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308 Lasani Town, Sargodha Road, Faisalabad - Pakistan  
Mob: +92 300 3008585, Fax: +92 41 8815544  
E-mail: [editorpjn@gmail.com](mailto:editorpjn@gmail.com)

## Proximate and Mineral Elements Composition of the Tissue and Peel of *Dioscorea bulbifera* Tuber

A.E. Abara

Department of Chemical Sciences, Cross River University of Technology, Calabar, Nigeria

**Abstract:** The proximate principles and mineral elements in the wet and dry tissue and peel of *Dioscorea bulbifera* were determined using standard methods. The proximate principles were analyzed using AOAC methods, the mineral elements namely calcium, magnesium, iron, zinc, copper, sodium and potassium by absorption and emission spectrophotometry and phosphorous by molybdovanadate method. All the parameters analyzed apart from carbohydrate and energy value showed tissue/peel ratios of less than 1.0 which was consistent with the observed significantly lower levels of the mineral elements and proximate principles in the tissue than the peel ( $p < 0.01$ ) excepting carbohydrate and energy value. Additionally, the about constant tissue/peel ratios observed for the mineral elements and some proximate principles such as ash, crude fibre, fat and protein for the wet and dry samples of *Dioscorea bulbifera* were indicative of the stability of these nutrients and in about the same proportions in the tissue and peel upon drying at 40°C. The nutritional significance of the mineral elements in the tissue and peel of *Dioscorea bulbifera* was also highlighted in the discussion.

**Key words:** Proximate, mineral elements, composition, tissue, peel, *Dioscorea bulbifera*

### INTRODUCTION

*Dioscorea bulbifera* (aerial yam or air potato) together with other yams, cassava, cocoyam and potato belong to the group of crops termed roots and tubers which together with cereals such as rice, wheat and maize constitute the main source of energy in the tropics. Yams including *Dioscorea bulbifera* are widely grown and consumed amongst various communities in the tropics. The edible species of *Dioscorea bulbifera* are grown and distributed extensively in West Africa, the Caribbean Islands, South East Asia, South Pacific and West Indies. The wild forms occur in both Africa and Asia. *Dioscorea bulbifera* yam is used as food and it is a good source of calories and minerals such as iron, calcium and phosphorous (Tindall, 1983; Abara *et al.*, 2000).

Data on proximate composition of yams including *Dioscorea bulbifera* in the available literature indicate that the proximate principles vary with species, level of maturity, between different parts of the tubers and cooking procedure (Coursey and Walker, 1960; Oyenuga, 1968; Martin, 1979; Ferguson *et al.*, 1980; Bell and Favier, 1981). Consequently, moisture, ash, protein, fat, fibre and carbohydrate content of yams vary widely among species and between cultivars. Available data indicate that the tuber peels are richer in ash, fat, protein and crude fibre than the tissue of the tubers (Oyenuga, 1968; Martin, 1979; Ferguson *et al.*, 1980) although the availability of the nutrients from the peel may be limited by the high fibre content as this may affect digestibility (Eka, 1985). Data from available literature also indicate that yams are generally low in fat and protein but high in moisture and carbohydrate content (Oyenuga, 1968; Ferguson *et al.*, 1980).

### Proximate principles

**Moisture:** Water is generally present in plant foods and in yams, the moisture content ranges from 60-80% in fresh yam tubers (FAO, 1968; 1972; Watson, 1971; Eka, 1978). Coursey and Walker (1960) and Abara *et al.* (2003) reported that the moisture content of yam tubers decreased with maturity and that this continued after harvest and might result in about 20% loss in weight on storage. The high moisture content of yams may adversely affect their keeping quality (Eka, 1985).

FAO (1968; 1972); Coursey (1983); Egbe and Treche (1984) and Abara *et al.* (2003) reported the moisture content of the fresh tissue of *Dioscorea bulbifera* to be 79.40%, 63.67% and 71.20% and 61.93% respectively. Abara *et al.* (2003) also reported a value of 8.33% in the dry tissue of *Dioscorea bulbifera*.

Data on the moisture content of *Dioscorea bulbifera* in the wet and dry peel are totally lacking.

**Carbohydrate:** The total carbohydrate as determined by difference consists of sugars, dextrans, starches, pectins, hemicelluloses, celluloses and lignin. The carbohydrate content of yam tubers ranges from 10-20% and constitutes the major dry matter component of yam tubers (Oyenuga, 1968; Ihekeronye and Ngoddy, 1985; Osagie, 1992).

The carbohydrate content of *Dioscorea bulbifera* has been reported by FAO (1968; 1972); Coursey (1983) and Abara *et al.* (2003). FAO (1968; 1972) reported the carbohydrate content to be 18% and Coursey (1983) reported a range of 27-33% while Abara *et al.* (2003) reported a value of 33.11% in the fresh tissue of *Dioscorea bulbifera*. Also, Abara *et al.* (2003) reported a value of 80.98% in the dry tissue.

There are no reports of the carbohydrate content of the wet and dry matter of *Dioscorea bulbifera* peel in the available literature.

**Crude fibre:** Crude fibre consists principally of cellulose and lignin together with small amounts of hemicelluloses (Southgate, 1973). The crude fibre content of *Dioscorea bulbifera* in the available literature ranged from 0.72% (Coursey, 1983) through 1.20% (FAO, 1968; 1972) to 1.39% (Abara *et al.*, 2003). There are no reports in available literature of the crude fibre content of *Dioscorea bulbifera* peel on wet and dry matter basis.

**Protein:** Available data show that yams contain protein in the region of 1-3% in the wet tissue and 6-9% in the dry tissue (Coursey, 1967; Bell and Favier, 1981). Available data also show that the yam peel has a higher protein content than the tissue (Oyenuga, 1968; Ferguson *et al.*, 1980). The protein content of yams from available literature also show considerable variation among species and between cultivars, a finding which has been attributed to factors such as climate, cultural practices, maturity at harvest and the length of storage time (Martin, 1979).

There are few reports on the protein content of *Dioscorea bulbifera* in the literature. Available reports indicate that the protein content of *Dioscorea bulbifera* ranges from 1.1-2.31% in the wet tissue. FAO (1968; 1972) reported a value of 1.40% and Coursey (1983) reported a range of 1.1-1.5%, Egbe and Treche (1984) reported a figure of 1.78% while Abara *et al.* (2003) found a value of 2.31% for protein in the wet tissue of *Dioscorea bulbifera*. Abara *et al.* (2003) also reported a figure of 5.75% in the dry tissue of *Dioscorea bulbifera*. There are no data on the protein content of the wet and dry peel of *Dioscorea bulbifera* in the literature.

**Crude fat:** Reports from available literature show that yam tubers contain generally low and similar levels of fats which do not exceed 2% on dry weight basis and 0.3% on wet weight (Oyenuga, 1968; Opute and Osagie, 1978; Ihekeronye and Ngoddy, 1985; Abara *et al.*, 2003). The distribution of fats in yam tubers show that the peel contains higher levels of fats than the tissue (Oyenuga, 1968; Faboya, 1981).

The crude fat content of *Dioscorea bulbifera* has been reported to be 0.20%, 0.15%, 0.04% and 0.07% in the wet tissue by FAO (1968; 1972), Abara *et al.* (2003), Coursey (1983) and Egbe and Treche (1984) respectively while Opute and Osagie (1978) and Abara *et al.* (2003) reported values of 1.5% and 0.43% on dry weight basis.

These reports deal only with the fat content of tissue and lack data on the content of fat in the peel of *Dioscorea bulbifera*.

**Ash and mineral elements composition:** The ash content of roots and tubers varies from as low as 0.6% to as high as 1.70% on wet weight basis (FAO, 1968; 1972; Watson, 1971; Eka, 1978; Abara *et al.*, 2003) and between 2.24% to 5.16% on dry weight basis (Oyenuga, 1968; Abara *et al.*, 2003) for yam tubers.

The ash is a source of minerals and contains a large variety of highly variable but generally substantial amounts of mineral and trace elements, the actual value of the mineral element depending upon the chemical composition of the soil, cultural practices, time of planting and the amount of water available to the tuber plant (Osagie, 1992).

There are limited reports on the ash content of *Dioscorea bulbifera* (FAO, 1968; 1972; Eka, 1978; Barquar and Oke, 1977; Abara *et al.*, 2003). FAO (1968; 1972) reported the ash content of the wet tissue of *Dioscorea bulbifera* to be 1.0% and Abara *et al.* (2003) reported a value of 1.21% while Coursey (1983) reported a range of 1.1-1.5%. There are no data on the ash content of the peel of *Dioscorea bulbifera* the available literature.

**Mineral elements:** The elements frequently reported in the literature on roots and tubers are calcium, phosphorous and iron and occasionally potassium and sodium. Trace metals such as manganese and copper are hardly reported. Studies show that most yam varieties contain over 20 mg/100 g of calcium on wet weight basis (Barquar and Oke, 1977; Eka, 1978). Data from other sources show that the phosphorous content of most yam species on either wet or dry weight basis exceeds 200 mg/100 g (Bell, 1984) while some yam tubers contain as low as 4 mg/100 g of phosphorous (FAO, 1968; 1972). Most of the phosphorous in yam tubers are in the form of phytic acid and is speculated to be influenced by the level of nitrogen fertilization (Oke, 1965).

Potassium content of yams is high and is about 0.3% of tuber wet matter (FAO, 1968; 1972) and about 1% of tuber dry matter (Barquar and Oke, 1977). On the other hand, the sodium content of yams is reported to be generally low and averages about 120 ppm of the tuber dry matter.

Yams also contain magnesium in the range of 40-85 mg/100 g wet matter and other elements such as zinc, copper, manganese in trace amounts (Bell, 1984) but which may be significant in the tropics because of widespread consumption of yams. Samarajeewa *et al.* (1988) estimated that consumption of 100 g of yams would provide about 50% of the daily iron need, 100% of the daily needs of manganese and copper and over 25% of zinc requirement. The iron content of yam tubers ranges from about 3 ppm to 62.7 ppm on dry weight basis (Barquar and Oke, 1977).

There are few available reports on the mineral element composition of *Dioscorea bulbifera* (FAO, 1968; 1972; Eka, 1978; Barquar and Oke, 1977; Egbe and Treche, 1984). Among these reports, only the works of Barquar and Oke (1977) and Egbe and Treche (1984) show any wide coverage in terms of the mineral elements analyzed but these reports are yet to be corroborated. The rest of the reports in the literature are limited to only a few mineral elements among which are phosphorous, calcium, sodium, potassium and iron.

Reports from available literature indicate that calcium, phosphorous and iron content of *Dioscorea bulbifera* are in the range of 6.6-45 mg/100 g, 37-62.15 mg/100 g, 1.3-1.68 mg/100 g respectively (FAO, 1968; 1972; Eka, 1978; Egbe and Treche, 1984) in the wet tissue while in the dry tissue, the level of calcium, phosphorous and iron are 0.0018-0.45%, 0.00036-0.23% and 3.47 ppm respectively (Barquar and Oke, 1977). Data from the work of Barquar and Oke (1977) show that *Dioscorea bulbifera* is rich in potassium but low in sodium with values of 1.1% and 126.54 ppm respectively on dry weight basis. There are limited reports in the available literature on the zinc, copper and manganese content of *Dioscorea bulbifera*. Barquar and Oke (1977) reported 18.52 ppm, 13.66 ppm and 5.55 ppm for zinc, copper and manganese respectively in the dry tissue of *Dioscorea bulbifera* while Egbe and Treche (1984) reported values of 0.51 mg/100 g and 0.42 mg/100 g for zinc and copper respectively in the fresh tissue of *Dioscorea bulbifera*.

There are no data on the mineral element composition of the peel of *Dioscorea bulbifera* and this gap needs to be filled besides corroborating the results of studies so far reported.

**Objective of study:** The objectives of the present study are to corroborate the limited data available on the proximate and mineral element composition of *Dioscorea bulbifera* tissue as well as generate data on the composition of the peel which are totally non-existent.

## MATERIALS AND METHODS

**Sampling:** *Dioscorea bulbifera* (aerial yam or air potato) tubers were bought from Watt and Ika Ika Oqua markets in Calabar in Southern Nigeria. The aerial tubers were pooled together and a sample was extracted from it.

**Preparation of samples:** The sample taken from the combined tubers were peeled and the tissue as well as the peel were each divided into two portions. One half of the tissue and the peel were crushed and dried at 40°C, ground into powder and stored in polythene bags while the other halves were crushed and used as such.

The determination of mineral elements involved the preparation of an acidic solution of the inorganic elements in the food after removal of the organic matter by wet oxidation. Two (2 g) grams of each sample were digested with an admixture of concentrated nitric acid and perchloric acid in the ration of 5:1. The digest was made up to 25 ml with distilled deionized water and the resultant acidic solution was used in the estimation of mineral elements, some by means of Atomic Absorption Spectrophotometry, others by Flame Photometry and phosphorous by the Molybdovanadate method.

**Determination of Cu, Fe, Mn, Mg, Ca and Zn by atomic absorption spectrophotometry (AOAC, 1975):** The acidic solution of the wet digestion was sprayed into the flame of atomic absorption spectrophotometer (Perkin-Elmer 403) and the absorption of each of the elements was measured at a specific wavelength using a suitable lamp. The concentration of each element was obtained from a standard absorption curve prepared by using standard solutions of the particular element.

**Determination of Na and K using flame photometry (AOAC, 1975):** The acidic solution containing the mineral elements obtained from the wet digestion of each sample was sprayed into the flame of the photometer where it was vaporized to produce vapours of metal atoms or molecules containing metal atoms excited by thermal energy of the flame to emit characteristic radiation. The emitted radiation was passed through a special filter which permitted only radiation characteristic of a particular element to reach a photocell whose output was measured on a suitable galvanometer. A standard calibration curve of the particular element was prepared and the concentration of the element in the sample was read from the curve.

**Determination of phosphorous by molybdovanadate method (AOAC, 1975):** Portions of the acidic solution from the wet digestion were used for the determination of phosphorous. Suitable aliquots were reacted with molybdovanadate reagents to give a pinkish coloured complex of phosphomolybdovanadate. The colour developed was quantitated colorimetrically at a wavelength of 440 nm using spectronic 20. The concentration of phosphorous was obtained from a standard calibration curve prepared using potassium dihydrogen phosphate (KH<sub>2</sub>PO<sub>4</sub>).

**Statistical analysis:** The data obtained for the proximate principles and mineral elements in the tissue and peel as well as the tissue/peel ratios of the wet and dry samples of *Dioscorea bulbifera* were subjected to analysis of variance at the 1% level of confidence (p<0.01).

Table 1: Proximate composition of *Dioscorea bulbifera* samples (g/100 g). Mean±standard deviation of five replicates

	Sample	Moisture	Ash	Crude fibre	Crude protein	Crude fat	Carbohydrate	Energy value
Wet matter	Tissue	<sup>a</sup> 62.50±0.31	<sup>a</sup> 1.50±0.02	<sup>a</sup> 1.68±0.15	<sup>a</sup> 2.55±0.24	<sup>a</sup> 0.20±0.09	<sup>a</sup> 34.60±1.56	<sup>a</sup> 150.40±00.76
	Peel	<sup>b</sup> 73.66±0.12	<sup>b</sup> 3.35±0.08	<sup>b</sup> 3.75±0.03	<sup>b</sup> 3.00±0.42	<sup>b</sup> 0.25±0.01	<sup>b</sup> 15.99±0.46	<sup>b</sup> 78.21±03.61
Tissue/peel ratio		0.85±0.05 <sub>s</sub>	0.45±0.02 <sub>s</sub>	0.45±0.04 <sub>s</sub>	0.85±0.02 <sub>s</sub>	0.80±0.07 <sub>s</sub>	2.16±0.32 <sub>s</sub>	1.92±00.15 <sub>s</sub>
Dry matter	Tissue	<sup>a</sup> 9.20±0.24	<sup>a</sup> 2.77±0.16	<sup>a</sup> 2.89±0.28	<sup>a</sup> 6.35±0.87	<sup>a</sup> 0.49±0.19	<sup>a</sup> 82.50±2.81	<sup>a</sup> 359.81±12.63
	Peel	<sup>b</sup> 12.00±0.00	<sup>b</sup> 6.15±0.64	<sup>b</sup> 6.36±0.45	<sup>b</sup> 7.47±0.95	<sup>b</sup> 0.61±0.24	<sup>b</sup> 67.41±2.63	<sup>b</sup> 305.01±16.48
Tissue/peel ratio		0.77±0.07 <sub>s</sub>	0.45±0.01 <sub>s</sub>	0.45±0.01 <sub>s</sub>	0.85±0.03 <sub>s</sub>	0.80±0.04 <sub>s</sub>	1.22±0.61 <sub>s</sub>	1.18±00.34 <sub>s</sub>

<sup>a</sup>-<sup>b</sup>Values in a column with the same letter(s) prefix(es) are not significantly different (p<0.01).  
 Values<sub>s</sub> in a column with the same letter suffix are not significantly different (p<0.01)

## RESULTS AND DISCUSSION

**Proximate composition:** The proximate composition of the wet and dry samples of the tissue and peel of *Dioscorea bulbifera* are as shown on Table 1.

The calculated tissue/peel ratios for the proximate principles in the wet and dry samples were below 1.0 except for carbohydrate and energy value which were greater than 1.0 while for the ash, crude protein and crude fat, the tissue/peel ratio was not significantly different for the wet and dry samples (p<0.01) indicating good retention of these nutrients in the same proportions upon drying at 40°C.

**Moisture:** The results of the analysis showed that the wet tissue contained 62.50% moisture while the dry tissue contained 9.20% moisture. The wet peel of *Dioscorea bulbifera* gave a moisture content of 73.66% while the dry peel gave a value of 12.00%.

FAO (1968), Coursey (1983), Egbe and Treche (1984) and Abara *et al.* (2003) reported values of 79.40%, 63.67%, 71.20% and 61.93% for the wet tissue of *Dioscorea bulbifera* respectively. The moisture content of 62.50% found in this study is comparable to the value of 63.67% and 61.93% reported by Coursey (1983) and Abara *et al.* (2003) respectively, but different from the values reported by FAO (1968) and Egbe and Treche (1984). The differences observed between the result of this study and the report of other workers might be due to experimental methods of analysis, level of maturity of the tuber (Coursey and Walker, 1960; Abara *et al.*, 2003) and the type of cultivar used.

**Protein:** The crude protein content of the wet and dry tissue of *Dioscorea bulbifera* was 2.55% and 6.35% respectively while the wet and dry peel contained 3.00% and 7.47% respectively. Thus the peel contained higher levels of protein than the tissue on both wet and dry weight basis. This finding agreed with the results of Oyenuga (1968) and Ferguson *et al.* (1980) that indicated that the peel of yam tubers contained more nitrogen than the tissue.

Coursey (1967) reported the crude protein content of yams to range from 1-3% on wet basis while Bell and Favier (1981) reported a range of 6-9% on dry weight basis. Martin (1979), Barquar and Oke (1976) reported protein levels of between 7.9-9.6% and 6.7-11.1% respectively for *Dioscorea bulbifera* on dry basis while

Abara *et al.* (2003) reported values of 2.31% and 5.75% in the wet and dry tissue respectively. The value of 2.55% protein found in this study for the wet tissue of *Dioscorea bulbifera* fell within the range of 1-3% reported by Coursey (1967). However, the value of 6.35% found in this study for the dry tissue was below and slightly outside the range reported by these workers.

Martin (1979) had reported that protein content of yams varied considerably among species and between cultivars and attributed the variations in the proximate principles to factors such as climate, maturity at harvest and length of storage time. These factors may be responsible for the differences observed in the crude protein content obtained in this work and those of the other workers.

**Crude fibre:** The crude fibre content of *Dioscorea bulbifera* tissue on wet and dry weight basis was found in this study to be 1.68% and 2.89% respectively. The peel on wet and dry weight basis was found to contain 3.75% and 6.36% of crude fibre respectively.

The data obtained for crude fibre in this study was consistent with the result of Oyenuga (1968) which indicated that the peel of *Dioscorea* species contain higher levels of crude fibre than the tissue. Additionally, the data obtained in this study were consistent with the generally low values associated with the wet tissue of *Dioscorea* species in the literature (FAO, 1968; 1972; Oyenuga, 1968; Watson, 1971; Eka, 1978; Abara *et al.*, 2003). FAO (1968; 1972), Coursey (1983) and Abara *et al.* (2003) reported crude fibre values of 1.2%, 0.7% and 1.39 respectively for the wet tissue. The crude fibre values of as low as 0.7% (Coursey, 1983) through 1.39% (Abara *et al.*, 2003) to 1.69% found in the present study might be due to climate, cultivar differences and level of maturity of the tuber.

**Fat:** The crude fat content of *Dioscorea bulbifera* tissue on wet and dry weight basis was found to be 0.20% and 0.49% respectively while the peel contained 0.25% and 0.61% on wet and dry weight basis respectively.

Reports from available literature show that yams contained generally low levels of fat which did not exceed 2% on dry weight basis and 0.3% on wet weight basis (Oyenuga, 1968; Ihekeronye and Ngoddy, 1985; Opute and Osagie, 1978). FAO (1968, 1972), Coursey (1983), Egbe and Treche (1984), Abara *et al.* (2003)

reported 0.20%, 0.04%, 0.07% and 0.15% of fat in the wet tissue of *Dioscorea bulbifera* respectively. The value of 0.20% obtained in this study for the wet tissue was similar to the 0.20% reported by FAO (1968; 1972) but higher than the values of 0.04%, 0.07% and 0.15% reported by Coursey (1983); Egbe and Treche (1984) and Abara *et al.* (2003) respectively.

The distribution of fat in *Dioscorea bulbifera* tuber seen in this study showed that the peel contained higher levels of fat than the tissue, a finding consistent with the results of other workers for yams (Oyenuga, 1968; Faboya, 1981).

**Carbohydrate:** The results of this study showed that the wet and dry tissue of *Dioscorea bulbifera* contained 34.60% and 82.50% of carbohydrate respectively. The peel of *Dioscorea bulbifera* on the other hand contained 15.99% and 67.41% of carbohydrate on wet and dry weight basis respectively. Thus the result of this study showed that the tissue of *Dioscorea bulbifera* contained more carbohydrate than the peel, a finding consistent with the result of other workers (Oyenuga, 1968).

Coursey (1983), FAO (1968; 1972) and Abara *et al.* (2003) reported the carbohydrate content of *Dioscorea bulbifera* tissue to range from 27-33%, 18% and 33.11% respectively on wet weight basis. The value of 34.60% found in this study for *Dioscorea bulbifera* in the wet tissue was at the upper end of the range of 27-33% reported by Coursey but higher than the 18% reported by FAO (1968, 1972) but comparable to the 33.11% reported by Abara *et al.* (2003).

The carbohydrate content of yams is affected principally by age of the tuber and by species and cultivar differences (Martin, 1979) and these factors might be responsible for the observed variations in the carbohydrate content of *Dioscorea bulbifera*.

**Ash and mineral elements composition:** The results of mineral analyses in the tissue and peel of *Dioscorea bulbifera* are as shown on Table 2. The results showed that the tissue of *Dioscorea bulbifera* contained lower levels of mineral elements than the peel on both wet and dry matter basis.

The tissue/peel ratios computed for the mineral elements in the wet and dry samples were all below 1.0 and practically constant for a mineral element since no significant difference was established for the tissue/peel ratio of each of the elements for the wet and dry samples ( $p < 0.01$ ). This was indicative of the stability of the mineral nutrients upon drying the sample at 40°C.

The ash content of the tissue of *Dioscorea bulbifera* on wet and dry weight basis was found in this study to be 1.50% and 2.77% respectively. The peel of *Dioscorea bulbifera* yielded values of 3.35% and 6.15% on wet and dry weight basis respectively. The computed tissue/peel ratio for ash for the wet and dry samples was constant at 0.45 which implied good retention of the mineral elements upon drying of either the tissue or the peel of *Dioscorea bulbifera*, a fact borne out by the near constancy of the tissue/peel ratio observed for each mineral element analyzed.

FAO (1968) and Coursey (1983) reported values of 1.0% and 1.1-1.5% for the tissue of *Dioscorea bulbifera* on wet weight basis while Abara *et al.* (2003) reported values of 1.21 and 2.24% for the wet and dry tissue respectively. The figures of 1.50% and 2.89% obtained in this study for the wet and dry tissue respectively of *Dioscorea bulbifera* are comparable to the results of other workers. Specific consideration of each mineral element is given as follows:

**Calcium:** The calcium content of *Dioscorea bulbifera* in this study was found to be 35.30 mg per 100 g for the tissue wet matter and 54.60 mg/100 g for the wet peel while the dry tissue and dry peel showed calcium levels of 205.60 and 316.31 mg/100 g respectively. FAO (1968; 1972), Eka (1978); Egbe and Treche (1984) and Abara *et al.* (2003) reported the calcium content of *Dioscorea bulbifera* tissue to be 40.00, 45.50, 6.60 and 36.50 mg/100 g respectively on wet weight basis while Barquar and Oke (1977) and Abara *et al.* (2003) found 0.45% (450 mg/100 g) and 209.00 mg/100 g on dry weight basis. Abara *et al.* (2003) also reported the calcium content of the wet and dry peel of *Dioscorea bulbifera* to be 56.50 and 323.00 mg/100 g respectively.

Table 2: Mineral element content of *Dioscorea bulbifera* samples (mg/100 g). Mean  $\pm$  standard deviation of five replicates

Mineral element	Wet matter			Dry matter		
	Tissue	Peel	Tissue/peel ratio	Tissue	Peel	Tissue/peel ratio
Calcium	<sup>a</sup> 35.30 $\pm$ 0.71	<sup>b</sup> 54.60 $\pm$ 0.04	0.65 $\pm$ 0.01 <sub>a</sub>	<sup>c</sup> 205.60 $\pm$ 4.24	<sup>d</sup> 316.31 $\pm$ 4.34	0.65 $\pm$ 0.00 <sub>a</sub>
Magnesium	<sup>e</sup> 24.30 $\pm$ 0.85	<sup>f</sup> 28.10 $\pm$ 0.21	0.86 $\pm$ 0.01 <sub>b</sub>	<sup>g</sup> 139.00 $\pm$ 2.83	<sup>h</sup> 161.00 $\pm$ 2.80	0.86 $\pm$ 0.01 <sub>b</sub>
Potassium	<sup>i</sup> 176.00 $\pm$ 1.41	<sup>j</sup> 368.00 $\pm$ 2.12	0.48 $\pm$ 0.02 <sub>c</sub>	<sup>k</sup> 440.00 $\pm$ 3.54	<sup>l</sup> 920.00 $\pm$ 7.07	0.49 $\pm$ 0.01 <sub>c</sub>
Sodium	<sup>m</sup> 220.00 $\pm$ 4.54	<sup>n</sup> 256.00 $\pm$ 2.83	0.84 $\pm$ 0.03 <sub>d</sub>	<sup>o</sup> 550.00 $\pm$ 6.36	<sup>p</sup> 640.00 $\pm$ 5.66	0.86 $\pm$ 0.02 <sub>d</sub>
Iron	<sup>q</sup> 2.36 $\pm$ 0.20	<sup>r</sup> 6.90 $\pm$ 0.08	0.34 $\pm$ 0.01 <sub>e</sub>	<sup>s</sup> 5.90 $\pm$ 0.28	<sup>t</sup> 17.35 $\pm$ 0.95	0.34 $\pm$ 0.01 <sub>e</sub>
Zinc	<sup>u</sup> 0.53 $\pm$ 0.01	<sup>v</sup> 1.43 $\pm$ 0.09	0.37 $\pm$ 0.01 <sub>f</sub>	<sup>w</sup> 1.52 $\pm$ 0.16	<sup>x</sup> 4.12 $\pm$ 0.06	0.37 $\pm$ 0.01 <sub>f</sub>
Phosphorous	<sup>y</sup> 64.40 $\pm$ 0.42	<sup>z</sup> 80.70 $\pm$ 0.65	0.80 $\pm$ 0.03 <sub>g</sub>	<sup>aa</sup> 150.00 $\pm$ 0.74	<sup>ab</sup> 184.00 $\pm$ 0.95	0.82 $\pm$ 0.02 <sub>g</sub>
Manganese (ppm)	<sup>ac</sup> 1.60 $\pm$ 0.15	<sup>ad</sup> 6.90 $\pm$ 0.41	0.23 $\pm$ 0.02 <sub>h</sub>	<sup>ae</sup> 4.00 $\pm$ 0.18	<sup>af</sup> 18.00 $\pm$ 0.13	0.22 $\pm$ 0.01 <sub>h</sub>
Copper (ppm)	<sup>ag</sup> 2.00 $\pm$ 0.29	<sup>ah</sup> 3.20 $\pm$ 0.12	0.63 $\pm$ 0.01 <sub>i</sub>	<sup>ai</sup> 5.00 $\pm$ 0.45	<sup>aj</sup> 8.00 $\pm$ 0.07	0.63 $\pm$ 0.01 <sub>i</sub>

<sup>a-z</sup>Values in a row with the same letter(s) prefix(es) are not significantly different ( $p < 0.01$ ).

Values<sub>s,1</sub> in a row with the same letter suffix are not significantly different ( $p < 0.01$ )

Thus the calcium content of *Dioscorea bulbifera* ranged from 6.5 mg to 45.50 mg per 100 g on fresh weight basis and from 209.00-450.00 mg/100 g on dry basis for the tissue. The calcium content of 34.60 mg/100 g found in this study for the wet tissue and 205.60 mg/100 g for the dry tissue of *Dioscorea bulbifera* fell within the ranges reported above for calcium and was thus consistent with the results of other workers. The values 54.60 and 316.31 mg/100 g obtained for the wet and dry peel respectively were lower than those earlier reported by Abara *et al.* (2003) for similar samples.

The differences observed between the calcium content of *Dioscorea bulbifera* in this study and those of other workers may be due to species differences, composition of the soil upon which it was grown, cultural practices, time of planting and amount of water available (Osagie, 1992).

Calcium is essential for proper bone and teeth formation. However, the mere presence of calcium in a food does not guarantee adequate nutrition because its absorption depends on such factors as the presence of vitamin D, oxalic and phytic acids. The presence of vitamin D facilitates absorption while oxalic and phytic acids precipitate calcium and inhibits its absorption.

The low level of calcium found in *Dioscorea bulbifera* in this study coupled with the presence in *Dioscorea bulbifera* of oxalic and phytic acids (Abara *et al.*, 2000) which further limits its absorption renders *Dioscorea bulbifera* a poor source of calcium. High consumption of *Dioscorea bulbifera* might therefore be deleterious if not supplemented with calcium from other sources.

**Magnesium:** The Magnesium content of *Dioscorea bulbifera* tissue was found to be 24.30 and 139.00 mg/100 g in the wet and dry matter respectively. The peel of *Dioscorea bulbifera* on wet and dry weight basis showed magnesium content of 28.10 and 161.00 mg/100 g respectively. The value of 24.30 mg/100 g obtained in this study for the wet tissue was higher than 7.10 mg/100 g reported by Egbe and Treche (1984). Also, the figure of 139 mg/100 g obtained for the tissue on dry weight basis was higher than the value of 0.032% (32 mg/100 g) reported by Barquar and Oke (1977).

The differences observed in these results could be explained on the basis of environmental and cultural factors associated with the growth of the *Dioscorea bulbifera* plant.

Magnesium is an essential constituent of all cells and is necessary for the functioning of enzymes involved in energy utilization and it is present in the bone. Deficiency of magnesium is rare and results from excessive losses in diarrhoea rather than from low intakes.

The values of 24.30 mg/100 g on wet weight basis and 139.00 mg/100 g on dry weight basis found for magnesium in *Dioscorea bulbifera* in this study showed that *Dioscorea bulbifera* is a good source of

magnesium as these figures compare favourable with those associated with good sources of magnesium such as raw potatoes (24 mg/100 g), cheese (25 mg/100 g), white bread (23 mg/100 g) and roasted peanuts (181 mg/100 g) (Fisher and Bender, 1975; Ihekeronye and Ngoddy, 1985).

**Potassium:** The potassium content of the tissue of *Dioscorea bulbifera* in this study was found to be 176.00 and 440.00 mg/100 g in the wet and dry respectively. The peel of *Dioscorea bulbifera* showed values of 368.00 mg/100 g and 920.00 mg/100 g on wet and dry weight basis respectively. The figure of 176.00 mg/100 g obtained for the tissue was lower than the value of 337 mg/100 g reported by Egbe and Treche (1984) while the value of 440.00 mg/100 g found for the tissue on dry weight basis was also lower than the value of 1.10% reported by Barquar and Oke (1977). The observed differences might be due to environmental and other factors earlier mentioned. *Dioscorea bulbifera* from the results of this study is a rich source of potassium.

**Sodium:** The sodium content of *Dioscorea bulbifera* was found in this study to be 220.00 and 550.00 mg/100 g on wet and dry weight basis respectively of the tissue while the peel showed values of 256.00 and 640.00 mg/100 g on wet and dry matter respectively.

Reports in available literature indicate that the sodium content of yams including *Dioscorea bulbifera* is low as against the high sodium content obtained in this study. Egbe and Treche (1984) reported the sodium content of the tissue of *Dioscorea bulbifera* to be 4.0 mg/100 g while Barquar and Oke (1977) found 126.00 mg/100 g. The values of 220.00 and 550.00 mg/100 g on wet and dry weight basis respectively found in the tissue of *Dioscorea bulbifera* in this study were thus higher than any so far reported and this could be attributed to the environmental factors upon which the plant was grown.

**Iron:** The iron content of *Dioscorea bulbifera* has been reported by a number of workers. FAO (1968; 1972); Eka (1978) and Egbe and Treche (1984) reported 2.00, 1.68 and 1.30 mg/100 g respectively of iron in the tissue of *Dioscorea bulbifera* on fresh weight basis. Barquar and Oke (1977) reported 3.46 ppm of iron on dry weight basis in the tissues of *Dioscorea bulbifera*.

The iron content of 2.36 and 5.90 mg/100 g obtained in this study for the wet and dry tissue respectively are higher than any so far reported. The observed disparity between the results of this study from the results of other workers could be explained on the basis of environmental conditions upon which the tuber was grown.

The values of 2.36 and 5.90 mg/100 g obtained for the wet and dry tissue respectively in this study were lower than the values of 7.30 and 18.30 mg/100 g found for the

wet and dry peel respectively. This pattern of variation of the iron content of *Dioscorea bulbifera* was consistent with that observed for the other mineral elements in this study.

People in the tropics suffer from anaemia because of parasitic infections which affect the absorption of iron apart from the inadequacy of supply through food. Also, phytic acid forms insoluble compounds with iron and thereby limits its absorption (Fisher and Bender, 1975). From the level of iron found in *Dioscorea bulbifera* in this study, it might be safe to conclude that *Dioscorea bulbifera* could be a major source of dietary iron despite the presence of phytic acid in it.

**Phosphorous:** The phosphorous content of the tissue of *Dioscorea bulbifera* on wet and dry weight basis was found to be 64.40 and 150.00 mg/100 g respectively while the peel contained 80.70 and 184.40 mg/100 g in the wet and dry matter respectively. Thus the peel contained higher levels of phosphorous relative to the tissue on both wet and dry weight basis. The range of phosphorous content of the fresh tissue of yams as found in the literature was between 37.00 and 62.15 mg/100 g as can be deduced from the reports of FAO (1968; 1972); Eka (1978) and Egbe and Treche (1984). The value of 64.40 mg/100 g of phosphorous in the fresh tissue of *Dioscorea bulbifera* found in this study lay slightly above the range of phosphorous content so far reported.

The mineral content of yams generally depends upon the composition of the soil upon which they are grown and the disparities observed in the various reports including the result of this study might be due to this fact as well as the method of estimation (Eka, 1985).

Phosphorous is the second most abundant mineral in the body after calcium and in the form of various phosphates, perform a wide variety of essential functions one of which is its role in the liberation and utilization of energy from food. The amount of phosphorous found in *Dioscorea bulbifera* in this study was low, but dietary deficiency of phosphorous is unknown in man because phosphorous is present in nearly all foods and therefore the consumption of *Dioscorea bulbifera* was unlikely to pose any nutritional hazard.

**Trace elements:** The elements copper, zinc and manganese were found in trace amounts in *Dioscorea bulbifera* in this study and are discussed below:

**Copper:** The amounts of copper found in the wet and dry tissue of *Dioscorea bulbifera* in this study were 2.00 ppm and 5.00 ppm respectively while the wet and dry peel contained 3.20 ppm and 8.00 ppm respectively. The amounts of copper found in this study in the tissue and peel on both wet and dry weight basis were lower than

any so far reported. Egbe and Treche (1984) reported a value of 0.42 mg/100 g (4.2 ppm) for the wet tissue of *Dioscorea bulbifera* while Barquar and Oke (1977) reported a value of 13.66 ppm for the dry tissue. From the result of this study and those of other workers, *Dioscorea bulbifera* is a poor source of copper but the implications are unclear as copper deficiency is not common.

**Zinc:** The results obtained for zinc showed that the wet and dry tissue of *Dioscorea bulbifera* contained 0.53 and 1.52 mg/100 g respectively while the wet and dry peel contained 1.43 and 4.12 mg/100 g respectively.

The zinc content of the wet tissue of *Dioscorea bulbifera* of 0.53 mg/100 g found in this study was basically similar to 0.51 mg/100 g reported by Egbe and Treche (1984). However, the zinc content of 1.52 mg/100 g obtained in this study for the dry tissue was lower than 18.52 ppm (1.852 mg/100 g) reported by the same author. The low level of zinc found in *Dioscorea bulbifera* coupled with the presence of phytic acid (Abara *et al.*, 2000) which form insoluble complexes with zinc makes *Dioscorea bulbifera* a poor source of zinc.

**Manganese:** The values of 1.60 ppm and 4.00 ppm of manganese were obtained for the tissue of *Dioscorea bulbifera* on wet and dry weight basis respectively in this study. The peel on the other hand contained 6.90 and 18.00 ppm in the wet and dry samples respectively. The manganese content of 4.00 ppm found in this study in the dry tissue of *Dioscorea bulbifera* was lower than 5.55 ppm reported on similar basis by Barquar and Oke (1977). The disparities observed in the mineral content of *Dioscorea bulbifera* and in yams generally had been explained elsewhere as due to environmental factors as well as experimental method of analysis (Osagie, 1992). The level of manganese in *Dioscorea bulbifera* established from this study was low, however, the implications are unclear as the exact role and significance of manganese in human nutrition are speculative excepting the fact of its involvement in a number of enzyme systems.

**The peel:** The result of this study has shown that the peel of *Dioscorea bulbifera* contained higher levels of both the proximate principles and mineral elements excepting the carbohydrate and energy value. In many parts of Nigeria, yam peels including those of *Dioscorea bulbifera* are usually fed to domestic animals such as goats and sheep. The peel contained substantial amounts of the proximate principles and mineral elements but the presence in fairly high levels also of toxic substances such as hydrocyanate, oxalate, tannins and phytate (Abara *et al.*, 2000; Abara, 2003) in *Dioscorea bulbifera* peel might limit its usefulness as animal feed.



**Energy value:** The energy value of the wet tissue of *Dioscorea bulbifera* was found to be 150.40 kcal/100 g while that of the dry tissue was 359.81 kcal/100 g. The peel of *Dioscorea bulbifera* showed energy values of 78.21 and 305.01 kcal/100 g on wet and dry weight basis respectively. Thus the tissue of *Dioscorea bulbifera* from the results of this study showed higher energy values than the peel on both wet and dry weight basis, a result consistent with the computed tissue/peel ratios which were greater than 1.0 and significantly different ( $p < 0.01$ ).

**Conclusion:** The results and findings of this study to a large extent have corroborated existing but limited data on the proximate and mineral elements composition of *Dioscorea bulbifera* and had provided data for the peel on both wet and dry matter basis. The tissue/peel ratios computed in this study for all the parameters analyzed showed values of less than 1.0 excepting carbohydrate and energy value and for the mineral elements the near constancy of the ratios was indicative of the stability of these nutrients in the tissue and peel upon drying at 40°C. The tissue/peel ratio of less than 1.0 was also consistent with the presence of higher levels of the given nutrient in the peel than in the tissue which agreed with the results of other workers (Coursey and Walker, 1960; Oyenuga, 1968; Ferguson *et al.*, 1980; Bell and Favier, 1981).

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