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COMPARATIVE EVALUATION OF THE NUTRIENT AND ANTI-NUTRIENT CONTENTS OF EDIBLE FLOURS CONSUMED IN NIGERIA

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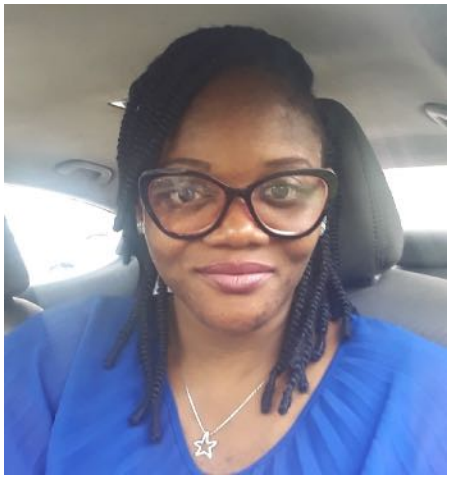

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ABSTRACT

Healthy foods/diets are essential for maintaining good health and preventing diseases. Recently, there has been increase in the incidence of non-communicable diseases (NCDs) worldwide and this has brought about a lot of research on the effect of various foods on the nutritional status of people. Also, this has led to the development of healthier alternatives to manage such health conditions. The aim of this study was to comparatively evaluate the nutrient and anti-nutrient content of four commonly-consumed flours. Processed wheat, oat and unripe plantain flours were purchased from the market while fonio was purchased as whole grain before it was cleaned and milled into fine flour. Samples were stored at room temperature in properly-labelled, air-tight sample glass bottles for analyses. Proximate composition was determined using standard methods of the Association of Analytical Chemists (AOAC). Micronutrients were estimated by Atomic Absorption Spectrophotometry, while anti-nutrients were determined using standard spectrophotometric methods. Inferential and descriptive statistics was used to analyze the data at a significance level of $P<0.05$. The proximate parameters varied significantly ($P<0.05$) among the flours. Carbohydrate varied from 76.38 $\pm$ 0.59% (oat flour) to 87.65 $\pm$ 0.36% (unripe plantain flour). Protein was least (8.75 $\pm$ 0.25%) in unripe plantain flour and highest (16.08 $\pm$ 0.26%) in wheat flour. Oat flour had significantly ($P<0.05$) higher content of *beta*-carotene (8.67 $\pm$ 0.03mcg/100g), while wheat flour had significantly ($P<0.05$) higher content of calcium (45.36 $\pm$ 0.29mg/100g). For the anti-nutrients, oat flour had the least content of hydrogen cyanide and oxalate, while wheat flour had the highest content of both. Generally, oat flour showed significantly ($p<0.05$) lower levels of the 6 anti-nutrients analyzed. From the results of this study, oat flour shows some food properties which may be beneficial for people who seek to reduce starch and caloric intake. Fonio flour could be a healthier alternative to most starchy meals, as a result of its good micronutrient content and preferred nutritional value. Consumption of these cereal flours as alternatives to some indigenous starchy meals should be encouraged for both adults and children.

Key words: Fonio, Oat, Wheat, Unripe plantain, Anti-nutrient, Comparative, Flours, NCDs, Nutrient

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INTRODUCTION

Background

Non-communicable diseases (NCDs) have been reported to be responsible for about 70% of deaths worldwide and these can be modified with nutritional interventions [1]. Influencing public nutrition is a key task in the global strategy for the prevention of chronic diseases. Due to nutrition transition as a result of globalization, there is need for an improved healthy diet. The formulation of single flours and sometimes composite flours for the prevention and management of diabetes and hypertension, from high-fiber cereal grains and low glycemic index foods such as wheat, sorghum, oats and unripe plantain, has been quite beneficial [2].

In the past decade, understanding the role of nutrition in health maintenance and disease prevention has advanced rapidly. The relationships between chronic diseases (such as diabetes and obesity) and poor diets have come under close scrutiny [3]. In Nigeria, NCDs are estimated to account for 24% of total deaths and the probability of dying between the ages of 30 and 70 years from the four main NCDs (cancer, diabetes, cardiovascular diseases, and chronic respiratory disease) is 20% [4]. In some African countries such as Namibia and Mauritius, NCDs cause over 50% of all reported adult deaths, implying that NCDs will soon be a leading cause of ill health, disability and premature death in the Region [5]. With increase in the incidence rates of diet-related NCDs, there has been a serious emphasis on the prevention/management of diseases using dietary interventions [3].

As a result of the increase in nutrition-related diseases, many strategies have been employed to combat the problem of malnutrition and also food insecurity. These strategies are either long-term or short-term and are usually designed to enhance the energy and nutrient density of cereal-based porridges, increase the production and consumption of micronutrient-dense foods, incorporate enhancers of micronutrient absorption, and reduce anti-nutrient (especially phytate) content of cereals [6].

In some countries like Nigeria, there has been a significant shift from the consumption of the regular starchy staples (such as cassava and yams) which are commonly processed into flour ‘meals’ and eaten with indigenous soups, to the consumption of meals prepared using other alternatives like guinea corn, millet, maize and even unripe plantain [6]. This is common particularly among adults who seek to modify their diets to reduce their carbohydrate and fat intakes to reduce their risk of NCDs.

Over the years, cereals have also been processed into flours and then prepared as meals for soups too. Cereals are rich in dietary fiber and micronutrients such as folate, niacin, iron and zinc [7]. Cereals are naturally low in saturated fats but have a good content of healthy polyunsaturated fats, while their high fiber content also helps in weight-loss as fiber increases gastrointestinal motility and takes longer to digest, thereby giving a feeling of fullness, which discourages overeating [7].

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This study, therefore, comparatively evaluates the nutrient and anti-nutrient content of four flours produced from wheat, unripe plantain, oats and fonio (commonly called 'acha'), respectively.

MATERIALS AND METHODS

Equipment

Weighing balance (Ohaus U.S) Jenway, UV visible spectrophotometer (Keison UK), Water bath. HH.1042-0 (Germany), Desiccator (Fisher Scientific U.S.A), Soxhlet apparatus (B.BRAN-England), Digestion unit (Kjeldahl, VELP Scientifica-Malaysia), reflux condenser, muffle furnace, and thermostatic oven.

Chemicals

All chemicals used were of analytical grade and produced by ELITECH Clinical systems France, and included: methanol, ethanol, n-hexane, potassium hydroxide, diethyl ether, hydrochloric acid, sodium hydroxide, boric acid, selenium crystals, potassium sulphate and sulphuric acid.

Methods

Wheat, unripe plantain and oat flour were purchased from the Spar shopping mall in Calabar, Nigeria. Fonio grains (the brown species) were purchased from Bogobiri market also in Calabar. The fonio grains were cleaned by removing the stones and dirt and other extraneous materials. The grains were then milled using a disc attrition mill (Binatone electric miller, China) to obtain flour followed by sieving using 300 m aperture before the samples were stored in airtight, well-labeled sample bottles pending analyses. The laboratory analyses were carried out at the agricultural laboratory service unit of the University of Calabar using standard analytical procedures.

Proximate analysis of Samples

Determination of Moisture content

Moisture content was determined by the gravimetric method as described by AOAC [8]. About five grams (5g) of fresh sample was weighed into a clean moisture dish, the sample was dried in the oven at 105^{o}C for 3 hours. It was then cooled and re-weighed. The weight was recorded, while the sample was retained in the oven, and further drying, cooling and weighing were continued until a constant weight was obtained. The weight of the lost moisture was determined and expressed in percentage as shown below:

$$\% \text{ Moisture} = W_2\text{-}W_3/W_2\text{-}W_1 \quad x \quad 100/1$$

Where:
W_1 - weight of an empty can
W_2= weight of can + sample before drying
W_3 = weight of can + sample after drying to a constant weight

Determination of Total ash

This was done using the incineration gravimetric method of AOAC, 2005 [9].

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About five (5)grams of sample was put in a previously weighed porcelain crucible. The sample in the crucible was then put in a muffle furnace, set at 550℃ and allowed to burn for 2 hours until light grey ash was obtained. The sample in the crucible was carefully removed from the furnace and cooled in a desiccator and weighed, as the weight of ash was obtained and calculated in percentage as shown:

$\%\ ash = W_3\text{-}W_2/W \quad x \quad 100/1$

Where:
W_1 = weight of sample
W_2 = weight of empty crucible +sample
W_3 = weight of crucible + crucible content after ashing

Determination of fat content
The fat content of the samples was determined by the continuous solvent extraction method using soxhlet apparatus as described by AOAC [6].

Soxhlet extractor with a reflux condenser and a small round bottom flask (250ml) was prepared. Five grams (5g) of each sample was wrapped in a porous paper (Whatman No 1 Filter paper) and the wrapped samples were put in a soxhlet reflux flask containing 200ml of petroleum ether. The upper end of the reflux flask was connected to a condenser. The solvent contained in the flask was heated through electrothermal heater; it vaporized and condensed into the reflux flask. Gradually, the wrapped sample became completely immersed in the solvent and remained in contact with it until the flask filled up and siphoned over, thus carrying oil extract from the sample down to the boiling flask. This process was allowed on repeatedly for 4 hours before the defatted sample was removed. The solvent was recovered and the extracting flask with its oil content dried in the oven at 60^{o}C for 3 minutes to remove any residual solvent. After cooling in a desiccator, the flask was re-weighed. The weight of fat was determined and expressed as a percentage of the sample weight as shown:

$\%fat = W_2\text{-}W_1/\text{weight of sample} \quad x \quad 100/1$

Where:
W_1= weight of empty extraction flask
W_2 = weight of flask + oil extract

Determination of Protein
This was determined by Kjeldahl digestion method described by AOAC [8].
The total nitrogen was determined and multiplied with the factor 6.25 to obtain the protein content.

Exactly 0.5g of each sample was accurately weighed into a Kjedhal digesting flask and mixed with 10ml of concentrated sulphuric acid (H_2SO_4) in a Kjeldahl digestion flask. A tablet of selenium catalyst (containing 1g Na_2SO_4 and Eq of 0.05g selenium was added to it and the mixture was digested (heated) under a fume cupboard until a clear solution

was obtained in a clean flask. The acid and reagents were digested (without sample) to form the blank control.

All the digests were carefully transferred to a 100ml volumetric flask and made up to mark in the flask. A 100ml portion of each digest was mixed with an equal volume of 45% NaOH solution in Kjeldahl distilling unit. The mixture was distilled and the distillate collected into 10ml of 4% boric acid solution containing three drops of mixed indicator (bromocresol green and methyl red) with the release of ammonia gas. Fifty (50) ml of the distillate was obtained and titrated against 0.02N H_2SO_4 solution. The end-point was from the initial green color to a deep redpoint. The nitrogen content was calculated as:

$$\%N2 = \{100/W \times N \times 14/100 \times Vf/Va\} T$$

Where:
W= weight of sample analyzed
N= Normality of H_2SO_4 titrant
Vf = Total volume of filtrate
Va = volume of digest distilled
T= titre value - Blank
% Protein = % N x 6.25

Determination of carbohydrates
The carbohydrate (sugar) content was determined by the method of Lane and Eynon [10], where the samples are dissolved in water to undergo hydrolysis with enzymes to release the sugars.

The test sample is dispersed in water and hydrolyzes with enzymes to release the sugars. The resulting sugars are then determined by titration with Fehling solution to produce a brick-red precipitate. The sugar content was calculated as follows:

$$\text{Carbohydrate (\%)} = \%\ \text{Total sugars} \times 0.9 \times W_2 / W_3 \times 1 / W_1$$

Where:
W_1 = weight of sample
W_2 = weight of carbohydrate extracted
W_3 = weight of carbohydrate taken for hydrolysis

Determination of Crude fiber
Crude fiber contents were determined by the method of AOAC [8].
Complex carbohydrates such as fiber can resist mild concentrations of acids and bases, while the other organic matters present in food samples easily undergo digestion with mild concentrations of acids and bases. The crude fiber was calculated as the loss in weight on ashing.
W_1=Weight of the original sample
W_2=Weight of dried sample
W_3=Weight of incinerated sample

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$$\% \text{ crude fibre} = \frac{W_2 - W_3}{W_1} \times 100$$

Determination of Minerals

The mineral elements were determined using appropriate methods as described by Pearson and Cox [11] and modified by Zhou and Yu [12], James [13] and AOAC [8]. The samples were subjected to acid digestion using concentrated perchloric acid prior to the analysis.

Acid digestion of samples: About 1 mg of each powdered sample was put in a digesting tube and 12ml of $HN0_3$ was added to the samples, the mixtures were kept overnight at room temperature. Thereafter, 4 ml of perchloric acid ($HCl0_4$) was added to the mixture and kept in the fume block for digestion. The temperature was increased gradually from 50^{o}C to 250^{o}C. Digestion lasted 85 minutes as indicated by white fumes. The mixture was allowed to cool after which the contents were transferred to a 100ml volume flask; the volume was made up to 100ml with distilled water. The digested solutions were transferred to clean bottles and labeled appropriately to be used for the determination of Fe, Zn, Mg and Ca by atomic absorption spectrophotometry.

Determination of vitamins

Vitamins B_1 and B_2 were determined by the spectrophotometric method described by Liu *et al*. [14], while beta carotene was determined by the HPLC methods described by Brubacher *et al*. [15].

Vitamin C content was determined by titration method using acetic acid for extraction. A blue dye 2, 6-dichlorophenol indophenol is de-colorized by ascorbic acid into its reduced state. Under standard conditions with a known weight of dye, a constant quantity of ascorbic acid is required to discharge the blue color to pink color.

The formula below was used to calculate the vitamin C concentration:

$$\frac{T - B \times 2}{TS - B}$$

Where:
B = Volume of acetic acid + water
TS = Titre value i.e. Volume of standard ascorbic acid
T = Acetic acid used for extraction dye

Determination of Anti-nutrients

Determination of Phytate:

Phytate was determined using a simple and rapid colorimetric method by Eskin and Latta [16]. Five grams of milled flour samples were weighed into a 25ml conical flask and 2.4M HCl was added, extraction was carried out for one hour at room temperature of 25^{0}C and centrifuged, the supernatant was decanted after which 1ml of 2.4% extract supernatant was diluted to 25ml with distilled water. Ten milliliter of the diluted sample was passed through the AG1-x8 chloride anion exchange column (0.5g). The phytate

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was eluted with 0.7M NaCl, 3ml of 0.7M eluent fraction was pipetted into 15ml conical test tubes, mixed on a vortex mixer for 5 seconds and centrifuged for 10 minutes. The absorbance of the supernatant was read at 500mm using water to zero the spectrophotometer.

Preparation of standard curve

Series of sodium phytate dilutions were made from 5 – 40mcg phytate in distilled water, 3ml of the solution was pipetted into 115ml, then 1ml of Wade reagent was added within 30mins of elution, it was mixed on a vortex mixer for 5secs and centrifuged for 10mins. The absorbance of the supernatant was read at 500nm using water to zero the spectrophotometer while the phytate content was estimated from the standard curve.

Oxalate determination [17]: Oxalic acid was extracted from the sample and precipitated as calcium salt. The oxalate was dissolved in sulphuric acid and its concentration was determined by titration with K_2MnO_4 for a faint pink endpoint. The flour samples (0.1g) were extracted thrice by warming it at 40 – 50^oC with constant stirring using a magnetic stirrer for 1 hour with 20ml of 0.3NHCl, the extract was diluted to 100ml with distilled water, then 1ml of 5N NH_4OH was used to alkanize 5ml of the extract, which was then made acidic with glacial acetic acid; 2 drops of phenolphthalein were used as an indicator. Thereafter, 1ml of 5% calcium chloride was added and the mixture was allowed to stand for 3 hours, then centrifuged (IEC centra GP8, England) at 1400 rpm for 15mins, then the supernatant was discarded and the precipitate was washed thrice with hot water and centrifuging repeated. The content of each testtube was titrated with freshly prepared 0.01N potassium per manganite solution, then titration was carried out at room temperature until the color of the solution turned pink. The solution was allowed to stand until it became colorless, then warmed at 70^oC and titrated again until a pink color persisted for 30 seconds.

Calculations for oxalate: $W \times \frac{100}{5}$

Where W is the mass of oxalate in 100ml

Determination of saponin: The method used was described by AOAC [8]. About 5.0g of dry sample was weighed in an extraction thimble and transferred into the soxhlet extractor chamber fitted with a condenser and a round bottom flask. Some quantity of acetone (enough to cause reflux) was poured into the flask, the sample was exhaustively extracted of its lipid and interfering pigments for 3 hours by heating the flask on a hot plate and the solvent distilled off (first extraction). For the second extraction, a pre-weighed round bottom flask is fitted onto the soxhlet apparatus (bearing the sample containing thimble) and the methanol poured into the flask (methanol enough to cause reflux), the saponin is then exhaustively extracted for 3 hours by heating the flask on a hot plate after which the difference between the final and initial weights of the flasks represents the weight of saponin extracted.

$$\% \text{ saponin} = \frac{\text{weight of saponin}}{\text{weight of sample}} \times \frac{100}{1}$$

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Determination of Tannins: The Folin-Denis spectrophotometric method was used. The method was described by Pearson & Cox [11]. About 1.0g of the sample was dispersed in 10ml distilled water and agitate. This was left to stand for 30mins at room temperature being shaken every 5mins at the end of the 30mins, it was centrifuged and 2-5ml of the supernatant was dispersed into a 50ml volumetric flask. Similarly, 3.5ml of standard tannic acid solution was dispersed into a separate 50ml flask. A 1.0ml Folin-Denis reagent was measured into each flask, followed by 2.5ml of sodium bicarbonate to mark in a flask (50ml) and incubated for 90mins at room temperature, the absorbance was measured at 250nm in a Genway model 6000 electronic spectrophotometer readings were taken with the reagent blank at zero. The tannin content was given as follows:

$$\% \text{ Tannin} = \frac{100}{W} \times \frac{An}{As} \times C \times \frac{vf}{va}$$

Where,
An = absorbance of test sample
As = absorbance of standard solution
C = concentration of standard solution
W = weight of sample used
vf = total volume of extract
va = volume of extract analyzed

Determination of Flavonoid: Flavonoid in the test samples was determined by the acid hydrolysis gravimetric method of Harbone and William [18]. Five grams of the sample was mixed with diluted 1ml HCl solution to form a ratio 1:10w/v, and the mixture was boiled for 30mins. The boiled extract was allowed to cool and filtered through a Whatman no. 42 filter paper. A portion of the extract 20ml was measured with a beaker and treated with ethyl acetate to precipitate the flavonoid. The precipitate was measured by filtering with a weighed filter paper and then determined by weight difference. It was given by:

$$\% \text{ flavonoid} = \frac{w_2 - w_1}{w_1} \times \frac{100}{1}$$

Where:
w_1 = weight of the sample
w_2 = weight of the precipitate

Cyanide determination: The hydrogen cyanide content was determined using the method described by Onwuka [19]. Five grams of the ground sample was dissolved in 50ml distilled water in a conical flask and allowed to stay overnight and filtered thereafter. Two milliliters of the filtrate were poured into a conical flask and 4ml alkaline picrate solution was added and incubated in a water bath for 5mins for color development (reddish-brown) and absorbance was taken at 490nm. Also, a blank was prepared using 2ml distilled water. The cyanide concentration was extrapolated using a standard curve.

$$\% \text{ hydrogen cyanide} = \frac{100}{W} \times \frac{An}{As} \times C \times \frac{vf}{va} \times \frac{1}{10^6}$$

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Where,
An = absorbance of test sample
As = absorbance of standard solution
C = concentration of standard solution
W = weight of sample used
vf = total volume of extract
va = volume of extract analyzed

Statistical analysis
Samples were analyzed in triplicates and data expressed as mean ± Standard error. The data were analyzed by one-way ANOVA with *post hoc* corrected two-tailed t-tests using the IBM SPSS statistic software version 22 (SPSS: Statistical Package for Social Sciences). Significant differences at $P < 0.05$ were considered significant.

RESULTS AND DISCUSSION

Proximate composition of flours
The results of the proximate analysis are shown in Table 1. Protein content was significantly ($p<0.05$) higher in wheat flour compared to the other three flours, while unripe plantain flour had the least protein content and also the least fat content. Wheat flour also had the highest content of crude fiber while oat flour had the least. Carbohydrate content differed significantly ($p<0.05$) between the four flour samples with oat flour having the least and unripe plantain flour having the highest value.

Results from this study show that these flours are a good source of nutritional value, though some of them contain significantly higher amounts of certain nutrients than others. Out of the four flours in this study, oat flour had the lowest carbohydrate content. Generally, the carbohydrate content of these flours was significantly lower than the 84% reported for garri by Sanni [20] making these flours better alternatives for people who need to reduce their caloric intake. Consequently, cereal-based flours with lower carbohydrate content and higher fiber and protein content, are a better alternative to cassava (garri) for diabetic patients. This is because in management of diabetes, lower glycemic index foods are preferable in order to keep patients' blood glucose levels from rising far above normal [21]. Carbohydrate metabolism is important in the development of type 2 diabetes and obesity [22]. Type 2 diabetes occurs either as a result of insufficient production of insulin or insulin resistance; insulin is the hormone produced by the pancreas, which regulates blood glucose levels by promoting the absorption of glucose from the blood into the liver, fat and skeletal muscle cells [22]. Cassava flour usually in form of ''garri" (the fried form of blended and processed cassava) is the most commonly consumed meal (starchy swallow used for soups) in Nigeria but its frequent consumption is usually discouraged in certain health conditions due to its high carbohydrate content of about 86% [23] and high glycemic index of 82 [24]. The glycemic index is a scale that ranks a carbohydrate-containing food by how much it raises blood sugar levels after it is consumed [25]. Research has shown that foods with Glycemic Index (GI) of 70 and above are classified as high GI foods and such foods should be consumed minimally [25].

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The higher content of protein and fiber of these flours also makes them recommendable in the treatment and management of obesity and diabetes. Increased intake of insoluble dietary fiber has been shown to increase gastrointestinal motility, thereby reducing the transit time of food and causing less absorption of nutrients. On the other hand, increased intake of dietary fiber reduces the risk of colon cancer [26]. In addition, evidence from epidemiological studies suggests that high fiber consumption contributes to a reduction in the incidence of certain diseases like diabetes, high blood pressure, and various digestive disorders [27]. In this study, oat, wheat and fonio flours had significant fiber content, which researchers have found to be beneficial in moderating the effects of hypertension, lowering LDL cholesterol, regulating blood glucose/insulin and controlling weight [27]. Despite the relatively lower fiber content of unripe plantain flour, its high mineral content (as seen in the ash) and low-fat content can be explored by combining it with any of the cereal flours to produce a composite flour of better nutritional value.

Vitamin and Mineral contents of the flours

Most of the flours varied significantly ($P<0.05$) in their content of the micronutrients. The micronutrient results are reported in Table 2. There was no significant ($P>0.05$) difference in the iron and zinc contents of unripe plantain flour and oat flour. Oat flour had the highest content of beta carotene but the least content of vitamin C, calcium and magnesium. Wheat flour had significantly ($P<0.05$) higher content of calcium and vitamin C.

All the four flours showed significant content of both minerals and vitamins but some had higher concentrations than others. Fonio flour had a relatively high content of vitamin C and the highest content of folic acid among the studied flours. Its consumption should be encouraged for pregnant mothers whose dietary requirements of micronutrients (such as the B complex vitamins and iron) are increased during the period of gestation. Among the four flours, fonio flour also had significantly higher content of riboflavin (vitamin B_2). Riboflavin plays an important role in the metabolism of carbohydrates and fats; it functions in converting those food molecules to adenosine triphosphate (ATP) which is the energy currency of the cell [22]. The concentration of beta carotene of oat flour reported here is similar to that of Singh *et al*. [28].

Anti-nutrient content of the flours

Oat flour contained significantly ($P<0.05$) lower amounts of all the anti-nutrients analyzed except for oxalate. Wheat and unripe plantain flour had higher contents of most of the anti-nutrients except for flavonoid and saponin which were highest in fonio flour. The results of this study show that the flours contain tolerable (safe) levels of the anti-nutrients studied. Oat flour particularly had the lowest levels of the anti-nutrients and this may be as a result of the processing that oats undergo in order to produce flour [29]. Wheat flour had the highest concentration of HCN among the four flours followed by unripe plantain flour. The HCN content of unripe plantain flour in this study is comparable with that reported for sweet cassava (*Manihot plamata*) flour by Obueh and Kolawole [30], but lower than that reported for the bitter cassava (*Manihot utillisima*) because the bitter cassava variety has higher HCN concentration. Proper processing

techniques is what reduces the HCN content of cassava as is done during the production of the commonly consumed 'garri' (air-fried form of the blended sweet variety cassava). Research has shown that high HCN content of foods can affect the bioavailability of iodine and also interfere with the functioning of certain organs and enzymes [31]. Goiter, cretinism, tropical ataxic neuropathy or spastic paralysis are some of the diseases attributed to toxic effects of HCN in the diet [32]. Consequently, it is necessary to further process foods containing HCN by boiling or frying to drastically reduce the HCN levels [33]. All the flours studied here usually undergo heat treatment especially boiling before consumed as meals. The results for oxalate in this study were lower when compared with that reported by Obueh and Kolawole [30] for garri, showing that these flours are healthier as oxalate has been shown to bind calcium [34].

CONCLUSION

The results of this study show that aside from the regularly consumed flours, less starchy fonio flour (which is not popularly known), showed significant content of micronutrients and its anti-nutrient content was minimal, hence it should also be explored as a healthy alternative to starchy or excessively processed flours. Additionally, based on these findings, oat flour should be more preferable for management/prevention of obesity since it had the lowest carbohydrate content, higher protein and significant fiber content.

Authors' contributions

Onyenweaku, E. O., principal investigator, conceptualized and designed the study, conducted the study and prepared the draft of the manuscript; Ebai, P. A. co-supervised the research and reviewed the manuscript; Okonkwo, C. O. and Fila, W. A. carried out data analysis and interpretation and gave useful input in the study. All the authors contributed financially to the success of the research.

Competing Interest Statement

The authors declare no conflict of interest.

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Table 1: Proximate content of flours

	Proximate content in g/100g					
Sample	**Protein**	**Fat**	**Crude fibre**	**Ash**	**Carbohydrate**	**Moisture**
Wheat flour	16.08 ± 0.26^{d}	1.83 ± 0.29^{b}	1.91 ± 0.14^{b}	1.77 ± 0.25^{a}	78.40 ± 0.66^{b}	10.01 ± 0.08^{a}
Unripe Plantain flour	8.75 ± 0.25^{a}	0.67 ± 0.29^{a}	0.83 ± 0.29^{a}	2.10 ± 0.36^{a}	87.65 ± 0.36^{d}	12.73 ± 0.25^{c}
Oat flour	14.77 ± 0.25^{c}	6.25 ± 0.25^{d}	1.10 ± 0.36^{a}	1.50 ± 0.50^{a}	76.38 ± 0.59^{a}	10.78 ± 0.31^{b}
Fonio flour	12.67 ± 0.38^{b}	2.75 ± 0.25^{c}	1.15 ± 0.53^{a}	1.76 ± 0.38^{a}	82.07 ± 0.28^{c}	12.52± 1.23^{c}

Values were presented as mean ± SD where n = 3. Significance accepted at $p < 0.05$. Values with homogeneous superscripts are statistically similar at $p < 0.05$

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Table 2: Vitamin & Mineral content of flours

Sample	Vit C mg/100g	Vit B_2 mcg/100g	Vit B_1 mg/100g	β-Carotene µg/100g	Fe mg/100g	Zn mg/100g	Mg mg/100g	Ca mg/100g
Wheat flour	9.04 ± 0.21^{c}	29.13 ± 0.39^{b}	0.065 ± 0.01^{c}	4.84 ± 0.03^{c}	3.67 ± 0.03^{b}	1.77 ± 0.02^{c}	32.28 ± 0.62^{c}	45.36 ± 0.29^{d}
Unripe plantain flour	7.83 ± 0.20^{b}	21.61 ± 0.39^{a}	0.036 ± 0.01^{a}	2.88 ± 0.02^{b}	2.87 ± 0.04^{a}	1.55 ± 0.02^{b}	29.15 ± 0.62^{b}	43.83 ± 0.28^{c}
Oat flour	3.73 ± 0.21^{a}	28.83 ± 0.39^{b}	0.063 ± 0.01^{c}	8.67 ± 0.03^{d}	2.75 ± 0.03^{a}	1.48 ± 0.01^{b}	26.08 ± 0.63^{a}	30.26 ± 0.28^{a}
Fonio flour	8.44 ± 0.20^{c}	34.88 ± 0.39^{c}	0.044 ± 0.02^{b}	1.78 ± 0.03^{a}	3.79 ± 0.04^{c}	1.35 ± 0.02^{a}	27.71 ± 0.62^{b}	36.88 ± 0.29^{b}

Values with homogeneous superscript in a column, are statistically similar at $p < 0.05$; Values were presented as mean ± SD

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Table 3: Anti-nutrient content of flours

Flours	Anti-nutrient content in mg/100g					
	HCN	**Tannin**	**Flavonoid**	**Oxalate**	**Saponin**	**Phytate**
Wheat flour	8.69 ± 0.05^{c}	0.74 ± 0.02^{b}	0.37 ± 0.01^{a}	1.29 ± 0.03^{b}	0.73 ± 0.02^{a}	1.11 ± 0.02^{b}
Unripe Plantain flour	7.60 ± 0.05^{b}	0.64 ± 0.01^{b}	0.84 ± 0.02^{b}	1.19 ± 0.02^{a}	0.84 ± 0.01^{b}	1.44 ± 0.02^{d}
Oat flour	4.36± 0.06^{a}	0.50 ± 0.02^{a}	0.37 ± 0.01^{a}	0.67 ± 0.01^{c}	0.71 ± 0.02^{a}	0.86 ± 0.01^{a}
Fonio flour	7.67 ± 0.05^{b}	0.69 ± 0.02^{b}	0.89 ± 0.02^{b}	0.85 ± 0.01^{d}	0.88 ± 0.01^{b}	1.26 ± 0.01^{c}

Values with similar superscripts in the same column are similar at $p < 0.05$; Values were presented as mean ± SD

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