



Variation in nutrient and antinutrient contents of tubers from yellow yam (*Dioscorea cayenensis*) genotypes grown at two locations

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Abstract

Eight genotypes of yellow yam (*Dioscorea cayenensis*) were planted at locations in two major yam-growing agroecologies of Nigeria (Onne in the humid forest zone and Ibadan in the forest/savannah transition zone) for assessment of the contents of minerals and antinutrients. Significant differences ($P < 0.05$) were observed among the genotypes in tuber contents of Fe, Zn, Ca, Mn, P, Cu and tannin. The levels of Fe, Zn, Ca, Mg, K, P and phytate (Phy) were higher ($P < 0.05$) in tubers grown at Ibadan than at Onne. Values for Cu and tannin were similar at the two locations for all genotypes. Significant ($P < 0.05$) genotype x environment interactions were detected for tuber contents of only Zn, Mn and Phy. The ranges of molar ratios Phy:Zn (2.2 - 4.1), Ca:Phy (8.3 - 15.0), and $[Ca][Phy]/[Zn]$ (0.01 - 0.02) suggest that phytate could inhibit bioavailability of calcium but not zinc in foods prepared from yellow yam. The tannin content was not high enough to influence the bioavailability of iron in yam-based foods. The levels of minerals and antinutrients in their tubers, the location and genotype x environment effects, and the potential influences on bioavailability of minerals in yam-based foods would be of interest to yam improvement and public health intervention programmes.

Key words: Minerals, antinutrients, genotype, genotype x environment, molar ratio, phytate, tannin, *Dioscorea cayenensis*, yellow yam.

Introduction

Over-dependence on staple food crops and lack of financial resources to buy other rich sources of nutrients such as milk, cheese, eggs have resulted in more than 3.5 billion people globally suffering from mineral deficiencies ¹. Minerals are crucial for many body functions ², and deficiencies of some minerals have been reported in Nigeria. A survey carried out in Nigeria showed that 36.3% of children under the age of 5 years and 30-43% of women of child bearing age are anaemic, while 26-37% of children under the age of 5 years and 23-73% of pregnant women are zinc deficient ³.

Solutions to mineral deficiency in the past have involved food fortification and supplementation ⁴. Although many of these intervention programs have been successful on short term basis, none has proven to be sustainable due to numerous problems involving logistics, compliance, political instability and continuity of funding ⁵. A food-based intervention program against mineral deficiencies is a potentially more sustainable and cost effective approach ⁶. Increasing the amount of bioavailable minerals in the edible part of staple foods and the concentrations of compounds such as ascorbic acid that promote their uptake will be a welcome approach. The amount of compounds which inhibit their uptake like phenolics and phytic acid may also be decreased.

Uptake of mineral nutrients by cowpea ⁷ is affected by weather conditions, chemical composition of the soil, time of planting and harvesting and amount of water available. High variability

has been reported in the zinc and iron content of rice ⁸ and common beans ⁹. Most of the variation in these minerals is due to the genetic component and environmental effects ¹⁰. Plant breeding can significantly improve the diet of the rural population through the development and distribution of varieties of crops which contain high levels of these minerals. This is possible for other plants and it is therefore important to have desirable levels of minerals expressed consistently in environments where the crops are grown.

Yams (*Dioscorea* spp.) are major staple food crops in West and Central Africa ¹¹. Annual world production is about 40 million tons and per capita consumption is estimated to be 256.24 g per day ¹². People in major food producing areas in Nigeria have been shown to consume 757 calories per capita per day from yams compared to 354, 298, 185 and 149 from cassava, rice, wheat and grain legumes respectively ¹³. *Dioscorea cayenensis* (yellow Guinea yam) is one of the most important species of cultivated yam and plays an important role as a source of nutrients ¹⁴. The supply of minerals in human diets may be limited by insufficient intake of food rich in these mineral nutrients, processing practices and the presence of dietary factors which may inhibit or enhance their bioavailability ⁵.

Antinutritional components like tannins, phenols and phytic acid (myoinositol hexaphosphate), present in yam are known to have adverse effects on human nutrition ¹⁵ by inhibiting iron and

zinc absorption¹⁶. Phytic acid is an important storage form of phosphorus in plants and is the most potent inhibitor of zinc absorption in animal and human studies, forming insoluble mineral complexes¹⁷. The inhibitory effect of phytate on zinc absorption has been quantified by the molar ratios of phytate to zinc in the diet. The critical values for Phy:Zn molar ratio has been suggested to be greater than 15¹⁸. Staple diets having such high ratios are possibly associated with an increased risk of zinc deficiency¹⁹. The critical phytate:zinc molar ratio may also depend on dietary calcium levels. The solubility of phytate and the proportion of zinc bound in a mineral complex in the intestine depend on the levels of calcium²⁰. Wise, in his model suggested that phytate precipitation is not complete until dietary Ca:Phy molar ratios attain a value of approximately 6:1. The critical molar ratio of Ca:Phy has been reported to be 6:1²¹. The nutritional evaluation, as well as the assessment of antinutritional factors and bioavailability of calcium and zinc in wild yam tubers of Nepal has been reported^{22, 23}.

Given the importance of yellow yam as a staple and source of essential nutrients there is need to assess the mineral and antinutritional contents. However, information on the variability of these nutrients and the influence of location is necessary for any effective improvement programme. The purpose of this study was to determine variability in the levels of mineral and antinutrients in tubers of yellow yam grown at Ibadan and Onne, and the effect of phytate and tannin on the bioavailability of zinc, calcium and iron contents.

Materials and Methods

Collection and preparation of samples: Tubers of eight genotypes of yellow yam (Table 1) planted in three replicates in a randomised complete block design were obtained from the experimental fields of the International Institute of Tropical Agriculture (IITA), Ibadan (Forest/Savannah zone) and Onne (Humid Forest zone), Nigeria. The locations, Ibadan (7°23'N 3°53'E) and Onne (4°43'N 7°8'E) were representatives of the major agroecological zones where yellow yam is produced. The soil type at Ibadan according to FAO classification is Ferric Luvisol, while that of Onne is Paleudult/Haplic Aerisol. The annual rainfall in year 2004 was 1119.6 mm at Ibadan and 2356.8 mm at Onne. The soil properties of the experimental plot used for this study at the two locations are shown in Table 2.

The harvested tubers were washed, hand-peeled and cut into small pieces with a stainless steel knife. They were dried at 60°C for 48 h in an oven. The dried samples were ground to fine flour using a stainless steel analytical mill (Analysenmühle Type A10, 79219 STAUFEN, Janke and Kunkel, GmbH and Co KG, IKA Labortechnik, Germany), packed in airtight plastic bags and stored at 4°C until used. All chemicals and reagents used were of analytical

Table 1. Sources of (*Dioscorea cayenensis*) genotypes used.

Accession	Genotype name	Source
TDc 04-167	Arapanagbogbo	Benue State, Nigeria
TDc 04-168	Ogoma-Odu	Benue State, Nigeria
TDc 04-169	Ogoma-Olaje	Benue State, Nigeria
TDc 04-170	Ogomude Kpakpa	Benue State, Nigeria
TDc 95-293	Karangua	Amponsakrom near Wenchi, Ghana
TDc 95-294	Kwaku-dadwo	Amponsakrom near Wenchi, Ghana
TDc 95-65	Jioku	Enugu State, Nigeria
TDc 98-136	Kyetutumula	Namulonge, Uganda

Table 2. Soil properties of *Dioscorea cayenensis* plots used in 2004.

Soil property	Ibadan	Onne
pH(H ₂ O)	6.1	3.6
pH(KCl)	5.5	3.2
Organic Matter	1.62	2.38
N (g/kg)	0.11	0.10
P (mg/kg soil)	20.28	20.76
Ca (cmol/kg)	2.25	0.46
Mg (cmol/kg)	0.56	0.10
K (cmol/kg)	0.24	0.06
Zn (µg/g soil)	5.58	2.96
Cu (µg/g soil)	2.23	1.15
Mn (µg/g soil)	63.81	2.88
Fe (µg/g soil)	62.42	143.74
Sand (g/kg)	820	720
Clay (g/kg)	80	80
Silt (g/kg)	100	200

grade and purchased from Sigma Chemical Company (USA) and British Drug House (Poole, England). All chemical analyses were carried out in duplicate.

Chemical analyses: Mineral analyses for dried and milled samples were carried out by Waite Analytical Service Laboratory, Adelaide, Australia using Inductively Coupled Plasma Atomic Emission Spectrometry (ICPAES) (ARL model 3580 B)²⁴. Tannins were determined by the vanillin-HCl method as modified by Chang *et al.*²⁵, using catechin as the tannin standard. Phytic acid (phytate) content was determined by the method of Wheeler and Ferrel²⁶. The Phy:Zn, Ca:Phy and [Ca][Phy]/[Zn] values were calculated according to the method of Wyatt and Triana-Tejas²⁷. All results are presented on a dry weight basis.

Statistical analysis: Data were analysed using descriptive, ANOVA and statistical tests with SAS (Statistical Analysis Systems) software version 8.02²⁸. Means were separated by Duncan's multiple range tests.

Results and Discussion

Mineral composition: The levels of iron ranged from 6.65 to 14.04 mg/kg on dry matter (DM) basis (Table 3a) and are in agreement with previous reports²⁹⁻³¹. The zinc contents ranged from 8.40 to 15.90 mg/kg DM (Table 3a) and are similar to values reported for Cameroonian yam³² and compare relatively well with values obtained for yellow yam³³. The calcium contents ranged from 75.17 to 264.26 mg/kg DM (Table 3a) and are similar to values previously reported^{32, 33}. The magnesium content ranged from 366.67 to 790.00 mg/kg DM (Table 3a). These levels are higher than values reported for wild yam species²² but are similar to values reported for other yam species²⁹ and for yellow yam³³. Manganese was the least abundant mineral element, ranging from 1.06 to 2.92 mg/kg DM (Table 3b) and compare relatively well with values for other yam species^{22, 33}. Potassium was the most

Table 3a. ^aContents of mineral nutrients (mg/kg) of *Dioscorea cayenensis* tubers grown at Ibadan and Onne.

Genotype	Fe		Zn		Ca		Mg	
	Ibadan	Onne	Ibadan	Onne	Ibadan	Onne	Ibadan	Onne
TDc 04-167	12.82 ± 1.09	6.70 ± 0.28	15.71 ± 2.34	8.60 ± 0.70	217.46 ± 140.90	209.00 ± 19.67	763.33 ± 198.58	393.33 ± 40.41
TDc 04-168	14.04 ± 1.89	7.82 ± 1.87	15.90 ± 2.71	9.62 ± 1.93	211.20 ± 73.59	154.99 ± 50.09	790.00 ± 55.68	403.33 ± 64.29
TDc 04-169	11.64 ± 2.23	7.04 ± 0.94	15.82 ± 2.68	9.00 ± 0.26	183.10 ± 24.57	75.17 ± 16.14	733.33 ± 30.55	366.67 ± 37.86
TDc 04-170	11.83 ± 0.25	7.16 ± 1.19	15.48 ± 2.57	8.72 ± 0.89	176.92 ± 12.52	122.29 ± 10.62	686.67 ± 28.86	386.67 ± 66.58
TDc 95-293	10.58 ± 1.75	6.65 ± 1.44	13.41 ± 3.10	8.40 ± 0.33	236.36 ± 81.14	196.99 ± 80.32	703.33 ± 94.52	443.33 ± 37.86
TDc 95-294	10.42 ± 0.41	7.86 ± 0.26	12.49 ± 1.54	10.15 ± 1.50	255.55 ± 77.64	144.09 ± 47.62	720.00 ± 95.39	510.00 ± 72.11
TDc 95-65	11.57 ± 2.42	7.33 ± 1.11	13.13 ± 0.44	10.89 ± 1.22	264.26 ± 94.60	263.00 ± 24.06	703.33 ± 25.17	486.67 ± 32.15
TDc 98-136	9.12 ± 0.58	6.88 ± 1.06	9.99 ± 0.38	8.47 ± 0.81	225.97 ± 106.10	188.70 ± 11.99	723.33 ± 68.07	470.00 ± 36.06
Mean	11.50 ± 1.94	7.18 ± 1.05	13.99 ± 2.74	9.23 ± 1.26	221.35 ± 77.30	169.28 ± 64.49	727.92 ± 83.30	432.50 ± 65.62
SEM	0.40	0.21	0.56	0.26	15.82	13.16	17.00	13.40

^aMean values (mg/kg on dry weight basis) ± S.D (standard deviation).

Table 3b. ^aContents of mineral nutrients (mg/kg) of *Dioscorea cayenensis* tubers grown at Ibadan and Onne.

Genotype	Mn		K		P		Cu	
	Ibadan	Onne	Ibadan	Onne	Ibadan	Onne	Ibadan	Onne
TDc 04-167	1.14 ± 0.37	2.92 ± 1.15	15366.67 ± 890.33	4433.33 ± 750.56	1800.00 ± 175.78	1266.67 ± 125.03	8.88 ± 0.81	7.02 ± 0.75
TDc 04-168	1.29 ± 0.38	2.10 ± 0.25	16700.00 ± 888.82	5233.33 ± 1069.27	1863.33 ± 126.62	1320.00 ± 122.88	9.35 ± 1.88	6.95 ± 0.42
TDc 04-169	1.25 ± 0.35	1.06 ± 0.35	14633.33 ± 577.35	4666.67 ± 404.15	1730.00 ± 20.00	1260.00 ± 160.93	8.71 ± 0.84	7.99 ± 0.71
TDc 04-170	1.32 ± 0.09	1.63 ± 0.28	14466.67 ± 208.17	4666.67 ± 568.62	1713.33 ± 64.29	1303.33 ± 170.10	8.31 ± 0.27	7.29 ± 1.44
TDc 95-293	1.58 ± 0.20	2.89 ± 0.54	15600.00 ± 1552.42	4333.33 ± 950.44	1713.33 ± 68.07	1200.00 ± 137.48	4.94 ± 0.90	3.91 ± 0.20
TDc 95-294	1.62 ± 0.48	2.57 ± 0.54	16833.33 ± 1305.12	5433.33 ± 1234.23	1763.33 ± 215.02	1350.00 ± 72.11	6.21 ± 2.45	5.57 ± 0.71
TDc 95-65	2.26 ± 0.41	1.68 ± 0.30	15600.00 ± 1044.03	5133.33 ± 568.62	1703.33 ± 265.02	1373.33 ± 227.23	5.32 ± 1.94	6.89 ± 2.64
TDc 98-136	1.11 ± 0.09	2.23 ± 0.23	15233.33 ± 1234.23	5433.33 ± 513.16	1973.33 ± 116.76	1576.67 ± 89.63	7.01 ± 0.94	8.17 ± 1.97
Mean	1.45 ± 0.45	2.14 ± 0.77	15554.17 ± 1290.43	4916.67 ± 795.46	1782.50 ± 55.90	1331.25 ± 162.57	7.34 ± 2.02	6.72 ± 1.74
SEM	0.09	0.16	263.41	162.37	31.82	33.18	0.41	0.36

^aMean values (mg/kg on dry weight basis) ± S.D (standard deviation).

abundant mineral element, ranging from a mean value of 4.3×10^3 to 16.8×10^3 mg/kg DM (Table 3b). These levels are similar to reported values for yam species ^{22, 32}. The phosphorus contents ranged from 1200 to 1973.33 mg/kg (Table 3b) and are higher than values reported for Cameroonian yam species ³² and yellow yam ³³. The phosphorus content was more than double the magnesium content and about six times the calcium content, this is similar to earlier reports ³⁴. Copper content ranged from 3.91 to 9.35 mg/kg DM (Table 3b) and was higher than values reported for wild yam species ²² and yellow yam ³³. The discrepancy possibly could be due to both species and environmental differences.

The mean iron, zinc, calcium, magnesium, potassium, phosphorus and copper contents were higher in tubers from Ibadan (the drier location) than from Onne (wet location) (Tables 3a and 3b). This could be due to the differences in edaphic and climatic conditions at the two locations (Table 2).

Tubers of TDc 04-168 planted at Ibadan had the highest level of

iron and zinc, while TDc 95-65 had the highest level of calcium at both locations (Table 3a). Tubers of TDc 04-168 planted at Ibadan had the highest level of magnesium (Table 3a). At both locations, tubers of TDc 95-294 had the highest level of potassium, while TDc 98-136 had the highest level of phosphorus (Table 3b).

Except for magnesium and potassium, the mineral contents of tubers (Table 4) were significantly different ($P < 0.05$) between yam genotypes tested. Also, except for copper, the mineral contents were significantly different ($P < 0.05$) between the locations tested. Genotype by environment interaction was significant ($P < 0.05$) for zinc and manganese.

Antinutrient composition: The tannin contents ranged from 240.9 to 441.8 mg/kg at both locations (Table 5). Values are similar to those reported for yellow yam (300 mg/kg) ³⁵ but lower than those reported for water yam (1300 mg/kg) ³⁶ and for other widely consumed food crops, for example, 2600 to 23700 mg tannin per

Table 4. Mean squares of mineral and anti-nutrient contents of *Dioscorea cayenensis* tubers grown at two locations.

Component	Genotype	Environment	Genotype x environment interaction
Iron (Fe)	4.36*	224.39**	3.13NS
Zinc (Zn)	7.63*	271.80**	8.31*
Calcium (Ca)	10480.88*	32540.94*	2471.98NS
Manganese (Mn)	0.79*	5.69**	0.94*
Phosphorus (P)	5.6x10 ⁴ *	2.4x10 ⁶ **	8623.5NS
Magnesium (Mg)	4140.18NS	1.0x10 ⁶ **	7609.23NS
Potassium (K)	2.0x10 ⁶ NS	1357x10 ⁶ **	7.8x10 ⁵ NS
Copper (Cu)	11.74**	4.58NS	2.78NS
Phytate	56.30NS	8060.45*	61.24*
Tannin	351.82*	33.39NS	142.29NS

* 0.05 > P > 0.01; ** P < 0.01; NS, not significant.

kg in sorghum³⁷. Tannic acid in plants did not affect their nutritional potential unless at very high levels (7.6-9.0 g/kg)³⁸. The yellow yam varieties could be considered safe in terms of the level of tannin, since this is far below the reported deleterious level of 7.6–9.0 g/kg³⁸.

The phytate contents ranged from 166.2 to 422.8 mg/kg (Table 5). These values are comparable to the phytate content (360 mg/kg) reported for Nigerian yam species³⁶ but higher than the 37.0 mg/kg reported for *D. cayenensis* tubers³⁵ and much lower than 4520 mg/kg reported by Adeyeye *et al.*³⁹, suggesting that *D. cayenensis* tubers have fairly low phytate contents.

The eight genotypes differed significantly (P<0.05) in tuber contents of tannin (Table 4), but the effect of environment and genotype by environment interaction was not significant. Phytate content was higher in tubers grown at Ibadan than at Onne. The effect of environment and genotype by environment interaction was significant (P<0.05) for phytate.

Table 5. ^aContents of phytate and tannin (mg/kg) in tubers of *Dioscorea cayenensis* genotypes grown at Ibadan and Onne.

Genotype	Phytate		Tannin	
	Ibadan	Onne	Ibadan	Onne
TDc 04-167	369.5 ± 44.3	174.0 ± 22.8	441.8 ± 278.1	369.2 ± 52.1
TDc 04-168	422.8 ± 50.8	182.5 ± 17.4	411.9 ± 135.5	427.2 ± 97.0
TDc 04-169	362.1 ± 63.8	166.2 ± 32.1	379.1 ± 69.1	343.5 ± 14.3
TDc 04-170	345.1 ± 93.9	166.8 ± 17.4	370.5 ± 50.6	352.6 ± 51.7
TDc 95-293	334.8 ± 20.8	187.9 ± 20.4	240.9 ± 110.3	302.4 ± 23.5
TDc 95-294	385.1 ± 108.3	194.9 ± 16.4	247.7 ± 61.3	297.0 ± 25.2
TDc 95-65	290.4 ± 57.0	194.9 ± 23.8	284.8 ± 129.2	422.9 ± 44.0
TDc 98-136	411.0 ± 82.8	187.5 ± 16.7	357.8 ± 30.8	314.0 ± 18.8
Mean	365.1 ± 76.5	181.8 ± 26.8	341.8 ± 140.0	353.6 ± 65.3
SEM	11.0	3.9	20.2	9.4

^aMean values (mg/kg on dry weight basis), ± S.D (standard deviation).

Table 6. Molar ratios (mol/kg) of calcium and zinc to phytate (Phy) of *Dioscorea cayenensis* tubers planted at Ibadan.

Accession	Phy:Zn ¹	Ca:Phy ²	[Ca][Phy]/[Zn] ³
TDc 04-167	2.33	9.71	0.01
TDc 04-168	2.67	8.25	0.01
TDc 04-169	2.29	8.32	0.01
TDc 04-170	2.50	8.85	0.01
TDc 95-293	2.50	11.82	0.02
TDc 95-294	3.05	11.02	0.02
TDc 95-65	2.20	15.00	0.01
TDc 98-136	4.13	9.11	0.02
Mean	2.71	10.26	0.01
CV ⁴	15:1	6:1	0.5

¹ (mg of Phy/MW (molecular weight) of Phy:mg of Zn/MW of Zn. ² (mg of Ca/MW of Ca:mg of phy/MW of phy). ³ (mol/kg Ca) (mol/kg Phy)/(mol/kg Zn) ⁴ CV means critical value

Molar ratios and interrelationships among Ca, Zn and phytate:

The molar ratio for Phy:Zn ranged from 2.2 to 4.13 with a mean of 2.71 (Table 6). In human studies, Phy:Zn molar ratios of 15:1 have been associated with reduced zinc bioavailability⁴⁰. Our results are lower than the values reported by Adeyeye *et al.*, for yellow yam (22.7)³⁹. They are also lower than the critical molar ratio of Phy:Zn indicating that the zinc availability is less likely to be inhibited by phytate in these yellow yam genotypes studied. The Ca:Phy molar ratio has been proposed as an indicator of calcium bioavailability. The molar ratios of Ca:Phy in the *D. cayenensis* genotypes studied ranged from 8.25 to 15.00 with a mean of 10.26 and are higher than values for yellow yam (1.4)³⁹. Our results are also higher than the critical value of Ca:Phy of 6:1²¹, indicating that absorption of calcium may be adversely affected by phytate in these yam genotypes. Ellis *et al.*¹⁸ indicated that the molar ratio [Ca] [Phy]/[Zn] is a better predictor of zinc availability and if the values were greater than 0.5 mol/kg, there would be interference with the availability of zinc. The molar ratios of [Ca][Phy]/[Zn] ranged from 0.01 to 0.02 mol/kg with a mean of 0.01 and are much lower than the critical value (0.5 mol/kg). Results obtained in this study are also much lower than the 0.21 mol/kg reported for yellow yam³⁹. Using this indicator, zinc bioavailability would not be inhibited by phytate in the yellow yam genotypes studied. The yellow yam tubers may be good sources of iron and zinc but not of calcium.

Recommended daily intake of minerals:

The recommended daily intake (RDI) of iron, zinc and calcium are 10, 15 and 800 mg respectively¹². TDc 04-168 planted at Ibadan had the highest levels of iron and zinc (14.04 and 15.90 mg/kg respectively). According to FAOSTAT¹², the quantity of yam consumed daily per capita in 2007 in Nigeria was 256.24 g. Tubers of TDc 04-167, TDc 04-168, TDc 04-169 and TDc 04-170 can provide about 33-35% of the RDI for iron and 25-27% of the RDI for zinc, all based on dry weight. The minerals present in these yam genotypes can substantially meet

the daily recommended intake, especially in West Africa where daily consumption may exceed 1 kg/person, if no significant loss is observed during processing. Bell ²⁷ reported no significant reduction in the iron, zinc, calcium, copper and magnesium content when yam tubers were boiled and processed into flour.

Conclusions

The variability for mineral and antinutrient among the eight genotypes can be utilized in breeding programmes designed for crop improvement. The levels of most of the minerals were higher in tubers grown in the drier location (Ibadan) when compared to the wet location (Onne), implying that a yellow yam genotype grown in one location can have higher mineral contents than in another location. It is suggested that a multi-locational testing of genotypes high in mineral contents be conducted in order to target specific genotypes to specific environment. Copper and tannin were less influenced by environmental changes as was indicated by their consistently similar nutrient values at both locations. Interaction between genotype and location was only significant for zinc, manganese and phytate. The levels of tannin were low and are not likely to have any adverse effect on the iron levels. The effect of phytate on the bioavailability of zinc from the molar ratios of Phy:Zn and [Ca]/[Phy]/[Zn] indicate that zinc absorption is unlikely to be inhibited. The molar ratio of Ca:Phy was higher than the reported critical molar ratio, indicating that calcium bioavailability may be adversely affected by phytate levels in these tubers. The molar ratios indicate that yellow yam tubers can be said to be fairly good genetic sources of iron and zinc. They are therefore very valuable in the programme for alleviation of micronutrient deficiency in the yam growing areas of Nigeria and the West African yam belt.

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