingestion of high amounts of oxalates [16]. The lethal dose for hydrogen cyanide (HCN) in humans is in the range of 35 – 300 mg/kg body weight [35, 36] which is far higher than contained in sample D. HCN inhibit cellular oxidation- it binds with catalytic ion of cytochrome oxidase leading to elimination of active unit responsible for transfer of electrons to molecular oxygen. HCN, also inhibits the activity of vitamin K. Inter-

estingly, the hydrogen cyanide (HCN) (0.90 mg/100g) and tannins (3.00 mg/100 g) contents in sample D were significantly ( $P < 0.05$ ) lower than in bread sample A (HCN- 1.50 mg/10g; Tannins- 5.20 mg/100 g). The low levels of HCN and tannins observed in sample D, could be as result of substitution effect of wheat flour with arrowroot starch. Tannins form complexes with protein and carbohydrates (reducing their digestibility) and also interferes with iron absorption [34, 37]. From results, the safe levels of these anti-nutrients in bread samples will assure improved human nutrition and organoleptic properties.

### Microbial load, pH and Peroxide values of bread samples A and D during six days' storage

It is important to note that shelf-life of bread is limited by physicochemical changes (i.e. stalling and microbiological spoilage). Bread has a shorter shelf-life than most other processed foods. It loses freshness and it is always prone to mold and bacteria spoilage. Thus, the results of the trends of microbial quality, pH and peroxide values of the bread samples A and D during storage of six days are shown in table 6. The aerobic plate count significantly ( $P < 0.05$ ) ranged from  $1.15 \times 10^2$  cfu/g in bread sample D on the zero day of storage to  $3.85 \times 10^2$  cfu/g (bread samples A and D) on the sixth day of storage. Surprisingly, total bacteria count, analyzed in each of the days apart from the sixth day, showed significantly ( $P < 0.05$ ) reduced numbers in bread sample D, relative to bread sample A- an indication of better keeping quality for bread sample D. Besides, bacteria counts of bread samples A and D were below the recommended limits ( $10^5$  cfu/g) for bacterial contamina-

**Table 5:** Anti-nutrient composition (mg/100g) of bread samples A and D.

Bread sample	Flour Blend (Wheat Flour: Arrowroot starch) (%)	Oxalates	Hydrogen cyanide (HCN)	Tannins
A	100.00 : 0.00	2.60 ± 0.13 <sup>b</sup>	1.50 ± 0.08 <sup>a</sup>	5.20 ± 0.00 <sup>a</sup>
D	70.00 : 30.00	3.9 ± 0.10 <sup>a</sup>	0.90 ± 0.04 <sup>b</sup>	3.00 ± 0.07 <sup>b</sup>

Values are mean ± standard deviation of triplicate determinations.

Values with different superscripts within the same column are significantly different at ( $P < 0.05$ ).

**Table 6:** Microbial load, pH values and peroxide values of bread samples A and D.

Bread sample	Flour Blend (Wheat Flour: Arrowroot starch) (%)	Storage period (day)	Aerobic plate count (cfu/g)	Mold count (cfu/g)	pH value	Peroxide value
A	100.00 : 0.00	0.00	$1.20 \times 10^{2f}$	$2.12 \times 10^{2d}$	6.12 ± 0.03 <sup>a</sup>	20.00 ± 0.08 <sup>a</sup>
D	70.00 : 30.00	0.00	$1.15 \times 10^{2g}$	$2.12 \times 10^{2d}$	6.04 ± 0.20 <sup>b</sup>	18.00 ± 0.04 <sup>b</sup>
A	100.00 : 0.00	2.00	$1.85 \times 10^{2d}$	$3.20 \times 10^{2c}$	6.25 ± 0.05 <sup>a</sup>	20.00 ± 0.00 <sup>a</sup>
D	70.00 : 30.00	2.00	$1.80 \times 10^{2c}$	$3.20 \times 10^{2c}$	6.15 ± 0.08 <sup>a</sup>	18.00 ± 0.42 <sup>b</sup>
A	100.00 : 0.00	4.00	$2.20 \times 10^{2b}$	$4.22 \times 10^{2b}$	6.34 ± 0.03 <sup>a</sup>	20.00 ± 0.05 <sup>a</sup>
D	70.00 : 30.00	4.00	$2.10 \times 10^{2c}$	$4.22 \times 10^{2b}$	6.40 ± 0.09 <sup>a</sup>	18.00 ± 0.22 <sup>b</sup>
A	100.00 : 0.00	6.00	$3.85 \times 10^{2a}$	$5.10 \times 10^{2a}$	6.91 ± 0.00 <sup>a</sup>	20.00 ± 0.04 <sup>a</sup>
D	70.00 : 30.00	6.00	$3.85 \times 10^{2a}$	$5.10 \times 10^{2a}$	6.90 ± 0.01 <sup>a</sup>	18.00 ± 0.06 <sup>b</sup>

Values are mean ± standard deviation of triplicate determinations.

Values with different superscripts within the same column are significantly different at ( $P < 0.05$ ).



**Table 7:** Sensory properties of the bread sample D during storage.

Bread sample code	Flour Blend (Wheat Flour: Arrowroot starch) (%)	Storage period (day)	Appearance	Taste	Aroma	Texture	Overall acceptability
D	100.00 : 0.00	0	4.4 ± 0.07 <sup>a</sup>	4.5 ± 0.00 <sup>a</sup>	4.6 ± 0.01 <sup>a</sup>	4.4 ± 0.05 <sup>a</sup>	4.1 ± 0.03 <sup>a</sup>
D	70.00 : 30.00	2	4.4 ± 0.00 <sup>a</sup>	4.5 ± 0.04 <sup>a</sup>	4.6 ± 0.11 <sup>a</sup>	4.4 ± 0.18 <sup>a</sup>	4.1 ± 0.08 <sup>a</sup>
D	100.00 : 0.00	4	4.4 ± 0.08 <sup>a</sup>	4.5 ± 0.01 <sup>a</sup>	4.6 ± 0.06 <sup>a</sup>	4.4 ± 0.01 <sup>a</sup>	4.1 ± 0.04 <sup>a</sup>
D	70.00 : 30.00	6	4.4 ± 0.04 <sup>a</sup>	4.5 ± 0.09 <sup>a</sup>	4.6 ± 0.10 <sup>a</sup>	4.3 ± 0.15 <sup>a</sup>	4.0 ± 0.06 <sup>a</sup>

Values are mean ± standard deviation of triplicate determinations.

Values with different superscripts within the same column are significantly different at (P<0.05).

tion for ready-to-eat food by International Commission on Microbiological Specification for foods [38]. The mold count significantly (P<0.05) ranged from  $2.12 \times 10^2$  cfu/g to  $5.10 \times 10^2$  cfu/g in both bread samples. The bread sample D, had a good keeping quality up to the sixth day. The aerobes counts expressed, were also below the values of Ijah et al. [39] for bread made with wheat flour and potato flour (i.e.  $3.0 \times 10^5$  cfu/g to  $1.09 \times 10^6$  cfu/g). Bread depreciates in quality due to the continued proliferation of mold and bacteria during storage, leading to spoilage. Surprisingly bread sample D was acceptable up till the sixth day and the parameters were within limits of  $1.0 \times 10^3$  cfu/g (bacteria count) and  $1.0 \times 10^5$  cfu/g (mold count) recommended by microbiology standards for ready to eat foods [40]. The pH values of the bread samples significantly (P<0.05) ranged from 6.04 (bread sample D) in zero day to 6.91 (bread sample D) in the sixth day of storage. The results are in conflict with the results of Monteiro et al. [41] who observed decrease in the pH of bread fortified with tilapia-waste flour during storage. The pH value determines product quality and shelf-life; thus consistent food product quality is possible with precise pH measurements during processing and storage. Of course, pH values of a food sample could be utilized to control the growth of pathogens and food-spoilage organisms. Surprisingly, in the sixth day of storage, the pH of bread sample D (6.91) did not differ significantly (P<0.05) from pH of bread sample A (6.90), which indicated comparable storage stability with control sample (Sample A). There were no changes observed in the peroxide values of the bread samples, indicating their good storage stabilities within the six days of storage. Peroxide value monitors the development of rancidity of fats and oils in the bread samples that leads to development of unpleasant odour and taste. From the results, it shows that the bread samples did not go rancid during the storage period of 6 days at ambient temperature. Therefore, all the results obtained during the storage study, have shown that improved keeping quality of bread could be achieved by changing bread formulation.

The results of the sensory scores of the bread sample D during the six days' storage are presented in table 7. The scores for appearance, taste, aroma, texture and overall acceptability of the bread sample D did not significantly differ (P>0.05) during the six days of storage; and therefore, the six days old bread sample D was as fresh (sensory-wise) as the zero day old bread sample D. These results have indicated that bread sample D (70% wheat flour; 30% arrowroot starch) could replace 100% wheat flour bread and store for 6 days with no loss of

sensory qualities.

## Conclusion

Flour blends of wheat flour and arrowroot starch, in the percentage ratios of 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60 and 0:100, were utilized in production of various composite bread of samples A, B, C, D, E, F, G and H respectively. Bread samples B - D exhibited great potentials in replacing 100% wheat bread. Furthermore, investigation revealed that sample D (70% wheat flour and 30% arrowroot starch) was richer in mineral composition (Zn, Na, K, Ca, Mg and P) and lower in anti-nutrient composition (HCN and tannins) than the 100% wheat flour bread. Also sample D showed overwhelming potentials in storage stability and keeping quality with minimal changes in sensory properties.

Therefore, adoption of flour blend of 70% wheat flour and 30% arrowroot starch in bread making will: mitigate the high wheat import bills ravaging Nigeria; widen the spectrum of domestic and industrial exploitations of arrowroots; control postharvest food losses; strengthen food security; help in fixing the fast-depleting economy of Nigeria; boost our local agriculture; and provide employment opportunities.

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## Conflict of Interest

Authors have declared that no competing interests exist. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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