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Estimation of Nutritional and Starch Characteristics of *Dioscorea alata* (Water Yam) Varieties Commonly Cultivated in the South-Eastern Nigeria

A. O. Oko[1] and A. C. Famurewa[2*]

[1]Department of Biotechnology, Ebonyi State University, P.M.B. 053 Abakaliki, Ebonyi State, Nigeria.
[2]Department of Medical Biochemistry, Faculty of Basic Medical Sciences, Federal University, Ndufu-Alike Ikwo, P.M.B. 1010, Abakaliki, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author AOO designed the study, performed the statistical analysis. Author AOO carried out the sample analyses. Author ACF wrote the first draft of the manuscript and managed literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background: Studies on the nutritional and mineral compositions of staple foods will provide evidence to regulate intake of certain common foods for optimal health condition.
Aim: To estimate the proximate, mineral and starch characteristics of five local varieties, *D. purpurea*, *D. atropurpurea*, *D. liliopsida* (purple yam), *D. vilgaris*, and *D. villosa* of *Dioscorea alata* grown in Izzi Area of Ebonyi State, Nigeria.
Methodology: Five (5) commonly cultivated varieties of *D. alata* were sampled, each variety in triplicates, and prepared for analysis by peeling, dicing, drying and milling into flour. The proximate, nutritional and starch characteristics were determined by standard methods. Minerals were quantified by Atomic Absorption Spectrophotometric Method.

**Corresponding author: E-mail: clementademola@yahoo.com;*

Results: The results showed that the varieties has moisture content 9.20-10.30%, ash content 2.48-3.53%, fiber content 3.31-3.53%, fat content 1.62-2.41%, protein content 8.40-10.46%, and carbohydrate content 70.88-73.90%. There were significant differences (*P<.05*) in the proximate compositions within the varieties. The ranges of minerals in mg per kg (dry weight) were Na 16.38-24.84, K 97.78-141.14, Ca 79.99-269.75, Mg 18.55-31.53, P 114.65-211.63, Fe 15.18-30.86. Glycaemic index ranged from 35.56-41.31, amylose content 12.42-16.11% and gelatinization temperature 85.00-87.00°C.

Conclusion: The results indicate that the protein and fiber contents of *D. alata* varieties estimated in this study were high. The low glycemic index confirmed the yam varieties as low glycemic index food. It was concluded that the yam varieties are good sources of protein nutrient and suitable staple food for the diabetics. However, low mineral compositions were reported. Therefore, there is a need for intense cultivation of improved varieties for improved mineral intake from the yam by the consumers.

Keywords: Dioscorea alata; proximate composition; mineral composition; nutritional quality; starch.

1. INTRODUCTION

Nutritional quality and mineral composition of primary agricultural and cultural foods in developing countries is a major health problem which has manifested as diet-associated disorders among the African population. Food and nutrition are known important modifiers of disease initiation and development. The major causes of illness and death appear to be the chronic degenerative diseases, such as cancer, heart disease, arthritis, respiratory diseases, diabetes, hypertension, cognitive impairment and various toxic states, which could be averted with proper nutrition and diet. Beside good quality of water, a well-balanced diet of essential macronutrients and micronutrients is required to achieve optimal health condition [1]. In recent years, there has been a tremendous interest in the field of nutrition on the assessment of nutrients, vitamins and mineral composition of staple foods considered to be economically, socially and culturally important in many tropic and subtropic regions of the world. In these regions, yam is being investigated for its whole nutritional quality. It is traditionally known that yam tubers have potential ability to provide one of the cheapest sources of dietary energy in the form of carbohydrate [2,3].

Yam (*Dioscorea species*) is a climbing, vigorously twining herbaceous plant that coils swiftly around the stake. They are perennial through root system but are grown as annual crops [4]. Yams are of great economic importance and nourishment to the people of Africa, the Caribbean, Asia and America [5]. They are well integrated into the social, cultural and religious lifestyle of the people who cultivate and consume them [6]. Large quantity consumption has been reported to provide the body not only with carbohydrate but also with vitamins and minerals [7]. It is second to cassava in tropical root crops but first in higher vitamin C content (40-120 mg/g edible portion) and crude protein content (40-140 g/kg dry matter) [8]. Yam belongs to a family of *Dioscorea* with over 600 species in which only few are cultivated for food and medicines [9]. The most cultivated species in Nigeria are the white yam (*D. rotundata*), yellow yam (*D. cayenensis*), water yam (*D. alata*) and trifoliate yam (*D. dumentorum*) [10].

Dioscorea alata, commonly called water yam or ten month yam is the most widespread yam species and more important as food in West Africa and the Caribbean than in Asia and in America where it originated and has been competing with the most important native species, *D. rotundata*. *D. alata* is an excellent source of starch, which provides calorific energy and protein three times more superior than the one of cassava and sweet potato [11,12]. It has low sugar content necessary for diabetic patients [13]. Cultivars of *D. alata* possess higher contents of protein, vitamin C and low lipids than *D. cayanensis*, *D. rotundata* and *D. trifida* [14]. It has comparative advantage for sustainable production due jto its better agronomic characteristics such as ease of propagation and yield, high nutritive value and longer storage of the fresh tubers [5]. It is considered to be among the most primitive of the angiosperms and contains many species of which only about few are considered edible. *D. alata* is popular and prevalent within Abakaliki agro-ecological zone of Ebonyi State where it is called “Mbala or Nvula” (Igbo names) [4]. Cultivated varieties of *Dioscorea alata* in this area includes, *D.*

purpurea (Okwale nkata), *D. atropurpurea* (Nvula ite), *D. liliopsida* (Nvula eke) or purple yam, *D. vilgaris* (Nvula ji), *D. villosa* (Akpuru akputo), *D. harmiltonii*, *D. persimilis* etc [9].

The objective of this study was to determine the nutritional and starch characteristics of five major varieties of *D. alata* commonly cultivated by the Igbo people of Ebonyi State. Results from the study will provide scientific evidence for the nutritional quality of the varieties, and possibly the need for improved varieties for cultivation in the area.

2. MATERIALS AND METHODS

2.1 Sample Collection

Five (5) variety samples of *D. alata*, sample A (*D. purpurea*), sample B (*D. atropurpurea*), sample C (*D. liliopsida*), sample D (*D. vilgaris*) and sample E (*D. villosa*) were obtained from different parts of Izzi Local Government Area of Ebonyi State, Nigeria. The yam tubers were carefully selected to avoid rot, bruises or sign of spoilage.

2.2 Sample Preparation for Analysis

The yam tubers were cut into two, thoroughly washed, peeled and cut into small pieces (cubes). It was sun-dried for 3 to 4 days, packaged and labeled sample A-E. Each sample variety was prepared in triplicates. The dried pieces were milled into powdered samples and sieved through 250 µm mesh and stored in plastic container for nutritional and mineral analysis.

2.3 Determination of Proximate Compositions and Starch Characteristics

The moisture and crude fibre content of each variety were determined by drying the sample in an oven at 105°C for 6 hrs and values expressed in percentage. The ash content was determined by incinerating in a muffle furnace 2 g of each sample at 550°C for 2 hrs [15]. Protein content, expressed in percentage, was obtained using Kjeldhal method (N × 6.25) by AOAC [15]. Crude fat content was estimated by Soxhlet extraction technique using petroleum ether (40-50°C) [16]. The carbohydrate content was determined by difference (% carbohydrate = 100% - sum of percentages of moisture, fat, ash, fibre and crude protein contents). Iodo-colorimetric method [17] based on the chemical reaction of starch and iodine was used to determine amylose content. Glycemic Index was calculated from the hydrolysis index expressed in percentage (area under curve procedure) as described by Hettiaratchi et al. [18]. To determine the gelatinization temperature, 10% suspension of the flour sample was prepared in a test tube. The aqueous suspension was heated in a boiling water bath, with continuous stirring. Gelatinization was observed after 30s and measured accurately as the gelatinization temperature.

2.4 Determination of Mineral Content

Sodium, potassium, calcium, magnesium, phosphorus and iron were analysed after digestion with HNO_3 and H_2SO_4, using Atomic Absorption Spectrophotometer (Model Buck 2006, Buck Scientific, USA). Phosphorus content was determined with the use of phosphomolybdate complex method.

2.5 Statistical Analyses

All measurements were carried out in triplicates and the mean triplicate values of the five varieties were subjected to One-Way ANOVA Duncan's t-test. Differences considered significant at 5% ($P<.05$).

3. RESULTS AND DISCUSSION

3.1 Proximate Compositions of *D. alata* Varieties

The proximate composition of *D. alata* varieties is presented in Table 1. The moisture content of the local varieties ranged from 9.2% for *D. atropurpurea* to 10.30% for *D. vilgaris*, with a mean of 9.76%. The mean values for moisture content showed significant differences ($P<.05$). Moisture content is an important factor in food quality, preservation, and resistant to deterioration. It is related to many properties that affect the quality and shelf life of food and food products, including bacterial growth and texture [19]. Low moisture content of a food indicates its stability for prolonged storage or permissive rate of spoilage. In this study, local varieties of *D. alata* have lower moisture content than those reported in the literature [5,8,20-22] Comparable to our result, Udensi et al. [4] have reported moisture content of 6.05% for local best variety of *D. alata*. In the same study, five high yielding and disease resistant water yam varieties gave low moisture content. The moisture content of

Table 1. Proximate composition of *Dioscorea alata* varieties (% dry weight)*

Proximate composition	Sample Varieties of *Dioscorea alata* (water yam)				
	A	B	C	D	E
	D. purpurea	***D. atropurpurea***	***D. liliopsida***	***D. vilgaris***	***D. villosa***
Moisture content	9.90±0.14[b]	9. 20±0.00[d]	9. 90±0.14[b]	10.30±0.14[a]	9.5±0.14[c]
Ash content	3. 40±0.14[a]	3. 45±0.07[a]	3. 53±0.04[c]	2.48±0.04[c]	3.14±0.04[b]
Crude fibre content	3. 38±0.03[b]	3.50±0.00[a]	3.53±0.01[a]	3.31±0.01[b]	3.33±0.04[b]
Fat content	1.99±0.01[d]	2.15±0.07[c]	2.39±0.01[b]	1.62±0.03[e]	2.41 ±0.01[a]
Protein content	10.46±0.06[a]	10.15±0.13[b]	8.71±0.06[c]	8.40±0.13[d]	10.02±0.06[b]
Carbohydrate content	70.88±0.78[c]	71.55±0.27[b]	71.95±0.24[b]	73.90±0. 04[a]	71.57±0.15[b]

Values are Mean±SD of triplicate determinations; means along a row with the same superscript are not significantly different, P<.05

sweet potato, 8.72% and red cocoyam, 9.02% corroborated the moisture content of *D. alata* varieties in this study [20] These local varieties of *D. alata* would be suitable for prolonged storage and more stable for industrial food product processing.

The crude fiber content ranged between 3.31 to 3.53% with a mean value of 3.41%. There was no significant difference (*P>.05*) between *D. atropurpurea* and *D. liliopsida* fibre contents, however, significant difference (P<.05) was observed between these varieties and others. Fibers in foods are plant non-digestible carbohydrate and lignin and have been shown to have health benefits. Studies have shown that increase in fiber consumption in foods reduces the incidence of obesity, cardiovascular disease, type 2 diabetes, digestive disorders and some cancers [23]. Fiber consumption also softens stools and lowers plasma cholesterol level in the body [24]. The mean fiber content in the current study is comparable to the 3.96% reported by Shajeela et al. [25]. Lower values have been reported for other varieties of *D. alata* [4], *D. rotundata*(white yam) and *Colocasia esculenta* (white cocoyam) [26]. The result indicates that the local varieties of *D. alata* investigated could be a source of dietary fiber with nutritional benefits.

The range of crude protein content (8.40-10.46%) was in agreement with the earlier studies [4,5,21,25,27]. Strikingly, a study by Alinnor and Akalezi, [26] reported crude protein content of 0.087% for *D. rotundata*, a widely cultivated and the most preferred specie of yam in Nigeria and West Africa. In earlier study carried out by Oyenuga [28], he found the protein content of *D. alata* to be in the range of 7.26-8.10 while that of *D. rotundata* 4.42-5.87. This suggests a higher nutritional potential for *D. alata*, at least in terms of protein content than *D. rotunda*. Intake of staple foods with low protein content may lead to several impaired biological processes in the body. This shows that *D. alata* is rich in protein and can provide this nutrient to the consumers.

The highest carbohydrate content in this study was 73.90% with no significance difference *(P>.05*) within the varieties. The result is in line with the findings of studies [27,29] which reported 76.57% and 75.65% respectively for *D. alata* but lower when compared with the carbohydrate contents reported for red cocoyam, 86.69% and sweet potato, 86.90% [29]. Improved varieties of *D. alata* contained a higher carbohydrate content ranged between 81.53 to 87.64% [4]. However, lower carbohydrate content has been reported for commonly consumed root tubers in Nigeria. Alinnor and Akalezi, [26] reported 40.61% and 57.78% carbohydrate contents for white yam (*D. rotundata*) and white cocoyam (*Colocasia esculenta*) respectively. *D.alata* varieties in this study may be considered as tolerable sources of enegy and this may be related to the recommendation of water yam and some other cocoyam varieties for the diabetics.

3.2 Starch Characteristics of *D. alata* Varieties

Table 2 presents the starch characteristics of the yam varieties. The glycemic indices of *D. alata* investigated ranged from 35.56 to 41.31, with mean value of 38.62. The glycemic index (GI) concept is based on the difference in blood glucose response after ingestion of the same amount of carbohydrates from different foods, and possible implications of these differences for health [30]. Based on this, previous studies have been able to provide evidence for the

classification of foods as low (≤ 55), intermediate (56 to 59) and high (≥70) GI foods. The glycemic index values of yam reported in literature ranged from low to high and generally the species and varieties were unspecified [30]. However, low GI foods have been associated with reduced risk for chronic and metabolic diseases including diabetes [31-34]. The GI phenomenon expresses the glycemic response to a food after ingestion of 50g of available carbohydrate and the possible implications on health [30]. Foods that raise blood glucose level quickly have high GI levels, whereas foods with low GI will raise blood glucose levels slowly [35,36]. The reported GI in the current study is classified as low for the local yam varieties specified in Table 2. A study reported a GI of 67 for white yam (*D. rotundata*), 56 for three-leaved yam (*D. domentorum*) and 24 for water yam (*D. alata*) [21]. Among the Chinese starch foods, a GI of 52 was obtained for yam, although the specie unspecified [37]. It is noteworthy that the *D. alata* varieties investigated in the current study are low-GI foods. Inconsistent in GI for yam may be due largely to different species. The yam varieties may be considered in diet and more importantly among the diabetics who are concerned about their postprandial blood glucose levels for effective diet management.

The amylose content of the varieties varied significantly (*P<.05*) and *D. purpurea* was found to have the lowest amylose content (12.42±0.03%) while *D. vilgaris* had the highest (16.11±0.56%). A similar result was obtained in a study that demonstrated inverse correlation between amylose content and swelling power of different food starches, reporting 12.24% amylose for *Dioscorea esculenta* [38]. However, previous studies have reported comparatively higher values for amylose content in *D. alata*, although varieties investigated were not specified [39,40]. Riley et al. [41] analysed eight *D. alata* cultivars grown in Jamaica and reported amylose content that ranged from 20.117 to 23.001%. The difference in amylose content observed may be attributed to genetic variations among the varieties, as it was found that the amylose content of starches is affected by the expression of the amylose extender gene [42]. The gelatinization temperature range of starch in the varieties was 85.00 to 87.00°C. The gelatinization temperature obtained was considerably higher than for wheat starch (55.6 to 63.0°C) according to Lineback and Ke [43]. This high temperature suggests slow swelling property of the starch granules which may be connected with protein-amylose formation [41]. In biotechnological application of foods for value-added products, starch with lower gelatinization temperature to minimize energy cost and for shorter cooking time may be more preferred.

3.3 Mineral Compositions of *D. alata* Varieties

Minerals are biological components of diets which perform biochemical and physiological functions in living cells through synergistic interactions and/or independent modulation of biological reactions. The mineral levels of the *D. alata* varieties are shown in Table 3. The low mineral levels indicate that these varieties may not be an important source of minerals to the consumers. This may be due to the species and the prevailing environmental factors. Considering the specialized functions of minerals in the human body, which include maintenance of acid-base balance, neurotransmission, cofactors of enzymes, bone and blood formation, energy transduction among others, there is need for improved varieties of *D. alata* for cultivation. The sodium to potassium ratio in the body is of great concern for the prevention of hypertension [26,44]. According to the World Health Organization [45], the sodium-to-potassium ratio should be ≤ one. The consumption of the varieties regarding sodium-to-potassium ratio would not promote high blood pressure,

Table 2. Starch characteristics of *Dioscorea alata* varieties

Starch characteristics	Sample varieties of *Dioscorea alata* (water yam)				
	A	B	C	D	E
	D. purpurea	*D. atropurpurea*	*D. liliopsida*	*D. vilgaris*	*D. villosa*
Glycemic index (%)	35.56±0.64[a]	36.47±1.09[a]	38.90± 1.09[a]	40.88±0.45[a]	41.31±1.77[a]
Amylose content (%)	12.42±0.03[c]	15.22±0.02[a]	13.68±0.60[b]	16.11±0.56[a]	13.99±0.13[b]
Gelatinization temp. (°C)	85.00±1.40[a]	85.00±0. 00[a]	85.50±2.10[a]	87.00±1.40[a]	87.00±1.40[a]

Values are Mean±SD of triplicate determinations; means along a row with the same superscript are not significantly different, P<.05

Table 3. Mineral composition of *Dioscorea alata* varieties (mg/kg)*

Minerals	Sample varieties of *Dioscorea alata* (water yam)				
	A	B	C	D	E
	D. purpurea	*D. atropurpurea*	*D. liliopsida*	*D. vilgaris*	*D. villosa*
Sodium	18.38±0.18[c]	16.38±0.46[d]	16.99±0.02[d]	24.84±0.37[a]	21.06±0.77[b]
Potassium	134.68±1.38[b]	141.14±1.35[a]	127.04±2.74[c]	111.30±1.06[d]	97.78±2.58[e]
Calcium	79.99±0.15[e]	269.75±1.77[a]	168.09±2.74[c]	196.90±0.28[b]	140.07±0.41[d]
Magnesium	25.58±0.67[b]	29.77±0.38[a]	21.04±0.06[c]	18.55±1.56[d]	31.53±0.76[a]
Phosphorus	114.65±0.43[d]	211.63±2.02[a]	117.10±0.64[b]	205.10±7.78[a]	169.76±1.05[c]
Iron	20.61±0.09[b]	19.25±0.64[c]	16.86±0.23[d]	30.86±0.29[a]	15.18±0.61[e]

Values are Mean±SD of triplicate determinations; means along a row with the same superscript are not significantly different, P<.05

Table 4. Ratios of Na to K and Ca to P of *Dioscorea alata* varieties

Ratio	Sample varieties of *Dioscorea alata* (water yam)				
	A	B	C	D	E
	D. purpurea	*D. atropurpurea*	*D. liliopsida*	*D. vilgaris*	*D. villosa*
Na/K	0.14	0.12	0.13	0.22	0.22
Ca/P	0.70	1.27	1.44	0.96	0.83

according to the ratios presented in Table 4. Food is considered "good" if Ca/P ratio is above one and "poor" if the ratio is less than 0.5, while the Ca/P ratio above two helps to increase the absorption of calcium in the intestine [46]. The Ca/P ratios of *D. atropurpurea* and *D. liliopsida* were above the recommended value of 1.00 Table 4. However, higher ratios have been reported for *Dioscorea rotundata* and *Colocasia esculenta* [26].

4. CONCLUSION

From the present study, it could be summarized that *D. alata* varieties investigated had nutritional proximate compositions with immense health benefits. The average moisture content was lower compared to the reported in the literature, an important food property for long-term food storage and industrial food processing. The varieties are good sources of protein, fiber and carbohydrate. *D. purpurea, D. atropurpurea and D. villosa* in particular could be selected for high protein level for intense cultivation in other parts of Nigeria and other regions of the world growing *D. alata*. Based on the standard criteria, *D. alata* varieties with mean glycemic index of 38.62 in this study are low GI foods. It is therefore relevant, noting the health benefits of these varieties to the consumers in prevention of chronic diseases, including type 2 diabetes mellitus. The tuber varieties had low mineral levels. There is a need for intense breeding of improved varieties for enhancing mineral quality of these varieties without loosing the enviable nutritional qualities. Taken together, *D. atropurpurea* may be regarded as the best variety according to the findings in this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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