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Comparative Assessment of the Proximate Composition, Functional Properties and Amino Acid Profile of *Dioscorea bulbifera*, *Dioscorea alata* and *Dioscorea rotundata* Found in Minna, Niger State

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Abstract

The proximate composition, functional properties and amino acid profile of samples of *Dioscorea alata*, *Dioscorea rotundata* and *Dioscorea bulbifera* were investigated using standard analytical methods. The results showed that *Dioscorea alata* had the highest ash (5.59±0.06 %) and crude fiber content (12.12±0.20 %), indicating that it has more mineral stuffing and is best to reduce the risk of obesity. *Dioscorea rotundata* had the highest fat content (11.63±0.04 %) as well as the lowest moisture content (7.04±0.06 %), indicating that it is a better source of calories and has a longer shelf-life than other yam species analysed. *Dioscorea bulbifera* also had the highest crude protein (8.64±0.03 %) and carbohydrates (77.51±0.08 %) than other yam species analysed, indicating high bodybuilding capacity and a better source of energy than other yam samples analysed. *Dioscorea alata* showed the highest bulk density (0.87±0.02 g/cm^3) and swelling capacity (15.25±0.03 g/g). It is indicating its usefulness in the reduction of paste thickness and water-holding capacity of starch granules respectively while *Dioscorea rotundata*, showed the highest water absorption capacity (164.02±0.02 %), oil absorption capacity (149.76±0.02 %) and dispersibility (72.17±0.01 %). This indicates its importance in the consistency and bulking of products, flavour retaining in food and reconstitution of flour samples in water to give a fine consistent paste during mixing. The yam species were also rich in amino acids which are building blocks of protein. However, *Dioscorea rotundata* was the richest in amino acid content, as it had 36.32±0.16 g/100g and 36.49±0.16 g/100g, for essential and non-essential amino acids respectively.

Keywords: Amino acid; functional properties; proximate composition; *Dioscorea alata; Dioscorea bulbifera*.

INTRODUCTION

Roots and tubers allude to any developing plant that stores food in the subterranean roots, corm and tuber. The nutritional value of roots and tubers lies in their capacity to provide one of the cheapest sources of dietary energy in the form of carbohydrates in impoverished climes (Ugwu, 2009). Roots and tubers crops are an important source of food, nutrition and financial revenue for many impoverished farmers and food-insecure individuals in developing countries (Oluwamukomi & Akinsola, 2015). Tubers are also used for the treatment of purgative, deflatulent, aphrodisiac, hemorrhoids, scrofula and polyureic (Dutta 2015). Furthermore, dietary plant estrogens of *Dioscorea* provide various health benefits including defence against cancers, osteoporosis, cardiovascular disease, and asthma, as well as being utilized in the preparation of contraceptives and the treatment of numerous genetic abnormalities (Sheikh *et al*., 2013). Yam is a popularly consumed tuber in the tropics with several varieties such as *Dioscorea rotundata* (white yam), *Dioscorea esculenta* (Chinese yam), *Dioscorea alata* (water yam), *Dioscorea bulbifera* (aerial yam), and *Dioscorea dumenterum* (trifoliate yam) among the economically important species (Ike and Inoni, 2006). However, this study focuses on aerial yam (*Dioscorea bulbifera*), white yam (*Dioscorea rotundata*) and water yam (*Dioscorea alata*).

According to FAOSTAT (2006), Nigeria is the world's largest producer of yam, accounting for 67 percent of global production and 72 percent of West African production in 2005. Yam is an important staple meal in West Africa and a vital source of carbohydrates for over 300 million people worldwide (Ettien *et al*., 2009). Despite these well-known facts regarding yam, it continues to be overlooked in West African national food policy plans. This has resulted in limited *Dioscorea* species research and development on the continent (Sanoussi *et al*., 2016).

This study investigates the proximate composition, functional properties and amino acid profile of *Dioscorea rotundata*, *Dioscorea alata* and *Dioscorea bulbifera* 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 Chanchaga, Mekunkele and Gunu areas of Niger State. The samples include cultivars of water yam (*Dioscorea alata*), a variety of white yam (*Dioscorea rotundata*) and aerial yam (*Dioscorea bulbifera*). The samples were cleaned by brushing off soil particles and transported at tropical ambient temperature to the laboratory for analysis.

Dioscorea bulbifera *Dioscorea rotundata* *Dioscorea alata*

Figure 1. Pictures of the studied *Dioscorea* varieties.

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

Standard analytical procedures for food analysis were adopted for the determination of moisture content, crude protein, crude fibre, percentage fat, carbohydrate and ash content.

Moisture Content

Two grams of the sample were placed in the crucibles and were then dried overnight at 105°C in the oven. After cooling in a desiccator for 30 minutes, the dry sample was weighed to a constant weight. On a dry weight basis, the percentage of weight loss was reported as a percentage of moisture content (AOAC, 2006). To acquire triplicate values, this was done three times. The moisture content was calculated as:

$$\%\ Moisture\ content = \frac{Weight\ of\ sample\ before\ drying - Weight\ of\ sample\ after\ drying}{Weight\ of\ sample\ before\ drying} \times 100$$

Ash Content

Two grams of the dried and pulverized sample were taken in triplicates, put in pre-weighed crucibles and ashed for three hours at 600°C in a muffle furnace. After cooling in a desiccator, the hot crucibles were weighed. The percentage residual weight was expressed as ash content (AOAC, 2006). The ash content was calculated as:

$$\%\ Ash\ content = \frac{Weight\ of\ ash}{Weight\ of\ sample\ taken} \times 100$$

Crude Fat Content

The percentage fat content of the samples was obtained using the method according to AOAC (2006). Five grams of the sample was weighed into a pre-weighed fat-free extraction thimble which was plugged tightly with cotton wool. On a heating mantle, the thimble was placed in the Soxhlet extractor fitted up with reflux condenser connected to a boiling flask containing 200 ml of petroleum ether (boiling point 60°C). As the flask and petroleum ether were heated, the solvent evaporated and condensed into the thimble extracting oil from the sample and refluxed into the boiling flask with the extracted oil. This was done for 4 hours. At the end of extraction, the solvent (petroleum ether) was evaporated by heating at 70°C on a hot plate leaving the lipid extract in the flask. The flask together with the sample was placed in an oven and dried at 110°C for 1 hour, cooled in a desiccator and re-weighed. The percentage crude fat content was calculated using the formula:

$$\%\ Crude\ fat\ content = \frac{Weight\ of\ oil}{Weight\ of\ sample} \times 100$$

Crude Protein Determination

The Kjeldahl method was used to determine the total protein. A Kjeldahl flask containing 0.5 g of the sample was filled with 8–10 cm^3 of concentrated H_2SO_4 after

being weighed in triplicate and the solution was digested in a fume cupboard until it became colourless. A 10 % NaOH solution with a 40 % concentration was used for distillation. The boric acid solution glowed green after the condenser tip was dipped into a conical flask containing 5 cm^3 of 4 % boric acid in a mixed indicator. HCl of 0.01M was titrated in the receiver flask until the solution turned red (AOAC, 2006). The crude protein content was calculated as:

$$\% N = \frac{(a-b) \times 0.01 \times 14 \times v}{W \times C} \times 100$$

Where a is the titre value of the digested sample, b is the titre value of the blank sample, v is the volume after dilution, W is the weight of the dried sample, C is the aliquot of sample used and 14 is the atomic weight of nitrogen.

$$Crude\ protein = 6.25 \times \% N$$

Crude fibre content

Using 20 % H_2SO_4 and 20 % NaOH solutions, 2.0 g of the pounded sample was utilized in triplicates to estimate the crude fibre by acid and alkaline digestion techniques (AOAC, 2006). The crude fibre content was calculated as:

$$\% Crude\ fibre = \frac{Loss\ in\ weight\ on\ ignition}{weight\ of\ sample} \times 100$$

Carbohydrate Determination

The carbohydrate content was calculated by difference using the following formula:

$$Available\ carbohydrate\ (\%) = 100 - [Protein\ (\%) + Moisture\ (\%) + Ash\ (\%) + Fibre\ (\%) + Crude\ fat\ (\%)]$$

Determination of Functional Properties

Dispersibility

Kulkani *et al*. (1991), described a method for determining flour dispersibility. Ten grams of flour was weighed into a 100 cm^3 measuring cylinder, followed by 100 cm^3 of distilled water. For 1 minute, the setup was vigorously agitated. After a regular time-step of 30 minutes, the volume of the settled particles was measured. The volume of settled particles was subtracted from 100. The difference was expressed as a percentage of dispersion.

Bulk Density

The bulk density was determined using the method published by Oladele and Ainaby (2007). In a 100 cm^3 measuring cylinder, 50 g of samples were placed. The measuring cylinder was then tapped repeatedly on a laboratory table until it reached a fixed volume. The bulk density was calculated using the formula:

$$BD\ (g/cm^3) = \frac{Weight\ of\ sample}{Volume\ of\ sample\ after\ taping}$$

Water Absorption Capacity (WAC)

Phillips *et al*. (1988) and Anderson *et al*. (1969) techniques were used to determine the water absorption capacity and solubility index of flours from the sample. One gram of flour samples (M_o) was weighed in a centrifuge tube and 10 cm^3 distilled water was added. In a KS 10 agitator, the content of the centrifuge tube was shaken for 30 minutes. The mixture was centrifuged at 5000 rpm for 15 minutes after being maintained in a water bath (MEMMERT) at 37°C for 30 minutes. The resulting sediment (M_2) was weighed and dried to a consistent weight at 105°C (M_1). After That WAC was calculated using the formula:

$$WAC\ (\%) = \frac{Weight\ of\ the\ water\ added\ to\ the\ sample - Weight\ of\ the\ water\ removed\ from\ the\ sample}{Weight\ of\ flour\ sample} \times 100$$

Oil Absorption Capacity (OAC)

Eke and Akobundu (1993) techniques were used to assess the oil capacity of the sample. In a weighed 20 cm^3 centrifuge tube, 1 g of sample (M_o) was mixed with 10 cm^3 of oil. The slurry was stirred for 2 minutes in a vortex mixer, then kept at 28°C for 30 minutes before being centrifuged at 4500 rpm for 30 minutes. The clear supernatant was decanted and discarded. The adhering drops of oil were removed and the tube was weighed (M_1). The OAC was determined as follows:

$$OAC\ (\%) = \frac{Weight\ of\ the\ oil\ added\ to\ the\ sample - Weight\ of\ the\ oil\ removed\ from\ the\ sample}{Weight\ of\ the\ flour\ sample} \times 100$$

Swelling Capacity

Kaushal *et al*. (2012) described the method that was used. One gram of flour sample was weighed into a graduated cylinder measuring 10 cm^3. The volume occupied by the sample was measured after 5 cm^3 of distilled water was added. The sample was left standing in water for 1 hour without being disturbed. The volume occupied after swelling was recorded and calculated as:

$$Swelling\ capacity = \frac{volume\ occupied\ by\ sample\ after\ swelling}{volume\ occupied\ by\ sample\ before\ swelling}$$

Determination of Amino Acid Profiles

This was evaluated by extracting 3.00 g of the sample using a Soxhlet extractor for six hours with petroleum ether (40–60°C) (Copper, 2000). In a glass ampoule, 30.00 mg of the defatted samples were weighed and 7.00 cm^3 of 6.00 mol/dm^3 hydrochloric acid was added. By injecting nitrogen into the ampoule, oxygen was expelled (to avoid possible oxidation of some amino acids during hydrolysis). The ampoule was sealed with Bunsen flame and put in an oven preset at 105°C for 22 hours, after which it was allowed to cool, broken at the tip and the content filtered. In a rotary evaporator, the filtrate was evaporated to dryness at 40°C under a vacuum. The residue was dissolved with 5.00 cm^3 of acetate buffer (pH 2.0), then stored in a plastic bottle for 24 hours in the deep freezer. The Technicon Sequential Multi-Sample (TSM) amino acid analyser was loaded with Five to ten microliters of the hydrolysate. This was dispensed into the cartridge of the analyser and the analysis lasted for 76 minutes.

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.alata	5.59 ± 0.06^{a}	9.54 ± 0.02^{b}	7.52 ± 0.03^{d}	12.12 ± 0.20^{c}	7.85 ± 0.02^{a}	57.38 ± 0.20^{d}
D.rotundata	3.05 ± 0.06^{f}	7.04 ± 0.06^{h}	11.63 ± 0.04^{e}	7.59 ± 0.10^{a}	2.19 ± 0.01^{c}	68.50 ± 0.20^{ab}
D.bulbifera	2.34 ± 0.02^{a}	8.63 ± 0.45^{b}	1.60 ± 0.01^{a}	1.28 ± 0.10^{e}	8.64 ± 0.03^{f}	77.51 ± 0.08^{f}

Values are means ± standard deviation of triplicate analysis.

Proximate Composition of Selected Yam Species

Moisture Content

The moisture content of the various yam species ranged from 7.04 ± 0.06^{h} % for *Dioscorea rotundata* to 9.54 ± 0.02^{b} % for *Dioscorea alata*. The result indicates that there was a significant difference ($p\leq0.05$) in the yam species analysed with *Dioscorea alata* showing the highest moisture content. However, according to Oko and Famurewa (2014), these values are comparable to its literature values that ranged from 2.1 % to 9.2 % for *Dioscorea dumenturom* and *Dioscorea alata* respectively. This means that *Dioscorea rotundata*, when compared to the other yam species chosen for analysis, has a stronger resistance to deterioration and a longer shelf life.

Crude Fiber Content

The crude fiber content ranged from 1.28 ± 0.10^{e} % for *Dioscorea bulbifera* to 12.12 ± 0.20^{c} % for *Dioscorea alata*. The result indicates that the analysed yam species were significantly different ($p\leq0.05$) with *Dioscorea alata* having the highest crude fibre content. However, this result 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 species of *Dioscorea dumenturom* and differs from reports by Oko and Famurewa (2014) that ranged from 3.31% to 3.53% for their *Dioscorea alata* species. According to studies, fiber intake reduces the risk of obesity, cardiovascular disease, diabetes and softening stools (Turner, 2014).

Ash Content

Ash contents of the yam varieties ranged from 2.34 ± 0.02^{a} % for *Dioscorea bulbifera* to 5.59 ± 0.06^{a} % for *Dioscorea alata*. The result indicates that the analysed yam species were significantly different ($p\leq0.05$) with *Dioscorea alata* having the highest ash content. However, these were different from reports by Sorh *et al*. (2015) that ranged from 1.64±0.03 % to 1.78±0.03 % for *Dioscorea alata* species. Ash content reveals how heavily the yam cultivars are stuffed with minerals (Akonor *et al*., 2017). As a result, compared to the other yam tubers examined, *Dioscorea alata* has a higher mineral stuffing.

Crude Protein Content

The crude protein content of the yam varieties ranged from 2.19 ± 0.03^{c} % for *Dioscorea rotundata* to 8.64 ± 0.03^{f} % for *Dioscorea bulbifera*. The result indicates that the analysed yam species were significantly different ($p\leq0.05$) with *Dioscorea bulbifera* having the highest crude protein content. However, the result can be

compared with reports by Ojinnaka *et al*. (2016) 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] %. This demonstrates that of the *Dioscorea* species examined, *Dioscorea bulbifera* is the greatest source of protein.

Crude Fat Content

The fat content in these analysed yam varieties ranged from 1.60±0.01[a] % for *Dioscorea bulbifera* to 11.63±0.04[e] % 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 fat content. These findings, however, differ from those reported by Ukom *et al*. (2014), who found that *Dioscorea cayenensis* had an abundance of 41.91%. *Dioscorea bulbifera* may be a superior source of calories than the other *Dioscorea* species examined because dietary fat provides the majority of the energy needed by humans.

Carbohydrate Content

Carbohydrate content of the *Dioscorea* varieties were quite high and ranged from 57.38±0.20[d] % for *Dioscorea alata* to 77.51±0.08[f] % for *Dioscorea bulbifera*. The result indicates that the analysed yam species were significantly different ($p \leq 0.05$) with *Dioscorea bulbifera* having the highest carbohydrate content. However, these values are comparable to literature values by Ukpabi and Akobundu (2014) that 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] % for *Dioscorea rotundata*. Carbohydrates are considered the primary source of energy for all organisms (Ojinnaka *et al*., 2016).

Table 2. Functional properties of selected yam species.

Yam species	Bulk density (g/cm^3)	WAC (%)	OAC (%)	Dispersibility (%)	Swelling capacity (g/g)
D.alata	0.87±0.02[a]	155.34±0.02[b]	140.71±0.01[d]	62.85±0.02[e]	15.25±0.03[b]
D.rotundata	0.85±0.02[d]	164.02±0.02[f]	149.76±0.02[h]	73.16±0.01[c]	14.29±0.01[g]
D.bulbifera	0.57±0.03[a]	148.73±0.03[a]	133.85±0.01[g]	60.54±0.04[a]	8.44±0.03[c]

Values are means±standard deviation of triplicate analysis, WAC: Water absorption capacity, OAC: Oil absorption capacity.

Functional Properties of Selected Yam Species

Bulk Density

Bulk density is a measure of the heaviness of a flour sample (Oladele and Aina, 2007). The bulk density of the *Dioscorea* varieties ranged from 0.57±0.03[a] g/cm^3 for *Dioscorea bulbifera* to 0.87±0.02[a] g/cm^3 for *Dioscorea alata*. The result indicates that the analysed *Dioscorea* species were significantly different ($p \leq 0.05$) with *Dioscorea bulbifera* having the least bulk density while *Dioscorea alata* had the highest. However, this result is comparable to that obtained from different cultivars of aerial yam which showed 0.810±0.01 g/cm^3 for purple cultivars and 0.573±0.01 g/cm^3 for white cultivars (Ojinnaka *et al*., 2016). Bulk density indicates the relative volume of packaging material required, as well as material handling and application in wet processing in food industries (Tapti *et al*., 2018). *Dioscorea alata* having the highest bulk density amongst the analysed yam species is often better for dispersibility and pastes thickness reduction, which is vital in convalescent child feeding (Udensi and Eke, 2000) while *Dioscorea bulbifera* having the least bulk density is most useful in the formulation of infants weaning foods (Akpata and Akubur, 1999).

Water Absorption Capacity

The ability of flour or starch to hold water against gravity is referred to as water absorption capacity (Moure *et al*., 2006). The water absorption capacity of the *Dioscorea* varieties ranged from 148.73±0.03 % for *Dioscorea bulbifera* to 164.02±0.02 % for *Dioscorea rotundata*. The result indicates that the analysed *Dioscorea* species were significantly different ($p \leq 0.05$) with *Dioscorea rotundata* having the highest water absorption capacity. However, this result is comparable to that obtained from Oluwamukomi and Akinsola (2015) which showed 174.60±9.3 g/cm^3 for *Dioscorea rotundata* and 167.00±0.17 g/cm^3 for *Dioscorea bulbifera* by Tapti *et al*. (2018). The water absorption capacity is an important parameter since it shows if the flours may be used in aqueous food formulations, product bulking and uniformity, as well as in several baking applications (Iwe *et al*., 2016). Consequently, *Dioscorea rotundata* having the highest water absorption capacity than other analysed yam species is best suited for this.

Oil Absorption Capacity

Oil absorption capacity has been attributed to the physical entrapment of oil. The oil absorption capacity showed a significant difference ($p<0.05$) between the yam varieties. The oil absorption capacity of the *Dioscorea* species ranged from 133.85±0.01 % for *Dioscorea bulbifera* to 149.76±0.02 % for *Dioscorea rotundata*. The result indicates that the analysed *Dioscorea* species were significantly different ($p \leq 0.05$) with *Dioscorea rotundata* having the highest oil absorption capacity. However, this result is higher than the results obtained by Kimbonguila *et al.* (2019) which ranged from 83.33% to 100% for different cultivars of *Dioscorea alata* analysed. Oil absorption capacity is an

indication of the rate at which the protein binds to fat in food formulations. It is important for flavour retention and boosting the mouthfeel of food. Consequently, *Dioscorea rotundata* is best suited for this, since it has the highest oil absorption capacity than the other yam species analysed (Abu *et al*., 2005).

Swelling Capacity

The swelling capacity the *Dioscorea* varieties ranged from 8.44±0.03 % for *Dioscorea bulbifera* to 15.25±0.03 % for *Dioscorea alata*. The result indicates that the analysed *Dioscorea* species were significantly different ($p \leq 0.05$) with *Dioscorea alata* having the highest swelling capacity. However, this result is comparable to that obtained from Eke-Ejiofor and Owuno (2012) which showed 10.81±0.01 % for *Dioscorea dumenturom* and slightly higher than reports by Ojinnaka *et al*. (2016) that showed 7.58±0.01 % for *Dioscorea bulbifera* sample. Swelling power is a measure of starch hydration and is used to show associative binding force within starch granules (Bello and Ekeh, 2014). Basically, it shows how much water starch granules can store (Soison *et al*., 2015). As such, *Dioscorea alata* is the best flour sample amongst the other yam species analysed for the formulation of infant weaning foods, since it has the highest swelling capacity (Ojinnaka *et al*., 2016).

Dispersibility

The percentage dispersibility gives an indication of water absorption capacity. The dispersibility of the yam species ranged from 60.54±0.04 % for *Dioscorea bulbifera* to 72.17±0.01 % for *Dioscorea rotundata*. The result indicates that the analysed *Dioscorea* species were significantly different ($p \leq 0.05$) with *Dioscorea rotundata* having the highest dispersibility. However, this result is comparable to that obtained from Bashirat *et al*. (2015) which showed 72.17±0.01 % for *Dioscorea rotundata* and 62.85±0.01 % for *Dioscorea alata*. A dispersibility of fifty percent or more is considered high, implying that the higher the dispersibility, the better the flour's capacity to reconstitute in water to form a fine and consistent paste when mixing (Adebowale *et al*., 2005).

Table 3. Amino acid profile of selected yam species (g/100g).

Amino acids	*Dioscorea alata*	*Dioscorea rotundata*	*Dioscorea bulbifera*
Leucine	6.29±0.06^{a}	8.46±0.04^{a}	7.18±0.02^{e}
Lysine	4.37±0.05^{a}	4.04±0.02^{d}	4.82±0.01^{f}
Isoleucine	3.59±0.16^{b}	3.66±0.02^{c}	3.54±0.04^{i}
Phenylalanine	6.65±0.04^{e}	5.68±0.12^{e}	4.44±0.03^{a}
Tryptophan	0.95±0.01^{c}	BDL	0.89±0.01^{b}
Valine	4.36±0.02^{f}	5.78±0.03^{a}	3.97±0.03^{d}
Methionine	1.76±0.03^{a}	2.37±0.02^{b}	2.07±0.06^{c}
Histidine	1.98±0.02^{d}	1.83±0.02^{c}	1.78±0.02^{a}
Threonine	3.46±0.03^{i}	4.49±0.01^{h}	3.18±0.02^{b}
***Proline**	1.98±0.04^{a}	1.64±0.02^{a}	2.03±0.03^{e}
***Arginine**	8.94±0.03^{b}	6.97±0.03^{d}	8.27±0.03^{f}
***Tyrosine**	3.10±0.02^{b}	4.14±0.02^{e}	2.76±0.03^{a}
***Cystine**	1.09±0.01^{e}	2.78±0.03^{a}	1.22±0.01^{b}
***Alanine**	3.27±0.03^{c}	2.99±0.03^{c}	2.99±0.03^{d}
***Glutamic acid**	5.76±0.02^{f}	6.96±0.01^{h}	8.55±0.01^{c}
***Glycine**	2.14±0.02^{d}	2.04±0.02^{b}	1.68±0.02^{a}
***Serine**	2.22±0.02^{i}	3.00±0.01^{c}	2.73±0.02^{h}
***Aspartic acid**	5.49±0.02^{h}	5.96±0.02^{a}	6.22±0.02^{f}
TEAA	33.42±0.41 (49.61 %)	36.32±0.16 (49.88 %)	31.89±0.24 (46.60 %)
TNEAA	33.95±0.18 (50.39 %)	36.49±0.16 (50.12 %)	36.45±0.19 (53.34 %)

Values are means ± standard deviation of triplicate analysis, TEAA: Total essential amino acid, TNEAA: Total non-essential amino acid, BDL: Beyond detection limit, *non-essential amino acids.

Amino Acid Profile

Table 3 depicts the results of the amino acids profile. Amino acids are the building blocks of proteins and they serve an important role in the body. The findings imply that *Dioscorea* species are rich in amino acids such as essential and non-essential amino acids. The essential amino acids include lysine, phenylalanine, valine, threonine, isoleucine, methionine, histidine and leucine. While the non-essential amino acids are alanine, arginine, aspartic acid, serine, tyrosine, proline, cysteine and glutamic acid. However, the results obtained showed that the non-essential amino acid was more than the essential amino acids in the yam species. The total non-essential amino acid values were 33.95±0.18 g/100g, 36.49±0.16 g/100g and 36.45±0.19 g/100g representing 50.39 %, 50.12 % and 53.34 % for *Dioscorea alata*, *Dioscorea rotundata* and *Dioscorea bulbifera* respectively. While the total essential amino acid contents were 33.42±0.41 g/100g, 36.32±0.16 g/100g and 31.89±0.24 g/100g representing 49.61 %, 49.88 %

and 46.60 % for *Dioscorea alata, Dioscorea rotundata* and *Dioscorea bulbifera* respectively. This result can be compared to reports by Alozie *et al*. (2009).

Dioscorea alata had the least non-essential amino acid content with 33.95±0.18 g/100g while *Dioscorea rotundata* had the highest with 36.49±0.16 g/100g. Also, for the essential amino acid, *Dioscorea bulbifera* had the least content with 31.89±0.24 g/100g, while *Dioscorea rotundata* had the highest with 36.32±0.16 g/100g. As such from the research it can be seen that *Dioscorea rotundata* had the highest total amino acid content. Furthermore, the percentage ratio of the essential amino acid (EAA) to the total amino acid (TAA) in the samples ranged from 46.66 % to 49.88 %. These values are well above the 39% considered adequate for ideal protein food for infants, 26% for children and 11% for adults.

Glutamic acid appeared to be the most abundant amino acid in *Dioscorea bulbifera* at 8.55 ± 0.01^{c} g/100g. While Leucine was the highest in *Dioscorea rotundata* at 8.46 ± 0.04^{a} g/100g. Like valine and isoleucine, leucine is a branched-chain amino acid (BCAA) that is essential for protein synthesis and muscle repair. It also aids in blood sugar regulation, wound healing and the production of growth hormones (Shimomura *et al*., 2004).

Arginine which can also be considered a conditionally essential amino acid just like glycine was the most abundant amino acid in *Dioscorea alata* at 8.94 ± 0.03^{b} g/100g. The high level of arginine in *Dioscorea alata* indicates its usefulness as a supplement during pregnancy, trauma and illness (cancer).

Tryptophan which is a sole precursor to serotonin, a neurotransmitter that regulates appetite, sleep and mood, was quite low in all the samples but was relatively absent in *Dioscorea rotundata* (Slominski *et al*., 2002).

Histidine levels were highest in *Dioscorea alata* at 1.98 ± 0.02^{d} g/100g. This shows its likeliness to produce more histamine which is a neurotransmitter that is vital to immune response, digestion, sexual function, maintaining levels of hemoglobin and sleep-wake cycles. It is also required for the growth and repair of tissues, red blood cell production and protecting tissues from damage from radiation and heavy metals. It is especially very important for the formation of myelin sheaths, which are layers surrounding nerves that enables faster transmission of signals to the brain (NCBI, 2022). The minimum amino acid intake of 1.5 g/kg/day is reported to be necessary in preventing negative nitrogen balance while 2.5 g/kg/day is not advisable (ESPGHAN, 1997).

CONCLUSIONS

This study provided vital information on the proximate composition, amino acid profile and functional properties of the selected yam tuber species (*Dioscorea alata*, *Dioscorea rotundata* and *Dioscorea bulbifera*) analysed. The generally high carbohydrate content indicates that these species are reliable sources of energy. They can also be considered to be rich in fibre, mineral stuffing and have a high shelf life due to their generally high crude fibre and ash content as well as low moisture content respectively. The amino acid profile of these studied species, suggests that they are rich in protein. However, *Dioscorea rotundata* was the richest in amino acid content, as it had 36.32±0.16 g/100g and 36.49±0.16 g/100g, for essential and non-essential amino acids respectively. Furthermore, the wide variation observed in the functional properties of the flour samples serves as a database for the selection and improvement of the yam species for specific food applications to stimulate their industrial processing and utilization.

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