ESTIMATION OF CALCIUM, ZINC, HYDROCYANATE, OXALATE AND PHYTATE IN *Dioscorea bulbifera* TUBER

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**ABSTRACT**

Calcium, zinc, oxalate, hydrocyanate and phytate were estimated in the wet and dry matter of the peeled, unpeeled and peeled *Dioscorea bulbifera* tuber. Calcium ranged from 36.50 to 56.50 mg% wet matter (WM) and 209.00 to 323.00 mg% dry matter (DM) while zinc ranged from 0.56 to 1.5mg% WM and 1.40 to 3.80 mg% DM of the peeled, unpeeled and peels respectively. The values of 1.19, 2.77 and 2.98 mg% WM and 3.03, 7.77 and 8.10 mg% DM for oxalate; 5.41, 7.71 and 8.22 mg% WM and 2.06, 2.59 and 2.73 mg% DM for hydrocyanate; 118.07, 129.25 and 147.95 mg% WM and 275.00, 286.53 and 338.07 mg% DM for phytate were found in the peeled, unpeeled and peels respectively. The calculated phytate:zinc, calcium:phytate and (calcium:phytate)/zinc molar ratios for the peeled (edible) portion were 20.77, 5.10 and 18.96 WM and 19.40, 12.53 and 101.34 DM respectively. The discussion focused on toxic levels of hydrocyanate, oxalate and phytate, and the significance of the molar ratios in predicting the bioavailability of dietary zinc.

**Key Words:** Calcium, zinc, oxalate, hydrocyanate, phytate.

**INTRODUCTION:**

Yams are widely used staples in the tropics and in Nigeria, it is a very popular food crop. There are several yam species, some of which by reason of quality are better patronised than others. One species, *Dioscorea bulbifera* which is commonly found in the South of Nigeria, is consumed mainly boiled, fried or roasted along with meats, vegetables or with palm oil spiced with pepper. Nigeria alone accounts for 78% of total world production *Dioscorea bulbifera* (Tindall, 1983).

The nutritional value of a food depends not only on the level of nutrients in it but also on the presence of toxic factors and anti-nutrients in the food. The common toxic factors and anti-nutrients in food especially those of plant origin include hydrocyanate, phytate, oxalate and tannins. These substances are present in food in variable amounts and act as antagonists by combining with other nutrients in the food to make them nutritionally unavailable. Phytates, and oxalates form complexes with cations of metals such as calcium, zinc and iron while tannins form complexes with proteins (Berk, 1976). Hydrocyanate is a potent cytochrome oxidase inhibitor and interferes adversely with the aerobic respiratory system. Besides its toxicity, hydrocyanate has also been implicated in chronic degenerative neuropathy (Oshuntokun et al, 1969). There are no reports on the oxalate and phytate contents of *Dioscorea bulbifera* in the available literature.

The mineral content of *Dioscorea bulbifera* has been reported by a number of workers. FAO (1968, 1972), Eka (1978), and Egbe and Trache (1984) have reported the calcium content of *Dioscorea bulbifera* to range from 6.5 to 45.5 mg% wet matter of edible portion while Banquar and Oke (1977) reported a value of 0.4% on a dry weight basis. Zinc content of *Dioscorea bulbifera* has been reported by Egbe and Trache (1984) to be 0.51 mg% of the edible wet matter while Banquar and Oke (1977) found 18.52 ppm in the edible dry matter.

These reports show that the level
of calcium and zinc in *Dioscorea bulbifera* is low.
The presence of oxalates and phytates in *Dioscorea bulbifera* may further reduce
the level of calcium and zinc because of the tendency of these substances to
combine with divalent cations. Turnlund *et al* (1984) have reported the effect of
phytate:zinc and (calcium)(phytate)/(zinc) molar ratios on bioavailability of dietary
zinc in humans while Wise (1983) have reported on the effect of calcium:phytate
molar ratios on phytate precipitation.

The main objective of this study was to estimate the levels of calcium and
zinc in the tuber of *Dioscorea bulbifera* and determine the effect of phytate and
calcium levels on the bioavailability of dietary zinc in *Dioscorea bulbifera*. The
significance of hydrocyanate and oxalate levels in *Dioscorea bulbifera* was also
examined.

**MATERIALS AND METHODS**

*Dioscorea bulbifera* tubers were harvested from an experimental farm at
The Polytechnic, Calabar, on a typical loamy soil to which no manure was
added. Samples were prepared from the tubers as described below and used for
analysis.

1. **PREPARATION OF SAMPLES:**

   (a) **UNPEELED SAMPLE:** A set of randomly selected tubers was crushed in
   a mortar with a pestle and the crushed material divided into two portions. One
   portion was used directly for analysis while the other portion was dried in a
draught oven (Gallenkamp model Ov-160) at 60°C to constant weight after which it
   was crushed to powder for use in mineral and antinutrient determinations on dry
   matter basis.

   (b) **PEELED SAMPLE:** Another set of randomly selected tubers was peeled
   with a knife and the peels collected. The peeled material was divided into two portions one of which
   was crushed in a mortar with pestle and used directly for analysis while the other
   was dried as in the unpeeled above, crushed to powder and subsequently used
   for analysis.

   (c) **PEELS ONLY:** The peels obtained in the sample (b) above were also
   divided into two portions. One portion was crushed as in the unpeeled sample
   (a) above and used directly for analysis while the other portion was dried
   and crushed to powder as in latter sample (a) and used for analysis.

2. **DETERMINATION OF CALCIUM AND ZINC:**
The wet digestion method of A.O.A.C. (1975) was applied to 1g portions of samples of *Dioscorea bulbifera*. The diluted digests were
wetted with 5% lanthanum oxide solution and the calcium and zinc contents were
determined by atomic absorption spectrophotometry (Pye Unicam, SP2900).

3. **DETERMINATION OF OXALATE:**
Oxalate was determined using 4g of each sample by the method of Dye
(1956). The sample was digested for 4 hours at 50°C by addition of dilute HCl.
An aliquot of the digest was evaporated to a brownish suspension which was
filtered and the filtrate treated with conc. ammonia. Oxalate was precipitated from
the solution by treatment with dilute CaCl₂ solution at 90°C. The precipitate
was solubilised with hot dilute H₂SO₄ and titrated against a dilute KMnO₄ solution.
The oxalate content was calculated taking 1 ml of 0.05 KMnO₄ as equivalent to
2.2mg of oxalate.

4. **DETERMINATION OF PHYTATE:**
A modification of the method of McCance and Widdowson (1935) was
used to estimate phytate. Phytate was extracted from the sample with dilute HCl
and precipitated from the solution as ferric phytate by addition of FeCl₃
solution. The precipitate was subsequently solubilised by adding a
dilute NaOH solution with heating to give sodium phytate solution which was
treated with a mixture of conc. H₂SO₄ and 65% perchloric acid to liberate
phytate phosphorous. The inorganic phosphorous was determined by the
A.O.A.C. (1975) method. Phytate content was calculated from inorganic
phosphorous taking the molecular weight of phytic acid to be 660.

5. **DETERMINATION OF HYDROCYANATE:**
The hydrocyanate content of the samples of *Dioscorea bulbifera* was
determined according to the A.O.A.C. (1975) method. A 10g sample was
soaked for 4 hours in distilled deionised water. The suspension was subsequently
steam-distilled into a dilute NaOH solution. The distillate was then treated
with dilute KI and titrated against AgNO₃ to a faint and permanent turbidity. The
RESULTS:
The results with standard deviations as shown in Tables 1 and 2 are means of three replicates. The calcium, zinc, hydrocyanate, oxalate and phytate contents of the wet and dry matter of unpeeled and peeled of Dioscorea bulbifera are as shown in Table 1 while the computed molar ratios for phytate: zinc, calcium: phytate and (calcium)/(zinc) are as shown in Table 2.

The calcium content of Dioscorea bulbifera ranged from 49.20mg% in the unpeeled through 36.50mg% in the peeled sample to 56.50mg% in the peels on wet matter basis while values of 281.20mg%, 209.00mg% and 332.00mg% were found in the unpeeled, peeled and the peels respectively on dry weight basis.

The zinc contents of Dioscorea bulbifera samples on wet weight basis ranged from 11.28mg% in the unpeeled sample through 0.56mg% in the peeled, edible portion to 7.30mg% in the peels while on dry weight basis the value for zinc ranged from 3.20mg% in the unpeeled sample through 1.40mg% in the peeled sample and 18.30mg% in the peels.

The hydrocyanate contents of the wet matter of the peels, the peeled and the unpeeled of Dioscorea bulbifera were 8.25mg%, 5.40mg% and 7.71mg% respectively; while values obtained on dry weight basis were 2.73mg%, 2.06mg% and 2.50mg% in the peels, peeled and unpeeled sample, respectively.

Soluble oxalate content was 2.77mg% in the unpeeled sample, 1.19mg% in the peeled edible portion and 2.92mg% in the peels of Dioscorea bulbifera on wet weight basis. The soluble oxalate contents of the samples on dry weight bases were 7.77mg%, 3.0mg% and 8.10mg% in the unpeeled, peeled and the peels, respectively.

The phytate contents of the unpeeled, peeled and the peels of Dioscorea bulbifera on wet weight basis were 129.25mg%, 118.07mg% and 147.95mg% respectively; while on dry weight basis the values for phytate were

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<th>TABLE 1. CALCULATING HYDROCYANATE, OXALATE, AND PHYTATE CONTENT OF Dioscorea bulbifera</th>
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<td>WET MATTER</td>
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The results showed that the peels of Dioscorea bulbifera contained significantly higher levels of the substances analysed than either the unpeeled and peeled samples.
unpeeled sample or the peeled edible portion (P<0.01). The results also showed that in all the substances analysed apart from hydrocyanate, the dry matter of Dioscorea bulbifera contained higher levels than the wet matter, which is to be expected.

DISCUSSION:

The value of 5.41 mg hydrocyanate per 100 g of edible wet matter obtained in this study was lower than the value of 58.5 mg per kilogram reported by Chakraborty and Eka (1978). The lethal dose of hydrocyanate is believed to be about 60 mg per head per day in adult man (Oyenuga and Amazigo, 1957) and the result of this study suggests that hydrocyanate poisoning is unlikely to arise from the consumption of Dioscorea bulbifera since it would require the ingestion of very large amounts of yam to meet this level of hydrocyanate. Additionally, the human body is able to detoxify hydrocyanate through the enzyme, thodanase, which converts the hydrocyanate in the presence of thiosulphates to thiooctonates which further reduces the risk of cyanide intoxication.

The nutritional significance of oxalate depends only on its content of soluble oxalate which inhibits calcium absorption and other divalent ions (Aremu, 1989; Chakraborty and Eka, 1978; Davidson et al, 1975). The soluble oxalate content of the edible portion of Dioscorea bulbifera found in this study was 1.19 and 3.03 mg per 100 g wet and dry matter respectively. The threshold of oxalate toxicity has been estimated to be between 2 and 5 g (Munno and Basir, 1969) and the chances of oxalate toxicity arising from ingestion of Dioscorea bulbifera are slim in view of the low level of soluble oxalate in this tuber.

The phytate levels in the wet and dry matter of peeled Dioscorea bulbifera samples were found to be 118.07 and 275.00 mg per 100 g respectively. Phytate is deleterious because it precipitates metal cations of calcium, zinc and iron and thus render them unavailable for absorption although the threshold of dietary toxicity in humans and animals is unknown (Ferguson et al, 1990; Taylor and Coleman, 1978; Thompson and Weber, 1981). Turnlund et al (1984) have shown that phytate:zinc molar ratios of 15:1 may lead to reduced bioavailability in humans. The phytate:zinc molar ratios of about 21:1 and 19:1 for the edible wet and dry matter respectively obtained in this study were far above the critical value of 15:1 reported, and indicated that the phytate level in Dioscorea bulbifera would lead to reduced bioavailability of zinc from the tuber. Wise (1983) reported that the solubility of phytate and the proportion of zinc bound to the complex in the intestine depended upon the dietary calcium levels.

According to this model, phytate precipitation is incomplete until dietary calcium:phytate molar ratios attain a value of 8:1. The calcium:phytate molar ratios of 5:1 and 13:1 for the edible wet and dry matter respectively obtained in this study suggest complete phytate precipitation in the dry but not in the wet matter. The values of about 19 and 101 per 100 g obtained in this study in respect of (calcium) (phytate)/zinc molar ratios for the wet and dry edible portions respectively also indicate that zinc bioavailability from Dioscorea bulbifera may be adversely affected by the phytate in the tuber since molar ratios greater than 0.5 mol per kilogram are reported to reduce the bioavailability of dietary zinc.

It may, therefore, be concluded that Dioscorea bulbifera on the basis of its phytate and calcium content is a poor source of dietary zinc. This point should be noted in area where consumption of Dioscorea bulbifera is high with a view to supplementing zinc intake from other sources.

Yam peels are known to be richer in certain nutrients such as the vitamins than the main flesh (Oyenuga, 1968). Consequently, cooking of small whole yam tubers (unpeeled) is favoured in the hope of retaining as much nutrients as possible in the yam food. However, in view of the high levels of hydrocyanate, oxalate, and phytate in the peels of Dioscorea bulbifera, the seeming wholesome practice of cooking small whole yams and of feeding yam peels to animals as feed may be inappropriate. Also, the low levels of zinc in the wet and dry matter of peeled Dioscorea bulbifera coupled with the unfavourable interaction of zinc with phytate as indicated by the phytate:zinc molar ratios found in this study, makes Dioscorea bulbifera a very poor source of dietary zinc.
REFERENCES


