GENETIC VARIATION IN NUTRITIONAL PROPERTIES OF AFRICAN YAM BEAN (*Sphenostylis stenocarpa* Hochst ex. A. Rich. Harms) ACCESSIONS

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ABSTRACT

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The genetic variability in the mineral and proximate compositions of the seeds of 40 accessions and tubers of four accessions of African yam bean (AYB), an underutilized tuberous legume in sub-Saharan Africa, was investigated. Proximate parameters; moisture content, total ash, crude protein, crude fiber, crude fat, carbohydrate and mineral elements; calcium, phosphorous, magnesium, potassium and iron of the flours were determined according to standard methods. Highly significant differences (p< 0.001) were observed in proximate compositions of the seeds. Crude protein in the seeds ranged from 19.3% (TSs153) to 25.6% (TSs51) and 15.1% (AYB 57) to 15.9% (TSs107) in tuberous accessions. Crude protein, total ash and crude fat were the major contributors (80.2%) to variation in the proximate components of the seeds. Accessions TSs140 and TSs107 were high in crude fibre contents. Magnesium and potassium were prominent in seeds (454.2 mg, 100g^{-1} and 398.3 mg 100g^{-1}) and tubers (166.7mg, 100g^{-1} and 1010.1 mg 100g^{-1}) respectively. ***This study revealed the nutritional benefits of AYB seeds and tubers which could be used as an alternative source of protein, energy requirement and food supplement for human and livestock nutrition.***

Keywords: *African yam bean; Canonical analysis; dendrogram; genetic variability; mineral composition;*

INTRODUCTION

Legumes remain a staple food for a significant part of global population especially at subsistence level where they are combined with cereals. Leguminous seeds are known to provide protein as well as have calorific values. African yam bean (AYB), *Sphenostylis stenocarpa* (Hochst ex. A. Rich) Harms is an underutilised tuberous legume grown in the Southern, Eastern and Western parts of Nigeria extending to the north. (Adewale *et al.*, 2008). It has its center of origin in Africa. The AYB produces edible seeds above the ground, and some produce tubers. The seed and tuber of AYB contains different food fractions and minerals that are comparable to other food legumes (Adewale *et al.*, 2013). The concentrations of the essential minerals in AYB however differ in response to genetic and environmental factors. Proximate analysis of AYB shows that the seeds contain 22.0 to 37.2% crude protein (Fasoyiro *et al*., 2006; Chinedu and Nwinyi, 2012). Due to its high crude protein content, the seed is highly priced as a food legume in South Eastern Nigeria (Asoiro and Ani, 2011). AYB is rich in essential amino acids especially Lysine and methionine making it a cheap substitute of protein for man. Higher amino acid profiles than those in pigeon pea, cowpea, and bambara groundnut have been reported in the seeds of AYB (Uguru and Madukhaife *et al*., 2001). Meals from AYB are choicest and mostly desired by the labourers during the various farm operations (Adewale *et al*., 2013).Much emphasis has been placed on the major staple crops with the neglect of other crops which are equally rich in nutrients. This results in a reduction in diversity and genetic variability within such crops and invariably affects global food security. Despite the nutritional benefits of AYB, it is still underutilised because of several factors such as the high presence of anti-nutritional factors (Oboh *et al.*, 1998; Ajibade *et al.*, 2005), long cooking time due to hardness of the seed coat (Fasoyiro *et al*., 2006), and the photoperiod sensitive nature of the crop (Anochilli, 1984; Ojuederie *et al.*, 2016). It is therefore necessary to assess the germplasm base which is narrow and the landraces grown by farmers for landraces that are more nutritious than other staple legumes. The objective of this research therefore, was to assess the genetic variability in the mineral and proximate composition of some AYB accessions for better utilisation in human and animal diets.

MATERIALS AND METHODS

Source of material

Seeds of twenty-seven AYB accessions were obtained from the Genetic Resources Center of the International Institute of Tropical Agriculture, Ibadan, Nigeria and thirteen accessions from the Institute of Agricultural Research and Training, Moor Plantation, Ibadan. Nigeria These seeds were characterized morphologically in 2011 and 2012 cropping seasons (Ojuederie *et al.*, 2015) and the harvested seeds and tubers used for proximate and mineral analyses.

Sample Preparation
Each seed sample was oven-dried at 80°C for 24 hours using the method of Odebunmi *et al.* (2007). The dried samples were milled into fine flour using an electric blender, passed through 250nm stainless sieve and packaged in air-tight polyethylene bags and labeled for analysis. Tubers of four African yam bean accessions: AYB57, AYB45 TSs107 and TSs140 were peeled, washed with distilled water, made into flakes using an oven (Fisher Scientific model) and ground into flour with an electric blender for mineral and proximate analysis.

Determination of the proximate and mineral composition of African yam bean seed and tuber
The following proximate parameters: moisture content, total ash, crude protein, crude fiber, and crude fat of the flours were determined using the method of Association of Official Analytical Chemists (AOAC, 2000). The minerals (iron, calcium and magnesium) contents of AYB accessions were determined using atomic absorption spectrophotometer (Alpha 4-Chem. Tech analytical). The phosphorus in the sample filterate was determined by using Vanadomolybdate reagent at 470nm using colorimetric method (Kilgour, 1987). Potassium was determined using Jenway Digital Flame photometer (PFP7 model) (Novozamsky *et al.,* 1983; Ojuederie *et al.,* 2016).

Statistical Analysis
Data were subjected to one way analysis of variance in a completely randomized design with three replicates. Means were compared using Student Newman Keuls test. Canonical discriminant analysis was performed to identify the proximate parameters that contributed most to differences in accessions using SAS software 9.3(SAS, 2010). Paired T test was used to compare the mineral composition of the seeds and tubers of the four AYB accessions evaluated.

RESULTS AND DISCUSSION

Proximate composition of African yam bean seed and tuber
All proximate components (Table 1) were highly significant ($P < 0.001$) in the seeds of AYB. Crude protein in the seeds ranged from 19.3% (TSs153) to 25.6% (TSs51). The highest crude protein content obtained in TSs51 (25.6%), was higher than that reported for AYB (21.7%) by Ajibade *et al.* (2005), peanut, cowpea, chickpea, lima bean and pigeon pea (Ameh, 2007), as well as the Mexican yam bean (*Pachyrhizus erosus*) (Sorensen, 1996). It was however, less than (37.2%) and (32.4%) reported for AYB and bambara groundnut by Chinedu and Nwinyi, (2012) and 32.5% for winged bean (Chimmad *et al.,* 1998). Although AYB showed lower crude protein values than bambara groundnut, winged bean and soybean, Uguru and Madukhaife (2001) reported that the amino acid contents in seeds of AYB are higher than those in pigeon pea, cowpea and bambara groundnut with lysine and leucine being predominant (Onyenekwe *et al.,* 2000). The moisture content of the seeds ranged from 11.3% (TSs150) to 12.6% (TSs41). Moisture content levels were higher (11.8%) in the seeds of AYB when compared to 9.6% reported for winged bean (Chimmad *et al.,* 1998), but lower than 88.9% reported for the *Pachyrhizus erosus* (Sorensen, 1996).

The proximate results obtained in this study are in agreement with the reports of Abbey and Berezi (1988) and Oshodi *et al.* (1997) that crude protein (21.0% to 29.0%) and carbohydrate (50.0% to 59.7%) are the major components of the seeds of AYB. Two canonical discriminant functions (CDFs) were sufficient to explain 98.9% of the total variation (Table 2). The first discriminant function had the highest weight in contribution accounting for 88.0% of total variance. Crude protein, crude fat and carbohydrate were the major contributors (88.0%) to variation in the proximate components. Correlations between discriminant functions and proximate variables are shown in Table 3.Carbohydrate had the highest negative correlation (-0.96) followed by crude protein and fat with positive correlations (0.93) and (0.55) respectively, with the first CDF. Crude fibre (0.68), crude fat (0.52) and total ash (0.45) had the highest correlations with the second CDF. This accounted for 10.82 % of total variance in proximate components. These components are important determinants for the nutritive and processing quality of AYB seeds.

Significant differences ($p<0.05$) were obtained in the proximate composition of the tubers of four AYB accessions evaluated as indicated in Table 4. Accession TSs107 had the highest protein and carbohydrate contents in the tuber (15.9% and 68.7%) respectively but was not significantly different from the protein and carbohydrate contents in TSs 140. Accession TSs 107 also had the highest calorific value (1469 Kjg^{-1}). The tubers of AYB have substantial amount of protein which makes it a good source of alternative protein for human and livestock consumption. The average moisture content of AYB tubers (10.3%) was lower than that reported for Irish potato (78.9%) and Sweet potato (70.6%) by Odebunmi *et al.* (2007) as well as the Mexican yam bean (87.0%) by Sorensen (1996).The moisture contents for all the AYB seeds and tubers fell within the recommended range of 0–13.0% (James, 1995). Tubers of AYB with low moisture contents could store for a longer time without spoilage unlike tubers of crops with higher moisture contents which could lead to food spoilage through increased microbial action (Onyeike *et al.,* 1995). Moreover, moisture contents below 13.0% are suitable for storage and processing of flours without degradation of triglycerides by microorganisms (Onyeike *et al.,* 1995). Accessions TSs140 and TSs107 with high values of crude fibre may be indicative of the digestibility of these accessions since food fibers are known to aid digestion (Ihekoronye and Ngoddy, 1995).

Table 1: Proximate composition of the seeds of 40 African yam bean accessions

Accessions	CP (%)	MC (%)	TA (%)	C. Fib. (%)	C. Fat (%)	CHO (%)	Caloric Value (Kjg^{-1})
TSs5	$20.8\pm0.0^{f-j}$	11.3 ± 0.0^{s}	$3.5\pm0.0^{a-d}$	3.3 ± 0.0^{hi}	$1.2\pm0.0^{j-n}$	59.9 ± 0.0^{bc}	$1392.2\pm0.5^{a-g}$
TSs19	$22.7\pm0.0^{b-f}$	12.2 ± 0.0^{d}	$3.4\pm0.0^{a-e}$	4.0 ± 0.0^{c}	0.7 ± 0.0^{nm}	$56.9\pm0.0^{e-h}$	$1358.9\pm0.3^{e-h}$
TSs26	$23.1\pm0.0^{b-e}$	11.9 ± 0.0^{g}	2.7 ± 0.0^{hi}	4.3 ± 0.0^{ab}	$1.3\pm0.0^{j-m}$	$56.8\pm0.0^{b-h}$	$1380.5\pm0.0^{b-h}$
TSs41	25.5 ± 0.8^{a}	12.6 ± 0.0^{a}	$3.3\pm0.3^{a-f}$	$3.3\pm0.0^{g-i}$	4.4 ± 0.1^{a}	$50.9\pm0.4^{a-d}$	$1437.6\pm 6.5^{a-d}$
TSs42	$21.4\pm0.3^{d-i}$	11.6 ± 0.0^{o}	$3.2\pm0.3^{b-g}$	4.0 ± 0.0^{c}	3.2 ± 0.9^{b}	$56.6\pm0.3^{a-e}$	$1421.5\pm23.2^{a-e}$
TSs45	$21.5\pm0.0^{c-i}$	11.9 ± 0.0^{j}	$3.3\pm0.0^{a-f}$	3.9 ± 0.0^{c}	$1.4\pm0.0^{h-k}$	$57.9\pm0.0^{d-h}$	1330.2 ± 70.9^{h}
TSs51	25.6 ± 0.0^{a}	11.5 ± 0.0^{q}	1.1 ± 0.0^{k}	$3.5\pm0.0^{d-f}$	$1.9\pm0.0^{f-h}$	$56.3\pm0.0^{a-c}$	$1438.7\pm0.2^{a-c}$
TSs52	$22.4\pm0.0^{b-g}$	11.6 ± 0.0^{no}	$2.7\pm0.7^{g-i}$	4.1 ± 0.0^{c}	$1.1\pm0.0^{j-n}$	$58.1\pm0.0^{c-h}$	1334.6 ± 70.9^{gh}
TSs66	$22.7\pm0.0^{b-f}$	12.3 ± 0.0^{c}	3.7 ± 0.0^{ab}	3.9 ± 0.0^{c}	$1.3\pm0.0^{j-l}$	$56.1\pm0.0^{e-h}$	$1363.6\pm0.1^{e-h}$
TSs68	$22.9\pm0.9^{b-f}$	11.6 ± 0.0^{p}	$3.1\pm0.3^{c-h}$	$3.6\pm0.0^{d-f}$	$2.1\pm0.0^{d-f}$	$56.8\pm0.6^{f-j}$	$1408.3\pm5.7^{a-f}$
TSs78	$22.5\pm0.8^{b-g}$	11.8 ± 0.0^{k}	$3.5\pm0.3^{a-d}$	4.1 ± 0.0^{c}	$2.1\pm0.0^{d-f}$	$56.1\pm0.4^{g-j}$	$1390.1\pm5.2^{a-g}$
TSs88	23.6 ± 0.8^{bc}	11.9 ± 0.0^{h}	$3.3\pm0.3^{a-f}$	$3.5\pm0.0^{d-f}$	2.6 ± 0.0^{cd}	55.1 ± 1.1^{jk}	$1409.9\pm5.2^{a-f}$
TSs107	$23.3\pm0.0^{b-d}$	12.2 ± 0.0^{d}	$3.4\pm0.0^{a-e}$	3.9 ± 0.0^{c}	$0.8\pm0.0^{l-n}$	$56.4\pm0.0^{g-j}$	$1349.3\pm13.9^{f-h}$
TSs123	$21.9\pm0.5^{c-h}$	11.8 ± 0.0^{l}	$3.1\pm0.3^{c-h}$	3.7 ± 0.0^{de}	$2.4\pm0.0^{c-e}$	$57.2\pm0.2^{e-j}$	$1409.6\pm5.3^{a-f}$
TSs133	$22.1\pm1.2^{b-h}$	11.7 ± 0.0^{m}	$3.6\pm0.3^{a-c}$	3.1 ± 0.0^{i}	$2.0\pm0.3^{e-f}$	$57.5\pm1.2^{e-i}$	$1403.8\pm11.1^{a-f}$
TSs134	$22.2\pm0.0^{b-h}$	12.1 ± 0.0^{f}	$3.2\pm0.0^{b-g}$	$3.6\pm0.0^{d-f}$	$1.3\pm0.0^{i-l}$	$57.7\pm0.0^{e-i}$	$1382.0\pm0.1^{b-h}$
TSs137	$21.8\pm0.0^{c-h}$	12.1 ± 0.0^{e}	$3.4\pm0.0^{a-e}$	$3.3\pm0.0^{g-i}$	$0.9\pm0.0^{k-n}$	$58.4\pm0.0^{b-g}$	$1375.8\pm0.3^{c-h}$
TSs138	19.9 ± 0.0^{ij}	12.3 ± 0.0^{c}	$2.9\pm0.0^{e-i}$	3.3 ± 0.0^{hi}	$1.4\pm0.0^{h-k}$	60.1 ± 0.0^{b}	$1390.8\pm0.3^{a-g}$
TSs139	$22.8\pm1.1^{b-f}$	11.4 ± 0.0^{r}	$3.4\pm0.3^{a-e}$	3.3 ± 0.0^{hi}	$2.3\pm0.0^{c-f}$	$56.8\pm1.4^{f-j}$	$1415.6\pm5.2^{a-e}$
TSs140	$21.9\pm1.1^{b-h}$	11.7 ± 0.0^{l}	$3.2\pm0.3^{b-g}$	3.6 ± 0.0^{de}	2.7 ± 0.0^{c}	$56.8\pm1.4^{f-j}$	$1415.5\pm5.3^{a-e}$
TSs148	$20.6\pm0.6^{g-j}$	11.6 ± 0.0^{p}	$3.3\pm0.3^{a-f}$	4.3 ± 0.0^{ab}	$2.5\pm0.0^{c-e}$	$57.7\pm0.3^{e-i}$	$1401.1\pm5.7^{a-f}$
TSs150	25.1 ± 0.1^{a}	11.3 ± 0.0^{s}	$3.0\pm0.1^{d-h}$	3.9 ± 0.0^{c}	$2.5\pm0.0^{c-e}$	54.2 ± 0.3^{k}	$1415.7\pm3.3^{a-e}$
TSs152	25.4 ± 0.0^{a}	12.0 ± 0.0^{g}	2.5 ± 0.0^{i}	3.1 ± 0.0^{i}	$1.1\pm0.0^{j-n}$	$55.9\pm0.0^{h-j}$	$1397.5\pm0.0^{a-f}$
TSs 153	19.3 ± 0.0^{j}	11.5 ± 0.0^{q}	$2.8\pm0.0^{f-i}$	3.7 ± 0.0^{de}	0.3 ± 0.0^{o}	62.5 ± 0.0^{a}	$1375.1\pm0.0^{d-h}$
TSs 154	$21.2\pm0.0^{e-i}$	11.8 ± 0.0^{l}	$3.0\pm0.0^{d-h}$	3.7 ± 0.0^{de}	$1.2\pm0.0^{j-n}$	$59.2\pm0.0^{b-e}$	$1385.9\pm0.6^{a-g}$
TSs 156	19.5 ± 0.0^{j}	11.8 ± 0.0^{l}	$2.9\pm0.0^{d-h}$	4.4 ± 0.0^{a}	$1.6\pm0.0^{g-j}$	$59.8\pm0.0^{b-d}$	$1383.4\pm0.3^{b-h}$
TSs 157	$20.4\pm0.0^{h-j}$	11.6 ± 0.0^{p}	$3.1\pm0.0^{c-h}$	3.6 ± 0.0^{de}	$1.4\pm0.0^{h-k}$	59.9 ± 0.0^{bc}	1393.9 ± 0.6^{a}f
AYB1	$22.6\pm0.6^{b-g}$	11.6 ± 0.6^{o}	$3.4\pm0.3^{a-e}$	$3.5\pm0.1^{e-g}$	2.6 ± 0.0^{cd}	$56.3\pm0.4^{g-j}$	$1414.9\pm2.4^{a-e}$
AYB4	$21.9\pm0.0^{b-h}$	12.4 ± 0.0^{b}	$2.8\pm0.3^{f-i}$	4.0 ± 0.3^{c}	$2.2\pm0.0^{c-f}$	$56.7\pm0.6^{f-j}$	$1394.7\pm9.9^{a-f}$
AYB9	$22.1\pm0.1^{b-h}$	11.8 ± 0.0^{l}	3.8 ± 0.3^{a}	3.9 ± 0.0^{c}	$2.2\pm0.0^{c-f}$	$56.3\pm0.2^{g-j}$	$1390.3\pm5.2^{a-g}$
AYB23	$21.6\pm0.3^{c-i}$	11.6 ± 0.0^{p}	1.9 ± 0.3^{j}	$3.6\pm0.0^{d-f}$	2.7 ± 0.0^{c}	$58.7\pm0.6^{b-f}$	1440.7 ± 5.2^{ab}
AYB26	23.5 ± 1.4^{bc}	11.7 ± 0.0^{n}	$3.6\pm0.3^{a-c}$	2.7 ± 0.0^{k}	$2.4\pm0.3^{c-e}$	$56.1\pm2.0^{g-j}$	$1420.0\pm0.5^{a-e}$
AYB 34	23.9 ± 0.0^{b}	12.0 ± 0.0^{g}	$2.9\pm0.0^{e-i}$	$3.5\pm0.0^{e-g}$	$0.9\pm0.3^{l-n}$	$56.7\pm0.0^{f-j}$	$1379.6\pm0.4^{b-h}$
AYB45	$22.8\pm0.3^{b-f}$	12.1 ± 0.0^{f}	$3.5\pm0.3^{a-d}$	3.7 ± 0.0^{de}	$2.5\pm0.0^{c-e}$	$55.4\pm0.6^{i-k}$	$1400.2\pm5.3^{a-f}$
AYB 50	$22.4\pm0.0^{b-h}$	11.7 ± 0.0^{l}	$3.4\pm0.0^{a-e}$	4.3 ± 0.0^{ab}	0.7 ± 0.0^{n}	$57.4\pm0.0^{f-i}$	$1357.9\pm0.3^{e-h}$
AYB 56	$22.0\pm0.0^{b-h}$	11.7 ± 0.0^{lm}	$3.4\pm0.0^{a-e}$	$3.4\pm0.0^{f-h}$	$1.8\pm0.0^{f-h}$	$57.7\pm0.0^{e-i}$	$1397.6\pm0.5^{a-f}$
AYB57	$23.4\pm0.7^{b-d}$	11.5 ± 0.0^{q}	$3.0\pm0.3^{d-h}$	2.9 ± 0.0^{j}	3.2 ± 0.0^{b}	$55.9\pm0.4^{h-j}$	1446.5 ± 5.2^{a}
AYB61	$21.7\pm0.3^{c-h}$	11.6 ± 0.0^{o}	$3.2\pm0.3^{b-g}$	3.8 ± 0.0^{d}	2.7 ± 0.3^{c}	$57.1\pm0.9^{f-j}$	$1416.1\pm0.2^{a-g}$
AYB 70B	$21.9\pm0.0^{b-h}$	11.9 ± 0.0^{i}	$3.1\pm0.0^{b-h}$	$3.4\pm0.0^{f-h}$	$1.4\pm0.0^{h-k}$	$58.2\pm0.0^{c-h}$	$1392.0\pm0.0^{a-h}$
AYBIFE	23.6 ± 0.7^{bc}	11.7 ± 0.0^{n}	$3.6\pm0.3^{a-c}$	2.2 ± 0.3^{l}	2.6 ± 0.0^{cd}	$56.4\pm0.1^{f-j}$	$1432.2\pm9.9^{a-d}$
Mean	22.4	11.8	3.1	3.6	1.9	57.2	1396.1
Std Error	0.17	0.03	0.06	0.05	0.1	0.21	3.33

CP-Crude protein, MC-Moisture content, TA-Total Ash, C. Fib.-Crude Fiber, C. Fat-Crude fat, CHO-Carbohydrate. Means followed by the same letter down the columns are not significantly different ($p<0.001$) using Student-Newman-Keuls test.

Table 2: Canonical discriminant analysis of proximate parameters of African yam bean seeds

	Discriminant functions			
Variable	1	2	3	4
Crude protein	0.9258	-0.2667	0.0469	-0.0225
Crude fat	0.5453	0.5165	-0.3757	0.6368
Crude Fibre	-0.1325	0.6757	0.6765	-0.0264
Moisture content	0.2660	-0.0434	0.1894	0.7052
Total Ash	-0.1209	0.4503	-0.1171	-0.5736
Carbohydrate	-0.9601	-0.2386	-0.1451	0.0113

Table 3: Correlations between discriminant proximate variables and discriminant functions

Function	Eigen Value	Percent variation (%)	Cumulative variation (%)
1	11.34	88.03	88.03
2	1.39	10.82	98.85

Cluster analysis of African yam bean accessions based on proximate parameters

The Dendrogram that described the 40 AYB accessions based on proximate parameters is presented in Fig. 1. The distances between the accessions spanned 0.0005 to 0.2101 with a mean distance of 0.1053. Phenotypically, TSs140 and TSs123 are the most similar accessions based on proximate analysis with the closest distance of 0.0005 joined under the first cluster. Both accessions had similar values for the proximate parameters analysed. The 40 AYB accessions were grouped into five clusters at a similarity distance of 0.10. Seventeen accessions were grouped into the cluster I. The protein and carbohydrate contents in this cluster ranged from 21.7 % to 23.6% and 55.1 % to 58.2%, respectively. Cluster 11 had ten accessions. Accession TSs66 in the second cluster, had the highest total ash content (3.68 %) while Cluster III had ten accessions. The protein content ranged from 19.3% to 23.1%. TSs153 had the least protein content but the highest carbohydrate content (62.5%). Accessions in this cluster also had high fibre content ranging from 3.3% to 4.4%. Cluster IV had only one accession TSs41 which had the highest moisture content (12.6%), crude fat (4.4%) and the lowest carbohydrate content (50.9%). Two accessions were grouped into the fifth cluster. Accession TSs51 in this cluster, had the highest crude protein content (25.6 %).

Table 4.: Proximate compostion of the tubers of four African yam bean accessions

Accessions	Crude protein (%)	Moisture content (%)	Total Ash (%)	Crude Fibre (%)	Crude Fat (%)	Carbohydrate content (%)	Caloric value (Kjg^{-1})
AYB57	15.1±0.1^{c}	10.4±0.2^{a}	3.4±0.1^{a}	1.5±0.0^{b}	2.0±0.2^{a}	67.7±0.1^{a}	1457.4±8.7^{a}
AYB45	15.3±0.2^{b}	10.5±0.1^{a}	3.4±0.0^{a}	2.6±0.0^{a}	0.8±0.0^{c}	68.3±1.9^{a}	1457.4±30.2^{a}
TSs107	15.9±0.2^{a}	10.2±0.8^{a}	2.4±0.2^{b}	2.6±0.0^{a}	1.5±0.0^{b}	68.7±2.6^{a}	1469.3±47.1^{a}
TSs140	15.5±0.2^{b}	10.4±0.2^{a}	2.7±0.0^{b}	2.7±0.1^{a}	0.8±0.0^{c}	67.9±0.4^{a}	1423.2±1.9^{a}
Mean	15.5	10.3	2.9	2.4	1.3	68.3	1445.7
Std Error	0.12	0.11	0.16	0.18	0.2	0.47	10.29

All values are of means± SD of triplicate determination. Means followed by the same letters down the columns are not significantly different ($P \leq 0.05$) using Least significant difference

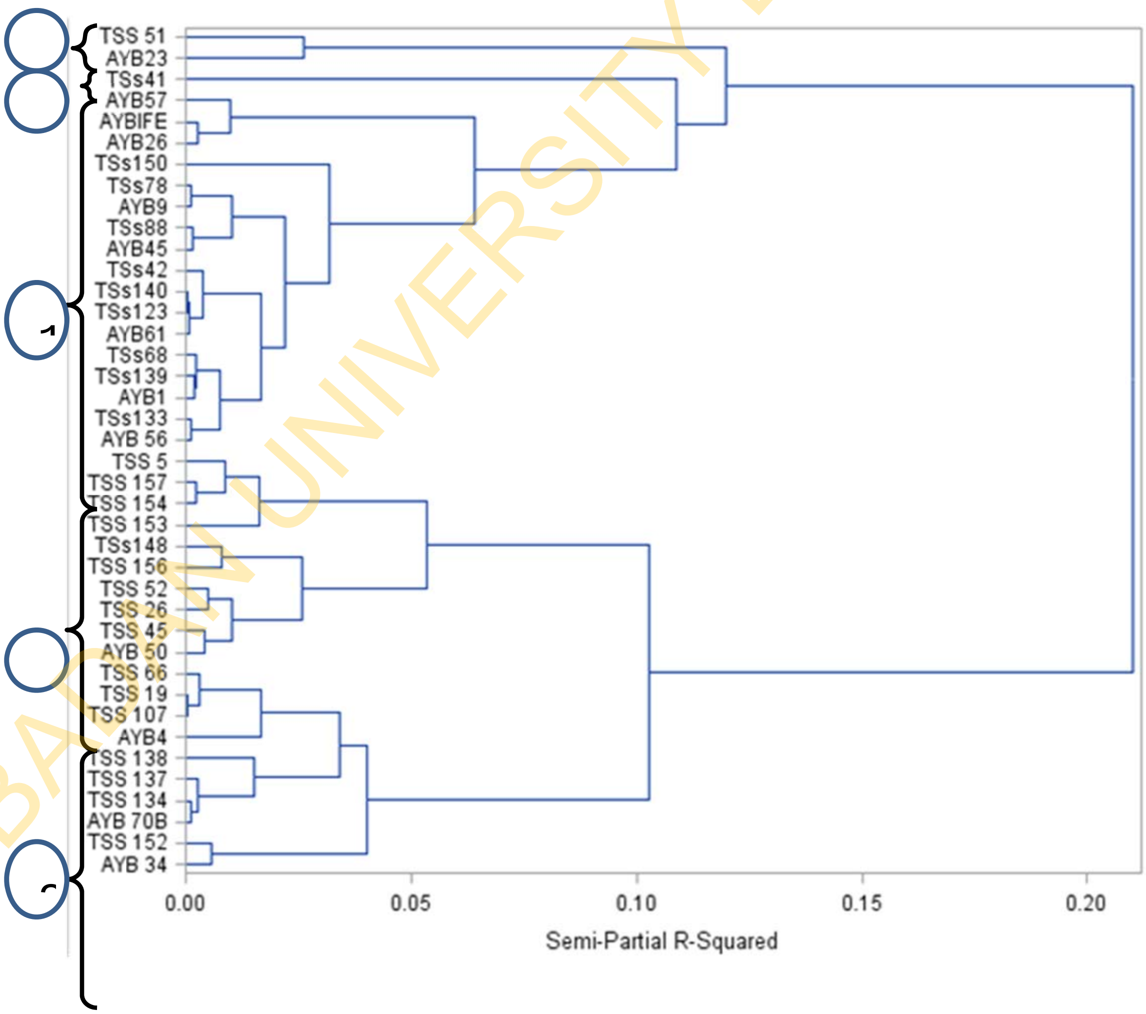

Fig: 1 Dendrogram produced from Ward's minimum variance cluster analysis showing genetic relationship among 40 African yam bean accessions based on proximate values

Mineral composition of African yam bean seed and tuber

The mineral composition of the seeds (calcium, phosphorous, magnesium, potassium and iron) of forty accessions of African yam bean is presented in Table 5. Highly significant differences (p<0.001) were observed in the mineral components of the seeds. Calcium levels were significantly highest in AYB34 (70.1±0.4**).**No significant difference was observed in the calcium levels in accessions AYB56 (67.7±0.3) and TSs153 (66.9±0.3) but both accessions had significantly different calcium levels than other accessions. Phosphorous levels were not significantly different in accessions AYB70B (250±0.0), TSs152 (255±7.1) and TSs66 (255±7.1) but was significantly highest in AYBIFE (381±0.0**).**Accession TSs148 had significantly higher magnesium content (788.9±10.3) compared to other accessions. Potassium levels in the seeds of AYB were significantly highest in TSs19 (770±10.3).However, no significant difference was observed in the concentration of potassium in accessions TSs139 (333.8±0.0), TSs140 (333±9.1) and TSs150 (333.9±18.2) respectively. Iron content was significantly higher in accessions TSs41 (28.5±0.1**)** and TSs42 (28.3±0.2**)** than in other accessions evaluated. The seeds of AYB had higher percentage of magnesium followed by potassium with iron content been the least mineral component. The mineral composition of the tubers of four accessions of African yam Bean is presented in Table 6. Calcium content was significantly highest in AYB45 (51.6 ±1.1) and least in TSs107 (48.4 ±0.4).Phosphorous content was significantly (p<0.001) lower in accessions AYB45 and AYB57 (1.5±0.0).

Table 5: Mineral composition (g kg^{-1}) of African yam bean Seeds

Accessions	Calcium	Phosphorous	Magnesium	Potassium	Iron
TSs5	0.39±0.01m	2.50±0.28e-g	2.73±0.00f-i	6.69±0.00b	0.14±0.00bc
TSs19	0.44±0.00ij	3.01±0.07b-d	2.55±0.08g-j	7.71±0.00a	0.21±0.01bc
TSs26	0.65±0.00c	0.95±0.09no	6.49±0.09c-e	3.02±0.04e-f	0.09±0.00bc
TSs41	0.17±0.01rs	1.18±0.07o	6.40±0.38c-e	3.24±0.11e-f	0.55±0.36a
TSs42	0.16±000rs	3.03±0.27bc	6.97±0.11c	3.08±0.04e-f	0.28±0.00b
TSs45	0.42±0.01j-l	2.25±0.07g-j	2.52±0.02g-j	6.57±0.00b	0.13±0.00bc
TSs51	0.64±0.01cd	2.70±0.00d-f	6.62±0.06c-e	2.89±0.04gf	0.08±0.00bc
TSs52	0.43±0.01j-l	2.11±0.00i-k	2.37±0.01g-j	5.56±0.12c	0.13±0.00bc
TSs66	0.43±0.00i-k	2.55±0.07e-g	2.10±0.01ij	5.75±0.00bc	0.14±0.00bc
TSs68	0.15±0.00s	1.02±0.07m-o	6.47±0.09c-e	2.92±0.00fg	0.12±0.00bc
TSs78	0.55±0.00g	3.26±0.09b	2.70±0.00f-j	2.53±0.12g	0.12±0.01bc
TSs88	0.17±0.01rs	1.19±0.00mn	2.90±0.00fg	2.93±0.00fg	0.14±0.00bc
TSs107	0.43±0.01j-l	2.35±0.07f-j	2.31±0.01c-e	5.75±0.11bc	0.14±0.00bc
TSs123	0.64±0.01cd	2.44±0.00f-i	2.95±0.21fg	2.62±0.06g	0.09±0.00bc
TSs133	0.16±0.00rs	0.82±0.08o	6.52±0.04c-e	3.44±0.00e-g	0.09±0.01bc
TSs134	0.53±0.00h	1.31±0.29lm	2.60±0.14g-j	4.15±0.00de	0.14±0.00bc
TSs137	0.42±0.01kl	2.05±0.01jk	2.04±0.01j	5.99±0.23bc	0.14±0.01bc
TSs138	0.59±0.01f	2.96±0.00cd	2.60±0.00g-j	4.02±0.00d-f	0.04±0.00c
TSs139	0.22±0.00p	0.82±0.00o	7.45±0.05b	3.34±0.00e-f	0.07±0.00bc
TSs140	0.19±0.01q	2.15±0.09i-k	6.94±0.04c	3.34±0.09e-f	0.08±0.00bc
TSs148	0.17±0.01rs	1.89±0.00k	7.89±0.99a	3.44±0.04e-f	0.08±0.00bc
TSs150	0.24±0.00d	2.38±0.02f-j	6.77±0.02cd	3.34±0.18e-f	0.08±0.00bc
TSs152	0.45±0.01i	2.55±0.07e-g	2.28±0.00g-j	6.36±0.12bc	0.14±0.00bc
TSs153	0.68±0.01b	1.58±0.00l	6.69±0.03c-e	3.18±0.00e-f	0.08±0.00bc
TSs154	0.42±0.01kl	2.60±0.00e-g	2.67±0.03g-j	4.62±2.04d	0.12±0.00bc
TSs156	0.43±0.01j-l	2.40±0.00f-j	2.35±0.01g-j	5.51±0.00c	0.15±0.00bc
TSs157	0.39±0.01m	2.30±0.00g-j	2.49±0.04g-j	6.32±0.18bc	0.15±0.00bc
AYB1	0.17±0.01rs	1.83±0.18k	6.77±0.19cd	2.58±0.06g	0.08±0.00bc
AYB4	0.15±0.00s	0. 97±0.08no	6.18±0.01de	2.76±0.04g	0.08±0.00bc
AYB9	0.61±0.01e	1.85±0.00k	2.80±0.14f-h	2.58±0.06g	0.15±0.01bc
AYB23	0.16±0.0rs	1.13±0.15m-o	6.14±0.07de	2.73±0.09g	0.07±0.00bc
AYB26	0.17±0.00rs	1.34±0.08lm	6.19 ±0.07c-e	3.08±0.04e-f	0.08±0.01bc
AYB34	0.70±0.00a	2.90±0.00cd	6.99±0.09e	3.08±0.09e-f	0.07±0.00bc
AYB45	0.16±0.01rs	2.52±0.00e-g	7.41±0.00k	2.74±0.05g	0.09±0.01bc
AYB50	0.63±0.01d	2.40±0.00f-j	6.28±0.13de	2.76±0.04g	0.08±0.00bc
AYB56	0.68±0.00b	2.80±0.00c-e	6.06±0.02e	3.43±0.01e-f	0.08±0.00bc
AYB57	0.18±0.01r	0.80±0.08o	6.61±0.11c-e	2.60±0.00g	0.08±000bc
AYB61	0.17±0.01rs	0.94±0.04no	6.14±0.02de	3.05±0.04e-f	0.08±0.00bc
AYBIFE	0.29±0.01n	3.61±0.29a	3.25±0.18f	2.32±0.06g	0.12±0.00bc
AYB70B	0.42±0.01lm	2.50±0.00e-h	2.17±0.01h-j	5.88±0.23bc	0.14±0.01bc
Mean	0.37	2.05	4.54	3.95	0.12
Std Error	0.03	0.12	0.34	0.24	0.01

All values are Means ± SD of triplicate determination expressed on dry weight basis. Means followed by the same letter(s) are not significantly different at p<0.001 using Student-Newman-Keuls–SNK Test.

Table 6: Mineral composition of AYB tuber (g kg^{-1})

Accessions	Calcium	Phosphorous	Magnesium	Potassium	Iron
AYB45	0.52±0.01a	0.02±0.00ab	1.69±0.00b	11.83±0.00a	0.08±0.00b
AYB57	0.51±0.00a	0.02±0.00ab	1.56±0.00d	10.95±0.00a	0.08±0.00b
TSs107	0.48±0.00a	0.01±0.00b	1.78±0.01a	9.31±0.16b	0.09±0.00a
TSs140	0.49±0.00a	0.03±0.00a	1.65±0.02c	8.33±0.62b	0.07±0.01c
Mean	0.5	0.02	1.67	10.1	0.08
Std. Error	0.71	0.2	2.91	4.86	0.48

All values are Mean ± SD of triplicate determination expressed on dry weight basis. Means followed by the same letter are not significantly different at p<0.001 using Least significant difference.

Accession TSs140 had the highest phosphorous content (2.3±0.0) in the tubers of African yam bean evaluated. Potassium content was not significantly different in accessions AYB45 (1182.5±0.1) and AYB57 (1095±0.0) but was significantly different in TSs107 and TSs140. Accession TSs107 had the highest amount of magnesium (177.9±0.9) which was significantly different from the other accessions, with AYB57 having the least magnesium content (156.2±0.0). Iron content was significantly highest in TSs107 (9.30±0.28). The tubers were high in potassium and magnesium (Table 5). In this study, iron, phosphorous, magnesium and potassium had higher levels in the seeds than the tubers. Also, magnesium and potassium contents were found to be higher in the tubers analysed. This is contrary to the report of Ameh (2007) that magnesium phosphorus, potassium, iron and manganese were more in the tuber than the seed with the quantity of sodium, calcium, zinc and copper in the tuber been less than those found in the seed. A ttest value of -0.51 was obtained which showed that both the seeds and tubers did not significantly differ in the composition of their mineral contents (Table 7). Most AYB accessions evaluated met the Recommended Dietary Allowance (RDA) of minerals in infants, children and adults. The iron levels in TSs41 (28.5 mg $100g^{-1}$), TSs4 (28.3 mg $100g^{-1}$), TSs19 (20.7 mg $100g^{-1}$) and TSs157 (15 mg $100g^{-1}$) were far above the RDA for infants, children and adults.

Table 7: Mineral composition of African yam bean seeds and tubers (g kg^{-1})

Accessions	Minerals	Seed	Tuber
TSs107	Iron	0.14	0.09
TSs140	Iron	0.08	0.07
AYB45	Iron	0.09	0.08
AYB57	Iron	0.08	0.08
TSs107	Calcium	0.43	0.48
TSs140	Calcium	0.19	0.49
AYB45	Calcium	0.16	0.51
AYB57	Calcium	0.18	0.52
TSs107	Potassium	5.75	9.31
TSs140	Potassium	3.34	8.33
AYB45	Potassium	2.74	11.83
AYB57	Potassium	2.60	10.95
TSs107	Magnesium	2.31	1.78
TSs140	Magnesium	6.94	1.65
AYB45	Magnesium	7.41	1.56
AYB57	Magnesium	6.61	1.69
TSs107	Phosphorous	2.35	0.01
TSs140	Phosphorous	2.15	0.03
AYB45	Phosphorous	2.52	0.02
AYB57	Phosphorous	0.80	0.02
Mean		2.34	2.48
CV (%)		55.9	89.71

t (0.05) for comparing the two means = -0.15, Pr > |t| 0.8826

Consumption of these accessions is recommended for pregnant and lactating mothers as well as infants. Fifty-five percent (55%) of accessions met the RDA for magnesium for infants, children and adults especially TSs148 (788.9 mg $100g^{-1}$), AYB45 (740 mg $100g^{-1}$), AYB34 (699.5 mg $100g^{-1}$) and TSs42 (697mg $100g^{-1}$).However, few accessions (32.5%) met the RDA for infants, children and adults for potassium. Accessions TSs19 (770.5 mg $100g^{-1}$), TSs5 (669.1 mg $100g^{-1}$) and TSs45 (656.9 mg $100g^{-1}$) met the RDA requirements. The levels of calcium and phosphorus in the AYB seeds of the 40 accessions did not meet the dietary requirement for infants, children, or adults. If seeds of AYB accessions below the RDA for calcium and phosphorous are consumed in conjunction with other foods rich in minerals, the RDA for calcium and phosphorous will be met. The nutritional benefits derivable from AYB can be harnessed by reduction of anti-nutritional contents and formulation of infant food and diets (Poulter and Caygill, 2006).

CONCLUSION

The tubers of AYB could be used as a staple food in West Africa where only the seeds are currently consumed as it is highly nutritious. The tubers are rich in protein and the minerals; potassium, magnesium and iron which are essential to man. Magnesium and potassium were the major essential minerals in the seeds and tubers of AYB evaluated. The concentrations of these minerals present in the seeds and tubers of AYB makes it a good source of magnesium and potassium as macronutrients. Accessions that are rich in proximate parameters and essential minerals; TSs5, TSs19, TSs41, TSs42, and TSs140 could be used as parents in breeding programmes to improve the nutritional content of other accessions.

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