



Nutritional and biochemical composition of *D. alata* (*Dioscorea* spp.) tubers

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Abstract

The nutrition of the people of developing countries is a major public health issue which has challenged breeders to enhance the nutritional quality of preferred and staple crops such as yam. This study was therefore aimed at investigating the chemical and nutritional composition of 16 *D. alata* varieties. Dry matter content ranged from 22.3 to 33.8% on a fresh weight basis with corresponding moisture content between 66.2 and 77.7%. The ranges of crude protein, ash, sugar, starch and total dietary fibre were 4.3-8.7, 2.9-4.1, 3.6-11.0, 60.3-74.4 and 4.1-11.0%, on dry weight basis, respectively. The ranges of minerals in mg per kg (dry weight) were P 878-1900, Ca 260-410, Mg 390-580, K 10,550-20,100, Na 84-131, Mn 4.8-22.1, Cu 12.3-15.7 and Zn 10.1-14.1. The results indicate that *D. alata* varieties could be good sources of nutrients to its consumers and could also be very useful in nutritional applications and diet formulations. Highly significant variations ($P < 0.05$) were observed among the varieties which suggest the potential for improvement through breeding programmes in promising varieties.

Key words: *Dioscorea alata*, nutritional quality, minerals, yams.

Introduction

Yams (*Dioscorea* spp.) are of great economic importance and nourishment to the people of Africa, the Caribbean, Asia and America. They are well integrated into the social, cultural and religious lifestyle of the people who cultivate and consume them¹. Apart from providing basic food security and income, yam is a rich source of carbohydrate and also contributes to vitamins and minerals, especially where it is consumed in large quantities². The crop is estimated to provide more than 200 dietary calories each day for over 60 million people in West and Central Africa³. Yam is second to cassava as the most important tropical root crop but from a nutritional standpoint, it is better than cassava on account of its higher vitamin C (40-120 mg/g edible portion) and crude protein content (40-140 g/kg dry matter)⁴.

Dioscorea alata, also referred to as greater yam or water yam, is among the six economically important species of yam cultivated. *D. alata* has been relegated behind as a result of traditional bias which disregards the nutritional and agronomic flexibility of the species. Although it is not grown in the same quantities as the African yams, it has the largest distribution world-wide of any cultivated yam, being grown in Asia, the Pacific islands, Africa and the West Indies⁵. It has comparative advantage for sustainable production due to its better agronomic characteristics such as ease of propagation and yields, high nutritive value and longer storage of the fresh tubers.

Yam in itself is not a balanced food. Nutritional deficiency diseases occur within poorer regions where yam and other root and tuber crops are consumed alone as staple foods, and a major

health issues, especially micronutrient deficiencies, can lead to several health consequences including impaired cognitive and physical development. These further affect educational progress; decreases work capacity and life expectancy, thereby affecting economic growth⁶. These deficiencies are common due to insufficient intake of micronutrients, food processing practices and/or poor absorption from foods⁷. Diets deficient in micronutrients are characterized by high intakes of staple food crops but low consumption of foods rich in bioavailable micronutrients such as fruits, vegetables and animal and fish products⁸. Most of the latter food materials are too expensive for the poor who tend to over-depend on staple starchy food products like yam. Information on the nutritive value of yam has been highlighted by other authors in their works on yams^{4,9}.

Food fortification and supplementation through intervention programs have long been used to combat nutrient deficiency problems. Even though they are effective, these programmes are not sustainable by the beneficiaries. Use of food-based approaches to combat micronutrient malnutrition is more likely to be sustainable. Researchers aim at investigating the nutritional quality of commonly consumed foods for possible improvement. This study investigated the biochemical and nutrient composition of 16 *D. alata* varieties with the aim of providing scientific information for the use of breeding programmes that aim at enhancing the general nutritional quality of local staples such as yam.

Materials and Methods

Source of materials: Sixteen varieties of *D. alata* were obtained from experimental plots of the yam breeding programme at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The varieties were planted in May 2006 and harvested in January 2007.

Sampling for laboratory analysis: Six tubers from representative varieties of *D. alata* were selected by simple randomization procedure from bulk of freshly harvested tubers. The tubers were washed and peeled and each cut into four portions longitudinally (from proximal to distal end). The opposite portions from each tuber were selected and pooled together, cut into small pieces (cubes) and thoroughly mixed. The fresh sample was converted to flour for the biochemical and mineral analysis.

Preparation of dried yam flour for chemical and mineral analysis: The freshly cut pieces of *D. alata* tubers were dried in an air convection oven at 60°C for 72 hours¹⁰. The resulting dried chips were milled into fine flour (0.5 mm) and stored in Whirl-pac sample bags at 20°C for analysis.

Determination of proximate composition: Moisture and ash contents of the samples were determined using standard AOAC¹¹ methods.

Protein content was determined using HACH¹² method by placing 0.20 g of the sample, concentrated sulfuric acid, peroxide and one tablet catalyst into a digestion tube and digesting the mixture at 375°C for 3 hours. Distilled water was added to the digest to bring the volume to 75 ml; then it was covered with paraffin and mixed thoroughly. One ml of the mixture was pipetted into 25 ml volumetric flask; 3 drops each of mineral stabilizer and polyvinyl alcohol solution were added and made up to 25 ml with distilled water. One ml of Nessler reagent was added for color development. Absorbance was read at 460 nm using HACH spectrophotometer (HACH Company, Loveland, Colorado, USA, Model, DR /3000) to determine the concentration of nitrogen. Protein content was calculated using a factor of 6.25.

Starch and total sugar contents were determined using a colorimetric method by Dubois *et al.*¹³. Absorbance was read at 490 nm using a spectrophotometer (Model Spectronic 601, Milton Roy Company, USA).

Total dietary fibre content was determined by the enzymatic-gravimetric method of Prosky *et al.*¹⁴. *D. alata* flour sample (1 g in duplicate) was weighed, cooked with heat-stable α -amylase at 100°C (to gelatinize, hydrolyse and depolymerise starch); incubated at 60°C with protease (to solubilise and depolymerise proteins) and amyloglucosidase (to hydrolyse starch fragments to glucose). Each sample was treated with four volumes of ethanol to precipitate soluble fibre and remove depolymerised protein and glucose (from starch). The residue was filtered, washed with 78% ethanol, 95% ethanol and acetone, dried and weighed. One duplicate was analysed for protein and the other incinerated at 525°C for ash determination. The total dietary fibre (TDF) was calculated as the weight of the filtered and dried residue less the weight of the protein and ash.

Determination of minerals: Mineral analysis was done using the method described by Hunter *et al.*¹⁵ and Benton *et al.*¹⁶. The flour

sample (0.48–0.52 g) was weighed into a clean ceramic crucible. An empty crucible was included as a blank. The crucible was placed in a muffle furnace and heated to 500°C over a period of 2 h. The sample was allowed to ash for another 2 h and cooled. The ashed sample was transferred into 50 ml centrifuge tube and the crucible was subsequently rinsed with 5 ml distilled water and 5 ml (3 times) of aqua regia making a total added volume of 20 ml. The sample was vortexed to mix the contents thoroughly and centrifuged at 3000 rpm for 10 min. The supernatant was decanted into micro-vials and P, Ca, Mg, K, Na, Mn, Cu and Zn were determined using flame atomic absorption spectrophotometer (Model Buck 205, Buck Scientific, USA). Aqua regia was prepared as follows: 1.2 L distilled water was poured in a 2 L volumetric flask, 400 ml conc. HCl and 133 ml of 70% nitric acid were carefully added and the volume was made to 2 L.

Statistical analysis: The general linear model (GLM) procedure of SAS Version 9.1¹⁷ was used to analyse duplicated sample results. Significant differences were reported at 95% confidence level using least significant difference (LSD) comparison test.

Results and Discussion

Chemical composition of *D. alata*: The chemical composition of the *D. alata* varieties is presented in Table 1. Moisture content of the varieties ranged between 66.2% for TDa 98-159 and 77.7% for TDa 92-2 with a mean of 71.83%. There were significant ($P < 0.05$) varietal differences in moisture content among the test varieties. Comparable range of moisture contents (65–76%) has been reported for *D. alata* species⁴. The observed high moisture levels of the tubers may influence the textural quality of *D. alata* food products or keeping quality of the tubers. The moisture content of a food sample reflects the amount of solid matter in the sample. The higher the moisture content, the higher the rate of spoilage. *D. alata* is also referred to as “water yam” due to the high moisture content in the tubers. The yam tuber, in general, has high moisture content and a low level of dry matter which makes it more prone to losses during the harvesting season. Yam is, however, processed to flour and stored for various food products throughout the bumper and the lean seasons.

Dry matter content ranged between 22.3 for TDa 92-2 and 33.8% for TDa 98-159. A comparable range of 13.68–37.4% dry matter content for *D. alata* varieties has been reported in the literature^{18,19}. Lebot *et al.*¹⁹ observed that *D. alata* varieties with good eating quality are characterized by high dry matter and starch contents. Similarly, Martin²⁰ associated high dry matter content with good eating quality; it is an important chemical index of food quality in root and tuber crops which has an influence on the textural perception of foods²¹.

Protein is essential in the human diet for growth. Protein content of the *D. alata* varieties ranged between 4.3% for TDa 01/00002 and 8.7% for TDa 85/00250 with a mean of 6.0%. There were varietal differences in protein content of the test varieties. Similar results were obtained by Lape and Treche¹⁰ who reported 8.2% protein content for *D. alata*. Lebot *et al.*¹⁹ had an average of 11.95% protein content when characterizing the physicochemical properties of *D. alata* tubers from Vanuatu. Many authors found a higher nutritional content (with regard to proteins and vitamin C) in *D. alata* than in *D. rotundata*, the most preferred species of yam in West Africa, as well as in other root and tuber crops such as cassava, sweetpotato and dasheen²²⁻²⁴.

Table 1. Chemical composition (%) of *Dioscorea alata*.

Variety	Fresh tuber		Flour				
	Moisture	Dry matter	Protein	Ash	Sugar	Starch	TDF*
TDa 00/00364	72.3	27.7	5.1	3.6	3.9	69.6	6.5
TDa 01/00002	72.3	27.7	4.3	3.3	3.7	66.6	5.8
TDa 01/00024	71.9	28.1	6.7	4.1	5.9	71.3	7.1
TDa 01/00041	74.1	25.9	6.9	3.9	3.6	64.6	6.3
TDa 01/00081	72.0	28.0	5.1	3.7	4.7	70.3	5.6
TDa 85/00250	76.7	23.3	8.7	4.0	8.4	69.7	7.0
TDa 92-2	77.7	22.3	5.7	3.1	8.7	69.3	7.0
TDa 95/00328	76.5	23.5	6.1	3.5	11.0	60.3	11.0
TDa 95-310	69.3	30.7	5.3	3.7	4.6	68.5	8.1
TDa 98/01174	71.4	28.6	6.5	3.4	5.6	72.7	4.1
TDa 98/01176	69.8	30.2	5.7	2.9	6.7	67.7	9.2
TDa 98/01183	66.9	33.1	5.3	3.1	5.7	68.6	8.2
TDa 98-159	66.2	33.8	6.2	4.1	4.2	74.4	5.2
TDa 99/00332	71.8	28.2	5.4	3.0	5.0	62.0	6.6
TDa 99/00395	71.1	28.9	5.0	3.2	5.7	68.6	5.4
TDa 291	69.3	30.7	5.9	3.2	5.2	69.8	5.0
Min	66.2	22.3	4.3	2.9	3.6	60.3	4.1
Max	77.7	33.8	8.7	4.1	11.0	74.4	11.0
Mean	71.8	28.2	5.9	3.5	5.8	68.4	6.8
SE	0.8	0.8	0.3	0.1	0.5	0.9	0.4
LSD	0.8	0.8	0.2	0.1	0.4	0.8	0.4

*TDF: Total dietary fibre.

Ash content is a reflection of mineral status, even though contamination can indicate a high concentration in a sample. Values ranged between 2.9 and 4.1% with a mean of 3.5%. Significant differences ($P<0.05$) were observed among the varieties which may be attributed to varietal effect. Comparable ash content (2.50-4.90%) has been reported for *D. alata* tubers¹⁹. The amount of ash in a tuber depends on the type of soil from which it was harvested, the moisture content and the maturity of the crop²².

Sugar contents ranged between 3.6% for TDa 01/00041 and 11.0% for TDa 95/00328 with a mean of 5.7%. There were significant differences ($P<0.05$) among the test varieties. A comparable range of 0.6-15.8% sugar has been reported for *D. alata* varieties^{18,19}. Sugar in yam is believed to confer sweetness in the cooked tuber which influences food quality¹⁹. Pona, a variety of *D. rotundata*, is preferred for boiled yam because of its sweet taste coupled with other qualities²⁵. Starch content, on the other hand, ranged between 60.3% for TDa 95/00328 and 74.4% for TDa 98/159. Significant differences ($P<0.05$) were observed among the varieties. Similar starch contents (39.9-84.9%) have been reported in *D. alata* varieties^{18,19}. Starch is known to account for about 80% on a dry weight basis of yam carbohydrate; hence, a rich source of carbohydrate to its consumers. It is also a dominant factor in determining the physicochemical, rheological and textural characteristics of yam food products^{26,27}.

Total dietary fibre (TDF) content ranged between 4.1% for TDa 98/001174 and 11.0% for TDa 92-2 with a mean of 6.8%. Dietary fibre (DF) is an essential component in human and animal nutrition²⁸. A high intake of DF is positively related to different physiological and metabolic effects. It contributes less to calories, and can bind and flush cholesterol, carcinogens and undesirable chemicals from the body. It provides bulk, regulates intestinal motility and thereby helps to prevent the development of

diverticulosis and chronic diseases including coronary heart disease, colonic cancer and other disorders of the gastrointestinal lining²⁹. Cereal grains, particularly whole grains are the most important sources of DF³⁰. Whole oat flour typically has 14% TDF, whole wheat flour 12% and whole brown rice 5%. Even at these low levels, the fibre contents of whole-grain flours would have a significant impact on performance³¹. In some of the test varieties, TDF contents were as high as 11%, higher than those reported in brown rice and more comparable to that of whole wheat flour. Woolfe³² reported that yam flour has higher levels of fibre than potato flour, refined wheat flour, maize and rice. Intake of TDF could, therefore, be increased by the consumption of foods from *D. alata* or by incorporating it into other sensorially accepted foods. The variations in TDF of *D. alata* flour could also be of significance in selecting specific varieties in the formulation of diets for diabetics and other health conscious individuals.

Mineral composition of *D. alata* flour: The mineral composition of the *D. alata* varieties is presented in Table 2. There were significant ($P<0.05$) varietal differences among all the minerals across the 16 varieties. Phosphorus (P) is found in most foods because it is a critical component of all living organisms. About 800 mg of P is recommended for adults per day. A range of 878 to 1900 mg/kg with a mean of 1535 mg/kg of P was obtained for the varieties. Yam starches are reported to contain 3-4 times as much phosphorus as found in cassava and aroid ones²⁶. Moorthy and Nair³³ reported 0.11 and 0.015% phosphorus in *D. rotundata* grown in India. The average value being reported in this study (1563.34 mg/kg or 0.156%) is higher than found in other studies and this could be due to varietal and environmental differences.

Calcium contents of the *D. alata* varieties ranged between 260 and 410 with a mean of 328 mg/kg. There were significant

Table 2. Mineral composition of *Dioscorea alata* flour (mg/kg).

Variety	P	Ca	Mg	K	Na	Mn	Cu	Zn
TDa 00/00364	1531	310	500	14,450	104	9.7	13.5	11.9
TDa 01/00002	1517	310	405	14,150	118	4.8	12.3	12.9
TDa 01/00024	1603	335	475	17,950	106	9.7	13.2	10.8
TDa 01/00041	1774	335	580	19,950	112	4.8	12.7	12.8
TDa 01/00081	1900	410	390	17,050	113	6.4	13.5	10.7
TDa 85/00250	1801	385	490	20,100	131	8.1	15.5	10.1
TDa 92-2	1484	410	515	15,600	115	5.6	15.1	12
TDa 95/00328	1502	360	410	16,000	111	15.4	14.7	12.3
TDa 95-310	1208	335	460	17,200	89	12.5	15.7	12.2
TDa 98/01174	1800	335	500	17,400	119	12.1	12.9	11.5
TDa 98/01176	1554	310	515	12,700	95	12.4	14.1	12.2
TDa 98/01183	1614	260	420	13,800	119	15.2	14.4	12.1
TDa 98-159	1457	310	500	10,550	101	13.2	15.6	12.3
TDa 99/00332	878	260	500	11,100	84	22.1	14.4	13.6
TDa 99/00395	1605	310	490	15,250	97	13.3	13.9	14.1
TDa 291	1343	285	435	12,100	96	21.9	13.7	12.9
Min	878.0	260.0	390.0	10,550.0	84.0	4.8	12.3	10.1
Max	1900.0	410.0	580.0	20,100.0	131.0	22.1	15.7	14.1
Mean	1535.7	328.8	474.1	15,334.4	106.9	11.7	14.1	12.2
SE	62.4	11.3	12.6	721.2	3.2	1.3	0.3	0.3
LSD	0.0	119.0	140.4	4,275.1	37.9	19.2	9.3	2.3

differences among the varieties. In a similar study on yam, Dilworth *et al.*³⁴ obtained 300 mg/kg calcium in cooked yellow yam and 410 mg/kg calcium in the uncooked, 14.3–46.9 mg/100 g (fresh weight) has also been reported in wild yams³⁵. The RDA for calcium is about 800–1200 mg for adults. Mineral calcium is vital for the development of healthy bones and teeth. It is also needed for muscle contraction and regulation of the heartbeat, and is involved in the formation of blood clots. A long-term shortage of calcium can lead to osteoporosis, when the bones become brittle and break easily. *D. alata*, from this study, may contribute to calcium requirement to its consumers.

The average test variety had potassium content of about 15,334 mg/kg ranging from 10,550 to 20100 mg/kg. Bhandari *et al.*³⁵ obtained 250–560 mg/100 g K on fresh weight bases unlike dry weight bases in this study. Potassium is a mineral that helps the kidneys to function normally and control blood pressure. With this appreciable content of K in the varieties, *D. alata* could be recommended for people with high blood pressure²² but may not be suitable for people with renal failure. The proper balance of potassium in the body depends on sodium. Therefore, an excessive use of sodium may deplete the body's stores of potassium. Daily intake of potassium (K) between 1875 and 5625 mg is considered adequate and safe, however, too much can be harmful.

Magnesium content ranged between 390 mg/kg for TDa 01/00081 and 580 mg/kg for TDa 01/00041 with a mean of 474 mg/kg for the varieties. In a similar study, Bhandari *et al.*³⁵ obtained Mg contents of 18.3–27.3 mg/100 g (fresh weight) in wild yams. The RDA of Mg is set at 300 mg for women and 350 mg for men. Yam is considered a good source of magnesium³⁶ and from the results obtained in this study; *D. alata* could be a very good source of Mg.

The mineral sodium (Na) is important for the control of water balance in the body. It also helps with normal nerve impulse regulation and muscle contraction. Na content of test varieties

ranged between 84 mg/kg for TDa 99/00332 and 131 mg/kg for TDa 85/00250 with a mean of 106 mg/kg. The recommended daily intake is between 1110 and 3300 mg, however, too much can be harmful to the body. The result of this study shows that *D. alata* is a low sodium source. The high potassium and low sodium contents of the varieties may make them good potassium-sodium balance in the human body and so protect against osteoporosis and heart diseases³⁷.

Manganese (Mn) content of the varieties ranged from 4.8 to 22.1 mg/kg. There were significant differences ($P < 0.05$) among the test varieties. Comparably low Mn (0.14–0.35 mg/100 g fresh weights) has been reported in the literature³⁵. This could be due to the differences in the state of the samples used in the two different studies. Mn is part of the bones and 2.5 to 5 mg per day is considered adequate and safe.

The measured content of Cu ranged between 12.3 and 15.7 mg/kg of the *D. alata* flour. The values in this study seem to be high as compared to what was obtained (0.10–0.21 mg/100 g fresh weight) in wild yams by Bhandari *et al.*³⁵. Again the high values could possibly be due the difference in the state of samples. Too much Cu can be harmful, however, 2 to 3 mg/day intake is considered adequate and safe. Good sources are liver, shellfish, whole grains, legumes and nuts; Cu is believed to help the body to absorb and use iron in making haemoglobin. It also helps the body to get energy from food.

Contents of Zn ranged between 10.10 and 14.10 mg/kg. The amount recommended is 15 mg/day for adults and good sources are sea foods, meat, fish and whole grains. With the range of zinc content of *D. alata* flour, the species could be recommended for diet formulations for hypertensive patients. Similar zinc contents were obtained in boiled yam (6.7–13.0 mg/kg) and yam flour (5.7–15.0 mg/kg) (Personal communication). Zn helps to regulate many of the human body's processes. It is essential for survival and deficiency has serious consequences for health³⁸.

Daily consumption of yam in most yam producing areas is quite high. Nweke *et al.*³⁹ established that people in major yam producing rural areas in Southeast Nigeria consumed as high as 757 calories per capita per day as compared to other root and tuber crops with lower but comparable figures in urban areas. However, yam consumption varies greatly across countries as well as across zones in individual countries. The average yam consumed per capita per day is estimated by FAOSTAT⁴⁰ at 108.0 kcal in West and Central Africa, 4.5 kcal in East and Southern Africa, 2.0 kcal in Asia, 70.0 kcal in the Pacific, 33.0 kcal in the Caribbean and 7.8 kcal in Latin America. With the high consumption of yam, particularly in West Africa, and the appreciable contents of these minerals in the varieties, *D. alata* could be an important contributor to their RDA.

Conclusions

The *D. alata* varieties on the average had comparable biochemical composition to what is reported in the literature. Moisture and protein contents were relatively high as compared to other root and tuber crops. Ranges for sugar and starch were from 3.6-11.0% and 60.3-74.4%, respectively. In some of the test varieties, TDF contents were as high as 11%. The tubers had appreciable levels of phosphorus, calcium, potassium, zinc, manganese and copper. Sodium content was low. The results indicate that *D. alata* varieties could be good sources of nutrients to its consumers and could also be very useful in nutritional applications and diet formulations. Highly significant variations ($P < 0.05$) were observed among the varieties which suggest the potential for improvement through breeding programmes in promising varieties.

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