Diversity in Proximate Analysis of Tubers of some African Yam Bean (*Sphenostylis stenocarpa*) (Hochst Ex. A. Rich.) Harms (Fabaceae) accessions

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ABSTRACT: This study was carried out to determine the proximate and mineral composition of fresh tubers of 17 African Yam Bean (AYB) accessions. Standard analytical procedures were adopted in the determination of bioactive compounds in the tubers of the different accessions. Data were subjected to descriptive statistics, principal component and clustering analysis. Ash content ranged between 4.59-9.99%, Carbohydrate (46.59-66.52%), Crude fibre (6.93-12.13), Fat (1.06-4.04%), Moisture content ranged between 11.36-21.91% and Protein (4.91-14.50%). The range of mineral content evaluated were: Calcium (1.53-5.82), Copper (10.59-44.93), Iron (63.52-240.48), Magnesium (0.59-2.26), Manganese (42.25-160.01), Nitrogen (0.75-2.23%), Potassium (1.34-5.08), Sodium (0.05-0.22) and Zinc (28.24-106.93. The proximate variables in the tubers significantly (P<0.05) distinguished the 17 AYB accessions. Three distinct clusters were visible. The seven accessions in cluster I had the highest protein, carbohydrate and moisture content. Cluster II had the least mineral content. Accessions with the highest fat and mineral content were grouped in cluster III. Food, nutritional and medicinal values inherent in AYB tubers is high and promising, its utilization in human and livestock feeds is greatly encourage.

Root and tuber crops are ranked the second largest group of cultivated species behind cereals in tropical countries; they contribute immensely to food security (Lebot, 2009). A lot of tuberous legumes are underexploited although, they have great potentials for food and nutritional security but lacks popularity amidst other important crops (Grueneberg, 1998). Saxon (1981) identified about fifty tuberous legumes which are of international significance; seventeen of them are of African origin, African yam bean (*Sphenostylis stenocarpa*) seem to be the most important. These tuberous legumes can serve as food, feed, insecticide, pharmaceutical, flavouring agents etc. (Adewale and Odoh, 2013). *Sphenostylis stenocarpa* (Hochst Ex. A. Rich) commonly known as African yam bean (AYB) is an orphan leguminous crop, it is a dual producer of tuber and pulse in tropical Africa. It is the most economically important species among the seven species in the genus Sphenostylis (Potter, 1992). Nyananyo and Osuji, (2007) noted that the seven species are endemic to Africa. This seem to corroborate the assertion of Adewale and Odoh (2013) and Ojuederie and Balogun (2017) that Africa is the centre of origin of AYB. Adewale (2011) described African yam bean as a vigorous climbing herbaceous vine whose height could be between 1.5-3metres depending on the height of the stakes. He also noted that the vegetative growth of AYB is noted for profuse production of trifolate leaves. In Nigeria (East and West), Ghana, Cote d'Ivoire, Togo and Cameroon AYB is cultivated majorly for the seeds, while it is grown for the tuber in, Gabon, Democratic Republic of Congo (NRC, 2006; Adewale and Aremu, 2013). In the south eastern part of Nigeria, the seeds of AYB are expensive; they are highly nutritious and contain crude protein between the ranges of 21-29% (Nnamani *et al.,* (2017). The tubers are richer in protein than sweet potatoes (Emiola, 2011). The report by NRC (2006) confirmed this, that the protein content of AYB tubers ranged from 11-19% which is about two and half times higher than that of sweet potatoes (*Ipomea batatas*) varieties. Tuber of African yam is a neglected product of the crop in West Africa (Adewale and Odoh, 2013); research focus on its utility is very low and rare; hence, information on the proximate and mineral component of the tuber is practically unavailable. Uguru and Madukaife (2001) and Adewale and Aremu (2013) noted that there are a lot of mineral component present in the seed and tuber of AYB compared to other legumes. The present investigation was thought worthy to unveil the proximate and mineral

composition profile of the tuber of some African yam bean accessions.

MATERIALS AND METHODS

Seeds of 17 accessions of AYB used in this study were obtained from the Genetic Resource Centre (GRC), International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The passport and names of collectors are presented in Table 1. Land was prepared and seed were sown in March, 2019 at the Centre for Ecological studies, Department of Plant Science and Biotechnology, University of Port Harcourt, Rivers State, Nigeria. Port Harcourt is in a humid forest zone of Nigeria within latitude 4^0N and 5^0N and longitude 6^0E and 7^0E. The marked land area was cleared, ploughed and harrowed after which mini mounds were made at a spacing of 1m by 1m. Two seeds were sown at a depth of 2cm on the mounds. At two weeks after planting, thinning was done to one plant per stand. A row plot contained 4 plants which were the sampling unit for all data collected. Weeds was manually controlled as at when due during the experiment. The experiment was terminated in November 2019 and the tubers were harvested for proximate and mineral analysis. The freshly harvested tubers were washed, peeled, cut into tiny pieces and dried in the oven at 65^0c for 48hours. The dried samples were pulverized using an electric blender.

Table 1: Passport data of the seventeen accessions used for this study

S/N	List of accessions	Country	Name of collector
1	TSs 49	Nigeria	R.J Williams
2	TSs 57	Nigeria	L. Igbokwe
3	TSs 119A	NA	NA
4	TSs 49A	NA	NA
5	TSs_2015_06	NA	NA
6	TSs 58	Nigeria	L. Igbokwe
7	AYB 119A	NA	NA
8	TSs 10	Nigeria	C.N Aniagu
9	TSs 66	Bangladesh	Dr. N. Haq
10	TSs 6A	Nigeria	NA
11	AYB 44C	NA	NA
12	TSs 98	Nigeria	NA
13	TSs 84A	NA	NA
14	TSs 109	Nigeria	James A. Sinnar
15	TSs 101	Nigeria	NA
16	TSs 158	Nigeria	DR J. Machuka
17	AYB30	NA	NA

NA= Not Available

Proximate Analysis on the tuber flour of AYB: The tuber of African yam bean was analysed using A.O.A.C (1984) procedure. Details of the process for each variable are below:

Moisture content (MC): Two grams of the flour were weighed (initial weight) into an aluminium dish, the samples were placed in an oven at 125^oc for 4hours, the samples were later transferred to a desiccator and allowed to cool at room temperature and weighed (final weight). The percentage moisture content was then derived as:

$$MC\ (\%) = \frac{\text{initial sample wt.} - \text{final sample wt.}}{\text{initial sample wt.}} \times 100$$

Ash content: Total ash content was determined by weighing two grams of the ground flour into a dish which has been previously ignited and weighed, the sample was ignited over a low flame. The dish was placed in a muffle furnace at 600^oc for 6 hours. The dish was transferred to a desiccator to cool. Percentage Ash was therefore estimated as:

$$\text{Ash content}\ (\%) = \frac{(W_2 - W_1)}{W_3} \times 100$$

Where: W_1 = Weight of dish, W_2 = Weight of dish plus ash and W_3 = weight of sample

Crude fibre: One gram of defatted sample was weighed into a digestion beaker followed by the addition of 100ml of Trichloro-acetic acid (TCA). The mixture was heated under reflux for 40minutes, filtered through a Whatman NO.4 (15.0cm dia) and washed thoroughly with hot water and alcohol followed by drying at 105^oc. On cooling, the mixture was weighed, ignited in a muffle, cooled in a desiccator and weighed again. The loss in weight was recorded as the crude fibre.

$$\text{Crude Fibre}\ (\%) = \frac{W_2 - W_3}{W_1} \times 100$$

Where: W_1 = Weight of Sample, W_2 = Weight after drying and W_3 = Weight after ignition

Crude protein: The crude protein in the sample was determined by the Kjeldahl method. The sample (0.5g) was weighed into the digestion tube of Kjeltec 2200 Foss Tector Digestion unit (Foss Tecator Analytical AB Hoganas, Sweden). Two Kjedahl catalyst mixture containing 5g of K_2SO_4 and 5mg of Selenium were added as well as 6ml of concentrated H_2SO_4 and concentrated orthophosphoric acid. Digestion was done for an hour at 42^{0C}. The distillation was done using 2200 Foss distillation unit with 25ml of 40% NAOH. The distillation was collected using 25ml of boric acid prepared with bromocresol green and methyl red indicators. Finally, the distillate was titrated with standardized 0.1N sulphuric acid to a reddish colour. The crude protein content was estimated using the formula.

$$\text{Total Nitrogen}\ (\%)\ \text{by weight} = \frac{(V_2 - V_1)\ X\ 14.007}{W} \times 100$$

Where: V_1 = Volume in ml of the standard acid solution, V_2 = Volume in ml of standard sulphuric acid solution used in the titration for the sample, N = Normality of standard sulphuric acid (0.01) and W = Weight in grams of the material

Crude fat: A soxhlet extraction unit with a reflux condenser and a small round bottom flask (250ml) was fixed up. The flask was weighed after washing and drying and half filled with petroleum ether (B.P 40-60Oc) and fitted back to the unit. Two gram of the dried sample was weighed, wrapped properly with a Whatmann paper and gradually lowered into the thimble which was fitted to a cleaned, dried and weighed round bottom flash containing 120ml of petroleum ether. The sample was slowly heated with a heating mantle for 6 hours at a condensation rate of 6 drops per second. Refluxed petroleum ether was recovered and the flask containing the fat was dried in the moisture extraction oven at 70oc to remove residual. After drying, the flask containing the fat was cooled in a desiccator and weighed

Carbohydrate: Carbohydrate content was by estimated through substitution. The content of the moisture, protein, fat, ash and crude fibre were summed up and subtracted from 100% as: Carbohydrate (%) = 100 – (Moisture + Protein + Fat + Ash + Crude Fibre).

Determination of Minerals: Selected minerals, including Nitrogen, Calcium, Magnesium, Potassium, Sodium, Manganese, Iron, Zinc and Copper were determined using Atomic Absorption Spectrophotometer (AAS).

Data Analysis: The mean values of 15 proximate and mineral component parameters of the 17 AYB accessions were subjected to SAS version 9.4, (2011) for: descriptive statistics, Pearson correlation coefficient analysis, principal component and clustering analysis. Moreover, graphic plots of the means of the 17 African yam bean accessions for the proximate and mineral variables was done in MS Excel (version 2013) using the chart wizard.

RESULTS AND DICUSSION
Proximate analysis: Table 2 presents the mean performances of the 17 accessions for the 15 proximate variables. Figure 1 showed the proximate composition evaluated for the 17 accessions of African yam bean studied. AYB44C recorded the least (4.91%) crude protein while TSs 49 recorded the highest crude protein content of 14.51%. The moisture content varied from 11.37% (TSs 58) to 21.92% (TSs 57). The ash content ranged between 4.59 (AYB 44C)

to 9.99 (TSs 109). Crude fibre ranged between 6.94% to 12.04%. The fat content ranged between1.06% (TSs 49A) to 4.05% (TSs 66). For carbohydrate, TSs 49 had the least (46.59%) and the highest carbohydrate content (69.52%) was obtained in AYB 44C.

Table 2: Descriptive statistics of the proximate and mineral profile on 17 African yam bean accessions

Variable	Mean ± SE	Minimum	Maximum
N	1.49±0.09	0.76	2.23
Protein	9.74±0.58	4.91	14.51
MC	15.50±0.77	11.37	21.92
Ash	7.69±0.37	4.59	9.99
Crude Fibre	9.80±0.42	6.94	12.14
Fat	2.77±0.21	1.07	4.05
CHO	54.47±1.25	46.60	66.52
Ca	4.245±0.30	1.54	5.83
Mg	1.66±0.11	0.60	2.26
K	3.58±0.26	1.34	5.09
Na	0.15±0.01	0.06	0.22
Mn	114.06±8.05	42.26	160.01
Fe	171.14±12.02	63.52	240.54
Zn	78.56±5.56	28.24	106.93
Cu	31.02±2.32	10.59	44.94

†N=Nitrogen, MC= Moisture, CHO= Carbohydrate, Ca= Calcium, Mg= Magnesium, K= Pottassium, Na=Sodium, Mn= Manganese, Fe= Iron, Zn- Zinc, Cu= Copper

Mineral composition: Figure 2 gives the mineral composition of the tubers of the 17 accessions of African yam bean. Iron was the most abundant mineral present in the tubers of African yam bean with a ranged of 63.52ppm (TSs 49A) to 240.53ppm (TSs66). Calcium in the tuber ranged between 1.53 (TSs49A) to 5.82ppm (TSs 66 and TSs109). The second most abundant mineral was Manganese and it ranged between 2.25 (TSs 49A) to 160.01 (TSs 66). The Magnesium ranged between 0.59 to 2.26 for TSs 49A and TSs 66. Potassium ranged between 1.34ppm (TSs 49A) to 5.08ppm (TSs 66 and TSs 109). The zinc content ranged between 28.24 for TSs 49A to 106.93ppm for TSs66. The nitrogen content ranged between 0.76% (AYB 44C) to 2.23% (TSs 49). The sodium content ranged between 0.05ppm (TSs 49A) to 0.22ppm (TSs 66 and TSs109) and the composition of copper ranged between 10.59 (119A) to 44.9ppm (TSs 6A).

Principal Component Analysis: In Table 3, the first three principal component axes explained 93.3% of the total variability among the 17 AYB accessions. The eigenvalue for the first three principal components (PC) axes were higher than 1.0 (Table 3). The first principal component (PC1) accounted for 60% of the total variability. The traits that mainly contributed to PC1 (with eigenvector > 0.2) were: ash, fat, calcium, magnesium, potassium, sodium, magnesium, iron, zinc and copper, while, nitrogen, protein, ash and crude fibre contributed to the variance proportion of PC2. (Table 3)
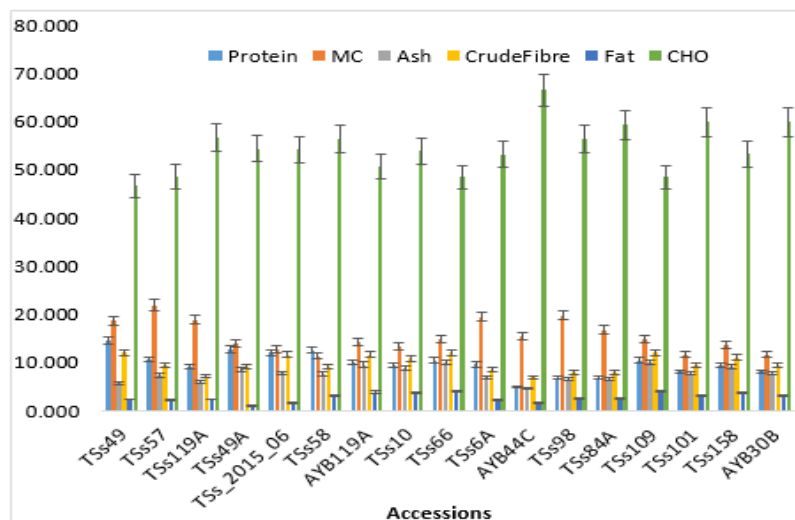
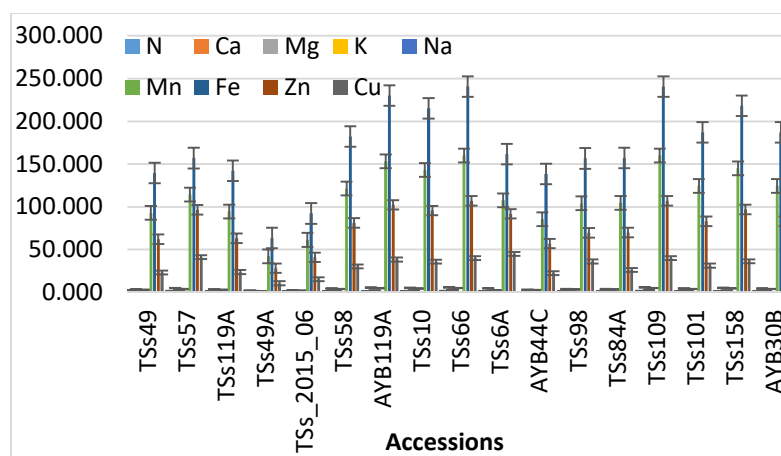**Fig 1**: Mean proximate composition of the 17 African yam bean accessions

Fig 2: Mean mineral composition of the 17 African yam bean accessions

Table 3: Eigenvalues, variance components of five PC axes and the different proportional contributions of the proximate and mineral composition as Eigenvectors loadings in the five PC axes

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	9.09	3.39	1.60	0.35	0.27
Proportion	0.61	0.23	0.11	0.02	0.01
Cumulative variance	0.61	0.83	0.94	0.96	0.98
Proximate characters	PC1	PC2	PC3	PC4	PC5
N	-0.02	0.52	0.05	0.31	0.28
Protein	-0.02	0.52	0.05	0.31	0.27
MC	-0.05	-0.06	0.76	-0.11	-0.33
Ash	0.22	0.26	-0.27	-0.78	0.17
Crude Fibre	0.17	0.41	-0.14	-0.09	-0.52
Fat	0.32	-0.01	-0.15	0.16	-0.21
CHO	-0.14	-0.42	-0.34	0.16	0.24
Ca	0.32	-0.04	0.11	0.02	0.19
Mg	0.32	-0.06	0.13	0.04	0.13
K	0.32	-0.05	-0.09	0.16	-0.23
Na	0.31	-0.09	-0.11	0.17	-0.09
Mn	0.33	-0.05	-0.03	0.12	-0.04
Fe	0.33	-0.07	-0.07	0.15	-0.09
Zn	0.32	-0.05	0.14	0.01	0.24
Cu	0.28	-0.10	0.32	-0.17	0.40

†N=Nitrogen, MC= Moisture, CHO= Carbohydrate, Ca= Calcium, Mg= Magnesium, K= Potassium, Na=Sodium, Mn= Manganese, Fe= Iron, Zn- Zinc, Cu= Copper

The third principal component (PC3) had 10.7% of the total variation. List of significant traits in PC3 and their eigenvectors were: moisture content (0.76), copper (0.32), Ash (-0.27) and carbohydrate (-0.33). Pearson's correlation coefficients shown in Table 4 presents the relationship between the mineral and proximate profile. Nitrogen had a strong and highly significant positive correlation (r = 0.61) with crude fibre and also highly but negatively correlation with carbohydrate (r = -0.72). Protein also strongly and significantly correlated with crude fibre (r = 0.61) while it negatively correlated with carbohydrate (r = -0.72). Fat had a highly strong significant relationship with all the minerals. Calcium, Magnesium, Potassium, Sodium, Manganese, Iron and Zinc all had a highly positive and significant correlation amongst themselves. The ward minimum variance dendogram that described the similarities among the 17 African yam bean accessions based on proximate and mineral profile is presented in (Figure 3). At 0.2 point of similarity in Figure 3, three clusters were visible. Seven accessions were grouped in cluster I (TSs 49, TSs 57, TSs 6A, TSs 119A, TSs 98, TSs 84A and AYB44C) while cluster II had two accessions (TSs 49A and TSs 2015-06) and cluster III had the highest number of accessions (TSs 58, TSs 101, AYB 30B, AYB 119A, TSs 66, TSs 109, TSs 10 and TSs 158).

Table 4 Pearson correlation coefficient of the proximate and mineral component of AYB accessions studied

	N	Prot	MC	Ash	CF	Fat	CHO	Ca	Mg	K	Na	Mn	Fe	Zn
Prot	1***													
MC	-0.055ns	-0.055ns												
Ash	0.319ns	0.319ns	-0.447ns											
CF	0.616**	0.616**	-0.297ns	0.722***										
Fat	-0.088ns	-0.089ns	-0.296ns	0.643**	0.505*									
CHO	-0.724***	-0.724***	-0.308ns	-0.530*	-0.750**	-0.315ns								
Ca	-0.113ns	-0.113ns	-0.014ns	0.554*	0.408ns	0.890***	-0.400ns							
Mg	-0.159ns	-0.159ns	0.017ns	0.500*	0.370ns	0.850***	-0.361ns	0.984***						
K	-0.154ns	-0.154ns	-0.215ns	0.581*	0.457ns	0.963***	-0.293ns	0.921***	0.927***					
Na	-0.221ns	-0.221ns	-0.243ns	0.536*	0.398ns	0.953***	-0.209ns	0.911***	0.871***	0.926***				
Mn	-0.152ns	-0.152ns	-0.160ns	0.583*	0.443ns	0.965***	-0.324ns	0.972***	0.954***	0.979***	0.967***			
Fe	-0.185ns	-0.185ns	-0.200ns	0.568*	0.431ns	0.970***	-0.276ns	0.952***	0.932***	0.975***	0.984***	0.996***		
Zn	-0.128ns	-0.128ns	0.020ns	0.525*	0.380ns	0.860***	-0.391ns	0.998***	0.984***	0.898***	0.898**	0.957***	0.937***	
Cu	-0.198ms	-0.198ms	0.254ns	0.368ns	0.207ns	0.688**	-0.367ns	0.914***	0.891***	0.722***	0.769***	0.822***	0.796***	0.932***

†N=Nitrogen, MC= Moisture, CHO= Carbohydrate, Ca= Calcium, Mg= Magnesium, K= Potassium, Na=Sodium, Mn= Manganese, Fe= Iron, Zn- Zinc, Cu= Copper. Significance *P ≤0.05, P≤0.01, P≤ 0.001, P>0.05=NS, NS= Non Significant
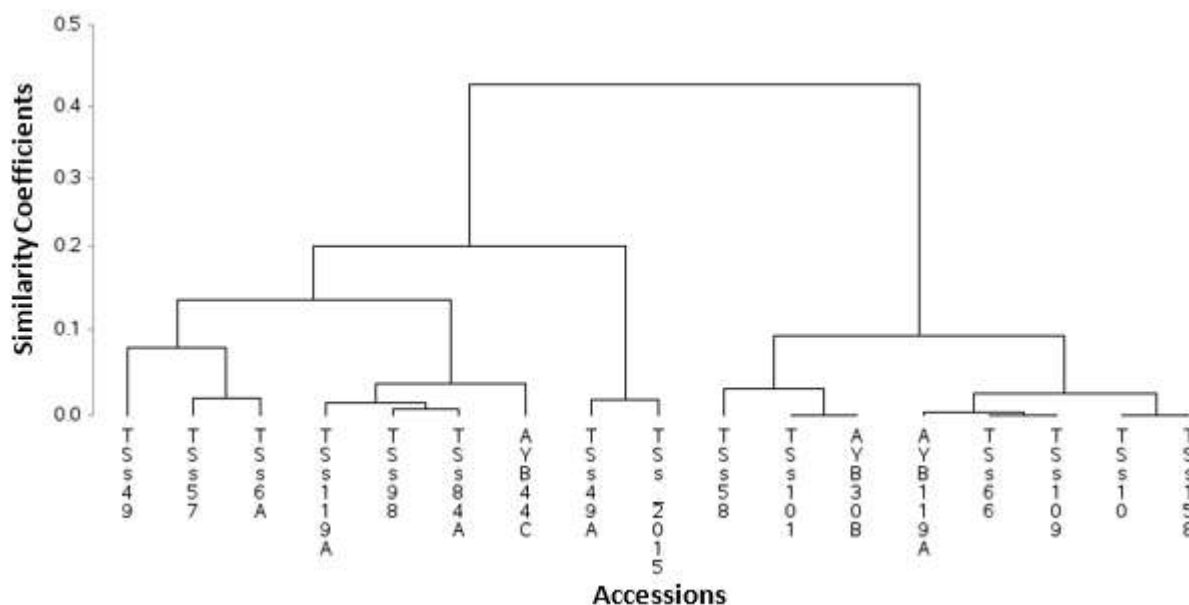

Fig 3. Dendrogram showing groupings of the 17 AYB accessions

The proximate and mineral profile of the tubers of 17 African yam bean accessions were investigated. The study clearly indicated that there exist considerable variation in protein, moisture, ash, fat, carbohydrate, crude fibre and mineral profile in the tuber of African yam bean. Carbohydrate ranged between 46.59% to 66.52%, AYB 44C had the highest carbohydrate content. This is in agreement with the works of Ojuederie *et al*. (2017) who reported a mean carbohydrate content in tuber of AYB as 68.7%. The moisture content of the tubers of African yam bean ranged between 11.37% (TSs 58) to 21.92% (TSs 57). Ojuederie *et al*. (2017) reported an average moisture content of 10.3% at Ibadan, Nigeria. Our present result had a mean moisture content of 15.5%, the noticed wide variation in the moisture content value could be due to the variation in the two environments (Ibadan and Port Harcourt). Moreover, the moisture content we obtained was lower than 78.9% and 70.6% respectively reported by Odebunmi *et al*. (2007) for Irish potatoes (*Solanum tuberosum*) and sweet potatoes (*Ipomea batatas*). The moisture content in mexican yam bean (*Pachyrhizus erosus*) was 87.0% (Sorensen, 1996). Tubers with higher moisture content are mostly and easily susceptible to microbial attack, meaning that AYB tubers with relatively low moisture contents can be stored for a long period of time (Onyeike *et al*., 1995). The very low moisture content equally reveal that the tubers of African yam bean hosts very high biomass. The tubers of AYB have substantial amount of protein which makes it a good source of alternative protein (Ojuederie *et al*., 2017). The protein content in the tuber ranged between 4.91% - 14.50%, this findings conform to the range (6.3 - 12.9%) reported by WU *et al*., (2016) for *Dioscorea spp*. The ash content varied from 4.60% to 10.0%. This is an indication that the tubers of AYB are rich in mineral salt. Minerals are vital in tuber nutrition. The mineral composition in the tubers of AYB studied indicated that Fe was the most abundant mineral present with mean values ranging from 63.52-240.54ppm. Iron plays a vital role in the body and it is an essential component of hundreds of proteins and enzymes (Wood and Ronnenberg, 2006).

Conclusion: The tubers can serve as a good source of food energy because of the high carbohydrate content it hosts. This study demonstrated that a great variability exists in the mineral and proximate compositions in the tubers of African yam bean. This study has breached a knowledge gap by providing information that will promote African yam bean tuber utilization in regions where their use is neglected. Further studies on the phytochemical and sensory testing is encouraged.

REFERENCES

Adewale, BD (2011). Genetic diversity, stability and reproductive biology of African yam bean Sphenostylis stenocarpa (Hochst. Ex. A. Rich.) Harms. PhD thesis, Federal University of Agriculture, Abeokuta, Nigeria.

Adewale, BD; Odoh, NC (2013). A review on Genetic resources, diversity and agronomy of African yam bean (Sphenostylis stenocarpa (Hochst. ex A. Rich.) Harms): A potential future food crop. *Sustain Agric Res.* 2:32-43.

Adewale, BD; Aremu, CO (2013). The Nutritional Potentials and Possibilities in African yam bean for Africans. *Int. J. Agric. Sci*. 3(1): 8-19.

AOAC, (1984) Standard official Methods of Analysis of Association of Analytical Chemists 14th ed, AOAC. Washington DC U.S.A. Pp. 516-524.

Emiola, IA (2011). Processed african yam bean (*Sphenostylis stenocarpa*) in broiler feeding performance characteristics and nutrient utilization. *J. Environ. Issues Agric Dev. Ctrie.* 3(3):123- 131.

Gruneberg, WJ (1998). Pre-breeding and Variety Development for Autogamous Tuberous Legumes-Concepts towards a Comprehensive Breeding Method in Under-utilized crops. In: Sorensen, M.; Estrella, JEE; Hamann, OJ; Ruiz, SAR (eds) Proceeding of 2nd International Symposium on Tuberous Legumes, Held at Celaya,Guanajuato-Mexico,5-8 August,1996. Pp 309-341.

Lebot, V (2009) *Tropical Root and Tuber Crops*: Cassava, Sweet Potato, Yams and Aroids. Crop Production Science in Horticulture no. 17, CABI Publishing, UK. Pp 413.

Lewu, MN; Adebola, PO; Afolayan, AJ (2010). Comparative Assessment of the Nutritional Values of Commercially available Cocoyam and

Potato Tubers in South Africa. *J. Food Qual.* 33:461-476.

Nnamani, CV; Ajayi, SA; Oselebe, HO; Atkinson, CJ (2017). *Sphenostylis stenocarpa* (ex. A. Rich) Harms., a Fading Genetic Resource in a Changing Climate. Prerequisite for Conservation and Sustainability. *Plants.* 6(3):30.

NRC (National Research Council) (2006). Lost Crops of Africa: Vol II: Vegetables and Yam bean Development, Security and Cooperation Policy and Global Affairs (DSC) Washington, D. C., USA. Pp. 322-344.

Nyananyo, BL; Osuji, JO (2007). Biosystematic Investigation into Sphenostylis stenocarpa (Hochst Ex A. Rich) Harms (Fabaceae) in Nigeria. *Niger. J. Bot*. 20(2): 411-419.

Odebunmi, EO; Oluwaniyi, OO; Sanda, AM; Kolade BO (2007) Nutritional compositions of selected tubers and root crops used in Nigerian food preparations. *Int. J. Chem*. 17(1): 37-43.

Ojuederie, OB; Balogun, MO (2017). Genetic variation in nutritional properties of African yam bean (*Sphenostylis stenocarpa* Hochst ex. A. Rich. Harm) accession. *Nig. J. Agric. Food Environ*. 13(1):180-187.

Onyeike, EN; Olungwe, T; Uwakwe, AA (1995). Effect of heat treatment and defatting on the proximate composition of some Nigerian local soup thickeners. *Food Chem.* 53: 173-175.

Potter, D (1992). Economic botany of Sphenostylis (Leguminosae). *Econ Bot*. 46: 262-275.

SAS Institute Inc (2011) SAS OnlineDoc_ 9.4. SAS Institute, Cary.

Saxon, EC (1981). Tuberous legumes: preliminary evaluation of tropical Australian and introduced species as fuel crops. *Econ. Bot*. 35: 163-173.

Sorensen, M (1996). Yam bean (Pachyrhizus DC). Properties of the species. In: Promoting the conservation and use of underutilized and neglected crops. 2. International Plant Genetic Resources Institute (IPGRI), Italy and The Institute of Plant Genetics and Crop Plant Research (lPK), Germany. Pp 143.

Uguru, MI; Madukaife, SO (2001). Studies on the variability in agronomic and nutritive characteristics of African yam bean (*Sphenostylis stenocarpa* Hochst ex. A Rich. Harms). *Plant Prod. Res. J.* 6 (2):10-19.

Wood, RJ; Ronnenberg, AG (2006). Iron. In: Shils, ME; Shike, M; Ross, AC; Caballero, B; Cousins, RJ (eds). Modern nutrition in health and disease, 10th Ed. Philadelphia, Lippincott Williams & Wilkins. Pp. 248-270.

Wu, ZG; Jiang, W; Nitin, M; Bao, XQ; Chen, SL and Tao, ZM (2016). Characterizing diversity based on nutritional and bioactive compositions of yam germplasm (*Dioscorea spp*.) commonly cultivated in China. *J. Food Drug. Anal.* 24:367-375.