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# Comparison of Nigerian Fermented Food Condiments

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## ABSTRACT

Food condiments in Nigeria are consumable ingredients added to meals to improve their taste, aroma or consistency. This research was conducted to evaluate and contrasts the phytochemical content, mineral element, vitamins levels, and overall nutritional value of ogiri okpeyi, ogiri and dawadawa. The analyses were performed in accordance with standard procedures outlined by the Association of Official Analytical Chemists (AOAC). The moisture levels observed in ogiri okpeyi, ogiri and dawadawa varied between ($11.20^{a} \pm 0.28$-$4.50^{b} \pm 0.14$). The fat levels of the condiments were found to fall within a range of ($7.80^{b} \pm 0.00$-$28.60^{a} \pm 0.28$). The ash ranged from ($3.30^{a} \pm 1.27$ – $4.70^{a} \pm 0.14$). The fibre, protein and carbohydrate ranged from $2.20^{b} \pm 0.00$-$65.85^{a} \pm 1.13$. The mineral content of the three food enhancer varied from ($3.67^{b} \pm 0.16$ – $313.05^{a} \pm 0.38$). The vitamin composition ranged from ($0.13^{a} \pm 0.01$-$9.48^{a} \pm 0.53$). The phytochemical content of all three samples investigated ranged from ($0.23c \pm 0.00$-$4.23 \pm 0.00$). The nutritional result revealed that ogiri had the highest nutritional content compared to others. Ogiri had the highest tannin. Flavonoid, alkaloid and phenol were highest in dawadawa. The highest saponin component was found in okpeyi. Calcium, potassium, sodium, phosphorus and iron were highest in ogiri. Magnesium was highest in Okpeyi. Vitamin E, beta-carotene, vitamin B1, and B2 were highest in ogiri, while dawadawa had the highest vitamin C. The use of ogiri should be encouraged because it has the highest nutritional content. Further studies should be done on the microbial quality of ogiri to know how safe it is for consumption.

**Keywords:** Ogiri Igbo, Okpenyi, Dawadawa, Fermented Condiments, Nigeria

## Introduction

A fermented condiment is a consumable product incorporated into foods to improve or modify their taste and textural qualities Aniebet *et al*. (2024). Traditional fermented foods are nutritional rich, easier to digest, and contribute a wide range of distinctive flavours, aromas and textures to food materials. "Ogiri" adds valuable protein, essential minerals and energy to the diet (Ifesan *et al*., 2019). Ogiri Igbo, Ogiri Okpeyi and Dawadawa are commonly described in West Africa as oily, patse-like products derived from oil-rich seeds. In West Africa, a variety of fermented vegetables are commonly consumed. Examples include iru or dawadawa, produce from the seeds of the locust bean tree (Parkia biglobosa); ogiri, obtained from melon seeds (Citrullus vulgaris); dawadawa also made from soybeans (Glycine max); ugba, prepared from the African oil bean seed (Pentaclethra macrophylla); okpeyi, processed from mesquite seeds (Prosopis africana); and owoh, which is fermented from the seeds of either the cotton plant (Gossypium hirsutum) or the African yam bean (Sphenostylis stenocarpa) Ayoade and Chimezie (2019).

"Ogiri " is a key soup condiment widely used in the Nigerian states of South-Eastern states, South-Western and North-Central. It is traditionally produced through fermentation of various seeds, a process driven by microorganisms that may be

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naturally present in the seeds or introduced from the surrounding environment Dimejesi and Iheukwumere (2014). "Ogiri" production from melon seeds involves a spontaneous (uncontrolled) fermentation process as reported by Achi (2005). The process starts with raw melon seeds which are first dehulled and boiled again. The softened seeds are then wrapped in leaves, packed into sacks, and allowed to ferment naturally at ambient temperature for about three to five days. After fermentation, the product is dried and ground into a patse commonly referred to as "ogiri".

Natural occurring fermentation fulfills many functions in food preparation. It develops desirable sensory qualities such as flavor, smell, and texture, prolongs storage life through acid and alkaline fermentative activities, and improves nutritional quality by increasing the availability of proteins, amino acids, essential fatty acids, and vitamins. Furthermore, it promotes easier digestion and better nutrient uptake, neutralizes anti-nutritional compounds, and lowers both cooking duration and energy requirements Steinkraus ( 2015). Dehulling is often done by hand, which can introduce a range of microorganisms into the seeds—some of which may be harmful—especially when coupled with unsanitary conditions. This can lead to inconsistent quality, unpleasant odors, short shelf life, and potential health risks in the final product Onawola *et al*. (2012). Fermented condiments help lower the risk of diet-related diseases like diabetes and cardiovascular conditions and improve nutrient availability Tachie *et al.* (2023).

The African Locust bean tree, a common perennial leguminous tree, is home to Parkia bigolosa seeds Abdoulaye (2012). They can be found growing in the West African savannah region up to the southern Sahel zone (13 °C). The plant yields pod-shaped, brownish seeds. After processing, the seeds become a valuable spice that enhances the flavor and taste of soup. In Nigeria's "nune" and southwestern middle belt regions, the processed cake is referred to as "Iru." When ripe, the thin, slightly flattened pods change from pink-brown to dark brown. According to Enujiugha (2015), these pods are roughly 45 cm long and 2 cm wide, and they may have up to 18 seeds lodged in a fleshy, yellowish endocarp.

Soybean (*Glycine max*) is a significant oilseed crop. A member of the Leguminosae family and is commonly cultivated for food. Dawadawa, a traditional seasoning or condiment, is produced from soybean and has gained widespread use. Today, it is also manufactured on an industrial scale by companies such as Nestlé and distributed across Africa. This culinary staple, especially popular in Northern Nigeria and the West African savanna, enhances the flavor and richness of soups, sauces, and various dishes Ejiofor and Nwakuche (2024).

This local condiment (Dawadawa) is known for its impressive nutritional profiles, featuring high mineral content, optimal moisture levels, low ash, and minimal crude fibre. They are also low in fat, rich in protein, and free of cholesterol Nwanisobi *et al*. (2022), making them a valuable dietary component—particularly in developing countries like Nigeria. In addition to their nutritional benefits, Dawadawa contain a variety of bioactive compounds and phytochemicals, including antioxidants (such as polyphenols), soluble fibre (like pectin and beta-glucans), probiotics (such as inulin and fructans), key nutrients such as vitamins A, B-complex, and C, along with flavone glycosides (example , hesperidin), and organic acids like tartaric acid.

Ogiri okpeyi, derived from the fermented seeds of *Prosopis africana*, is a traditional food condiment. This plant, a member of the Leguminosae family—commonly called African mesquite or the iron tree, it is highly prized for its nutrient-dense seeds which are widely used as a seasoning. These seeds are notably high in protein, fatty acids, and essential mineral element including phosphorus, potassium, and calcium Ayanwuyi *et al*. (2010); Amusa *et al*. (2010). Originating from West Africa, specifically among the Igbo people of Nigeria, ogiri okpeyi is typically recognized by its dark brown color. Odibo *et*. *al*. (2008) Fermented ogiri okpeyi the condiment is characterized by a very intense aroma and is

commonly added to soups to enhance flavor Achi, (2005); Ezeocha *et al*. (2022).

This article aims to evaluate and compare bioactive compounds, minerals, vitamin, and overall nutritional composition of selected Nigerian food condiments; ogiri-okpeyi, ogiri-igbo, and dawadawa.

## Materials and Method

### Source of Materials

The fermented food condiment samples (ogiri-okpei, ogiri-igbo, and dawadawa) used in this study were obtained from Orie-Ugba market, Umuahia, Abia State. The comparative analysis was analyzed in the Plant Science and Biotechnology laboratory, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

### Sample Preparation

The ogiri samples were dried in an oven at $50^0$ C for 24hours, after which they were ground with an electric milling machine and kept in plastic container prior to analysis.

### Method of Analysis

### Proximate Analysis

The proximate composition of each sample was analyzed using standard procedures outlined by AOAC (1995).

### Determination of moisture content

The moisture content of each composite flour blend was measured using 5 g of flour. The flour samples, previously weighed, were transferred into pre-weight drying crucibles and oven-dried at 105±1°C for four hours. Once dried, the samples were cooled in a desiccator and weight recorded.

Moisture content (%) was calculated using the equation: % moisture =

$$\frac{W_3\text{-}W_1 \times 1}{W_2\text{-}W_1} \qquad (1)$$

Where;

$W_1$= weight of empty crucible,

$W_2$ = weight of crucible + food before drying

$W_3$ = Final weight of crucible + food after drying

### Determination of Crude Protein Content

Crude protein content was determined using the Kjeldahl method as described by AOAC (2010). 0.5g of flour sample was digested with 25 mL of concentrated sulphuric acid in the presence of a catalyst until a clear solution was obtained. The digest was then neutralized placed in 0ml of 2% sodium hydroxide solution and 2 drops of methyl red indicator were added. The released ammonia was distilled into a boric acid solution and titrated with standardized hydrochloric acid. The nitrogen content was calculated and multiply by a factor of 6.25 to obtain the crude protein content (%):

$$\% \text{ crude protein} = \frac{N \times T \times 10ml \times 14 \times 100 \times 6.25}{1000} \qquad (3)$$

Where;

N is the normality of the hydrochloric acid (HCI) solution used in the titration of the sample

Tis Titration value Weight of a 10ml sample

1000 is the number of milligrams equivalent to one gram

14 is the equivalent weight of nitrogen

6.25 is Protein conversion factor for nitrogen-protein

### Fat Content Determination

Five grams of each flour sample were measured into pre-weighed filter papers and securely wrapped. The wrapped samples were transferred into extraction thimbles, oven-dried, and then cooled in a desiccator prior to reweighing. Subsequently, 25ml of petroleum ether was added to the flask to facilitate fat extraction. Following extraction, the solvent was removed by oven drying. The flask and its contents were then cooled in a desiccators and weighed. The fat content was determined as a percentage using the following

calculation:

$$\% \text{ Crude fat content} = \frac{W_2 - W_1}{W} \times \frac{100}{1} \quad (4)$$

Where;
$W_1$ is weight of empty flask
$W_2$ is weight of flask + fat extract
W is weight of sample.

**Determination of Crude Fibre**

Crude Fibre in each flour sample was quantified using standard gravimetric method. Five (5)g of the defatted sample was boiled under in 200ml 0f 1.25% $H_2SO_4$ solution for 30 minutes. Subsequently, the samples were washed with repeated portions of hot water through a two-fold muslin cloth to trap collect the residues. The washed samples were transferred quantitatively reintroduce into the flask, and 200ml of 1.25 % NaOH solution was added to each. The residues were reheated by boiling for 30 minutes, followed by repeated rinsing with hot water. The material were then carefully transferred into previously weighed porcelain crucibles and dried in a hot air- oven at 105°C for 3 hours. After cooling in a desiccator, the dried sample were weighed ($W_2$). Thereafter, the samples were ashed in a muffle furnace at 550°C for 2 hours until the complete combustion was achieved. The crucibles were allowed to cool in a desiccator and reweighed to obtain ($W_3$) .
The crude fibre content of each sample was determined gravimetrically as;

$$\% \text{ crude fibre} = \frac{W_2 - W_3}{W_1} \times \frac{100}{1} \quad (5)$$

Where,
$W_2$ is weight of crucible and sample after washing and oven drying
$W_3$ is weight of crucible containing the ash
$W_1$ is initial weight of the sample

**Determination of Carbohydrate**

Carbohydrate content was evaluated and expressed by difference of the nitrogen-free extractive (NFE).
The nitrogen free extractive (NFE) was obtained using the following calculation:
The nitrogen-free extract (%NFE) evaluated by subtracting the sum of a, b, c, d, and e from 100.
Where; a is protein
b is fat
c is fibre
d is ash
e is moisture

**Mineral Analysis**

Mineral content was computed from each sample by the dry Ash standard method. Two grams of each flour sample was subjected to dry ashing in a muffle furnace at 80 °C. After ashing, the residue was solubilized in 100 ml of 2M hydrochloric acid. The resulting ash was gently heated for 30 minutes. The digest was then brought to 100 ml volume with distilled water. The prepared digest was used for further analyses evaluation.

**Determination of Phosphorus**

The phosphorus content of each flour sample was quantified via the vanadomobydate spectrophotometry method outlined by James (1995). For each sample, 1mL of digest was dispensed into a 50mls volumetric flask. Distilled water (1) ml and standard Phosphorus solution (1ml) were dispensed into separate flasks to serve as the reagent blank and calibration standard, respectively. Two (2) mL of the vanadomobydate phosphorus color assay was dispensed to each flask were left at ambient temperature for 15minute to develop colour. Each flask was diluted to 50ml mark with distilled water and absorbance was recorded on a spectrophotometer **(**Pecmedical spectrophotometer; model no:721, China). The absorbance measurement were taken at 540nm, using the reagent blank at the zero reference.

Phosphorus level (mg/100) was determined by multiplying 100, the sample absorbance(Au), the calibration factor(C) and the total volume(Vt) divided by ash weight of the sample, absorbance phosphorus

solution and extract volume analyzer

### Determination of Calcium and Magnesium

Determination of calcium and magnesium were quantified by complexometric titration using the EDTA versanate) titrimetric procedure as described by AOAC (2005). Twenty mil portions of each flour extract was transferred into a Erienmeyer flask, respectively. Small quantities of masking agents-hydroxylamine hydrochloride, sodium cyanide, and sodium potassium ferrocyanide- were introduced into the extract to adjust the pH to 10.00 a condition under which both calcium and magnesium form stable complexes with EDTA. Each prepared sample was then titrated with 0.02N EDTA using Erichrome dark T as an indicator. A reagent blank was similarly titrated, and the endpoint and was identified by a colour change from a wine red to a permanent blue. The recorded titre corresponded to the combined concentration of calcium and magnesium ions in the sample. To quantify calcium exclusively, a separate reagent titration was performed for each extract. The calcium- specific followed the same procedure as described previously, except that a 10% sodum hydroxide solution replaced the ammonia buffer, and Solochrome Dark Blue was used as the indicator instead of Eriochrome Black T. The titre values obtained, the $Ca^{2+}$ and Mg2+ content were calculated as:

Ca/Mg (mg/mg) =

$$\frac{100 \times T - B\,(N \times Ca/Mg)}{W} \times \frac{Vt}{Va} \qquad (6)$$

Where;

W is weight of sample
T isTitire value of the sample
B is Titire value of Blank
Ca is calcium equivalence
Mg is magnesium equivalence
N isNormality of titrant (0.02N EDTA)

### Determination of Sodium and Potassium

Sodium and Potassium were determined by Flame photometry. Sodium and potassium standard were prepared separately and diluted in to concentrations of 2-10 ppm.. After calibrating the instrument, 1ml of each standard was aspirated and introduced into a non-luminous flame. The corresponding emission readings were obtained using the appropriate elemental filter. Prior to flame analysis, the appropriate element. The sodium or potassium sample was measured under the same conditions used for the standard. Similarly, each flour extract was aspirated into the Flame photometer. A calibration curve was constructed and used to estimate the concentration of each element in the samples. Computed as: Sodium or potassium content (mg/100g) was calculated as the product of the measured concentration, total volume, and dilution factor, multiplied by 100 divided with volume of extract and sample weight.

### Quantification of Iron

Iron levels of the flour samples were assessed following the AOAC (2005) orthophenantroline procedure. Each flour extract (10mL) was measured and introduce into a 50mls titration flask. Two millimeters of 10% hydroxylamine hydrochloride solution, and each sample received 20$cm^3$ of 10% sodium citrate solution. Orthophenantroline solutions (2mL) was introduce, after which the mixture was adjusted to 50 mls with distilled water. The solution was homogenized and allowed to stand at room temperature for 30 minutes. Pecmedical spectrophotometer (model no:721; made in China) absorbance was recorded at 510nm using reagent blank adjusted to zero. Iron concentration was determined as: Product of concentration of standard solution, dilution factor, multiply by 10 divided with sample weight.

$$\text{Iron (mg/100g)} = \frac{C \times DF \times 10}{W} \qquad (7)$$

## Vitamin Analysis

### Thiamine ($B_1$) Determination

Concentration of thiamine was calculated following the procedure of AOAC (2005). Five grams flour sample was thoroughly mixed with 50ml ethanolic sodium hydroxide. The filtrate was added into a 100 ml volumetric flask. Colour development was achieved by treating 10 ml of the filtrate with 10mL of potassium dichromate after which absorbance was determined at 360 nm. A similarly prepared blank was read at 360nm.

$$\text{Thiamine mg/100g} = \frac{100}{W} \times \frac{Au}{As} \times C \times \frac{Vt}{Va} \quad (8)$$

Where,
W is weight of sample ash
Au is absorbance of test sample
As is absorbance of standard thiamine solution
C is concentration of standard thiamine solution
Vt is total extract volume
Va is volume of extract analyzer

### Determination of Riboflavin (Vitamin $B_2$)

Riboflavin concentration of each flour specimen was calculated by following the procedure outlined by AOAC (2005). Five (5) g of the flour were extracted with 100mL of 50% ethanol by continuous shaking for one hour, after which the extract was filtered. A ten mL aliquot of the sample solution was transferred into a 50ml Erinemeyer flask, treated with 10 ml of 5% potassium permanganate and 10 ml of 3% hydrogen peroxide ($H_2O_2$) were added, allowed to stand over a hot in water bath for about 30 minutes. Two (2) ml of 4% sodium sulphate ($Na_2SO_4$) solution was added which yellowish-pale colour was formed after being made up to 50ml and recorded at an absorbance of 510nm in a Pecmedical spectrophotometer (model no:721; made in China)
Riboflavin concentration was determined as mg per 100 g of sample was obtained by multiplying 100, the absorbance of sample, total extract volume (Vt) and divided by sample weight, absorbance of standard vitamin A solution, volume of extract analyzer.

### Niacin $B_3$ Determination

The niacin concentration of the flour samples was analyzed following an AOAC (2005) approved procedure. A 5g portion of each flour sample was extracted using 50 ml of 1N sulphuric acid with continuous shaking for 30 minutes. The solution was then neutralized with three drops of ammonia and subsequently filtered. A 10 ml aliquot of each filtrate was dispensed into a 50 ml calibrated flask, followed by the addition of 5 ml of potassium cyanide. The solution was acidified with 5 ml of 0.02 N sulphuric acid and its absorbance was measured at 470 nm using spectrophotometer
The niacin content (mg/100g) was calculated as 100 times the product of the sample absorbance (Au), standard concentration (C), and total extract volume (Vt), divided by the product of the sample weight (W), standard absorbance(As) and aliquot volume(Va).

### Determination of Beta Carotene (Vitamin A)

The ten grams of each well ground specimen was extracted with 80% acetone. The resulting solution was then filtered with a Whatman's No. 1 filter paper. The filtrate was placed in a separating funnel and extracted with 25ml of petroleum ether. The funnel was shaken gently to obtain a uniform mixture. The mixture was subsequently left undisturbed until two separate layers formed. The lower layer was decanted into a beaker while the top layer was collected into a 50ml beaker. The lower layer was separated and subjected to repeated extraction with 10ml petroleum ether for 5-6 cycles until a uniformly yellow was obtained. All the petroleum ether extract was collected into a 50ml beaker. The final extract was made up to 50ml with pet ether. Absorbance readings were taken at 450nm wavelength on a spectrophotometer (model 22UV/VIS). The spectrophotometer was calibrated to zero point using a cuvette filled with petroleum ether as the blank. Aliquots of each extract were placed in cuvettes, and absorbance readings were recorded once the display stabilized. β-Carotene levels were quantified using Beer-Lambert's Law, which states that the absorbance (A) is directly proportional to the concentration(C) of the pigment, as shown by the equation:

$$C = \frac{A}{e\text{-}\iota} \quad (9)$$

Where:
C is concentration of β-carotene (µg/mL)
A is absorbance at450nm
e is molar absorptivity (extinction coefficient)
l is path length of the cuvette (cm)

**Vitamin C (Ascorbic acid) Quantification**

Vitamin C levels of the flour specimen was quantified following procedure outlined by Okwu and Ndu (2006). Five grams of each test material was homogenized in a 100ml of EDAT/TCA extraction solution. Each flour sample uniform solution was filtered. The filtrate was titrated and corresponding titrations were used for the analysis. The filtrate obtained from each test sample was passed through a packed cotton wool containing activated charcoal to decolorize them, after which the filtrate volume was made up to 100ml of water. Additional portions of the extraction solvent was used to enhance the washing process. An aliquot (20) mls of each filtrate was measured into a conical flask, followed by the sequential addition of 10mls of a 20% potassium iodine solution and 5mls of starch solution (indicator). Titration of each sample solution was carried out using 0.01N copper (II) sulfate, and the end point was identified by the formation of distinct black specks in the reacting mixture. Quantification of vitamin C was achieved by applying the established conversion factor in which 1ml of 0.01mol $CUSO_4$ represent 0.880 mg of ascorbic acid.

The vitamin C content of each sample was determined by calculating the amount present in 100 g of the flour. This was achieved by considering the volume of the extract, the titre value obtained during titration, the weight of the sample, and the volume of the aliquot analyzed. A conversion factor of 0.88, corresponding to the amount of vitamin C per milliliter of titrant, was applied to obtain the final concentration.

**Determination of Vitamin E**

The Vitamin E content of each flour sample was computed by the procedure outlined by Kirk and Sawyer (1998). A mixture of 10mls of absolute ethanol and 20 mls of 2M ethanolic sulfuric acid was thoroughly mixed with 2g of the respective samples. To prevent photo degradation, the beaker was completely wrapped in aluminum foil. Following 45 minutes of reflux, the mixtures were permitted to cool before further processing. A peach colour was observed. The mixture was diluted with 20mls of distilled water and subsequently poured into a separating funnel. To ensure complete transfer, the beaker was rinsed with 50mls distilled water into the separating funnel. Each sample solution was mixed thoroughly with 150 mls of diethyl ether. The layers were allowed to partition. The organic layer was removed and placed in a desiccator with anhydrous sodium sulphate for complete drying. Each sample residue was re-dissolved in 10mls of absolute ethanol and was employed for the determination. A 1ml aliquot of the respective sample solution were dispensed into labelled test tubes and 1ml of conc. $HNO_3$ was added. Heating was carried out at 90°C for 3 minutes and water cooled. Vitamin E calibration standard (0.2-1.0 ppm) were prepared to obtained concentration respectively. Spectrophotometer measurement were recorded for the sample at 470nm. Reagent blank was prepared without Vitamin E or the test sample.

Vitamin E is calculated in mg per 100g using the measured absorbance values and the following equation: 100 multiplied by the absorbance of the sample (Au) and the concentration of the standard (C) and the total extract volume (Vt), divided by the product of the sample weight (W), the absorbance of the standard (As), and the volume of the aliquot analyzed (Va).

**Phytochemical Determination**

**Saponin Determination**

The saponin content of each flour sample was determined following the gravimetric method involving repeated solvent extraction as outlined by

Harborne (1973). For each analysis, 5 g of the flour sample was weighed into a 250 mL conical flask and homogenized with 50 mL of 20% aqueous ethanol. The mixture was incubated at 55 °C for 12 hours under continuous agitation to facilitate extraction. After incubation, the mixture was filtered using Whatman No. 42 filter paper. The solid residue obtained was subjected to a second extraction with an additional 50 mL of the same ethanol solution for 30 minutes, and the resulting filtrates were pooled.

The combined extracts were concentrated to approximately 40 mL through evaporation and subsequently transferred into a separating funnel. Forty milliliters of diethyl ether was added, and the mixture was vigorously shaken to allow phase separation. The ether layer was discarded, while the aqueous phase was retained and re-extracted with fresh diethyl ether. The pH of the retained aqueous layer was then adjusted to 4.5 by the gradual addition of dilute sodium hydroxide solution.

Saponins present in the extract were recovered through successive extraction with 60 mL of n-butanol. The pooled butanolic extracts were washed with a 5% sodium chloride solution to remove impurities and then evaporated to dryness in a previously weighed evaporating dish. The residue was further dried in an oven at 60 °C to eliminate any remaining solvent, cooled in a desiccator, and reweighed to obtain the saponin fraction.
The percentage saponin content was calculated using the expression:

$$\text{Saponin (\%)} = \frac{(W2-W1)\times 100}{W} \qquad (10)$$

where $W$ represents the weight of the sample analyzed, $W_1$ is the weight of the empty evaporating dish, and $W_2$ is the combined weight of the dish and the extracted saponin

**Phenol Determination**

The total phenolic content of the flour samples was quantified using the Folin–Ciocalteu spectrophotometric method as outlined by AOAC (2005). Phenolic compounds were extracted from each flour sample by mixing the extract with 10 mL of absolute methanol. The resulting mixture was agitated for 30 minutes at ambient temperature to ensure adequate extraction, after which it was centrifuged at 500 rpm for 15 minutes. The clear supernatant obtained was used for subsequent analysis.

For the assay, 1 mL of the supernatant from each sample was transferred into a test tube and reacted with 1 mL of Folin–Ciocalteu reagent. This was followed by the addition of 2 mL of 2% sodium carbonate ($Na_2CO_3$) solution to initiate color development. In parallel, a standard phenol solution was prepared at known concentrations, and 1 mL of each standard was treated in the same manner as the samples.
The reaction mixture was allowed to develop a characteristic blue coloration, the intensity of which was measured spectrophotometrically at a wavelength of 560 nm. A reagent blank was used to zero the instrument prior to absorbance readings. The phenolic content of the samples was calculated using the expression:

$$\text{Phenol (\%)} = \frac{100\times Au\times C\times Vt}{W \text{ x } As \text{ x } Va} \qquad (11)$$

where $W$ represents the weight of the sample, $A_u$ is the absorbance of the test sample, $A_s$ is the absorbance of the standard phenol solution, $C$ is the concentration of the standard phenol, $V_t$ denotes the total volume of the extract, and $V_a$ is the volume of the extract analyzed

**Tannin Determination**

annin content of the flour samples was determined using the Folin–Denis colorimetric procedure as described by AOAC (2005). Five grams of each flour sample were weighed into a volumetric flask and extracted with 50 mL of distilled water. The mixture was shaken for 30 min at room temperature and filtered to obtain a clear extract.

A standard tannic acid solution was prepared, while distilled water served as the reagent blank. Aliquots (2 mL) of the standard solution, reagent blank, and each sample extract were transferred into separate 50 mL volumetric flasks. To each flask, 35 mL of distilled water was added, followed by 1 mL of Folin–Denis reagent and 2.5 mL of saturated sodium carbonate ($Na_2CO_3$) solution. The mixtures were diluted to volume with distilled water, mixed thoroughly, and incubated for 90 min at room temperature for color development.

Absorbance was measured at 760 nm using a spectrophotometer, with the reagent blank used to zero the instrument. Tannin content was calculated using the equation:

$$\text{Tannin (\%)} = \frac{100 \times Au \times C \times Vt}{W \times As \times Va} \quad (12)$$

where $W$ is the weight of the sample, $A_u$ is the absorbance of the test sample, $A_s$ is the absorbance of the standard tannic acid solution, $C$ is the concentration of the standard tannin solution, $V_t$ is the total extract

**Alkaloid Determination**

Alkaloid content of the flour samples was quantified using the alkaline precipitation gravimetric procedure following Harborne (1973). Five grams of each flour sample were weighed and extracted with 100 mL of 10% acetic acid in ethanol. The mixture was thoroughly shaken and allowed to stand at room temperature for 4 hours, with intermittent agitation at 30-minute intervals to enhance extraction.

Following extraction, the mixture was filtered through Whatman No. 42 filter paper to obtain a clear filtrate. The resulting extract was concentrated by evaporation to approximately one-quarter of its initial volume. Concentrated ammonium hydroxide ($NH_3$) solution was then added dropwise until complete precipitation of the alkaloids occurred, ensuring excess alkali.

The alkaloid precipitate was collected by filtration using a pre-weighed Whatman No. 42 filter paper, washed with 1% ammonium hydroxide ($NH_4OH$) solution, dried in an oven at 60 °C, cooled in a desiccator, and reweighed. Alkaloid content was calculated using the equation:

$$\text{Alkaloid (\%)} = \frac{(W2-W1)\times 100}{\text{Weight of sample}} \quad (13)$$

where $W_1$ is the weight of the empty filter paper and $W_2$ is the combined weight of the filter paper and alkaloid precipitate.

**Determination of Flavonoids**

Flavonoid content of the flour samples was determined using an acid hydrolysis and gravimetric procedure following Harborne (1973). Five grams of each flour sample were refluxed with 10 mL of 2 M hydrochloric acid (HCl) for 40 minutes to liberate flavonoid compounds. The hydrolysate was allowed to cool to room temperature and subsequently filtered to obtain a clear filtrate.

Each filtrate was then mixed with 10 mL of ethyl acetate and transferred into a separating funnel for phase separation. The flavonoids were recovered from the ethyl acetate fraction and collected by filtration using a pre-weighed filter paper. The retained residue was dried in an oven, cooled in a desiccator, and reweighed.

Flavonoid content was expressed as a percentage of the original sample weight and calculated using the equation:

$$\text{Flavonoid (\%)} = \frac{(W2-W1)\times 100}{\text{Weight of sample}} \quad (14)$$

where $W_1$ represents the weight of the empty filter paper and $W_2$ is the combined weight of the filter pap

**Data Analysis**

All data obtained were analyzed using the Statistical Package for the Social Sciences (SPSS,2022). Analysis of variance (ANOVA) was employed to determine significant differences among sample means at the

5% level of significance ($p < 0.05$). Where significant differences were observed, Duncan's Multiple Range Test was applied for mean separation. Results are presented as mean ± standard deviation.

## Results and Discussion

The proximate composition of the ogiri samples is presented in Table 1. Moisture content of the samples ranged from 4.50 to 11.20%. Ogiri-igbo recorded the lowest moisture value, followed by dawadawa, while ogiri-okpei had the highest moisture content. The moisture levels observed in this study were considerably lower than the 52.4% reported for dawadawa by Olasupo and Princewill (2019). Similarly, Ejinkoye *et al.* (2018) reported a moisture content of 34.25% for ogiri produced from watermelon seeds. The comparatively lower moisture values obtained in the present study may be attributed to the expression of results on a dry matter basis, which reduces the apparent water content of the samples.

Ash content of the ogiri samples ranged between 3.30 and 4.70%. Ogiri-igbo had the highest ash content, followed by dawadawa, while ogiri-okpei recorded the lowest value. The relatively higher ash content of ogiri-igbo may be linked to the extended fermentation period of the seeds, which could enhance mineral concentration. The ash values obtained in this study are comparable to the 3.6% reported for dawadawa by Olasupo and Princewill (2019), indicating similar mineral composition.

Fat content varied markedly among the samples, with values of 7.80% for ogiri-okpei, 9.40% for dawadawa, and 28.40% for ogiri-igbo. The significantly higher fat content observed in ogiri-igbo is likely attributable to the inherent high oil content of castor oil beans used in its production. Comparable fat values have been reported in previous studies, including 18.57% for watermelon seed ogiri (Ejinkoye *et al*., 2018), 10.04% for ogiri-okpei Balogun and Oyeyiola (2011), and 28.33% for groundnut seed ogiri Chukwu *et al.* (2018).

Crude fibre content ranged from 2.20% to 2.80%, with ogiri-igbo containing the highest fibre level, followed by ogiri-okpei, while dawadawa had the lowest value. These differences were statistically significant ($p < 0.05$). The relatively higher fibre content of ogiri-igbo suggests an added nutritional advantage. The fibre values recorded in this study are consistent with earlier findings by Chukwu *et al.* (2018) and Ejinkonye *et al*. (2018), who reported fibre contents of 2.12% and 2.51% for groundnut seed and watermelon seed ogiri, respectively. Dietary fibre plays a crucial role in human nutrition by promoting efficient digestion, facilitating bowel movements, and reducing the risk of constipation Elleuch *et al*. (2011).

**Table 1.** Proximate composition of the Ogiri samples (%)

| Parameters | Okpei | Dawadawa | Ogiri Igbo |
|---|---|---|---|
| Moisture | $11.20^{a}$±0.28 | $11.00^{a}$±0.00 | $4.50^{b}$±0.14 |
| Ash | $3.30^{a}$±1.27 | $4.00^{a}$±0.00 | $4.70^{a}$±0.14 |
| Fat | $7.80^{b}$±0.00 | $9.40^{b}$±0.28 | $28.60^{a}$±0.28 |
| Fibre | $2.40^{b}$±0.00 | $2.20^{c}$±0.00 | $2.80^{a}$±0.00 |
| Protein | $9.45^{b}$±0.14 | $9.15^{b}$±0.00 | $12.98^{a}$±0.18 |
| Carbohydrate | $65.85^{a}$±1.13 | $64.25^{a}$±0.28 | $46.43^{b}$±0.11 |

Values are expressed as mean ± standard deviation of duplicate determinations. Means in the same row with different superscripts are significantly different ($p < 0.05$).

Protein content ranged from 9.15% in dawadawa to 12.98% in ogiri-igbo, comparable to the 13.77% reported for watermelon seed ogiri (Ejinkonye *et al*., 2018). The relatively higher protein content of ogiri-igbo may be attributed to the protein-rich nature of castor oil beans and the fermentation process, which is known to enhance protein availability in leguminous seeds. Carbohydrate content ranged from 43.46% in ogiri-igbo to 65.85% in ogiri-okpei, with no significant difference ($p > 0.05$) observed between ogiri-okpei and dawadawa. The lower carbohydrate level in ogiri-igbo likely reflects its higher ash, fat, fibre, and protein contents, as carbohydrate was determined by difference. Similar carbohydrate values (41.80%) for ogiri-okpei have been reported previously Balogun and Oyeyiola, (2011).

Table 2 presents the mineral composition of the ogiri samples. Significant differences ($p < 0.05$) were observed among samples for calcium content, which ranged from 155.34 mg/100 g in dawadawa to 172.67 mg/100 g in ogiri-igbo. Magnesium content ranged from 45.56 to 60.66 mg/100 g. Sodium, potassium, phosphorus, and iron contents ranged from 21.34–31.65 mg/100 g, 278.83–313.05 mg/100 g, 147.76–178.23 mg/100 g, and 3.04–4.87 mg/100 g, respectively. Ogiri-igbo contained significantly higher ($p < 0.05$) levels of potassium, phosphorus, and iron compared with ogiri-okpei and dawadawa, while dawadawa recorded the highest sodium content. Ogiri-okpei had the lowest sodium and potassium levels, whereas dawadawa had the lowest phosphorus and iron contents.

Overall, the results indicate that the ogiri samples are rich sources of essential minerals. The calcium values obtained in this study were higher than those previously reported for ogiri-okpei, ogiri-igbo, and dawadawa Olasupo and Princewill (2019). Variations in mineral composition may be attributed to differences in seed age and genetic characteristics of the raw materials used Balogun and Oyeyiola (2011).

Minerals play critical metabolic and physiological roles in the human body Enechi and Odonwodo (2019). Calcium is essential for bone formation, muscle contraction, blood clotting, nerve transmission, and enzymatic regulation, while magnesium functions as a cofactor for enzymes involved in carbohydrate metabolism Ugwuona (2014). Phosphorus contributes to bone and teeth development and supports nervous system function. Sodium and potassium are vital for fluid balance, muscle contraction, and nerve impulse transmission, with a sodium–potassium ratio below unity recommended for optimal physiological function Chaturvedi *et al.* (2014). Iron is a key component of haemoglobin responsible for oxygen

**Table 2.** Mineral profile of ogiri samples (mg/100 g)

| Parameters | Okpei | Dawadawa | Ogiri Igbo |
|---|---|---|---|
| Calcium | $165.05^{b}\pm1.00$ | $155.34^{c}\pm0.80$ | $172.67^{a}\pm0.00$ |
| Magnesium | $60.66^{a}\pm0.62$ | $45.56^{c}\pm0.00$ | $58.65^{b}\pm0.58$ |
| Sodium | $24.34^{c}\pm0.00$ | $31.65^{a}\pm0.00$ | $28.76^{b}\pm0.00$ |
| Potassium | $278.83^{b}\pm1.20$ | $285.49^{b}\pm0.71$ | $313.05^{a}\pm0.38$ |
| Phosphorus | $167.32^{b}\pm0.18$ | $149.76^{c}\pm0.00$ | $178.23^{a}\pm0.97$ |
| Iron | $3.67^{b}\pm0.16$ | $3.04^{c}\pm0.20$ | $4.87^{a}\pm0.21$ |

Values are expressed as mean ± standard deviation of duplicate determinations. Means in the same row with different superscripts are significantly different ($p < 0.05$).

transport, and inadequate intake may result in anaemia and impaired physiological function Chaturvedi *et al.* (2014).

Table 3 presents the vitamin composition of the ogiri samples. Vitamin C content ranged from 6.45 to 9.80 mg/100 g, vitamin E from 5.12 to 6.66 mg/100 g, and β-carotene from 3.86 to 6.22 µg/g. Vitamins $B_1$, $B_2$, and $B_3$ were present in the ranges of 0.08–0.16 mg/100 g, 0.30–0.45 mg/100 g, and 0.92–1.67 mg/100 g, respectively. Ogiri-igbo contained significantly higher ($p < 0.05$) levels of vitamin E, β-carotene, vitamin $B_1$, and vitamin $B_2$. Dawadawa recorded the highest vitamin C content, whereas ogiri-okpei had the highest vitamin $B_3$ level. Conversely, ogiri-igbo had the lowest vitamin C and $B_3$ contents, while dawadawa showed the lowest β-carotene, $B_1$, and $B_2$ levels.

Variations in vitamin composition among the samples may be attributed to differences in seed type, seed maturity, and fermentation duration Balogun and Oyeyiola (2011). Comparable values for vitamin $B_1$ (0.17 mg/100 g) and vitamin E (6.43 mg/100 g) in castor bean ogiri have been reported by Okwunodulu *et al.* (2020), although higher levels of vitamins $B_2$, $B_3$, and C were observed. Similarly, Peter *et al*. (2020) reported comparable vitamin $B_3$ levels but substantially higher B-vitamin and vitamin C contents in pumpkin seed ogiri, likely reflecting differences in raw material and genetic composition.

Vitamin E, a fat-soluble nutrient, primarily functions as an antioxidant by neutralising free radicals that may otherwise cause cellular damage Shahidi & Naczk (2004). It also plays a role in enhancing immune responses and may prevent thrombosis by inhibiting clot formation within coronary arteries (IM, 2000).

Vitamins are essential micronutrients required in small quantities to support metabolism, growth, and development. B-complex vitamins act as coenzymes in energy metabolism, while vitamin C functions as a potent antioxidant, promotes collagen synthesis, enhances iron absorption, and protects against oxidative stress Bursal *et al*. (2013); Akinsola *et al*. (2017). Deficiencies in these vitamins may result in metabolic, neurological, and connective tissue disorders (Enechi and Odonwodo, 2019).

Vitamin A is crucial for normal growth, reproduction, vision, and the maintenance of healthy epithelial tissues, including skin, hair, and nails. It also plays a role in cellular differentiation, energy regulation, and immune function by supporting white blood cell production. Inadequate intake of vitamin A can lead to keratomalacia (night blindness) and increased susceptibility to infections Ojimelukwe *et al.* (2005); Akinsola *et al*. (2017); Ikpeme-Emmanuel *et al.* (2012).

**Table 3.** Vitamin composition of the Ogiri samples (mg/100g)

| Parameters | Okpei | Dawadawa | Ogiri Igbo |
|---|---|---|---|
| Vitamin C | $8.77^{a}$±0.30 | $9.48^{a}$±0.53 | $6.45^{b}$±0.00 |
| Vitamin E | $5.12^{c}$±0.00 | $5.82^{b}$±0.13 | $6.66^{a}$±0.30 |
| B β-carotene | $4.73^{b}$±0.54 | $3.86^{b}$±0.17 | $6.22^{a}$±0.00 |
| Vitamin B1 | $0.13^{a}$±0.01 | $0.08^{b}$±0.01 | $0.16^{a}$± .01 |
| Vitamin B2 | $.40^{a}$± .02 | $.30^{b}$± .03 | $.45^{a}$ ± .01 |
| Vitamin B3 | $1.67^{a}$±0.00 | $1.19^{b}$±0.00 | $0.92^{c}$±0.01 |

Values are expressed as mean ± standard deviation of duplicate determinations. Means in the same row with different superscripts are significantly different ($p < 0.05$).

**Table 4.** Phytochemical composition of the Ogiri samples

| Parameters | Okpei | Dawadawa | Ogiri Igbo |
|---|---|---|---|
| Tannin | $3.39^{b}\pm0.24$ | $2.12^{c}\pm0.00$ | $4.23^{a}\pm0.00$ |
| Flavonoid | $2.67^{c}\pm0.00$ | $4.20^{a}\pm0.23$ | $3.15^{b}\pm0.00$ |
| Alkaloid | $0.51^{b}\pm0.06$ | $0.68^{a}\pm0.00$ | $0.23^{c}\pm0.00$ |
| Phenol | $0.11^{b}\pm0.00$ | $0.20^{a}\pm0.01$ | $0.13^{b}\pm0.01$ |
| Saponin | $2.10^{a}\pm0.08$ | $1.62^{b}\pm0.06$ | $1.34^{c}\pm0.00$ |

Values are expressed as mean ± standard deviation of duplicate determinations. Means in the same row with different superscripts are significantly different ($p < 0.05$).

Table 4 presents the phytochemical composition of the ogiri samples. Tannin content ranged from 2.12 to 4.23 mg/g, while flavonoid levels varied between 267 and 420 mg/g. Alkaloid, phenol, and saponin contents were within the ranges of 0.23–0.68 mg/g, 0.11–0.20 mg/g, and 1.34–2.10 mg/g, respectively. Ogiri-igbo recorded the highest tannin content, whereas dawadawa exhibited the highest concentrations of flavonoids, alkaloids, and phenols. Ogiri-okpei contained the highest saponin level. Conversely, dawadawa had the lowest tannin content, ogiri-okpei recorded the lowest flavonoid and phenol levels, and ogiri-igbo had the lowest alkaloid and saponin contents.

The phytochemical values obtained are consistent with previous reports. Peter et al. (2020) reported flavonoid, alkaloid, and phenol contents of 0.15, 0.28, and 0.18 mg/g, respectively, while Ejinkonye et al. (2020) documented tannin and saponin contents of 0.40 and 0.60 mg/g, respectively, in watermelon seed ogiri. Observed variations in phytochemical composition may be attributed to differences in seed type, processing methods, and fermentation conditions.

## Conclusion

This study assessed the nutritional and phytochemical characteristics of three Nigerian fermented condiments—ogiri-igbo, ogiri-okpei, and dawadawa—obtained from local markets. The results indicate that all samples are nutritionally rich, with ogiri-igbo exhibiting higher levels of most nutrients analyzed, followed by dawadawa, while ogiri-okpei generally recorded the lowest values. Phytochemical analysis revealed that ogiri-igbo contained the highest tannin content, dawadawa exhibited the highest levels of flavonoids, alkaloids, and phenols, and ogiri-okpei recorded the highest saponin content.

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