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Nutrient Composition and Functional Properties of Major Cultivars of Aerial Yam (Dioscorea bulbifera) in Nigeria

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Abstract
Flour from three major cultivars (white, purple and yellow) of aerial yam (*Dioscorea bulbifera*) in South-East Nigeria were analyzed and compared in terms of their nutrient and functional properties. The results of the proximate analysis showed that flour from the yellow cultivar had the highest protein value of 6.27% while the white cultivar produced flour with the lowest protein content of 4.92%. The three cultivars had relatively low values for ash, fat and crude fibre. Though the yellow cultivar flour had the highest ash and fat content values of 2.67% and 0.98% respectively; the white cultivar flour recorded the highest crude fibre value of 1.17%. The proximate results also revealed moisture content range of 6.99 – 7.12% for all the three cultivars of aerial yam. The result of the antinutritional factors determined (tannin, phytate, alkaloids, oxlate, flavonoid) were low and falls within acceptable limits for consumption. The flour samples recorded bulk density values of 0.60g/cm^3 (purple cultivar), 0.62 g/cm^3 (white cultivar) and 0.63 g/cm^3 (yellow cultivar). The swelling capacity of the flour samples were higher in the yellow cultivar (1.56%) while the least swelling power was recorded by the purple cultivar (1.25%). The three major cultivars (white, purple and yellow) of aerial yam have great potential for use in different food product development.
Keywords: aerial yam, nutrient, functional properties

1.0 Introduction

Root and tubers are the most important food crops since time immemorial in the tropics and subtropics (Behera *et al*., 2009). Yams (*Dioscorea*) belong to *Dioscoreaceae* family. They are herbaceous plants with twine. Approximately 600 *Dioscorea* species are eaten in various parts of the world. (Agbor-Egbe and Treche, 1995).

Yams have been suggested to have nutritional superiority when compared with other tropical root crops. They are reported as good sources of essential dietary nutrients (Arinathan *et al.,* 2009). The edible tubers of yams (*Dioscorea spp*.) are important staple food for millions of people in tropical countries especially in West Africa (Martine and Mario, 1991). Yams are annual or perennial tuber-bearing and climbing plants with over 600 species in which only few are cultivated for food and medicine (IITA, 2006).

Aerial yam (*Dioscorea bulbifera*) is a variety of yam grown in some part of the world. This bulbils-bearing yam belongs to the Order *Dioscoreal*, Family *Dioscoreaceae*, and Genus *Dioscorea* and is an unpopular specie among the edible yam species. It is cultivated in the Southeast Asia, West Africa, and South and Central America. The wild form also occurs in both Asia and Africa (Nwosu, 2013). Aerial yam (*Dioscorea bulbifera*) is recorded to be an unpopular yam among the edible yam species which unlike the traditional yam produces aerial bulbis that look like potatoes hence the name aerial/air potatoes (Igyor et al., 2004). This specie of yam is consumed by a small number of communities and is generally underutilized both at subsistence and commercial levels. This study is aimed at evaluating the nutrient composition and functional properties of flour from major cultivars (white, purple, yellow) of aerial yam (*Dioscorea bulbifera)*.

2.0 Materials and Methods

2.1 Sample Collection

Three cultivars of aerial yam (*Dioscorea bulbils*) were obtained from Ubani ibeku main market Umuahia Abia State, Central market in Afikpo North Ebonyi State, and Ntigha market in Isialangwa North, Abia State. They were identified at the Yam Programme Section of the National Root Crops Research Institute Umudike as white, purple and yellow cultivars. The reagents that were used for different analysis were of high analytical grade

2.2 Sample Preparation

The method described by Nwosu (2013) was used in the aerial yam flour preparation. The freshly harvested tubers of the aerial yam (*Dioscorea bulbils*) were sorted to remove unwholesome ones, and then washed, cleaned and rinsed very well with copious amounts of distilled water. *Dioscorea bulbifera* flour was prepared by peeling and slicing the bulbils into 1cm thick and washing them in distilled water to remove all grits and mucilaginous material as much as possible. The slices were blanched for 5 minutes and were oven dried for 72 hours at 60^{0}C. The dried slices were milled in a hammer mill into very fine particle size and the milled slices were sieved with

1mm test sieve and were stored in an airtight polyethylene bag prior to analysis.

2.3 Proximate Analysis

The aerial yam flour samples were analyzed for moisture, ash, fibre, protein and fat contents according to the method of AOAC (2000)|. The carbohydrate content was determined by difference.

2.4 Antinutrient Determination

2.4.1 Determination of Oxalate

The permanganate titration method described by *(Onwuka, 2005).* A measured weight of the sample was suspended in 100mls of distilled water and 5mls of 6mHCl was added. The mixture was digested by heating at 100^0C for an hour. It was cooled and filtered. Then the pH was adjusted by adding 2 drops of methyl red indicator followed by drop wise addition of concentrated aqueous ammonia solution (NH_40H) until a faint yellow colouration was obtained, at pH between 4-4.5. The mixture was heated to 90^0C in a water bath, cooled and filtered (to remove ferrous ion precipitates). The filtrate was again heated 90^0C and 10mls of 5% $CaCl_2$ solution was added with constant steering. It was allowed to cool and then allowed to stay overnight in the refrigerator (5^0C) the mixture was centrifuged at 3000xg for 6 minutes. The supernatant was decanted and the precipitate was dissolved in 10mls of 20% H_2S0_4. The solution was made up to 100mls with distilled water and was titrated against 0.05 KM_n04 solutions to a faint pink colour which persisted for 30 seconds. The oxalate content was given by the relationship that 1ml of 0.05m

$KM_n{}^o4$ solution = 0.00225g oxalate

Calculation of oxalate content

$$\% \text{ oxalate} = \frac{100 \times \text{titre} \times 0.00225}{W}$$

Where W = weight of sample used

2.4.2 Determination of Phytate

The oberlease Spectrophotometer method described by (*Onwuka, 2005)* was used. A weighed processed sample (2g) was extracted by mixing it with 50mls of 0.2N HCl solution and shaken for 30mins. It was filtered through whatman No. 42 filter paper to obtain the extract. Meanwhile standard phytate solution (sodium phytate), was prepared and diluted to a chosen concentration. An aliquot, 0.5mls of the extract as well as 1ml of the standard phytate solution was put in separate test tubes and treated with 1ml ferric solution (ferric ammonium sulphate). The tubes were corked with stoppers and boiled in a water bath for 30mins. They were cooled in ice for 15mins and then allowed to attain room temperature, then 2.0mls of 2,2 –Bipyrimidine solution was added to each tube, mixed well and their respective absorbance was read in a spectrophotometer at 519 nanometer wavelength.

Calculation of phytate content of a sample

$$\% \text{ phytate} = \frac{100}{w} \times \frac{au}{as} \times \frac{C}{1000} \times \frac{vt}{va}$$

Where W = weight of sample

Au = absorbance of sample

As = absorbance of std phytate solution

C = concentration of std phytate (mg/ml)

Vt = total extract volume

Va = volume of extract used

2.4.3 Determination of Tannin

Tannin content of the sample was determined by Folin Denis Colometric method *(Krik and Sawyer, 1998).* A measured weight of the processed sample (5.0g) was mixed with distilled water in the ratio of 1:10 (w/v). The mixture was shaken for 30 minutes at room temperature filters the obtain the extract

A standard tannic acid solution was prepared, 2ml of the standard solution and equal volume of distilled water was dispersed into a separate 50ml volumetric flask to serve as standard and reagent blank respectively. Then 2mls of each of the sample extract were put in their respective labelled flask. The content of each flask was mixed with 35ml distilled water and 1ml of the Folin Denis reagent was added to each. This was followed by 2.5mls of saturated Na_2C0_3 solution. There after each flask was diluted to the 50ml mark with distilled water and incubated for 90 minutes at room temperature. Their absorbance was measured at 760 min in a Spectrophotometer with the reagent blank at zero

Calculation of tannin content

$$\% \text{ tannin} = \frac{100}{w} \times \frac{au}{x} \times \frac{C}{as} \times \frac{Vt}{Va}$$

W = weight of sample

Au = absorbance of test sample

As = absorbance of test sample

C = concentration of standard tannin solution
Vt = total volume of extract
Va = volume of extract analyzed

2.4.4Determination of Alkaloids

The determination of alkaloid was done using method described by Harborne (1973) method. Five grame of the sample was weighed into a 250 ml beaker and 200 ml of 10% acetic acid in ethanol was added and covered and allowed to stand for 4 h. This was filtered and the extract was concentrated on a waterbath to one-quarter of the original volume. Concentrated ammonium hydroxide was added dropwise to the extract until the precipitation was complete. The whole solution was allowed to settle and the precipitated was collected and washed with dilute ammonium hydroxide and then filtered. The residue is the alkaloid, which was dried and weighed.

2.4.5 Determination of Flavonoid.

Flavonoid determination by the method of Bohm and Kocipai-Abyazan (1994): Ten gramme of the plant sample was extracted repeatedly with 100 ml of 80% aqueous methanol at room temperature. The whole solution was filtered through whatman filter paper No 42 (125 mm). The filtrate was later transferred into a crucible and evaporated into dryness over a water bath and weighed to a constant weight.

2.5 Functional Properties

2.5.1 Bulk Density

The method of Onwuka (2005) was used. Bulk density of flour samples were determined by
weighing the sample (50g) into 100ml graduated cylinder, then tapping the bottom ten times against the palm of the hand and expressing the final volume as g/ml.

2.5.2 Swelling Index Determination

Three gram portions (dry basis) of each flour were transferred into clean, dry graduated (50ml) cylinders. Flour samples were gently levelled into it and the volumes noted. Distilled water (30ml) was added to each sample; the cylinder was swirled and allowed to stand for 60 minutes while the change in volume (swelling) was recorded every 15 minutes. The swelling power of each flour sample was calculated as a multiple of the original volume as done by Ukpabi and Ndumele (1996).

2.5.3 Viscosity

The method of Onwuka (2005) was adopted. Ten (10) percent of the flour was suspended in distilled water and mechanically stirred for 2h at room temperature. Oswald type Viscometer was used to measure the viscosity.

2.5.4 Gelatinization point

10 g of flour sample was suspended in distilled water in a 250 ml beaker and made up to 100 ml flour suspension. The aqueous suspension was heated in a boiling water bath, with continuous stirring using a magnetic stirrer. A thermometer was then clamped on a retort stand with its bulb submerged in the suspension. The heating and stirring continued until the suspension began to gel and corresponding temperature was recorded 30 secs after gelatinization was visually noticed.

2.5.5 Wettability

The method of Onwuka (2005) was used. Into a 25ml graduated cylinder with a diameter of 1cm,1g of sample was added. A finger was placed over the open end of the cylinder which was invested and clamped at a height of 10cm from the surface of a 600ml beaker containing 500ml of distilled water. The finger was removed and the rest material allowed to be dumped. The wettability is the time required for the sample to become completely wet.

2.5.6 Water Absorption Capacity Determination

The method of Abbey and Ibeh (1998) was adopted for determination of water absorption capacity. Flour sample (1g) of each treatment was weighed separately (and also together with a clean, dry centrifuge tube, into which it was placed). Distilled water was mixed with the flour to make up to 10ml of dispersion. It was then centrifuged at 3500 rpm for 15 minutes. The supernatant was discarded and the tube with its contents reweighed as gram water absorbed per g of sample. The gain in mass was the water absorption capacity of the flour sample.

2.6 Statistical Analysis

Statistical analysis of all the data were subjected to Analysis of Variance (ANOVA) using SPSS version 17.0 for windows, SPSS inc. Means were separated using Least Significant Difference (LSD).

3.0 Results and Discussion

The proximate composition of the cultivars (white, purple and yellow) of aerial yam are presented in Table 1. There was significant difference in all the three major cultivars. The moisture content of the purple cultivar was higher (7.12%) while the yellow cultivar had the least moisture content value of 6.99%. Nwosu (2013) reported 10.87% moisture content in 100% aerial yam flour while Ogbuagu (2008) reported moisture content values of 7.38% and 7.02% in cooked and uncooked *Dioscorea bulbifera* (potato yam) and 7.04% and 6.53% in

Dioscorea dumentorum (bitter yam). Amandikwa (2012) in her study on the proximate and functional properties of open air, solar and oven dried cocoyam flour reported moisture content values in the range of 6.5 – 13.2%. The moisture content of every food sample reflects the quantity of solid matter in the sample. The rate of spoilage is closely related to the amount of moisture present. The higher the amount of moisture present, the higher the rate of spoilage (Sanful et al., 2013). Cultivars with low moisture content may have a longer shelf life.

The protein content of the samples varied significantly between 4.92 – 6.27% and was highest in the yellow cultivar. The values obtained in this study differed slightly from the values obtained by Shajeela et al., (2011) which recorded 7.28% for *D. bulbifera var vera* while Sanful and Engmann (2016) in their study of the physico-chemical and pasting properties of flour and starch from aerial yam reported protein content value of 7.12%. The ash and crude fibre contents of the three major cultivars were significantly different and ranged between 2.58 -2.67% and 1.03- 1.17% respectively. These values are in agreement with the values reported in literature (Ogbuagu, 2008; Kouakou et al., 2010). However the observed variations in the protein content could be attributed to the differences in the cultivars, cultural, climatic and other environmental factors during their growth stage.

The crude fat content of the cultivars were low and in the range of 0.88 – 0.98%. This is contrary to reports by Shajeela et al., (2011) who reported crude lipid content of 6.14% for *D. bulbifera var vera* as well as Sanful and Engmann (2016) who reported fat content of 1.59% in aerial yam flour from Ghana . Lipids contribute to the palatability of the crops. All the cultivars have high carbohydrate content values in the range of 81.93 – 82.22%. The high carbohydrate content indicates that the aerial yam cultivars are an excellent source of energy. Enwere (1998) also reported that carbohydrates predominate in all the solid nutrients in roots and tubers.

The antinutritional factors determined namely: tannins, phytate, oxalate, alkaloids and flavonoids are presented in Table 2. The white cultivar produced flour with higher tannin content value of 0.72mg/100g, phytate 0.12mg/100g and flavonoid 1.63mg/100g while the yellow cultivar had the lowest values in the flavonoid, oxalate and alkaloid contents (1.54mg/100g; 0.24mg/100g; 0.92mg/100g). The alkaloid and oxalate contents of the samples reduced appreciably probably due to the blanching and oven-drying methods used during flour production. The bitter principles of *D. bulbifera* may be due to the presence of tannins in them (Okwu and Ndu, 2006). The small quantities of tannin available in the tubers act as a repellants against rot in yams. The level of tannins, phytate, alkaloids and oxalate were found to be lower when compared with the earlier reports of the tubers of *Dioscorea alata, D. cayenensis, D. rotundata and D. esculenta* (Esuabana, 1982). Tannins are water soluble compounds (Uzogara *et al*., 1990) and as such can be eliminated by soaking followed by cooking (Singh and Singh, 1992; Shanthakumari *et al*., 2008). Oxalic acid and oxalates occur naturally in plants but they have little or no useful effect on human health as high levels in diets lead to irritation of the tissues; the digestive system, particularly the stomach and kidney (Hodkinson, 1977). Some alkaloids are toxic to animals. In spite of the medicinal uses of alkaloids, they cause gastro intestinal upsets and neurological disorders. However, alkaloids, including the toxic ones are found more in the wild and bitter varieties of yams (Eka, 1985). All the cultivars produced low level of antinutrients that are within acceptable limit for human consumption.

The results obtained for bulk density, water absorption capacity, swelling index, emulsion capacity, wettability, gelation and viscosity of flour produced from three major cultivars (white, purple and yellow) of aerial yam are shown in Table 3. There was no significant difference ($p>0.05$) in the bulk density of flour from white and yellow cultivars of aerial yam. Though the bulk density values were in the range of 0.60 – 0.63g/cm^3 with the purple cultivar having the least value of 0.60 g/cm^3. Hayata *et al.* (2006) reported that drying decreases the bulk density of flour. Bulk density gives an indication of the relative volume of packaging material required. Low bulk density of flour are good physical attributes when determining transportation and storability since the products could be easily transported and distributed to required locations (Agunbiade and Sanni, 2003). Low bulk density is also advantageous for the infants as both calorie and nutrient density is enhanced per feed of the child (Onimawo and Egbekun, 1998).

There was significant difference in the water absorption capacity of flour samples at $P<0.05$. The white cultivar produced flour with the highest water absorption capacity of 6.71g/g followed closely with yellow cultivar with WAC of 6.61g/g. A higher WBC is relevant in ensuring that food products possess good texture as well as having the ability to stabilize starches, which invariably reduces retrogradation and syneresis during storage, retorting and freezing (Baker et al., 1994; Ellis et al., 2003). Water absorption capacity of the flour will determine the rate of water absorption by the flour sample which will affect the rate at which the water granules swell during reconstitution of the flour (Nwosu, 2013). The swelling index of the samples were closely in the range of 1.25 – 1.56g/g. The swelling index depends on the water intake of the flour.

There was significant difference in the gelling point of the flour samples. The gelatinization point of the aerial yam flour samples varied from 80.03°C – 80. 47°C with flour from white cultivar having the lowest while sample from the purple cultivar have the highest value. Amandikwa (2012) reported gelatinization temperature of 82+ 1.7°C to 90+ 2.16°C in her study of the proximate and functional properties of open air, solar and oven dried cocoyam flour. High gelling point indicates low starch content. The gelation concentration of air yam is

lower when compared to that of other yam species. The difference could be due to the difference in amylose content of the yams. Raspier and Coursey (1967) reported that amylose molecules are believed to form gels more rapidly than amylopectin molecules. The greater the percentage of amylose fraction, the quicker the formation of gels. This result agreed with Moore et al. (1984) and Richard (1991) who showed that the resultant structural and organloleptic characteristics of food product are reflection in single or combination of the specific starch or flour fractions.

The flour samples from the major cultivars of aerial yam all had low viscosity values. The factors which may influence this property include the size and shape of the starch granules, presence or absence of fat and protein and perhaps molecular size and degree of branching of starch fractions (Schoch and Maywald, 1968). Low wettability values were recorded for all the flour samples from the aerial yam cultivars. The values were in the range of 1.03 – 1.29secs. It has also been discovered that the lower the level of denatured protein in the starch, the slower it takes to get wetted or imbibe water (Oti and Akobundu, 2008).

4.0 Conclusion

Based on the nutritive and functional properties evaluation studies on the flour from three major cultivars (white, purple and yellow) of aerial yam found in South-East Nigeria, it can be summarized that the purple and yellow cultivars had higher protein content than the white cultivar. The three cultivars also had low values for the antinutrients determined which could be due to the heat treatment given to them during production into flour. All the investigated samples also exhibited variations in the levels of the functional properties determined but can be well incorporated into weaning foods and other food product formulations.

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TABLE 1. PROXIMATE COMPOSITION OF FLOUR FROM THREE MAJOR CULTIVARS OF AERIAL YAM (%)

Samples	Moisture	Ash	Fat	Crude protein	Crude fibre	Carbohydrate
White Cultivar Flour	7.12±0.00	2.62±0.01	0.91±0.01	4.92±1.33	1.17±0.01	81.93±0.16
Purple Cultivar Flour	7.07±0.01	2.58±0.01	0.88±0.01	6.18±0.00	1.07±0.01	82.22±0.01
Yellow Cultivar Flour	6.99±0.01	2.67±0.00	0.98±0.00	6.27±0.00	1.03±0.00	82.05±0.14

TABLE 2. ANTINUTRIENT COMPOSITION OF FLOUR FROM THREE MAJOR CULTIVARS OF AERIAL YAM (mg/100g)

Samples	Tannin	Phytate	Alkaloids	Oxalate	Flavonoid
White Cultivar Flour	0.72±0.00	0.12±0.01	0.94±0.01	0.25±0.00	1.63±0.00
Purple Cultivar Flour	0.69±0.01	0.10±0.00	0.96±0.00	0.26±0.00	1.59±0.01
Yellow Cultivar Flour	0.68±0.00	0.11±0.00	0.92±0.00	0.24±0.00	1.54±0.01

TABLE 3: FUNCTIONAL PROPERTIES OF FLOUR FROM THREE MAJOR CULTIVARS OF AERIAL YAM

Samples	Bulk density (g/cm^3)	Water absorption capacity (g/g)	Swelling Index (g/g)	Gelation (^oC)	Wettability (secs)	Viscosity (Cp)
White Cultivar Flour	0.62±0.00	6.71±0.03	1.27±0.00	80.03±0.03	1.07±0.00	1.5600E2±1.00
Purple Cultivar Flour	0.60±0.00	4.22±0.05	1.25±0.00	80.47±0.03	1.03±0.00	1.5200E2±1.00
Yellow Cultivar Flour	0.63±0.00	6.61±0.01	1.56±0.00	80.07±0.06	1.29 +0.01	1.5367E2±0.66