E-ISSN: 2346-7290

Minerals and nutrients variability assessment in seeds and tubers of ten accessions of African yam bean (*Sphenostylis stenocarpa* hoshst ex a. rich)

[1]Anjorin F. B.*, [2]Famuyiwa, Z.O., [1]Akinyosoye S. T., [1]Agbeleye O. A, [1]Odeyemi, O.O and [1]Olowolafe, M. O.

[1]1nstitute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation Ibadan.
[2]Federal College of Agriculture, Moor Plantation, Ibadan. *Email of corresponding author:

*Corresponding author: (Email: folakeawoeyo@yahoo.com, Phone: +2348030701385)

ABSTRACT
To assess minerals and nutritional constituent in seeds and tubers of African Yam Bean (AYB) (*Sphenostylis stenocarpa* Hoshst ex A. Rich), ten accessions of African yam beans coded as AY01, AY02, AY03, AY04, AY05, AY06, AY07, AY08, AY09 and AY10 of AYB were grown in pots (15 L; 10 kg soil) using complete randomized design (r=4) in I.A.R&T, Moor Plantation Ibadan. At maturity, seeds and tubers harvested were processed and analysed using laboratory procedures to determine the mineral and nutrient constituents. Results obtained showed that minerals and food constituents in seeds and tubers of AYB accessions varied significantly ($p<0.001$). The seeds of AYB contain higher N, Ca, Na, Mg and K than tubers, while the tubers had more P and Zn than AYB seeds. The seeds had more crude protein, crude fat and total ash than the tubers while the tubers had more crude fiber, carbohydrate and moisture content than the seeds. Each of the accessions also showed variations in the mineral and nutrient constituents ($p<0.001$). Accession AY10 with the highest seed Nitrogen content had least seed Phosphorus. Accession AY03 had highest tubers and seeds Zinc composition compared to other AYB accessions. Highly significant variation exists in the mineral and nutrient composition of seeds and tubers of AYB. The information obtained in this study is valuable for germplasm collection, conservation and genetic improvement of AYB.

Keywords: African yam bean, calcium, crude fat, crude protein, nitrogen, phosphorus, zinc

INTRODUCTION
African Yam Bean (AYB) (*Sphenostylis stenocarpa* Hoshst ex A. Rich) is an important underutilized crop with tremendous nutritional potential. African yam bean is a trifoliate, vigorously climbing herbaceous plant with well extended vine that could attain height up to 1.5 - 3.0 m or more (Adewale, 2011). African yam bean thrives in diverse ecologies; soil and climatic conditions which makes it an important crop for national food security. Africa is the only centre of diversity of AYB with Nigeria being the highest producer (Potter's, 1992; Abbey and Berezi, 1991). African Yam Bean could partitions its accumulated assimilates into both the seed and tubers, while some genotypes do not form tubers. Its edible seed is popularly known as "Girigiri" (Hausa, West Africa), "Norouko" and/or "Roya" (Sudan), "Okpududu" (Igbo, Nigeria) and "Sese"(Yoruba, Nigeria). African yam bean is valuable for the preparation of different delicacies in many African villages. Historically, AYB was extensively explored by the "Igbos" as a good source of dietary protein in feeding the displaced and severely malnourished refugees during Nigeria civil war between 1967 and 1970

(Nwokolo, 1996). African yam bean seeds are cherished in West Africa while tubers are valuable in East and Central African (Potter, 1992).

Medicinally, AYB has been reported to be important in the treatments of several ailments in Togo, Ghana and Nigeria (Azusu, 1986). Paste made from AYB seeds is used in the treatment of stomach ache and cure for acute drunkenness (Azusu, 1986). The leaf litter from African yam bean is a good source material for soil improvement, while the nodules have potential for fixing nitrogen into the soil. Nutritionally, AYB tubers have been reported to contain more than twice the quantity of protein that could be obtained in sweet and Irish potatoes and even more than those in yam and Cassava, respectively (Amoatey *et al*., 2000; Ekpo (2006). Similarly, the quantity of amino acid in AYB compares favourably with whole chicken egg. The amount of minerals like magnesium, potassium, phosphorus, sodium, calcium, zinc, copper, and manganese content in AYB were reported to be higher than other common pulses and legumes (Nwokolo 1987; Temple *et al*., 1991; Claydon, 1975). These macro nutrients are vital for numerous body metabolic processes while micronutrients like Zinc is required in trace amount in the body for controlling and regulating immune responses (Shankar and Prasad, 2013), attacking infected or cancerous cells, treatment of osteoporosis among many other uses. Deficiency of Zn in the body could result into low sperm quality and male infertility (Nordqvist, 2017). African yam bean contain certain anti-nutritional factors (ANF) like Oxalate, Saponin, Lectin, alkaloids, flavonoids, trypsin and phytate. Most of these ANF are heat labile and could be inactivated by heat generated during cooking processes (Ndidi *et al*., 2014). There are several insect pests that attack African yam bean, mainly the orthopterous and lepidopterus insects. Both the vegetative and reproductive growth stages of the crop are attacked by one pest or the other among which are; cutworm (*Agrotis sp.),* aphids (*Aphis craccivora*), *Maruca testulalis*, *Cydia ptychora*, leaf roller caterpillar (*Sylepta derogata*), *Riptortis dentipes, Nezera viridula* and *Apion varium* (Ameh and Okezie, 2006). There exist relationship between nutritional composition of plant species and insect infestation levels. In a report, plant leaves with higher levels of protein were found to support higher population of thrips (than in non-host species). Likewise, insect oviposition and feeding was influenced by the levels of soluble protein present in plants (Scott Brown *et al*., 2002).

African Yam Bean is gradually becoming an underutilized crop because of increasing rural - urban migration coupled with modern life style and inadequate awareness on its nutritional potentials. However, much report has not been documented on the essential nutrients profile in the seeds and tubers (sinks) of this important leguminous crop. Understanding the pattern of mineral and nutrient partition in seeds and tubers of AYB, would enhance the awareness on its nutritional benefits. And at the same time provide information that could assist in genetic improvement of this neglected crop. Hence, this present study was carried out to explore the nutritional benefits embedded in the seeds and tubers of AYB with the aim of increasing the awareness on the nutritional benefit potentials of this crop in tackling food security problems in our society.

MATERIALS AND METHODS

Seeds of ten accessions of African yam beans coded as AY01, AY02, AY03, AY04, AY05, AY06, AY07, AY08, AY09 and AY10 previously collected from six southern states of Nigeria were obtained from the germplasm of the Institute of Agricultural Research and Training (IAR&T), Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria. Two seeds of each of AYB were sown into 15 litres plastic pots containing 10 kg soil were arranged in a completely randomised design with four (4) replicates in the screen house of IAR&T, Ibadan in 2015. The emerged tendril were staked with long dry sticks three weeks after sowing while hand weeding and insect control were appropriately carried out till the crops reached physiological maturity.

At maturity pods and tubers of AYB were harvested, properly cleaned and dried in the oven at 70 ºC to constant weights and milled using electrical grinding machine (Lexus. co). Samples were analysed for various mineral and food content. The proximate analysis was carried out using the method described by AOAC (2005). Nitrogen content was determined using the method of Bremner (1965). Metal Analysis on Na, Ca, K, Mg and Zinc were determined using Model 210 VGP of the Buck Scientific AAS series with air-acetylene gas mixture as oxidant. Phosphorus was determined using Colorimetric method.

DATA ANALYSIS

Data obtained were subjected to analysis of variance using SAS version 2009, while differences between the means were separated using Duncan Multiple Range Test (DMRT) at $p<0.05$. Relationship among the minerals and the nutrient content were also established using the Pearson correlation coefficient (SAS, version 2009)

RESULTS

Table 1 shows the mean variability estimates for mineral and nutrient composition in seeds and tubers of ten accessions of AYB (*Sphenostylis stenocarpa Hochst ex. A. Rich.*). Results obtained from this study showed that mean mineral and nutrient composition in seeds and tubers of AYB differed significantly ($p<0.001$). The values of N (36.6 mg/g), K (8.0 mg/g), Na (7.0 mg/g), Ca (36.8 mg/g) and Mg (0.44 mg/g) in AYB seeds > N (14.1 mg/g), K (6.3 mg/g), Na (5.6 mg/g), Ca (35.5 mg/g) and Mg (0.36 mg/g) in AYB tubers. The mean values of P (5279.7 mg/g) and Zn (49.54) in AYB seed < mean values of P (5644.3 mg/g) and Zn (57.76) in AYB tubers. Mean crude protein content, crude fat and total ash content observed in the seeds of the ten accessions of AYB was significantly higher than the those found in the tubers ($p<0.001$). However, the crude fiber, carbohydrate and moisture contents were significantly higher in the tubers than the seeds of the ten AYB accessions

Table 2 present result of variability estimates of Mineral composition in seeds and tubers among the ten AYB accessions. Accessions AY 09 and AY10 had highest seed N compared with other accessions while, AY01 had least seed N. Accession AY08 had highest tuber N while AY01 was least. Although, the mean P content in AYB tubers was significantly more than P obtained in the seeds however, the P content in the seeds of AYB 02 (7371.2 mg/g) and AY07 (6149.2 mg/g) were more than the P obtained in the corresponding tubers (5917.1 and 3201.4 mg/g), respectively. Accession AY02 (7371.2 mg/g) with very low seed N content had the highest seed P content, while AY10 with highest seed N had the least seed P of 3564.1 mg/g. Highest tuber P content was observed in AY03 (8675.5 mg/g) followed by P values observed in AY05 (8059.4 mg/g) and AY09 (8032.8 mg/g), respectively.

Accession AY02 which had highest seed phosphorus content also had the highest seed K content (8.60 mg/g) followed by AY04, while the least seed K content was observed in AY08 (6.80 mg/g). Accession AY03, with highest tuber P also had the highest tuber K (7.50 mg/g). There was no significant difference between the tuber's potassium content obtained in AY07 (5.60 mg/g) and AY08 (5.40 mg/g), while least tuber K content was observed in AY09 (5.30 mg/g). The AYB accessions varied significantly in Na content ($p<0.001$). Highest seed Na content was observed in accession AY09 (7.50 mg/g) and was not significantly different from Na content observed in accessions AY07 (7.50 mg/g), AY04 (7.40 mg/g), AY03 (7.30 mg/g) and AY02 (7.30 mg/g), while AY08 (6.00 mg/g) had least Na content. Accessions AY03 (6.60 mg/g) and AY05 (6.80 mg/g) had the highest tuber Na content, both accessions were however not significantly different in tuber Na content. Least Na content was obtained in the tuber of AY01 (4.50 mg/g), this was however not significantly different from tuber Na content obtained in accessions AY06 (5.20 mg/g) and AY07 (5.20 mg/g), respectively.

The AYB accessions differed significantly in Ca content ($p<0.001$). The Ca obtained in AYB seed was significantly higher than Ca contained in the tubers (Table 1). However, among the AYB accessions, the tubers of AY01, AY02, AY05, AY06, and AY07 had higher Ca than their corresponding seeds (Table 2). African yam bean accession AY10 seeds which had the highest N content also had highest seed Ca (55.0 mg/g). Least seed Ca content was observed in AY05, this accession was however not significantly different from accession AY06 (23.8 mg/g). Accession AY02 had highest tuber Ca content, followed closely by accession AY01, while least Ca was observed in tubers of AY09 (30.2 mg/g), this was however not significantly different from accessions AY10 (30.3 mg/g) and AY04 (30.6 mg/g), respectively.

However, higher Mg was observed in the tubers than the seeds of AYB in accessions AY01 and AY05. Accessions AY04 which had the highest seed Na content also had highest Mg content of 0.64 mg/kg. There was no significant different in Mg observed in seeds of accessions AY08 (0.48) and AY09 (0.49) while the least Mg content was observed in the seed of AY05 (0.29 mg/kg). Highest Mg content was observed in the tubers of AY01 which had lowest N and Na, this was closely followed by tubers of AY05 (0.42), AY06 (0.42) and AY07 (0.42), while least Mg was observed in the tuber of AY08 (0.28 mg/kg). The AYB tubers had more Zn than the seeds except for AYB accessions AY04, AY08 and AY10 which had more seeds Zinc than their corresponding tubers (Table 2). Highest Zinc was found in seeds AY03 (65.07 mg/kg) which also had highest seed Na content, least Zn value was however observed in AY01 (37.17 mg/kg) seeds. Accession AY03 with highest seed Zn content also had the highest tuber Zn content 91.32 mg/kg, while AY04 had the least tuber Zn value of 34.55 mg/kg.

Table 1: Mean Mineral and Nutrient profile in Seeds and Tubers of Ten Accessions of African Yam Bean (*Sphenostylis stenocarpa Hochst ex. A. Rich.*)

AYB	N (mg/g)	P (mg/g)	K (mg/g)	Na (mg/g)	Ca (mg/g)	Mg (mg/kg)	Zn (mg/kg)	Crude protein (%)	Crude Fat (%)	Crude Fiber (%)	Total Ash (%)	Moisture content (%)	Carbohydrate (%)
Seeds	36.6a	5279.7b	8.00a	7.00a	36.8a	0.44a	49.54b	22.91a	3.70a	6.16b	3.94a	7.37b	55.89b
Tubers	14.1b	5644.3a	6.30b	5.60b	35.5b	0.36b	57.76a	8.85b	1.82b	11.41a	2.59b	8.78a	66.52a
Mean	25.4	5462.0	7.2	6.3	36.1	0.40	53.65	15.88	2.76	8.79	3.27	8.07	61.20
SE	1.5	210.0	0.1	0.1	1.1	0.01	1.99	0.91	0.12	0.34	0.08	0.09	0.69
CV (%)	4.8	6.6	24.7	27.4	17.8	3.47	2.05	0.44	1.93	0.49	1.23	0.48	0.16

Means with same alphabets within the column are not significantly different according to DMRT (p=0.05)

Table 2: Mineral composition in seeds and tubers of ten accessions of African yam beans (*Sphenostylis stenocarpa)*

	N (mg/g)		P (mg/g)		K (mg/g)		Ca (mg/g)		Na (mg/g)		Mg (mg/kg)		Zn (mg/kg)	
Acc.	Seed	Tubers	Seed	Tubers	Seed	Tubers	Seed	Tubers	Seed	Tubers	Seed	Tubers	Seed	Tubers
AY01	35.9e	13.3f	5072f	5083.2e	8.10e	5.80d	28.2f	38.6b	6.9b	4.5g	0.32g	0.44a	37.17i	76.10c
AY02	36.0de	13.6e	7371.2a	5917.1c	8.60a	6.20c	36.9d	46.5a	7.3a	5.5de	0.42de	0.41b	40.79h	86.21b
AY03	36.0de	13.6e	5238.8e	8675.5a	8.30cd	7.50a	53.8b	37.9bc	7.3a	6.6a	0.58b	0.34c	65.07a	91.32a
AY04	36.8c	14.2cd	3632.6i	4028.6f	8.51ab	7.00b	36.1d	30.6f	7.4a	6.1b	0.64a	0.32cd	49.95d	34.55h
AY05	36.2d	14.1cd	6871.3b	8059.4b	7.50g	7.30ab	23.8g	34.0e	6.4c	6.8a	0.29h	0.42ab	44.40f	58.41d
AY06	36.7c	14.0d	4175.7h	3874.4g	7.70f	6.30c	23.9g	36.6d	6.8b	5.2ef	0.38f	0.42ab	47.87e	48.68c
AY07	37.0b	14.3c	6149.2c	3201.4i	8.40bcd	5.60de	32.1e	36.9cd	7.5a	5.2ef	0.40ef	0.42ab	41.77g	43.72e
AY08	37.1b	15.2a	4822.3g	5763.3d	6.80h	5.40de	32.7e	33.6e	6.0d	5.0f	0.48c	0.28e	56.92c	51.07e
AY09	37.5a	14.8b	5900.2d	8032.8b	8.20ed	5.30e	46.0c	30.2f	7.5a	5.7cd	0.49c	0.30de	49.80d	49.53e
AY10	37.7a	14.8b	3564.1j	3807.9h	8.50bac	7.20ab	55.0a	30.3f	6.9b	6.0bc	0.44d	0.32dc	61.75b	38.08g
Mean	36.6	14.2	5279.7	5644.3	8.00	6.30	36.8	35.5	7.0	5.6	0.44	0.36	49.54	57.76
S.E	0.1	0.1	228.8	353.4	0.1	0.2	1.9	0.9	0.1	0.1	0.02	0.01	1.62	3.52
CV (%)	3.3	8.4	6.6	0.66	13.4	35.8	17.7	17.8	18.4	37.1	3.51	3.37	0.62	2.64

† Means with same alphabets along the column are not significantly different according to Duncan Multiple Range Test at P=0.05

Correlation among minerals and nutrient composition in seeds of ten accessions of African yam bean (AYB)

Table 3 presented the correlation coefficient of minerals and nutrient composition in seeds of ten accessions of African Yam Bean (AYB). Nitrogen showed very strong and positive association with protein content ($p<0.001$), Ca and Zn ($p<0.05$) of AYB seed. Nitrogen also showed non-significant positive correlation with Sodium, Mg and moisture content, however AYB seed N was significantly and negatively correlated with carbohydrate ($p<0.001$), total ash ($p<0.01$), crude fibre ($p<0.001$), crude fat ($p<0.05$) and phosphorus ($p<0.05$). Potassium content also showed positive and significant association with Na ($p<0.001$), Ca and crude fat content ($p<0.05$). The Na was positively correlated with Ca and Mg and crude fat content ($p<0.05$), while the Na showed significant negative association with moisture content ($p<0.05$). The calcium content in AYB seed showed positive association with Mg ($p<0.01$), Zn ($p<0.001$) and crude protein ($p<0.05$), but negatively correlated with total ash ($p<0.01$) and crude fat ($p<0.05$) content.

The Mg content in the AYB seed showed strong positive association with Zn ($p<0.01$), but was negatively associated with P and crude fat content ($p<0.05$). The Phosphorus content showed positive and significant association with crude fat and carbohydrate content ($p<0.05$), however the P showed significant but negative association with Zn ($p<0.01$) and crude protein content ($p<0.05$). Zinc content in AYB seed was positively and significantly associated with N ($p<0.05$), Ca ($p<0.001$) Mg ($p<0.01$) and crude protein content ($p<0.05$), but was negatively correlated with crude fat ($p<0.01$), crude fibre ($p<0.05$) and the total ash content ($p<0.05$). A very strong positive association was observed between AYB seed crude protein content with N ($p<0.001$), Ca ($p<0.05$), while fat, carbohydrate, total ash and the crude fibre content were negatively and significantly associated with crude protein.

Crude fat content in AYB seed showed significant positive association with the seed total ash, but was negatively correlated with seed moisture content. The crude fibre in the seed also showed significant positive correlation with the total ash and the carbohydrate content. A significant negative relationship was also observed between total ash content and the moisture content.

Table 3: Pearson coefficient of correlation between minerals and nutrient composition in seeds of African yam bean.

	N	K	Na	Ca	Mg	P	Zn	Crude Protein	Crude Fat	Crude Fibre	Total Ash	Moisture content
K	-0.05											
Na	0.02	0.86***										
Ca	0.37*	0.48*	0.40*									
Mg	0.24	0.27	0.41*	0.58**								
P	-0.44*	0.03	0.11	-0.24	-0.43*							
Zn	0.41*	-0.09	-0.13	0.73***	0.59**	-0.50**						
Crude Protein	0.99***	-0.05	0.03	0.38*	0.30	-0.42*	0.44*					
Crude Fat	-0.47*	0.44*	0.44*	-0.24	-0.19	0.41*	-0.59**	-0.47*				
Crude Fibre	-0.79***	-0.11	-0.26	-0.38*	-0.48*	0.32	-0.41*	-0.84***	0.33			
Total Ash	-0.59**	0.03	0.13	-0.59**	-0.04	-0.09	-0.49*	-0.59**	0.43*	0.45*		
Moisture content	0.23	-0.22	-0.44*	0.10	-0.33	0.03	0.11	0.22	-0.39*	0.09	-0.52**	
Carbohydrate	-0.85***	0.05	0.02	-0.09	-0.09	0.48*	-0.11	-0.82***	0.25	0.53**	0.27	-0.35

* ** ***, significant at p=0.05, 0.01 and 0.1 probability levels.

Nutrient profile of seeds and tubers of ten accessions of AYB (*Sphenostylis stenocarpa*)

Accessions AY09 (23.22%) and AY10 (23.40%) had highest seed crude protein contents (Table 4). Crude protein content of accessions AY09 and AY10 were followed by crude protein contained in accessions AY02 (22.51%), AY03 (22.54%), AY05 (22.60%), AY06 (22.59%) which were not significantly different. African yam bean accession AY01 however had the least seed crude protein content of 22.31%. Highest AYB tuber crude protein content was observed in AY08 (9.80%) followed by AY09 (9.21%) and AY10 (9.29%), while AY01 had the least tuber crude protein content of 8.29%.

Accession AY02 (3.82 %) had highest seed crude fat content, followed by AY01 (3.77%) (Table 4). There was no significant difference in crude fat contents among AY04 (3.73%), AY05 (3.74%), AY06 (3.71%) and AY09 (3.72%), while AY08 had the least seed crude fat content of 3.54%. Accession AY08 with the least seed crude fat content however had the highest tuber crude fat content and was closely followed by AY10 (1.89%), AY07 (1.88%) and AY01 (1.86%). There was no significant difference in the tuber crude fat content of AY09 (1.80%) and AY02 (1.82%), while AY04 had the least tuber crude fat content of 1.69%.

Accession AY01 with least seed crude protein however had the highest seed crude fiber content of 6.32% followed by AY02 (6.22%) and AY05 (6.23%), which were similar respectively (Table 4). Least seed crude fiber content were observed in AY09 (6.07%) and AY10 (6.09%) which were not significantly different. Accession AY01 also had highest tuber crude fiber content of 11.88% which was followed by accessions AY02 (11.79), AY03 (11.73%), AY06 (11.72%) which were not significantly different. Accessions AY09 (10.86%) and AY10 (10.82) also had very low tuber crude fiber content while least tuber crude fiber content was observed in AY08 (10.68%). Accessions AY01 (4.08%) and AY06 (4.16%) had highest seed total ash content. These were followed by accession AY04 (4.09%), while AY10 (3.72%) had the least total ash content. Accession AY01 with highest crude fiber content also had the highest tuber total ash content of 2.87% and was not significantly different from AY03 (2.81%), while AY09 had the least tuber total ash content of 2.40%. Accession AY10 had highest seed moisture content of 7.51%, followed by AY03 (2.81%), least moisture content values were observed in accessions AY04 (7.27%), AY06 (7.26%) and AY09 (7.28%), which were not significantly different (Table 4). Accessions AY10 (8.91%), AY02 (8.89%) and AY07 (8.93) had highest tuber moisture contents while AY05 had the least tuber moisture content of 8.63%. Accession AY03 had highest seed carbohydrate content, followed by AY05 (56.13%) while AY10 (55.52%) had the least seed carbohydrate content. Highest tuber carbohydrate was observed in AY09 (66.99%) while AY07 with the highest moisture content had the least carbohydrate of 66.11%.

Table 4: Nutrient profile of seeds and tubers of ten accessions of African yam beans (*Sphenostylis stenocarpa*)

	Crude protein (%)		Crude Fat (%)		Crude Fiber (%)		Total Ash (%)		MC (%)		Carbohydrate (%)	
Acc	Seed	Tubers	Seed	Tubers	Seed	Tubers	Seed	Tubers	Seed	Tubers	Seed	Tubers
AY01	22.31f	8.29g	3.77ab	1.86ab	6.32a	11.88a	4.08a	2.87a	7.39c	8.78b	56.03b	66.24f
AY02	22.51e	8.50f	3.82a	1.82bc	6.22b	11.79b	4.00c	2.57cde	7.37c	8.89a	56.08b	66.38e
AY03	22.54e	8.52f	3.67bc	1.84abc	6.19bc	11.78b	3.92d	2.81a	7.31d	8.75b	56.32a	66.28ef
AY04	23.00cd	8.92c	3.73abc	1.69d	6.10de	11.32d	4.09b	2.63bc	7.27d	8.76b	55.78c	66.67c
AY05	22.60e	8.79de	3.74abc	1.77cd	6.23b	11.49c	3.91d	2.66b	7.40c	8.63d	56.13ab	66.63cd
AY06	22.89e	8.72e	3.71abc	1.70d	6.17bcd	11.72b	4.16a	2.58bcd	7.26d	8.79b	55.81c	66.50d
AY07	23.13bc	8.86cd	3.70bc	1.88ab	6.10de	11.73b	3.90de	2.49ef	7.42bc	8.93a	55.74cd	66.11g
AY08	23.22b	9.40a	3.54d	1.92a	6.14cde	10.68f	3.85ef	2.43fg	7.47ab	8.71bc	55.73cd	66.80b
AY09	23.40b	9.21b	3.72abc	1.80bc	6.07e	10.86e	3.81f	2.40g	7.28d	8.67cd	55.73cd	66.99a
AY10	23.53a	9.29b	3.62cd	1.89ab	6.09e	10.82e	3.72g	2.52de	7.51a	8.91a	55.52d	66.55cd
Means	22.91	8.85	3.70	1.81	6.16	11.41	3.94	2.59	7.37	8.78	55.88	66.51
S.E	0.07	0.06	0.01	0.01	0.01	0.08	0.02	0.03	0.01	0.02	0.04	0.05
CV (%)	0.35	0.67	1.59	2.61	0.65	0.41	0.89	1.74	0.50	0.46	0.22	0.11

†Means with same alphabets along the column are not significantly different according to Duncan Multiple Range Test at P=0.05, MC=Moisture content, DMC=Dry Matter Content

Correlation coefficient of minerals and nutrient composition in tubers of ten accessions of African Yam Bean (AYB)

Table 5, presented the correlation analysis of Minerals and Nutrient composition in tubers of ten accessions of African Yam Bean (AYB). The N content correlates very strongly and positively with crude protein and carbohydrate content ($p<0.001$) of the AYB tubers, but showed strong negative correlation with Ca, Mg, Zn, crude fibre and total ash content. Similarly, K exhibited strong and positive association with Na ($p<0.001$) and ash content ($p<0.05$) of AYB tuber. Potassium also showed positive association with Mg, P and Zn though not significantly different. Sodium also showed significant association with P content in AYB tubers.

The calcium showed very strong significant association with Mg, Zn, crude fibre ($p<0.001$) and moisture content ($p<0.05$). However, Ca showed very strong negative association with crude protein and carbohydrate. The Mg in AYB tuber showed positive and strong association with crude fibre and total ash content, but was significantly and negatively associated with crude protein and carbohydrate content. A strong positive and significant association was observed between P and Zn content in AYB tubers, P was however negatively and significantly correlated with the moisture content. The Zn showed significant and positive association with crude fibre and ash content ($p<0.01$), but correlated significantly and negatively with crude protein and carbohydrate ($p<0.05$).

The Crude protein showed strong and positive association with carbohydrate but correlated negatively with crude fibre and total ash content in AYB tubers in this study. The crude fat showed positive association with AYB tuber moisture content and negatively correlated with crude fibre, total ash and carbohydrate. However, the associations in both cases were not significant. Furthermore, crude fibre in AYB was significantly and positively correlated to the total ash content while negative and significant relationship was observed between crude fibre content and the carbohydrate content. The tuber total ash and moisture content showed significant negative association with carbohydrate content in this study.

Table 5: Pearson coefficient of correlation between minerals and nutrients composition in tubers of African Yam Bean

	N	K	Na	Ca	Mg	P	Zn	Crude Protein	Crude Fat	Crude Fibre	Total Ash	Moisture content
K	-0.28											
Na	0.03	0.78***										
Ca	-0.68***	-0.08	-0.26									
Mg	-0.71***	0.04	-0.22	0.61***								
P	-0.09	0.18	0.49*	0.04	-0.19							
Zn	-0.69***	0.12	0.03	0.76***	0.32	0.57**						
Crude Protein	0.99***	-0.19	0.09	-0.72***	-0.74***	-0.11	-0.71***					
Crude Fat	0.22	-0.29	-0.31	0.05	-0.17	0.00	0.15	0.19				
Crude Fibre	-0.92***	0.18	-0.08	0.72***	0.83***	-0.04	0.57**	-0.93***	-0.24			
Total Ash	-0.81***	0.45*	0.12	0.33	0.45*	0.18	0.58**	-0.79***	-0.13	0.66***		
Moisture Content	-0.11	-0.07	-0.28	0.37*	0.23	-0.66***	-0.04	-0.09	0.24	0.23	-0.12	
Carbohydrate	0.66***	-0.13	0.17	-0.60***	-0.66***	- 0.31	-0.42*	0.67***	-0.22	-0.79***	-0.53**	-0.61***

* ** ***, significant at p=0.05, 0.01 and 0.1 probability levels.

DISCUSSION

African yam bean is an important under utilised legume with high nutritional benefits, of which when properly explored could ameliorate the problem of nutrient deficiency associated with increasing population growth in Africa. African yam bean like several other lesser legumes is under the threat of extinction. There are several sensitization programmes from different quarters on the relative importance of this endanger crop. The importance of this study is to compare the minerals and nutrients profile in the seeds and tubers of AYB. The information obtained from this study would assist in creating more awareness on the nutritional potential and benefit of this important crop in modern day diet.

Accessions of African yam beans under this study differed in the pattern of nutrient and mineral distribution between the respective seed and the corresponding tubers. The partitioning of a specific mineral between the seeds and tubers of AYB appeared not to follow a definite pattern. However, it seems that the partitioning of mineral and food components between the seeds and tubers of African yam bean were inversely related. Such that when a particular mineral or nutrient appeared high in the seed of a particular AYB accession, the mineral or nutrient becomes low in its corresponding tuber. For instance, AYB accession with the least seed crude fat content, however had the highest tuber crude fat content, accession AY01 with highest crude fiber content also had the highest tuber total ash content. This rule was however not valid for AYB03, which had highest seed Zn content and also showed highest Zn tuber content. Similarly, these mineral seems to have some affinity in the way and manner of distribution or partitioning. For instance, accession with highest seed N also had the highest seed calcium content, similarly AYB accession with highest tuber phosphorus also had the highest tuber potassium. Accessions which had the highest seed Na content also had highest Mg content. Highest Zinc was observed in AY03 (65.07 mg/kg) which also had highest seed Na content. Accession AY01 with least seed crude protein however had the highest seed crude fiber content whereas highest Mg content was observed in the tuber of AY01 which had lowest tuber N and Na.

There was an inverse relationship between N and P, AYB accessions with highest nitrogen content had lowest phosphorus content. Similarly, an accession with very low N and Na content seems to have highest magnesium content. In summary, more Na, K, N, Ca and Mg are found in the seeds of African yam bean seeds than in the tubers of AYB, while the tubers contained more phosphorus and zinc than seeds of AYB, this finding was different from the report of Ameh, (2007) which observed no significant differences between the proportion of minerals content in tubers and seeds of African yam beans. In this study, more zinc were observed in the tubers of seven out of the ten AYB accessions than their seeds, while the other three AYB accessions (AY04, AY08 and AY10) had more zinc in seed than corresponding tubers. This result also agreed with the earlier report of Ameh, 2007 which observed higher Zn in the tubers of five accessions of AYB evaluated. More crude protein content were observed in the seed of AYB compared with the crude protein found in the tubers, this finding corroborates the report of Ameh, 2007. The proportion of crude protein observed in AYB seeds in this study was in the range of 50 - 60 per cent as earlier highlighted by Watson, (1979). More carbohydrates and crude fiber were partitioned into the tubers of AYB than the seeds. The range of carbohydrate content obtained in the seeds of AYB in this study compared well with the values reported by Ajibola and Olapade, (2016), Ojukwu *et al*., (2012). Carbohydrate constituted the major portion of both the seeds and tubers of AYB.

Nitrogen is a major component of the amino acids which is the molecular block of protein. This explains the strong association observed between N and crude protein in both seed and tuber of AYB in this study. Similarly from the result, increasing crude protein content in the seed also enhances Ca and Zn content in the seed of AYB. Interestingly, increasing crude protein in the tubers also enhances the carbohydrate content in the AYB tubers significantly. Higher moisture content in the tubers indicated low storage potential compared with the seeds. African yam bean represent an important nutrient and minerals repository which if properly explore could replace those obtained from animal source.

CONCLUSION

Minerals and nutrient in the seeds and tubers of African yam accessions evaluated in this study varied considerably. Information obtained in this study also consolidates the relative minerals and nutritional benefits associated with both seeds and tubers of this important legume. Such information is vital for genetic improvement, germplasm conservation and varietal development of African yam bean. We suggest creation of more awareness on the nutritional potential of this neglected crop in tackling current food crises associated with increased birth rate in the country. The information obtained showed that AYB is highly nutritious and thus needs further introgression into the breeding programme. The floral biology could be vividly studied and hybridize with other adapted legumes of the tropical African for sustainable growth and increasing the lively hood of the people especially those who could not afford animal protein.

REFERENCES

Abbey, B.W. and Berezi, P.E. 1988. Influence of processing on the digestibility of African yam bean (*Sphenostylis stenocarpa* (Hoechst Ex. A. Rich.) Harms) flour. *Nutritional Report International* 37, 819-827.

Adewale, B. D. 2011. Genetic Diversity, Stability and Reproductive Biology of African yam bean, *Sphenostyli sstenocarpa* (Hochst. ex A. Rich.) Harms. PhD Thesis, University of Agriculture, Abeokuta, Nigeria.; 203pp.

Ajibola, G.O. and Olapade, A. A. 2016. Physical, Proximate and Anti-nutritional Composition of African yam bean (*Sphenostylis stenocarpa*) Seeds Varieties *Journal of Food Research*; 5, (2), 67 - 72

Ameh, G. I. 2007. Proximate and mineral composition of seed and tuber of African yam bean, *sphenostylis stenocarpa* (Hoechst. ex. a. rich.) Harms. *ASSET Series. B*, *6*, 1-10

Ameh, G.I and Okezie, C.E.A. 2006. Pest and diseases of African yambean Sphenostylis stenocarpa (Hoechst. Ex.A.Rich) harms. *Bio-Resource*; 3 (1), 14-20.

Amoatey, H.M., Klu, G.Y.P., Bansa, D., Kumaga, F.K., Aboagye, L.M., Benett, S.O. and Gamedoagbao, D.K. 2000. African yam bean (Sphenostylis stenocarpa) A neglected crop in Ghana. *West African Journal of Applied Ecology*; 1, 53-60

AOAC. 2005. Method of soil analysis. Soil Science Society of America.

Asuzu, I. U. 1986. Pharmacological evaluation of the folklore use of Sphenostylis stenocarpa. *Journal of Ethnopharm*; 16, 263-267. https://doi.org/10.1016/0378-8741(86)90092-9

Bremner. J.M. 1965. Total Nitrogen. In: C. A. Black (ed.) Methods of soil analysis. Part 2: Chemical and microbial properties. Number 9 in series Agronomy. *American Society of Agronomy,* Inc. Publisher, Madison, USA; 1049-1178.

Claydon, A. A. 1975. Review of the nutritional value of the Winged bean (*Psophocarpus tetragonolobus L.)* with special reference to Papua, New Guinea. *Sci. in New Guinea* 3(2), 103.

Ekpo, A.S. 2006. Changes in Amino Acid Composition of African Yam Beans (Sphenostylis stenocarpa) and African Locust Beans (Parkia filicoida) on Cooking. *Pakistan Journal of Nutrition*; 5, 254-256. https://doi.org/10.3923/pjn.2006.254.256

Ndidi, U.S., Ndidi, C.U., Abbas, O., Aliyu, M., Francis, G.B. and Oche, O. 2014. Proximate, antinutrients and mineral composition of raw and processed (Boiled and Roasted) *Sphenostylis stenocarpa* seeds from Southern Kaduna, Northwest Nigeria. http://dx.doi.org/10.1155/2014/280837

Nordqvist, J. 2019. "What are the health benefits of zinc?." 2017 *Medical News Today*. MediLexicon,Intl.,Dec.2017.Web.. https://www.medicalnewstoday.com/articles/263176.

Nwokolo, E. A. 1987. Nutritional Assessment of African yam bean *Sphenostylis stenocarpa* (Hochst ex A. Rich) and Bambara groundnut Voandzeia subterranea L. *J. Sci. Food Agric.*,; 41, 123-129 .http://dx.doi.org/10.1002/jsfa.27404 10205ces

Ojukwu, M., Olawuni, I.A., Ibeabuchi, C. and Amandikwa, C. 2012. Physical, proximate and functional properties of 'Nsama' A local variety of African yam bean (*Sphenostylis stenocarpa*) grown in southern states in Nigeria. *African Journal of Food Science and Technology,* 12*3*(10), 260-267.

Potter, D. 1992. Economic botany of *Sphenostylis* (Leguminosae). *Economic Botany*, 46, 262-275. https://doi.org/10.1007/BF02866625

Scott Brown, A.S., Simmonds, M.S.J. and Blaney, W.M. 2002. Relationship between nutritional composition of plant species and infestation levels of thrips. *Journal of Chemical Ecology*; l28 (12); 2399 - 2409. https://doi.org/10.1023/A:1021471732625

Shankar, A.H. and Prasad, A.S. 2013. Zinc and immune function: the biological basis of altered resistance to infection. *Am J Clin Nutr.* 68(2 Suppl),1-17. DOI:10.1093/ajcn/68.2.447S

Temple, V.S., Odewumi, L. and Joseph, K. 1991. Soybeans and soybean based diets. *In:* Proc. of 3rd Regional Workshop on Rural Development, Jos, 45 - 50.

Watson, J.D. 1979. Chemical composition of some less commonly used legumes in Ghana. *Food Chem.*; 2, 267-271. https://doi.org/10.1016/0308-8146(77)90044-9