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Proximate Composition, Levels of Some Essential Mineral Elements and Anti-Nutritional Components of Some Yam Species Found in Minna, Niger State

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Abstract

Samples of *Dioscorea dumenturom*, *Dioscorea rotundata* and *Dioscorea cayenensis* were investigated for their proximate composition, anti-nutritional and mineral contents using standard analytical methods. These varieties of *Dioscorea* analysed showed a significant difference ($P \leq 0.05$) amongst them. However, from the results, it was observed that *Dioscorea rotundata* had the highest ash (8.05±0.05 %) and crude fibre content (13.11±0.10 %) which indicates that it contains more mineral stuffing and is best for softening of stool. *Dioscorea cayenensis* had the highest fat content (16.31±0.30 %), indicating that it is a better source of calories than other yam species analysed. *Dioscorea dumenturom* had the lowest moisture content (3.51±0.01 %) as well as the highest crude protein (12.29±0.01 %) and carbohydrates (69.04±0.10 %) than other yam species analysed, indicating its longer shelf-life, high bodybuilding capacity and better source of energy than other yam species analysed. The anti-nutritional constituent of alkaloid and tannin were lowest in *Dioscorea cayenensis* while *Dioscorea rotundata* had the least cyanide, phytate and oxalate content. This implies that these particular yams are safer for consumption. The elemental analysis in mg/100g indicated that the yam species contained appreciable levels of essential minerals, with *Dioscorea dumenturom* having the highest sodium, calcium, iron, potassium, phosphorous and magnesium concentration of 32.05±0.07 mg/100g, 190.57±0.01 mg/100g, 5.98±0.03 mg/100g, 80.12±0.17 mg/100g, 237.10±0.48 mg/100g and 100.22±0.03 mg/100g respectively. All these mineral concentrations exist within the permissible limit of WHO and hence indicate that the yam species can serve as a good source of minerals.

Keywords: proximate composition; anti-nutritional; mineral content; *Dioscorea dumenturom*; *Dioscorea rotundata*; *Dioscorea cayenensis*.

INTRODUCTION

Yam is a staple cuisine in many tropical and subtropical areas throughout the world. Nigeria in particular has the world's largest annual output and consumption per capita (Ukom *et al*., 2014). There are over 600 *Dioscorea* species, with more than 10 species farmed for food and 6 species used in pharmaceuticals (Okigbo *et al*., 2015). However, white yam (*Dioscorea rotundata*), water yam (*Dioscorea alata),* aerial yam (*Dioscorea bulbifera),* yellow yam (*Dioscorea cayenensis),* trifoliate yam (*Dioscorea dumentorum)* and Chinese yam (*Dioscorea esculenta)* are the six most economically important species.

Yam cultivation not only helps rural farmers survive but also provides a significant number of calories, essential micro-nutrients and phytochemical compounds such as iron, zinc, ascorbic acid and flavonoids (Ukom *et al*., 2014). In many regions of west Africa particularly Nigeria, yam is processed in a variety of culinary forms, such as pounded yam, fried yam, roasted yam, boiled yam, yam balls, mashed yam, yam chips and flakes (Orkwor *et al*., 1997), which are typically served with protein-rich soups and sources. The species has historically influenced how yams are processed.

West Africa is the world's most important yam-producing region, with Nigeria as the leading producer, accounting for more than half of global production (Modu *et al*., 2015). Despite these facts regarding yam, it continues to be overlooked in West African national food policy programs. This has resulted in limited *Dioscorea* species research and development on the continent (Sanoussi *et al*., 2016).

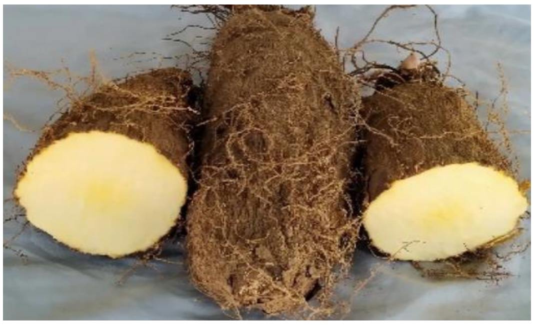
This study compares the proximate composition, mineral content and anti-nutritional constituents of several yam varieties which includes *Dioscorea rotundata*, *Dioscorea dumenturom* and *Dioscorea cayenensis* obtained from Minna, Niger State.

MATERIALS AND METHOD

Sample Collection

Matured accessions of the three cultivated yam species were harvested randomly from rural farms in the Chanchaga, Mekunkele and Gunu areas of Niger State. The samples include cultivars of yellow yam (*Dioscorea cayenensis*), a variety of white yams (*Dioscorea rotundata*) and trifoliate yam (*Dioscorea dumentorum*). The samples were cleaned by brushing off soil particles and transported at tropical ambient temperature to the laboratory for analysis.

Dioscorea dumenturom



Dioscorea rotundata

Dioscorea cayenensis

Figure 1. The images of the studied plants.

Sample Pre-Treatment

The yam samples were washed thoroughly with water, peeled and cut using a knife. These yam species were ground separately using a laboratory mortar and pestle and then sieved using a 250 µm mesh size sieve. The three samples were stored in airtight properly labeled polythene bags and kept in a cool and dry place before analysis.

Determination of Proximate Composition

The proximate analysis of samples for moisture, crude fat, crude fiber and ash was determined using the method described by AOAC (2006).

The protein content was determined using the micro Kjeldahl method (N x 6.25) and the carbohydrate was calculated by difference.

Mineral Analysis

The digestion of samples for mineral analysis was carried out according to the method described by AOAC (2006). A 250 cm^3 beaker was filled with 1.00 g of the pulverized sample. The beaker was filled with an acid mixture (15.00 cm^3 concentrated HNO_3 and 5.00 cm^3 concentrated perchloric acid). The mixture was agitated thoroughly to ensure adequate mixing, then heated on a hot plate until a clear digest appear. The digest was allowed to cool and filtered quantitatively into a 100 cm^3 volumetric flask. The filtrate was made up to the 100 cm^3 mark, transferred to a plastic bottle and aspirated into the machine for trace metal analysis.

Determination of Anti-Nutrients

Determination of Total Alkaloids

This was accomplished utilizing the method described by AOAC (2005). 0.50 g of the sample was dissolved in 5.00 cm^3 of 96% ethanol and 5.00 cm^3 of 20% H_2SO_4 (1:1) and the resulting solution was filtered. 1.00 cm^3 of the filtrate was added to 5.00 cm^3 of 60% H_2SO_4 and allowed to stand for 5 minutes. After that, 5.00cm^3 of 0.5% formaldehyde was added and allowed to stand for 3 hours. The reading was taken at an absorbance length of 565 nm using an ultra-violet (UV) spectrophotometer. The extinction coefficient of vincristine (E296, ethanol {ETOH} = 15136 $M^{-1}cm^{-1}$) was chosen as a reference alkaloid (AOAC, 2005).

Determination of Saponins

This was accomplished utilizing the method described by Krishnaiah *et al*. (2009). 0.50 g of the sample was boiled for 4 hours in a 20.00 cm^3 of 1 mol/dm^{-3} HCl solution. After cooling, 50.00 cm^3 petroleum ether was added to the filtrate for the ether layer, which was then evaporated to dryness. 5.00 cm^3 of acetone ethanol was added to the residue and 0.40 cm^3 of each was divided among three test tubes. They were filled with 6.00 cm^3 of ferrous sulfate reagent followed by 2.00 cm^3 of concentrated H_2SO_4. The absorbance was measured at 490 nm after 10 minutes of complete mixing. The calibration curve was established using standard saponin.

Determination of Tannin

Jaffe (2003) described that 1.00 g of each sample A and B were dissolved in 10.00 cm^3 distilled water and agitated, left to stand for 30 minutes at room temperature. The extract was obtained from each sample after centrifugation. In a 50 cm^3 volumetric flask, 2.50 cm^3 of the supernatant was dispersed. Similarly, in a separate 50.00 cm^3 flask, 2.50 cm^3 of the standard tannic acid solution was dispersed. In each flask, a 1.00 cm^3 folin Dennis reagent was added, followed by 2.50 cm^3 of saturated Na_2CO_3 solution. The mixture was then diluted to 50.00 cm^3 and incubated for 90 minutes at room temperature. The sample's absorbance was measured at 250 nm with the reagent blank at zero. The % tannin was calculated using the formula:

$$Tannin\ (mg/g) = \frac{(A_s - A_b) - intercept}{Slope \times d \times W} \times 10 \qquad \text{(Eqt. 1)}$$

Where A_s is the sample absorbance, A_b is the blank absorbance, d is the density of the solution (0.791g/ml), W is the weight of the sample in grams and 10 is the aliquot.

Determination of Phytic Acids

Markkar *et al*. (1993) described the process for determining phytic acid. In a 250 cm^3 conical flask, 2.00 g of each sample (A and B) were weighed. Each sample was soaked in 100.00 cm^3 of 2% concentrated HCl acid for 3 hours in the conical flask before being filtered through a double layer of hardened filter papers. 50.00 cm^3 of each filtrate was placed in a 250 cm^3 beaker and 100 cm^3 of distilled water was added to each to give proper acidity. 10.00 cm^3 of 0.3% ammonium thiocyanate solution was added to each solution as an indicator. Each solution was titrated with standard iron chloride solution, which contains 0.00195 g iron per cm^3. The endpoint color was slightly brownish-yellow which persisted for 5 min. The percentage of phytic acid was calculated using the formula:

$$\%\ Phytic\ acid = y \times 1.19 \times 1 \qquad \text{(Eqt. 2)}$$

Where y is the titre value × 0.00195

Determination of Cyanides

Cyanide content was determined by the alkaline picrate method as described by Onwuka (2005). Here 5.00 g of powdered sample was dissolved in 50.00 cm^3 of distilled water in a corked conical flask and the extraction was allowed to stand overnight and filtered. In a corked test tube, 1.00 cm^3 of the filtered sample was mixed with 4.00 cm^3 alkaline picrate and incubated in a water bath for 5 minutes. The absorbance of the blank containing 1.00 cm^3 distilled water and 4 cm^3 alkaline picrate solution was also measured at 490 nm after colour development (reddish-brown colour). The cyanide content was extrapolated from a cyanide standard curve prepared from a different concentration of KCN solution containing 5-50 μg cyanide in a 500 cm^3 conical flask followed by 25.00 cm^3 of 1 mol/dm^{-3} HCl. It was calculated as:

$$Cyanide\ (mg/100g) = \frac{Absorbance \times GF \times DF}{Sample\ weight} \qquad \text{(Eqt. 3)}$$

Where GF is the gradient factor and DF is the dilution factor.

Determination of Oxalates

The oxalate content of the samples was determined using the titration method described by Munro and Bassiro (2000). In a 250 cm^3 volumetric flask suspended in 190.00 cm^3 distilled water, 2.00 g of each sample A and B was inserted. Each sample received a 10 cm^3 of 6 mol/dm^{-3} HCl solution, which was digested at 100ºC for 1hour. The samples were then cooled and made up to the 250 cm^3 mark of the flask. The samples were filtered and a duplicate portion of 125.00 cm^3 of the filtrate was measured into a beaker and 4 drops of methyl red indicator were added, followed by the addition of concentrated NH_4OH solution (dropwise) until the solution changes from pink to yellow colour. Each portion was then heated to 90ºC, cooled and filtered to remove the precipitate containing ferrous ion. Each of the filtrates was again heated to 90ºC and 10.00 cm^3 of 5% $CaCl_2$ solution was added to each of the samples with consistent stirring. After cooling, the samples were left overnight. The solutions were then centrifuged for 5 minutes at 2500 rpm. The supernatant was decanted and the precipitates completely dissolved in 10.00 cm^3 20% H_2SO_4. The total filtrate resulting from the digestion of 2.00 g of each of the samples was made up to 200 cm^3. The filtrate was heated to near boiling points in aliquots of 125.00 cm^3 and then titrated against 0.05 mol/dm^{-3} standardized $KMnO_4$ solution to a pink colour which persisted for 30 seconds. Each sample of the oxalate contents was then calculated using the formula:

$$Oxalate = \frac{T \times (Vme)(Df) \times 10^5}{(ME) \times Mf} \qquad \text{(Eqt. 4)}$$

Where T is the titre value of $KMnO_4$, Vme is the volume-mass equivalent, Df is the dilution factor, ME is the molar equivalent of $KMnO_4$ in oxalate and Mf is the mass of the sample.

Statistical Analysis

The obtained results were subjected to statistical analysis using mean standard deviation and analysis of variance (ANOVA) as described by Duncan's multiple range test to determine the level of significance between different samples and significance was set at $p \leq 0.05$.

RESULTS AND DISCUSSION

Table 1. proximate composition of selected yam species (%).

Yam species	Ash content	Moisture content	Crude fat	Crude fibre	Crude protein	Carbohydrate
D. cayenensis	3.09±0.19[a]	4.51±0.07[d]	16.31±0.30[j]	8.30±0.40[b]	10.14±0.40[h]	57.65±0.10[b]
D. dumenturom	5.06±0.80[c]	3.51±0.01[c]	3.56±0.03[a]	6.54±0.01[a]	12.29±0.01[f]	69.04±0.10[g]
D. rotundata	8.05±0.05[f]	5.60±0.06[f]	12.46±0.10[h]	13.11±0.10[e]	2.15±0.03[b]	58.63±0.08[d]

Values are means ± standard deviation of triplicate analysis.

Moisture Content

The moisture content of the various yam species ranged from 3.51±0.01[c] % for *Dioscorea dumenturom* to 5.60±0.06[f] % for *Dioscorea rotundata*. The result indicates that the analysed yam species were significantly different ($p \leq 0.05$) with *Dioscorea rotundata* having the highest moisture content. However, these values are comparable to literature values as reported by Oko and Famurewa (2014) that ranged from 2.1% to 9.2% for *Dioscorea dumenturom* and *Dioscorea alata* respectively and lower than the research carried out by Anthony *et al*. (2014) which reported its moisture content within the range of 30.51±0.06[d] % to 37.90±0.08[a] % for *Xanthosoma maff* and *Dioscorea cayenensis* respectively. As such it could be said that *Dioscorea dumenturom* has a higher resistance to deterioration and longer shelf life than any of the selected yam species.

Crude Fibre Content

The crude fibre content ranged from 6.54±0.01[a] % for *Dioscorea dumenturom* to 13.11±0.10[d] % for *Dioscorea rotundata*. The result indicates that the analysed yam species were significantly different ($p \leq 0.05$) with *Dioscorea rotundata* having the highest crude fibre content. However, these results can be compared with reports by Afiukwa *et al*. (2013) that ranged from 6.01±0.04[b] % to 13.03±0.80[a] % for varieties of *Dioscorea dumenturom* and is different from reports by Oko and Famurewa (2014) that ranged from 3.31% to 3.53% for their *Dioscorea alata* species. Studies have shown that an increase in fiber consumption in foods reduces the incidence of obesity, cardiovascular disease, diabetes and digestive disorders (Turner, 2014).

Ash Content

Ash contents of the yam varieties ranged from 3.09±0.19[a] % for *Dioscorea cayenesis* to 8.05±0.05[f] % for *Dioscorea rotundata*. The result indicates that there was a significant difference ($p \leq 0.05$) in the yam species analysed with *Dioscorea rotundata* showing the highest ash content. However, these results were different from reports by Sorh *et al*. (2015) that ranged from 1.64±0.03[a] % to 1.78±0.03[a] % for varieties of *Dioscorea alata*. The ash content is an indication of the extent of mineral stuffing in the *Dioscorea* species (Akonor *et al*., 2017). As such, *Dioscorea rotundata* is stuffed with more minerals than the other yam tubers analysed.

Crude Protein Content

The crude protein content showed a significant difference ($p \leq 0.05$) between the yam varieties. It ranged from 2.15±0.03[b] % for *Dioscorea rotundata* to 12.29±0.01[f] % for *Dioscorea dumenturom*. However, *Dioscorea dumenturom* proved to be the tuber variety with the highest protein content. Nevertheless, the result can be compared with reports by Ojinnaka *et al*. (2017) that showed 2.43±0.11[b] % for *Dioscorea bubilfera* and in contrast with the report by Ukom *et al*. (2014) that showed crude protein of *Dioscorea dumenturom* to be 69.15±4.49[b] %. As such, this shows that *Dioscorea dumenturom* is the richest in protein among the analysed *Dioscorea* species.

Crude Fat Content

The fat content in these analysed varieties of yam tubers ranged from 3.56±0.03[a] % for *Dioscorea dumenturom* to 16.31±0.30[j] % for *Dioscorea cayennesis*. The result indicates that there was a significant difference ($p \leq 0.05$) in the yam species analysed with *Dioscorea cayenensis* showing the highest fat content. However, these results contradict Ukom which showed 4.4±1.91[a] % for *Dioscorea cayenensis*. That dietary fat supplies most of the energy required by man suggests that *Dioscorea cayenensis* is a better source of calories than other *Dioscorea species* analysed.

Carbohydrate Content

The carbohydrate content of the analysed yam varieties was significantly different ($p \leq 0.05$) and ranged from 57.65±0.10[b] % for *Dioscorea cayenensis* to 69.04±0.10[g] % for *Dioscorea dumenturom*. Despite the huge carbohydrate content contained by the *Dioscorea* species, *Dioscorea dumenturom* appeared to be more than *Dioscorea cayenensis* and *Dioscorea rotundata*. However, these values are comparable to literature by Ukpabi and Akobundu (2014), which had 78.32±0.29 % for *Dioscorea dumenturom* and in contrast with Frank and Kingsley (2014) that ranged from 24.25±0.62[b] % for *Dioscorea alata* to 32.03±0.89[c] % *Dioscorea rotundata*. Carbohydrates are considered as the primary source of energy for all organisms, playing a nutritional as well as structural role (Ojinnaka *et al*., 2017).

Table 2. Mineral concentration of selected yam species (mg/100g).

Yam samples	Ca	Fe	Mg	Na	K	P
D. cayenensis	67.12±0.11^{b}	3.09±0.01^{a}	74.38±0.03^{d}	24.10±0.14^{b}	50.06±0.09^{d}	131.51±0.05^{b}
D. dumenturom	190.57±0.01^{i}	7.37±0.04^{i}	100.22±0.03^{i}	32.05±0.07^{e}	72.23±0.37^{g}	193.11±0.01^{b}
D. rotundata	60.60±0.17^{a}	3.18±0.03^{a}	60.85±0.21^{b}	31.10±0.14^{g}	42.08±0.11^{b}	117.20±0.01^{b}

Values are means ± standard deviation of triplicate analysis.

Iron Concentration

Minerals are an important component of diet because of their physiological and metabolic function in the body. Table 2 shows iron concentrations that ranged from 3.09±0.01^{a} mg/100g for *Dioscorea cayenensis* to 7.37±0.04^{i} mg/100g for *Dioscorea dumenturom* samples. The result indicates that the analysed yam species were significantly different ($p \leq 0.05$) with *Dioscorea dumenturom* having the highest iron concentration. However, this result was low when compared to results reported by Mergedus *et al*. (2015) which ranged from 10.10±0.01^{a} mg/100g to 11.60±0.01^{a} mg/100g for cultivars of *Colocasia esculenta* (Cocoyam). Iron is a major component of hemoglobin, a type of protein in red blood cells that carries oxygen from the lungs to all parts of the body (Mergedus *et al*., 2015). The recommended dietary allowance for iron is 13.7–15.1 mg/day for children and 17.0–18.9 mg/day for adults (WHO, 2014).

Sodium Concentration

The sodium concentration in this study ranged from 24.10±0.14^{b} mg/100g for *Dioscorea cayenensis* to 32.05±0.07^{e} mg/100g for *Dioscorea dumenturom*. The result indicates that there was a significant difference ($p \leq 0.05$) in the yam species analysed with *Dioscorea dumenturom* showing the highest sodium concentration. However, the sodium concentration was comparable to the report by Oko and Famurewa (2015) which had 24.84±0.37^{a} mg/100g and 21.06±0.77^{b} mg/100g for *Dioscorea vilgaris* and *Dioscorea villosa* respectively. Sodium as a macronutrient plays an important role in various metabolic processes including excitation and transmission of nerve impulses during action (Olajumoke *et al*., 2014). The recommended daily dietary intake for sodium is 10 mg/day for adult males and below 15 mg/day for females (WHO, 2014).

Potassium Concentration

Potassium is a macro-nutrient required by both plants and animals and is involved in various metabolisms. In this study, the concentration of potassium ranged from 42.08±0.11^{b} mg/100g for *Dioscorea rotundata* to 72.23±0.37^{g} mg/100g for *Dioscorea dumenturom*. The result indicates that the analysed yam species were significantly different ($p \leq 0.05$) with *Dioscorea dumenturom* having the highest potassium concentration. However, these values were lower when compared with reports by Ellong *et al*. (2014) that ranged from 338.00±59.29 mg/100g to 407.04±168.36 mg/100g for varieties of sweet potato (*Ipomoea batatas*). Potassium is important in the regulation of heartbeat, neurotransmission, signal and immune response and water balance in the body (Olajumoke *et al*., 2014). The recommended dietary intake of potassium is 2000 mg/day for adults and 1000 mg/day for children (WHO, 2014).

Calcium Concentration

The calcium content in this study ranged from 60.60±0.17^{a} mg/100g for *Dioscorea rotundata* to 190.57±0.01^{i} mg/100g for *Dioscorea dumenturom*. The result indicates that there was a significant difference ($p \leq 0.05$) in the yam species analysed with *Dioscorea dumenturom* showing the highest calcium concentration. However, this concentration was low when compared to reports by Sorh *et al*. (2015) which ranged from 150±14.50^{ab} mg/100g to 185±18.14^{d} mg/100g for varieties of *Dioscorea alata*. Calcium is necessary for blood clotting, muscle contraction, neurological function, bone and teeth formation (Trailokya *et al*., 2017). The recommended dietary intake of calcium is 500–800 mg/day for children and 1000 mg for adults (WHO, 2014).

Magnesium Concentration

Magnesium was also present in small quantities in the range of 60.85±0.21^{b} mg/100g for *Dioscorea rotundata* to 100.22±0.03^{i} mg/100g for *Dioscorea dumenturom*. The result indicates that the analysed yam species were significantly different ($p \leq 0.05$) with *Dioscorea dumenturom* having the highest magnesium concentration. However, its results were comparable to reports by Cyrile *et al.* (2014) that showed 53.70±0.32^{b} mg/100g for its *Dioscorea dumenturom* species. Magnesium is involved in muscle degeneration, growth retardation, alopecia, dermatitis, immunologic dysfunction, poor spermato-genesis, congenital abnormalities and bleeding disorders among other things (Mergedus *et al*., 2015). The recommended dietary intake of magnesium is 80–320 mg/day (WHO, 2014).

Phosphorous Concentration

Phosphorus, together with calcium, helps to strengthen bones and teeth, particularly in children and breastfeeding mothers. The phosphorus content of the samples analysed ranged from 117.20±0.01^{b} mg/100g for *Dioscorea rotundata* to 193.11±0.01^{c} mg/100g for

Dioscorea dumenturom. The result indicates that the analysed yam species were significantly different ($p \leq 0.05$) with *Dioscorea dumenturom* having the highest phosphorous concentration. However, these values are low when compared to those of 410 mg/100g of sweet potato reported by Sorh *et al*. (2015). Furthermore, phosphorous appeared to be the most abundant mineral in all the yam samples analysed. The recommended dietary allowance for both children and adults is 800 mg/day (WHO, 2014).

Table 3. Anti-nutritional contents of the selected yam species (mg/100g).

Yam species	Tannin	Phytate	Cyanide	Alkaloids	Oxalate
D. cayenensis	30.06±0.30[d]	49.44±0.30[h]	1.70±0.06[d]	8.35±0.10[b]	4.86±0.08[d]
D. dumenturom	72.99±0.50[j]	30.00±0.20[f]	3.38±0.06[e]	24.17±2.70[g]	3.67±0.30[c]
D. rotundata	62.00±0.50[h]	15.06±0.30[d]	1.54±0.06[c]	11.58±0.20[d]	3.19±0.90[bc]

Values are means ± standard deviation of triplicate analysis.

Tannin Content

Tannins have been reported to form complexes with proteins and impair their digestibility and palatability. However, cooking is known to diminish the contents in foods (Lewu *et al*., 2010). Tannin concentration in the yam samples studied ranged from 30.06±0.30[d] mg/100g for *Dioscorea cayenensis* to 72.99±0.50[j] mg/100g for *Dioscorea dumenturom*. The result indicates that the analysed yam species were significantly different ($p \leq 0.05$) with *Dioscorea cayenensis* having the least tannin concentration. However, these values are relatively lower than those of 20-255 mg/100g reported on various under-utilized *Dioscorea* tubers (Arinathan *et al*., 2009) and higher than reports by Polycarp *et al*. (2012) that ranged from 4.56±0.01[a] to 19.23±0.03[b] mg/100g for different *Dioscorea* species. Tannin has been shown to decrease the activity of several enzymes including trypsin, amylase and lipase as well as interfere with the absorption of dietary iron (Rao and Desothe, 2008). The total acceptable tannin intake for a man is 560 mg/kg (Stephene, 2004). As such the tannin contents in these yam species are low and within permissible limits and thus, cannot be harmful to consumers (Stephene, 2004).

Phytate Content

The phytate contents of the yam tuber ranged from 15.06±0.30[d] mg/100g for *Dioscorea rotundata* to 49.44±0.30[h] mg/100g for *Dioscorea cayenensis* samples. The result indicates that the analysed yam species were significantly different ($p \leq 0.05$) with *Dioscorea rotundata* having the least phytate concentration. However, these values were higher when compared to the report by Otoo *et al*. (2008) that showed 2.60±0.20[a] mg/100g for its *Dioscorea rotundata* cultivars and lower than sweet potato which contained 119.98±0.01[a] mg/100g (Akaninwor, 2004)**.** The issue with phytate in diets is that it can bind some essential mineral nutrients in the digestive tract, leading to mineral deficiencies. There is no particular recommended daily allowance for phytic acid as it differs from country to country (Bello *et al*., 2008).

Oxalate Content

Comparatively, the oxalate content of the various yam species analyzed ranged from 3.19±0.90[bc] mg/100g for *Dioscorea rotundata* to 4.86±0.08[d] mg/100g for *Dioscorea cayenensis* samples. The result indicates that the analysed yam species were significantly different ($p \leq 0.05$) with *Dioscorea rotundata* having the least oxalate concentration. However, these values are lower than reports according to Princewill and Ibeji (2012) that had 12.60[a] mg/100g for their *Dioscorea bubilfera* specie and higher than 0.48±0.01[a], 0.50±0.03[a] mg/100g for *Dioscorea rotundata* and *Dioscorea alata* respectively according to reports by Afoakwa *et al*. (2012).

Oxalic acid and oxalate are found naturally in plants but they have little or no benefit for human health. Though high levels in diet irritate tissues and the digestive system notably the stomach and kidney (Ogbuagu, 2008). Soluble oxalate is known to be poisonous at high concentrations, particularly above 3mg/kg (Norwood and Fox, 1994). The oxalates levels found in this study indicate that while the analysed yam tubers were slightly above the maximum permitted limit, they lose most of their toxicity when treated (boiled) and so cannot be consumed raw.

Cyanide Content

The cyanide contents ranged from 1.54±0.06[c] mg/100g for *Dioscorea rotundata* to 3.97±0.06[e] mg/100g for *Dioscorea dumenturom*. The result indicates that the analysed yam species were significantly different ($p \leq 0.05$) with *Dioscorea rotundata* having the least cyanide concentration. However, these values are low when compared to reports by Afiukwa *et al*. (2013) that showed 26.687±0.081[a] and 21.827±0.058[b] mg/100g for *Dioscorea villosa species* (okpura and ighobe) respectively. It is also higher than reports by Umoh (2013) that had 0.22±0.02[a] to 0.53±0.01[b] mg/100g for raw and processed false yam flour. The permissible limits for cyanide are 0.5-3.5 mg/kg which indicates that the level of the cyanide in the samples is above the acceptable range for human consumption and as such must not be consumed in their raw state (Mohammed *et al*., 2013).

Alkaloid Content

The observed values for the alkaloid samples ranged between 8.35 ± 0.10^{b} mg/100g for *Dioscorea cayenensis* to 24.17 ± 2.70^{g} mg/100g for *Dioscorea dumenturom*. The result indicates that the analysed yam species were significantly different ($p\leq0.05$) with *Dioscorea cayenensis* having the least alkaloid concentration. However, the values obtained for the alkaloids contents of these yam species were higher when compared to some varieties of *Dioscorea cayenensis* that ranged from 0.38 ± 0.12 mg/100g to 0.68 ± 0.02 mg/100g and 1.68 ± 0.01 mg/100g for *Dioscorea rotundata* (Okwu and Ndu, 2006) and lower than reports by Ogbuagu (2008) that contained 30.62 ± 0.03^{a} and 32.46 ± 0.01^{b} mg/100g for different species of *Dioscorea dumenturom*. Because of their effect on the nervous system, electrochemical transmission and disruption of the cell membrane in the gastrointestinal tract, alkaloids are considered to be anti-nutrients (Friedman, 2001). However, human lethal dosages range between 3-6 mg/kg body weight and a dose above 3 mg/kg is usually considered toxic (Habtamu and ratta, 2014). The good news is that it loses most of its toxicity when treated or processed (cooked or boiled).

CONCLUSIONS

This study provided vital information on the proximate composition, mineral content and anti-nutritional constituents of the selected yam tuber species (*Dioscorea dumenturom, Dioscorea rotundata, Dioscorea cayenensis*). This research observed that these analysed *Dioscorea* species were rich in protein, carbohydrate, fibre, and fat and had a high shelf-life. However, the anti-nutritional constituents of these yam species, if properly treated or processed (cooked or boiled), tend to lose more than 95% of their toxicity and can be exploited as good food sources. Furthermore, all the species of yam analysed contained an appreciable amount of macro and micro-nutrients which are essential to human nutrition. Specifically, *Dioscorea dumenturom* had the highest concentrations of Na, Ca, Mg, Fe, K, and P.

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