Acta Scientific Nutritional Health

Volume 2 Issue 7 July 2018

Research Article

Comparative Analyses of Phytochemical and Nutritional Compositions of Four Species of *Dioscorea*

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Received: May 15, 2018; **Published**: June 27, 2018

Abstract

Dioscorea alata L., *D. bulbifera* L., *D. cayenensis* Lam. and *D. rotundata* Poir. are starchy staple food of Nigeria. Phytochemical, proximate, mineral and vitamin components of these species of *Dioscorea* were carried out on dry matter basis with standard methods. Test of significant was measured with Least Significant Difference. *Dioscorea bulbifera* had the highest levels of alkaloid (0.64 ± 0.01 mg/100g), tannin (0.54 ± 0.00 mg/100g), saponin (0.58 ± 0.00 mg/100g), oxalate (0.75 ± 0.01 mg/100g), ash (5.49 ± 0.04 %), crude fibre (3.45 ± 0.01%), crude protein (5.86 ± 0.00%), vitamin B1 (0.042 ± 0.00 mg/100g), vitamin B3 (0.037 ± 0.00 mg/100g) and vitamin C (0.63 ± 0.02 mg/100g), calcium (378.52 ± 0.10 mg/100g), magnesium (128.73 ± 0.04 mg/100g), sodium (87.80 ± 0.10 mg/100g), iron (3.14 ± 0.02 mg/100g) and zinc (2.79 ± 0.01 mg/100g). *Dioscorea cayenensis* had the highest compositions of fat (2.24 ± 0.05%), carbohydrate (77.89 ± 0.27%), vitamin B_2 (0.03 ± 0.00 mg/100g), vitamin A (69.50 ± 0.04 IU/100g) and total carotene (12.85 ± 0.07 IU/100g) while *D. rotundata* had the highest potassium and phosphorus contents (530.70 ± 0.10 and 168.70 ± 0.01 mg/100g) respectively. This study, therefore, suggested that medicinal and nutritive benefits abound in *D. bulbifera, D. cayenensis* and *D. rotundata.*

Keywords: *Dioscorea alata*; *D. bulbifera*; *D. cayenensis*; *D. rotundata*; Vitamins; Minerals

Introduction

Dioscorea species commonly known as yam are herbaceous tropical perennial monocotyledonous plants with tubers that are smooth or prickly, with climbing or trailing vines which are either smooth or prickly. They belong to the family Dioscoreaceae, in the order Dioscoreales and the class Liliopsida. They are easily distinguished on the basis of their morphological features. Dioscoreaceae is among the earliest angiosperms and probably originated in Southeast Asia [1]. Planting season of *Dioscorea* in Southeastern Nigeria is from March - May; and harvesting is from August - January but those farming in fluvial areas cultivate earlier, that is, from November - January and harvest in July - August.

Yam has a wide range of economic, cultural, social and religious values in Southeastern Nigeria. It is the first starchy staple tuber crop of Southeastern Nigeria. Moreover, it is a very important food and income source for millions of producers, processors and consumers in West Africa [2]. Apart from being a food source, yam serves as medicinal treatment of arthritis and several allergies [3]. Some traditional ceremonies are celebrated with yam as the major food item, such as the New Yam Festival locally known as 'Iri-Ji Ohuru' or 'Iwa-Ji Ohuru', depending on the dialect. The festival reminds Igbo people that they cherish the bounteous gifts of nature; especially those products that have sustained their lives over the years and have enriched some members of their community, enabling them to become 'Ndi Ogaranya bara Eze', (rich and wealthy men) in traditional Igbo society before the advent of British currency and a market economy [4]. Yam also serves as a major item in payment of dowry in some part of Southeastern Nigeria. Furthermore, these four species of *Dioscorea* are used in culinary skills, industrially and medicinally in making 'amala', pounded yam, roasted or fried yam, mashed yam, fried yam-balls, yam flour or flakes, yam chips and manufacture of corticosteroid drugs [5].

However, people consider this tuberous root vegetable as only starchy and hence consume it little, without concerning themselves with other nutritional values. Therefore, the objective of this work

was focused on identifying and comparing the phytochemical, proximate, mineral and vitamin constituents of *Dioscorea alata* L., *D. bulbifera* L., *D. cayenensis* Lam. and *D. rotundata* Poir. with the aim of providing the nutritional and health benefits of these species of *Dioscorea*.

Material and Methods

Sources of Materials

Fresh tubers of *D. alata, D. bulbifera, D. cayenensis* and *D. rotundata* were collected from local farmers in Umudike, Umuahia, Abia State, Nigeria, in the month of March. They were authenticated and then, the voucher specimens were deposited in Herbarium of Department of Botany, Nnamdi Azikiwe University, Nigeria.

Preparation of Plant Materials

The raw tubers were dried in the laboratory oven, at the temperature of 65oC for 4 hours. The dried samples were ground to powder using electric blender (Century, CB-8231-J, China) and after grinding, each sample was tagged and stored in air tight container for analyses.

Quantitative Phytochemical Determinations

Alkaloid content was determined by the alkaline precipitation gravimetric method, and saponin content determination was done by the double solvent extracting gravimetric method [6]. Determination of tannin was done by Folin-Denis spectrophotometric of Pearson [7] whilst phenol content was determined by the Folin-Denis spectrophotometric method described by AOAC [8]. Alkaline picrate colorimeter method of Trease and Evans [9] was used for hydrogen cyanide (HCN) determination.

Nutrients Analyses

Analysis of the crude fibre, carbohydrate, crude protein, moisture contents and phosphorus were determined by Weende, difference as the nitrogen free extractive (NFE), Kjeldahl digestion, gravimetric methods and vanadomolybdate (yellow) spectrometry respectively as described by James [10] whilst total ash was determined by using the incineration gravimetric method [11]. Continuous solvent extraction method using a soxhlex apparatus was used for fat determination while Versanate EDTA complexiometric titrimetric method was used for calcium and magnesium determinations [7]. Determinations of iron and zinc were done by simple spectrophotometric methods of Tidemann-Andersen., *et al.* [12]. Determination of sodium and potassium was done by Atomic absorption spectrometry [13]. Vitamins A, B_1, B_2 and B_3 were determined by method described by Onwuka [14] whilst vitamin C was determined by the method of Okwu and Josiah [15].

Analyses of Anti-nutrients

Determination of phytate was done by method described by Oberleas [16]. Oxalate was determined by the method described by AOAC [17].

Statistical Analysis

The statistical analysis was done using SPSS software version 21. Data generated were subjected to analysis of variance (ANOVA). Test of significant was measured with Least Significant Difference (LSD). The data were expressed as mean ± standard deviation of triplicate determinations.

Results

Phytochemical, proximate, mineral and vitamin compositions of the four species of *Dioscorea* were shown in tables 1 - 4 respectively. *Dioscorea bulbifera* had highest values of alkaloid, tannin, saponin and oxalate being 0.64 ± 0.01, 0.54 ± 0.00, 0.58 ± 0.00 and 0.75 ± 0.01 mg/100g respectively. *Dioscorea cayenensis* had the highest levels of HCN and phenol (0.26 ± 0.02 and 0.85 ± 0.00 mg/100g) while *D. alata* had the highest contents of phytate at 0.36 ± 0.05 mg/100g (Table 1). There was a significant difference between the different species of yam in the compositions of alkaloid, tannin and saponin ($p < 0.05$) whereas there was no significant difference among the different species of yam in the concentrations of phytate, HCN, phenol and oxalate ($p > 0.05$).

Compositions / Plant species	Alkaloid (mg/100g)	Tannin (mg/100g)	Saponin (mg/100g)	Phytate (mg/100g)	HCN (mg/kg)	Phenol (mg/100g)	Oxalate (mg/100g)
D. alata	$0.43^{d} \pm 0.00$	$0.38^{d} \pm 0.00$	$0.44^{b} \pm 0.05$	$0.36^{a} \pm 0.05$	$0.25^{a} \pm 0.09$	$0.44^{a} \pm 0.36$	$0.61^{a} \pm 0.12$
D. bulbifera	$0.64^{a} \pm 0.01$	$0.54^{a} \pm 0.00$	$0.58^{a} \pm 0.00$	$0.35^{a} \pm 0.01$	$0.23^{a} \pm 0.00$	$0.82^{a} \pm 0.00$	$0.75^{a} \pm 0.01$
D. cayenensis	$0.60^{b} \pm 0.02$	$0.50^{b} \pm 0.00$	$0.43^{b} \pm 0.02$	$0.30^{b} \pm 0.00$	$0.26^{a} \pm 0.02$	$0.85^{a} \pm 0.00$	$0.69^{a} \pm 0.001$
D. rotundata	$0.48^{c} \pm 0.00$	$0.44^{c} \pm 0.01$	$0.44^{b} \pm 0.01$	$0.26^{c} \pm 0.01$	$0.20^{a} \pm 0.00$	$0.66^{a} \pm 0.001$	$0.64^{a} \pm 0.01$
p-value	0.000	0.000	0.023	0.088	0.640	0.245	0.288

Table 1: Mean quantitative phytochemical compositions of the tuber extracts of different species of yam.

Results are in Mean ± Standard Deviation. Means with the same superscript at shows that there is no significant different ($p > 0.05$).

Proximate contents of the tuber extracts of species of yam shown in table 2 revealed that *D. bulbifera* had the highest compositions of ash, crude fibre, crude protein being 5.49 ± 0.04, 3.45 ± 0.01 and 5.86 ± 0.00% respectively; *D. cayenensis* had the highest levels of dry matter, fat and carbohydrate (91.60 ± 0.02, 2.24 ± 0.05 and 77.89 ± 0.27%) respectively while highest value of moisture being 10.35 ± 0.10% was detected in *D. alata*. There was a significant difference among all the nutritional values in all the species ($p < 0.05$).

For mineral contents, *D. bulbifera* had the highest compositions of calcium, magnesium, sodium, iron and zinc being 378.52 ± 0.10, 128.73 ± 0.04, 87.80 ± 0.10, 3.14 ± 0.02 and 2.79 ± 0.01 mg/100g respectively while *D. rotundata* had the highest levels of potassium and phosphorus at 530.70 ± 0.10 and 168.70 ± 0.01 mg/100g respectively. There was a significant difference among all the minerals assayed in the different species ($p < 0.05$) (Table 3).

Compositions / Plant species	Moisture Content	Dry Matter	Ash Content	Crude Fibre	Fat	Crude Protein	Carbohydrate
D. alata	$10.35^{a} \pm 0.10$	$89.42^{c} \pm 0.02$	$4.28^{c} \pm 0.02$	$2.46^{a} \pm 0.04$	$1.73^{c} \pm 0.02$	$4.51^{c} \pm 0.04$	$76.26^{b} \pm 0.05$
D. bulbifera	$9.78^{b} \pm 0.02$	$90.22^{b} \pm 0.02$	$5.49^{a} \pm 0.04$	$3.45^{a} \pm 0.01$	$1.64^{d} \pm 0.01$	$5.86^{a} \pm 0.00$	$73.87^{d} \pm 0.17$
D. cayenensis	$8.40^{c} \pm 0.02$	$91.60^{a} \pm 0.02$	$4.86^{b} \pm 0.04$	$3.26^{b} \pm 0.02$	$2.24^{a} \pm 0.05$	$4.48^{c} \pm 0.28$	$77.89^{a} \pm 0.27$
D. rotundata	$9.70^{b} \pm 0.08$	$90.30^{b} \pm 0.08$	$4.92^{b} \pm 0.02$	$2.90^{c} \pm 0.00$	$1.85.^{b} \pm 0.04$	$5.31^{b} \pm 0.04$	$74.41^{c} \pm 0.14$
p-value	0.000	0.000	0.000	0.000	0.000	0.002	0.018

Table 2: Percentage proximate composition of the tuber extracts of species of yam.

Results are in Mean ± Standard Deviation. Means with the same superscript at shows that there is no significant different ($p > 0.05$).

Compositions / Plant species	Calcium	Magnesium	Potassium	Sodium	Phosphorus	Iron	Zinc
D. alata	$285.80^{c} \pm 0.02$	$116.29^{d} \pm 0.69$	$476.80^{d} \pm 0.10$	$68.88^{d} \pm 0.02$	$163.70^{c} \pm 0.10$	$2.48^{c} \pm 0.02$	$2.12^{d} \pm 0.00$
D. bulbifera	$378.52^{a} \pm 0.10$	$128.73^{a} \pm 0.04$	$525.80^{b} \pm 1.41$	$87.80^{a} \pm 0.10$	$159.50^{d} \pm 0.04$	$3.14^{a} \pm 0.02$	$2.79^{a} \pm 0.01$
D. cayenensis	$345.79^{b} \pm 0.01$	$120.15^{c} \pm 0.55$	$523.80^{c} \pm 0.04$	$76.80^{c} \pm 0.03$	$167.80^{b} \pm 0.02$	$2.50^{c} \pm 0.08$	$2.18^{c} \pm 0.02$
D. rotundata	$278.80^{d} \pm 0.15$	$125.74^{b} \pm 0.08$	$530.70^{a} \pm 0.10$	$80.75^{b} \pm 0.14$	$168.70^{a} \pm 0.01$	$2.88^{b} \pm 0.02$	$2.34^{b} \pm 0.00$
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 3: Mean mineral compositions of the tuber extracts of different species of yam (mg/100g).

Results are in Mean ± Standard Deviation. Means with the same superscript shows that there is no significant different ($p > 0.05$).

Vitamin composition revealed that *D. bulbifer*a had highest values of vitamins B_1, B_3 and C (0.042 ± 0.00, 0.037 ± 0.00 and 0.63 ± 0.02 mg/100g) respectively while *D. cayenensis* had the highest levels of vitamin B_2, vitamin A and total carotene being 0.03 ± 0.00 mg/100g, 69.50 ± 0.04 IU/100g and 12.85 ± 0.07 IU/100g respectively. Except for vitamin B_3 ($p > 0.05$), there was a significant difference between the different species of yam in all the vitamins assayed ($p < 0.05$) (Table 4).

Compositions / Plant species	B1 (mg/100g)	B2 (mg/100g)	B3 (mg/100g)	C (mg/100g)	A (IU/100g)	Total Carotene (IU/100g)
D. alata	$0.038^{c} \pm 0.00$	$0.02^{b} \pm 0.00$	$0.02^{a} \pm 0.00$	$0.44^{c} \pm 0.01$	$10.69^{d} \pm 0.03$	$5.82^{d} \pm 0.02$
D. bulbifera	$0.042^{a} \pm 0.00$	$0.02^{b} \pm 0.00$	$0.037^{a} \pm 0.00$	$0.63^{a} \pm 0.02$	$27.70^{b} \pm 0.11$	$9.44^{b} \pm 0.01$
D. cayenensis	$0.040^{b} \pm 0.00$	$0.03^{a} \pm 0.00$	$0.03^{a} \pm 0.00$	$0.53^{b} \pm 0.01$	$69.50^{a} \pm 0.04$	$12.85^{a} \pm 0.07$
D. rotundata	$0.034^{d} \pm 0.00$	$0.01^{c} \pm 0.00$	$0.03^{a} \pm 0.00$	$0.37^{d} \pm 0.01$	$12.80^{c} \pm 0.04$	$7.72^{c} \pm 0.11$
p-value	0.002	0.002	0.455	0.000	0.000	0.000

Table 4: Mean vitamin compositions of the tuber extracts of species of yam.

Results are in Mean ± Standard Deviation. Means with the same superscript at shows that there is no significant different ($p > 0.05$).

Discussion

The phytochemical compositions of the tuber extracts of the four species of *Dioscorea* revealed that *D. bulbifera* had the highest levels of alkaloid, tannin, saponin and oxalate. *Dioscorea* cayenensis contained the highest concentrations of HCN and phenol while *D. alata* had the highest value of phytate. Saponins exhibit a wide range of biological activities like anti-fungal, anti-inflammatory, anti-viral, anti-parasitic and anti-tumour activities [18]. *Dioscorea cayenensis* could serve as an antioxidant due to high level of phenol. This secondary metabolite has antioxidant activity and protects cells against oxidative damage and reduces the risk of developing certain types of cancer [19]. The high composition of the tannin in *D. bulbifera* suggested that it could be used to hasten healing of wounds in a flamed membrane. Concentrations of phytate, hydrogen cyanide and oxalate in all the species were negligible.

These four species of *Dioscorea* contained a wide range of nutrients. *Dioscorea bulbifera* had the highest percentage compositions of ash, crude fibre and crude protein whilst *Dioscorea cayenensis* had highest percentage values of dry matter, fat and carbohydrate. Although the highest level of fibre was found in *D. bulbifera*, the fibre contents of all the four species were considerably high. The high protein content of *D. bulbifera* would be of nutritional importance in most developing countries like, Nigeria where yam is one of the commonest staple foods. Proteins are body building blocks, and also energy provider; fibre promotes digestion, cleanses the digestive track and prevents absorption of excess cholesterol; fat insulates the body, provides greater energy to the body and helps in absorption of fat-soluble vitamins in the gut [20].

Mineral compositions of the tuber extracts of the four species of *Dioscorea* revealed that calcium, magnesium, sodium and zinc were found in highest levels in *D. bulbifera* while highest value of potassium and phosphorus were detected in *D. rotundata. Dioscorea rotundata*, popularly known as white yam is the main species that is cultivated in Southeastern Nigeria. It has the highest economic, cultural, social and religious values. The body needs these minerals in minute quantities for proper growth and maintenance. In addition, the high potassium content of *D. rotundata* could help in reducing high blood pressure. High blood pressure is a major risk factor for coronary heart diseases and stroke [21]. Highest values of vitamins B_1, B_3 and C were found in *D. bulbifera* while highest levels of vitamins B_2 and A, were detected in *D. cayenensis*. The total carotene was highest in *D. cayenensis*, which makes it rich in the supply of vitamin A to the body. The rich contents of vitamins B_1, B_3 and C in *D. bulbifera* makes it a good source of vitamins A, B_1 and B_2, which are excellent factors for good body vitality and also protect the body against diseases. Vitamin C has healing powers, and helps to remove dead skin and unplug pores, making skin soft and radiant [22].

Conclusion

Findings of this study will encourage the level of consumption of *Dioscorea* species because of their rich nutritional and medicinal values. They may be considered as good sources of carbohydrates, protein, vitamins A and C, calcium, phosphorus and potassium. *Dioscorea alata* had least levels of all the nutrients with the exception of moisture. In addition, yam is one of the most important cash crops of many developing countries and is recently been regarded as a source of foreign exchange in Nigeria. Hence, further studies should be focused on value addition of these species of *Dioscorea*.

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