



Comparative Nutritional and Phytochemical Evaluation of the Aerial and Underground Tubers of Air Potato (*Dioscorea bulbifera*) Available in Abakaliki, Ebonyi State, Nigeria

A. Afiukwa Celestine^{1*} and O. Igwe David¹

¹Department of Biotechnology, Faculty of Biological Sciences, Ebonyi State University, Abakaliki, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author AAC designed the study, wrote part of the protocol, and performed the proximate, phytochemical and statistical analysis and wrote the first draft of the manuscript, author OID wrote part of the protocol, performed the mineral analysis and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The wild yam species (*Dioscorea bulbifera*), known as *edu* in Abakaliki, Ebonyi State, Nigeria, has two types of edible tubers (underground tubers and aerial bulbils) produced by the same plant. The yam species is highly neglected in the region and all over the world such that it is only consumed in the rural areas of the region often not out of preference but at periods of food scarcity. Both tuber forms are consumed in Abakaliki. The objective of this study was to evaluate and compare the nutritional and antinutritional profiles of the two tuber forms. The proximate and phytochemical constituents were determined using standard official methods of the Association of Analytical Chemists while mineral elements were quantified by Atomic Absorption Spectrophotometry (AAS) method. The study revealed no significant difference between the tuber forms in their contents of crude fats, fibre ash and carbohydrates and calorific values ($P>0.05$) while crude protein was

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

significantly higher in the aerial bulbils ($P < 0.05$). The mineral elements K, Na, Ca, Mg, Fe, Zn, Cu and P but Mn were all significantly higher in the underground tubers while the heavy metals Cd, Pb, Cr, Ni, Se and Co were not detected. Oxalate, tannins and phenols were significantly higher in the underground tubers while the bulbils were richer in alkaloids, HCN saponins and flavonoids. Compared with nutritional values of common edible yam species in the literature, this study also showed that this neglected yam species is a good source of protein, lipid, crude fibre, carbohydrates and minerals. Its contents of the toxic substances (phytate, oxalate, tannins, alkaloids and HCN) were not exceedingly higher compared to common yams. Considering the levels of proximate, minerals and phytochemicals and also the various literature reports on the medicinal potentials of *D. bulbifera*, we advocate for increased utilization of this yam species in the area and beyond to reduce food crisis.

Keywords: *D. bulbifera*; tuber types; proximate; minerals; toxic substances; Abakaliki.

1. INTRODUCTION

Air potato (*Dioscorea bulbifera*), is a species of yam (Dioscoreaceae) family. It is called air potato because it produces potato-like aerial bulbs in the leaf axils of the twining stems. Some varieties are edible and are cultivated as food crops in most hot humid tropical region of the world [1] including Abakaliki, Southeast of Nigeria. It is native to Africa, Asia and Australia [1,2], and is called *edu* by the people of Abakaliki in Ebonyi State of Nigeria. In India, *D. bulbifera* is classified as a wild yam [3] and a medicinal plant [4]. The species is not as popular as other yam species in the study area where in it is utilized mostly by the rural dwellers at periods of foods scarcity rather than consumed out of preference.

The yam species has two types of edible storage organs. One type is aerial tubers or bulbils formed in the leaf axils of the twining aerial stems while the second type are underground tubers formed beneath the ground. Abakaliki people call the bulbils *ogboji* *ogboro-edu* and the tubers *umuda-edu* in their vernacular language. Although the plant can be propagated through either storage organs, the bulbils are the primary organ of cultivation and distribution of the yam species in the region. Boiling and roasting are the common methods of preparing the food for consumption by the people and it is eaten either with vegetable sauce or palm oil. The people also boil tubers, slice and sundry it to form a product known as *echa*, which can be stored for long and used at periods of food scarcity. To prepare *echa* for consumption, it is first soaked in water for few hours, boiled and then mashed in mortar and eaten as *fufu* (*utara-echa*). Both the bulbils and the tubers have bitter taste which disappears after proper boiling or roasting. The plant is known to be a highly invasive plant that will readily overgrow,

choke and displace native plant communities via asexual propagation of bulbils that drop from the parent vines to the ground [2,5-7].

The medicinal properties of *D. bulbifera* are well documented. Among several other medicinal constituents, the yam species is reported to be rich in diosgenin, a steroid saponin believed to possess preventive and therapeutic properties against several ailments including arthritis, cancer, diabetes, gastrointestinal disorders, high cholesterol and inflammation [8-15]. Diosgenin is a known major bioactive component of synthetic birth control pills. [16] also recorded the use of the plant in folk medicine for treatment of diarrhea, dysentery, conjunctivitis and other ailments.

Some wild varieties of *D. bulbifera* and other wild yam species are believed to be poisonous due to high content of Diosgenin. However, this does not seem to be generally true. A toxicological study in rat models have shown that extracts of *Dioscorea villosa*, a non-edible wild yam species, which is supposedly high in content of diosgenin, was safe even at a dose as high as 562.5 mg/kg/day and did not significantly change toxicological parameters up to a dose of 255 mg/kg/day [17]. Another scientific report by [18] similarly showed that administration of extracts of *Dioscorea villosa* at an oral dose as high as 790mg/kg/day for less than 28 days did not cause acute renal or hepatic toxicity, thereby lending support to the safety of diosgenin.

At the moments, there are little or no data on the nutritional differences existing between the two types of *D. bulbifera* edible tubers, and on the nutritional quality of the yam species from the study area (Abakaliki, Ebonyi State, Nigeria). The objective of this study was therefore to evaluate and compare the nutritional (proximate and

minerals) and phytochemical constituents of the two tuber forms of the yam species and to reveal the nutritional quality of *D. bulbifera* from the area in order to create awareness on its nutritional potential to contribute reasonably to reducing food crisis in the region.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

The *D. bulbifera* bulbils and underground tuber used in this study were collected from rural farmers in Izzi local Government Area of Ebonyi State, Nigeria. The samples were washed clean with de-ionized water, air-dried and then peeled using a stainless knife. Thereafter, the yam tissue was chopped into small cubes which were later oven-dried to a constant weight at 60°C for 48 hours. Water content was calculated and the dry sample chips were subsequently milled into fine flour using a stainless coffee blender, and then stored in airtight plastic containers ready for analysis for the content of other nutrient parameters.

2.2 Analysis of Proximate Components

Analysis of the proximate components was done using the standard official methods of the Association of Analytical Chemists [19]. Crude protein was estimated by determining the percent nitrogen content using the micro-Kjeldahl method and multiplying by a factor of 6.25; ash content was estimated by incinerating 2 grams of the dry powder in a muffle furnace at 550°C for 2 hours; crude fats was determined by soxhlet extraction from 2 g of the sample with n-hexane for 8 hours; crude fibre was determined by treating 2 grams powdered sample with 1.25% tetraoxosulphate (VI) acid (H_2SO_4) and 1.25% sodium hydroxide (NaOH); carbohydrate was estimated by difference, while the energy value (in KCl) was calculated from the Atwater general factor system based on net metabolizable energy (NME) of the major energy-yielding substrates (protein, fat, and carbohydrate) using the equation:

$$\text{Energy (kJ/g)} = (\text{Carbohydrate} \times 17) + (\text{Crude fats} \times 37) + (\text{Crude protein} \times 17) \text{ [20]}$$

2.3 Analysis of Mineral Elements

The minerals composition of the samples was determined according to the method reported by

[21]. The finely milled samples (2 grams) were subjected to dry ashing in an acid-washed porcelain crucible at 600°C in a muffle furnace. The resultant ash was dissolved in 5 ml of $\text{HNO}_3/\text{HCl}/\text{H}_2\text{O}$ (1:2:3) and heated gently on a hot plate until brown fumes disappeared. To the remaining material in each crucible, 5 ml of deionized water was added and heated until a colourless solution was obtained. The mineral solution in each crucible was transferred into a 100 ml volumetric flask by filtration through a Whatman No 42 filter paper and the volume was made to the mark with deionized water. This solution was used for mineral analysis by atomic absorption spectrophotometer (model: A Analyst 200; Perkin Elmer, USA). The concentration of each mineral element was calculated from its standard calibration curve generated from standard solutions of the individual minerals.

2.4 Phytochemical Analysis

Phytates and oxalates were determined by the method of [22]; tannins was estimated using the Folin Dennis colorimetric method [23]; alkaloids, saponins, phenols and flavonoids were determined qualitatively by methods described by [24]; hydrogen cyanide content was measured by the alkaline picrate colorimetric method of the Association of Analytical Chemists.

2.5 Statistical Analysis

The data was subjected to a One-way ANOVA using SPSS version 20 and expressed as mean \pm standard deviation of triplicate determinations. Differences were considered significant at 95% confidence level.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition

Table 1 shows the chemical nutrient composition of the two tuber types of *D. bulbifera*. The result shows that the tubers did not differ significantly in their contents of crude fats, crude fibre, ash, carbohydrate and energy. They differed significantly only in crude protein content and fresh weight moisture, with the aerial tubers higher in protein and the underground tubers higher in moisture. The contents of carbohydrate and fibre observed in the roots and tubers of this yam species are remarkably high, indicating its high potential to provide dietary energy [25] and lower the risks of several human health disorders

such as diverticulosis, colonic cancer, constipation, heart diseases, diabetes and other gastro-intestinal tract diseases [26-30].

The values observed in this study were low for protein, fats, moisture and calorie but very comparable for ash and carbohydrates when compared to the values reported for air potatoes from Kanikkars in India by [3] and lower than those reported by [31] for wild yams from Tamil Nadu in India, except for fibre and carbohydrate. However, the obtained values of protein, fats and carbohydrates are respectively much higher than 3.40%, 1.20% and 22.16% reported by [4] for samples from Uttarakhand also in India, while the values of fibre, ash and moisture contents did not differ much from those reported by these authors (7.50%, 2.94% and 62.80%, respectively). The values were also much higher than those adopted by [32] from [33]. [34] reported much lower values of fibre (2.59%) for a Nigerian air potato sample. The obtained values of protein and ash in this study were lower than those reported for five conventional edible yam species from the same locality by [35], but the detected amounts of crude fibre and crude fats were higher, while the carbohydrate contents were comparable to those reported by these authors. Environmental and genotypic differences as well as differences in analytical procedures may have played significant roles in the observed differences.

3.2 Mineral Element Composition

With the exception of manganese, all the mineral elements detected differed significantly between the two tuber types ($P < 0.05$), while the heavy metals (Cd, Pb, Cr, Ni, Se and Co) were not detected in both samples (Table 2). The result showed that the underground tubers were clearly higher than the aboveground tubers (bulbils) in mineral contents. The largest difference (about 2.24 times) was observed in Cu content, followed by zinc (about 2.14 times). Their difference in the rest of the minerals ranged from only about 1.01 times (magnesium) to 1.61 times (calcium). The higher levels of the mineral elements in the underground tubers may be explained by the direct contact of the underground tubers with the soil which is the major source of the minerals. The detected levels of Na, K, Mn, Zn, Fe and Cu elements in both tuber types were lower, while Ca, Mg and P were higher than values report for the same species in India by [3] and generally lower than those reported by [31] for wild yams

from Tamil Nadu in India. The mineral levels obtained in this study are much higher than those adopted by [32] from [33] and those reported by [35] except for Fe content. The detected levels of magnesium in the yam species is particularly high and an individual who consumes over 65 gram of the food would have exceeded the recommended upper limit of 500 mg/day [36]. However, [3] has reported similar high levels of Mg in *Dioscorea spp.* The absence of the toxic heavy metals in both tuber types indicates the safety of the food resource with respect to heavy metal toxicity, perhaps the plant is not a high accumulator of the elements or the soil load is minimal. The Na/K ratio (0.12 for both tuber types) is < 1.0 , an indication that the food resource has the potential to prevent hypertension [37]. Their Ca/P ratio were found to be 1.80 for the underground tubers and 1.16 for the aerial tubers. These values are higher than 1.0 suggesting that the food has the potential to promote calcium absorption in the intestine [38]. [35] and [39] have similarly reported ratios higher than 1.0 in yam spp. With the exception of Mg, all the mineral elements are present in the food substance at concentrations too low to exceed the RDA [36,40].

3.3 Phytochemicals

Table 3 presents the result of the composition of the phytochemicals determined in the two tuber types of the air potato samples. According to the result, only phytate did not differ significantly between the two tuber types. The underground tubers were higher than the aboveground tubers in oxalate, phenols and especially tannins which was about 3.17 times higher, whereas the aerial bulbils were higher in contents of alkaloids, hydrogen cyanide, saponins and flavonoids. This suggests possible differences between the tuber types in the metabolic processes leading to synthesis of these toxic and defence substances. It is already known that these toxic principles exhibit useful medicinal properties. So their presence in the yam species is a pointer to the medicinal value of the food material. The present study revealed comparable amounts of oxalate with the value (0.78 mg/100 g) reported by [31], whereas the amounts of HCN and tannin were respectively higher than 0.19 mg/100 g and lower than 1.48 mg/100 g submitted in this same report. Information on the contents of the other phytochemicals investigated in the present study are not contained in this report.

Table 1. Proximate composition of the two types of *D. bulbifera* tubers

Proximate components	Underground tubers	Aerial bulbils	P _{0.05}	Mean difference
Crude Protein (%)	4.36±0.216	6.18±0.230	0.001	Sig.
Crude fats (%)	3.51±0.300	3.30±0.400	0.501	Not sig.
Crude fibre (%)	8.70±0.998	7.97±0.751	0.365	Not sig.
Ash (%)	2.43±0.216	2.33±0.155	0.564	Not sig.
Moisture (dry weight) (%)	3.50±0.255	3.55±0.414	0.885	Not sig.
Moisture (fresh weight) (%)	68.74±1.344	66.57±1.276	0.000	Sig.
Carbohydrate (%)	77.49±1.187	76.68±0.780	0.376	Not sig.
Energy value (KJ/100 g)	1521.44±19.085	1530.61±26.336	0.663	Not sig.

Table 2. Mineral profile of the two types of *D. bulbifera* tubers

Mineral element (mg/100 g)	Underground tubers	Aerial bulbils	P _{0.05}	Mean difference
Potassium	334.71±0.911	316.72±0.431	0.000	Sig.
Sodium	39.80±0.108	38.52±0.053	0.000	Sig.
Calcium	280.25±0.762	174.44±0.237	0.000	Sig.
Magnesium	764.52±20.798	758.94±10.317	0.001	Sig.
Manganese	0.46±0.006	0.46±0.016	0.089	Not sig.
Iron	2.00±0.005	1.61±0.032	0.000	Sig.
Zinc	0.36±0.016	0.17±0.013	0.000	Sig.
Copper	0.22±0.050	0.10±0.022	0.001	Sig.
Phosphorus	156.09±1.245	149.93±1.089	0.000	Sig.
Cadmium	ND	ND	-	-
Lead	ND	ND	-	-
Chromium	ND	ND	-	-
Nickel	ND	ND	-	-
Selenium	ND	ND	-	-
Cobalt	ND	ND	-	-

Table 3. Phytochemical profile of the two types of *D. bulbifera* tubers

Phytochemicals	Underground tubers	Aerial bulbils	P _{0.05}	Mean difference
Phytate (mg/100 g)	2.07±0.040	2.00±0.045	0.116	Not sig.
Oxalate (mg/100 g)	678.33±16.803	550.00±22.000	0.001	Sig.
Tannins (mg/100 g)	118.47±6.235	37.41±6.235	0.000	Sig.
Alkaloids (%)	2.51±0.261	3.10±0.100	0.021	Sig.
Hydrogen cyanide (mg/100 g)	31.05±2.612	43.69±1.211	0.002	Sig.
Saponins	+	++		Sig.
Phenols	++	+		Sig.
Flavonoids	+	++		Sig.

4. CONCLUSION

This study has revealed that the two types of edible tubers of *D. bulbifera* did not differ significantly in their contents of the basic chemical nutrients including fats, ash, fibre, carbohydrate and calorific value except protein and moisture. We observed that the two forms differed significantly in mineral composition with

the underground tubers generally richer in minerals than the aerial bulbs. No clear cut pattern was found in their composition of phytochemicals as the underground tubers were richer in some of the phytochemicals (oxalate, tannins and phenols) while the bulbils were higher in alkaloids, HCN, saponins and flavonoids. The amounts of most of the substances measured are comparable to those

documented in the literature for common edible yam species, thus both types of *D. bulbifera* tubers are good food sources.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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