INTRODUCTION

Starchy foods are important part of human diet and may contain essential nutrients required in the body. Yam is one of the staple foods in Nigeria and other tropical African countries with Nigeria as the largest producer. Yam is a member of the genus *Dioscorea* which is the largest genus of the family Dioscoreaceae, containing between three and six hundred species (Vernier *et al*., 1998). Only a few members of the family Dioscoreaceae are cultivated as food crops. In West Africa, a major proportion of yam is consumed as boiled, roasted, fried or pounded. Yam is also consumed as “Amala” which is stiff glutinous dough. There is no doubt that yam tubers contribute to the daily calorie and other nutrients need of Nigerians.

There is also lack of local data on the nutritive value of most yam meals and nutritionists are left with the option of relying on foreign data in estimation of nutrient intakes related to yam consumption. Most of the available food composition tables (*Food Standards Agency*, 2002), including the West African Food Composition Table (Stadlmayr *et al*., 2012) did not report composition of fried yams. The objective of this study was to determine and compare the nutrient and anti-nutrient composition of different fried yam samples (*D. rotundata, D. alata, and D. cayenensis*) commonly consumed in Nigeria and other African countries.

MATERIALS AND METHODS

Collection and Preparation of Samples

Yam tubers were purchased at Yankura market, Kano – Nigeria in August, 2015. The tubers were identified at the Department of Plant Biology, Bayero University Kano. Sample specimen numbers BUKHAN 0467, BUKHAN 0519 and BUKHAN 0520 for white, yellow and water yams respectively were kept at the Herbarium, Department of Plant Biology, Bayero University Kano.

Yam tuber samples were peeled, sliced into small pieces and washed under running water. Each sample (500 g) was boiled separately in distilled water for 25 minutes using a stainless steel pot at 100°C into which one teaspoon of salt was added. The boiled samples were then deep-fried in vegetable oil for 15 minutes after which the samples were allowed to cool and weighed. The fried yam samples were used for proximate and minerals analyses.

Determination of Proximate Composition

Proximate nutrient composition of the yam samples was determined using the standard methods of analysis of Association of Official Analytical Chemists (AOAC, 2004). Moisture content of the samples was determined by an automatic moisture analyzer at 115°C. The crude protein of the samples was determined using micro-Kjeldahl method. Crude lipid was determined by Soxhlet extraction method using petroleum ether as extracting solvent, while the ash content was determined using a muffle furnace set at 550°C for 4 h.
Analysis of variance (ANOVA) was used in results. The level of cyanide in fried yam samples was determined by titration. Phytate in each sample was determined by titration according to the methods of AOAC (2004). Determination of Anti-nutrients Minerals in the samples were analyzed from solution obtained when 5g of the ash sample was digested with 10ml of 5N hydrochloric acid. Iron (Fe), Calcium (Ca), and Magnesium (Mg) content of samples were determined by atomic absorption spectrometry and Potassium (K) was determined by flame photometry according to the methods of AOAC (2004). Determination of Anti-nutrients Phytate in each sample was determined by titration. Each sample (4 g) was soaked in 100ml of 2% hydrochloric acid (HCl) for 5 hrs and filtered. To 25ml of the filtrate in a conical flask, 5ml of 0.3% ammonium thiocyanate solution was added. The mixture was titrated with standard solution of iron(III)chloride (FeCl₃) as described by Lucas and Markakis (1975). The level of cyanide in fried yam samples was determined by alkaline filtration method (AOAC, 1984). Sample (10 g) was dispersed into 200ml distilled water and 10ml of orthophosphoric acid was added. The mixture was mixed and left to stand for 12hours to release the bound hydrogen cyanide. A drop of tannic acid as an anti-foaming agent was added. To 20ml of the distillate 40ml of distilled water was added followed by the addition of 8ml of 0.06N sodium hydroxide (NaOH) and 2ml of 0.05N potassium iodide (KI). The mixture was titrated with 0.02N silver nitrate (AgNO₃) solution until a faint turbidity was obtained. Each 1ml of 0.02N AgNO₃ is equivalent to 1.8 mg of cyanide. Statistical Analysis Analysis of variance (ANOVA) was used in results analysis. Statistical significance was considered at p<0.05. RESULTS Results of proximate, minerals and anti-nutrients content of the fried yam samples studied are shown in Tables 1, 2 and 3 respectively. Moisture, fat and ash content showed no significant difference (p > 0.05) among all four samples. However, significant difference was recorded (p < 0.05) when means of protein, carbohydrate and fiber content were compared. Water yam have significantly (p < 0.05) higher protein content compared to other samples studied. Carbohydrate content significantly (p < 0.05) differed between samples with highest amount observed in old white yam. New white and water yams showed significantly (p < 0.05) higher fiber content than both yellow and old white yams. Concentration of iron in the fried yam samples was not significantly different (p > 0.05). However, calcium, potassium and magnesium concentrations differed significantly (p < 0.05) between samples with new white, water and yellow yams respectively higher in calcium, potassium and magnesium. There was significant (p < 0.05) variation in the phytate and cyanide content among the fried yam samples studied. The highest cyanide and phytate contents were respectively in new white and yellow yams. DISCUSSION According to the Nigerian Food Composition Table (Sanusi et al., 2017), raw white, yellow and water yams have respective proximate content (in g/100 g) of water (61.43; 70.31; 65.50), protein (2.00; 2.25; 2.40), fat (0.4; 0.28; 0.10), Carbohydrate (31.57; 24.22; 26.50), fibre (1.05; 2.73; 2.50) and ash (1.23; 1.58; 1.40). Protein content of pre-boiled fried yam samples studied ranged from 4.97 – 5.77 g/100 g. Surprisingly, the findings of Nduka et al. (2016) reported very low protein content of 0.00413 to 0.00525 g/100 g in raw D. rotundata yam tubers. This is unexpected of a raw yam tubers and may possibly be due to conversion errors as the authors showed protein calculated in percentage but presented it as mg/100g in the results table. On the other hand, the protein contents obtained in this study is less than the protein content (7.10 – 9.12 g/100g) reported in boiled D. rotundata in previous study (Ezeocha and Ojumelukwe, 2012) suggesting the advantage of boiling over frying on the protein content of yam. It is worthy of note that in northern Nigeria, most people fry yam with egg and this may compliment the protein loss due to frying. Adepoju (2012) reported a protein content of 9.7 g/100g in yam (D. rotundata) porridge but that fried yam has 3 % protein. The protein content reported in fried yam is less than the amount found in the present study. This could be due difference in processing method as Adepoju (2012) did not pre-boil before frying. The higher protein content in the yam porridge reported by Adepoju (2012) could be due to contribution of protein from other ingredients used. Other related studies (Marfo et al., 1990; Udensi, et al., 2010; Udensi, et al., 2008; Lawal et al., 2012; Chandrasekara and Kumar, 2016; Bradbury et al., 1988; Shajeela et al., 2011; Polycarp et al., 2012) reported variable amounts of protein in yam and yam – based meals. These variations related to processing or cooking methods underscore the importance of developing a detailed country and regional food composition tables to enable more accurate estimates of nutrient intake of the consumers. This is necessary to guide nutrition policy making and advice. The high mean fat content of fried yam (5.07 to 7.00 g/100g) found in this study is in agreement with the finding of Adepoju (2012) who reported 5.3 g/100g crude lipid in fried yam (D. rotundata). According to Lawal et al. (2012), fried yam with stew have mean fat content of 12.72 g/100g. The fat content in fried yams or fried yam with stew could be largely contributed from the vegetable oil and ingredients used in frying or stew making. The fat will contribute to overall gross energy of the fried yam meal. Ezeocha and Ojumelukwe, (2012) reported the presence of 1.15 g/100g in raw and less than 1 g/100g lipids in boiled yam samples. Nduka et al. (2016), Marfo (1990), Lawal et al. (2012) and Polycarp et al. (2012) observed less than 1 g/100g fat content in raw yam samples. This further suggest the need for a comprehensive food table with details of yam variety types and processing methods.
The content of carbohydrate (31 - 37 g/100g) found in fried yams studied is in close agreement with Marfo et al. (1990) who found carbohydrate content of 36.5 g/100g and 38.30 g/100g in raw yam and cocoyam respectively. On the other hand, Polycarp et al. (2012) reported that carbohydrate in different yam varieties range from 7.75 to 87.3 g/100g. However, the carbohydrate content in fried yams in this study were lower than the reported carbohydrate content (53.8 g/100g) obtained in fried yam (Adepoju, 2012) previously. The lower carbohydrate content in this study could be due to pre-boiling of samples prior to frying.

It is worthy of note that Adepoju (2012) obtained variable amounts of carbohydrate (from 20 g/100g in hot water pounded yam to 60.6 g/100g qamala, a thick yam powder paste) depending on the processing methods. It is obvious that differences in yam samples and processing methods play significant role in determining nutrient content of various yam – based meals commonly consume in Nigeria and other African countries.

The low fibre content in fried yam samples (0.9 - 2.0 g/100g) concur with previous findings of 1.2 g/100g in various yams processed in various ways ranging from raw, boiled, pounded, porridge, etc. (Lawal et al., 2012; Marfo et al., 1990; Udensi et al., 2008 and 2010; Ezeocha and Ojumelukwe, 2012; Polycarp et al., 2012; Adepoju, 2012; Shajeela et al., 2011). These results suggest the effect of processing methods on fibre content of yam. Dietary fibre consumption has been associated with decreased risk of chronic diseases development (Lockyer et al., 2016).

Dietary minerals are known to play various roles (transport across biological membrane, signal transduction through creation of membrane potentials, enzyme cofactors, relaxation and contraction of muscles, etc.) in ensuring normal running of physiological processes of the body. The calcium, potassium, magnesium and iron contents in fried yam studied suggest their potential as a contributor to the daily/adequate intake of these minerals among habitual yam consumers. The variations observed in the amount of calcium (9 to 13.7 mg/100g), potassium (383 to 683 mg/100g), iron (0.3 to 0.5 mg/100g) and magnesium (11.3 to 16.3 mg/100g) among the fried yam samples studied could be as a result of possible differences in varieties of yams studied as well as their cultivation conditions. Previous studies (Chandrasekara and Kumar, 2016; Hailu and Addis, 2016; Adepoju, 2012; Udensi et al., 2008 and 2010; Shajeela et al., 2011; Akin-Idowu et al. 2009) have shown similar trends of variation in minerals content of raw and processed yam varieties. For example, Polycarp et al. (2012) have reported calcium content of 6.5 to 116.5 mg/100g, potassium content of 475 to 1475 mg/100g, iron content of 1.5 to 9 mg/100g and magnesium content of 35.5 to 83.5 mg/100g. These data further supported the need for a comprehensive yam and yam-based foods composition to ease nutrient intake assessment in areas where yam is one of the frequent foods consumed.

Anti-nutrients in foods are known to inhibit proper absorption and utilization of essential nutrients thereby decreasing bioavailability. Phytate content of fried yam studied is lower than the previously reported in different varieties of yam (Polycarp et al., 2012). Phytate content of yam was found to be significantly reduced in boiled and pounded yam (Akin-Idowu et al., 2009). The cyanide content (3.2 to 7.2 mg/kg) in fried yam samples studied is less than the previously (Udensi et al., 2010) reported cyanide content of 9.62 to 12 mg/kg in different varieties of yam. Collectively, these findings have shown variation in cyanide and phytate contents of yam possibly due to variety differences and processing methods. Frying is relatively associated with lower phytate and cyanide content.

### Table 1: Proximate Composition(g/100g) of Yam Tuber Samples Studied

<table>
<thead>
<tr>
<th>Sample</th>
<th>Protein</th>
<th>Fat</th>
<th>Ash</th>
<th>Moisture</th>
<th>Carbohydrate</th>
<th>Fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWY</td>
<td>4.97±0.1a</td>
<td>7.00±0.3a</td>
<td>2.45±1.13a</td>
<td>52.5±8.40a</td>
<td>31.20±0.15a</td>
<td>2.0±0.02a</td>
</tr>
<tr>
<td>OWY</td>
<td>5.03±0.1b</td>
<td>5.22±0.5b</td>
<td>3.22±0.23b</td>
<td>47.1±0.70b</td>
<td>37.47±0.5d</td>
<td>1.92±0.02b</td>
</tr>
<tr>
<td>WY</td>
<td>5.77±0.2a</td>
<td>7.67±2.0a</td>
<td>2.53±0.23a</td>
<td>49.2±1.36a</td>
<td>33.17±1.5a</td>
<td>1.96±0.03a</td>
</tr>
<tr>
<td>YY</td>
<td>5.13±0.4a</td>
<td>5.07±0.1a</td>
<td>2.33±0.12a</td>
<td>51.0±1.00a</td>
<td>35.7±0.4a</td>
<td>0.90±0.03a</td>
</tr>
</tbody>
</table>

Results are presented as mean± standard deviation of triplicate determinations. Values with different superscripts on the same column are significantly different (P<0.05). New white yam (NWY), old white yam (OWY), water yam (WY) and yellow yam (YY).

### Table 2: Calcium, Potassium, Iron and Magnesium Content (mg/100g) of Yam Tuber Samples Studied

<table>
<thead>
<tr>
<th>Sample</th>
<th>Calcium</th>
<th>Potassium</th>
<th>Iron</th>
<th>Magnesium</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWY</td>
<td>13.7±0.5a</td>
<td>383±3.6a</td>
<td>0.4±0.05a</td>
<td>11.3±1.15a</td>
</tr>
<tr>
<td>OWY</td>
<td>9.0±1.7b</td>
<td>493±11.5b</td>
<td>0.3±0.05a</td>
<td>11.7±2.08a</td>
</tr>
<tr>
<td>WY</td>
<td>11.7±0.5c</td>
<td>683±3.6c</td>
<td>0.5±0.39a</td>
<td>14.1±2.08a</td>
</tr>
<tr>
<td>YY</td>
<td>10.3±1.5d</td>
<td>507±30.5d</td>
<td>0.5±0.2a</td>
<td>16.3±1.52b</td>
</tr>
</tbody>
</table>

Results are presented as mean ± standard deviation of triplicate determinations. Values with different superscripts on the same column are significantly different (P<0.05). New white yam (NWY), old white yam (OWY), water yam (WY) and yellow yam (YY).
Table 3: Phytate and Cyanide Content (mg/kg) of Yam Tuber Samples Studied

<table>
<thead>
<tr>
<th>Sample</th>
<th>Phytate</th>
<th>Cyanide</th>
</tr>
</thead>
<tbody>
<tr>
<td>NWY</td>
<td>11.3±0.08a</td>
<td>7.2±0.15a</td>
</tr>
<tr>
<td>OWY</td>
<td>11.8±0.04d</td>
<td>3.2±0.15b</td>
</tr>
<tr>
<td>WY</td>
<td>13.9±0.05b</td>
<td>3.5±0.11b</td>
</tr>
<tr>
<td>YY</td>
<td>31.2±0.40c</td>
<td>4.5±0.06d</td>
</tr>
</tbody>
</table>

Results are presented as mean ± standard deviation of triplicate determinations. Values with different superscripts on the same column are significantly different (P<0.05). New white yam (NWY), old white yam (OWH), water yam (WY) and yellow yam (YY).

CONCLUSION
Results of this study suggests that the proximate composition of fried white, yellow and water yams studied varies slightly. However, the fried yams studied appear to be potential contributors of calories and essential minerals to the daily requirements of habitual consumers.

REFERENCES

Authors’ Contributions
S. M. Abubakar designed and supervised the conduct of the study. F. A. Gana conducted sampling, carried laboratory and statistical analyses. F. A. Gana drafted the manuscript. Both authors read, corrected and approved the final manuscript.

Conflict of Interest: No conflict of interest to declare.