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African Yam Bean (*Sphenostylis Stenocarpa*) tubers for nutritional security

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Abstract

African yam bean (AYB) is an "orphan" crop in Africa, despite its nutritional benefits and potentials as a food security crop. It produces two valuable products, edible seeds and tubers. The tubers which are consumed in most parts of East and Central Africa have not been given much attention in West Africa. This study also evaluated 40 AYB accessions for tuberization and investigated the proximate, mineral and anti-nutritional composition of tubers of some AYB accessions harvested in the 2011/2012 cropping season. Tuberization occurred in 42.5 % of accessions investigated. Accession TSs 140 produced the highest number of tubers (6 tubers/plant) while AYB1 had the least (1 tuber). Three different tuber shapes were identified; ovate, spindle and irregular, with the spindle shape being the most dominant. Tuberization was more pronounced in 2012 with less rainfall (185.74mm) and sunshine hour (4.9 hr), compared to the 2011 season. The tubers were low in moisture content (10.3%) while crude protein content ranged from 15.05 % (AYB 57) to 15.86 % (TSs 107); and the carbohydrate content ranged from 67.34 % (AYB 45) to 67.96 % (TSs 140). Magnesium and potassium were prominent in AYB tubers evaluated (1.67gkg^{-1} and 10.09gkg^{-1}). Antinutrients were generally less in the tubers compared to the seeds. Accessions TSs 107 and TSs 140 had the least anti-nutrients in harvested tubers and had high amounts of protein (15.9% and 15.4%) and carbohydrate (68.7% and 67.9%) respectively. The tubers of AYB could therefore be incorporated into animal feeds and serve as an alternative staple food for man.

Keywords: Food security, *Sphenostylis stenocarpa*, Tuberization, Photoperiod, Leguminous crop

Introduction

Root and tuber crops contribute to the energy and nutrition requirement of more than two billion people and constitute an important source of income in rural and marginal areas. They have multiple uses, most notably as food security crops, regular food crops, cash crops and are increasingly used as livestock feed and raw materials for industrial purposes (Scott, 2000). Tuberous legumes are good examples of underutilised crops with considerable potentials but they are rarely recognized as important crops by the agronomist (Grueneberg, 1998). African yam bean (AYB) is one of the numerous underutilised legumes in Africa with great potentials as a food security crop. It is cultivated for both edible seeds and underground tubers but the cultivation for tubers is limited to most of East and Central Africa especially among the Bandudus, the Shabas and at Kinshasa in Zaire while the seeds are preferred in West Africa (Nwokolo, 1987). AYB is cultivated in Nigeria mainly for seed but it is also grown for tubers in Ghana, Cote d' Ivoire, Togo, Cameroon, Gabon, Democratic Republic of Congo, Ethiopia, and parts of East Africa especially Malawi and Zimbabwe (NRC, 2006). The underground tubers also serve as organs of perennation in the wild (Klu et al., 2001). Among the outstanding remarks on the importance of African yam bean (AYB) includes: cultural link to Africa (Potter and Doyle, 1992), nutritional potentials and status (Nwokolo, 1987; Uguru and Madukaife, 2001; Azeke et al., 2005; Ekpo, 2006), suitability for wide climatic conditions (Anochili, 1984; Betsche et al., 2005) and nitrogen fixation (Oganale, 2009; Tettey, 2014). Underutilised crops provide essential micro-nutrients and thus able to complement staple foods (Padulosi et al., 2013). Different minerals and food components are present in AYB seed and tuber, comparable to other food legumes (Adewale et al., 2013). AYB possesses essential minerals and amino acids as well as high protein content (Ndidi et al., 2014) hence, serves as alternative food supplement in the diets of malnourished children in Africa. Higher levels of amino acid profiles have been reported in AYB seeds compared to the other well known legumes, pigeon pea, cowpea and bambara groundnut (Uguru and Madukhaife, 2001; Ojuederie and Balogun, 2017). AYB seed and tuber have a lot of nutritional benefits, which if put into use, will go a long way in enhancing food security and invariably alleviate poverty in Sub Saharan Africa.AYB has some similarities to the Mexican yam bean (*Pachyrhizus erosus*) which is cultivated on a large scale for export. There is paucity of information on tuberization in AYB and its utilization in Nigeria despite its rich nutritional content. In Nigeria during harvest, the tubers are often discarded by farmers. It is necessary to identify tuber producing accessions for better utilization and assess the diversity present in the available landraces which are mostly in the hands of resource poor farmers. The objective of this research therefore, was to evaluate 40 accessions of AYB for tuber production and determine the genetic variability of the tubers and their nutritional composition.

Materials and Methods

Source of Plant Materials

Forty accessions of AYB were evaluated in 2011 and 2012 cropping seasons at the Research farm of the Institute of Agricultural Research and Training, (IAR&T), Obafemi Awolowo University, Moor Plantation Ibadan (Latitude 7^{o} 22' 37.5" and longitude 3^{o} 50' 38''.46) for tuber production. Twenty-seven accessions of AYB were obtained from the Genetic Resources Center of the International Institute of Tropical Agriculture (IITA) Ibadan while 13 accessions were from the Institute of Agricultural Research and Training (IAR&T) Obafemi Awolowo University, Moor plantation Ibadan, all of Nigerian origin (Table 1).

Field evaluation of African yam bean accessions

The experimental field was ploughed, harrowed and the accessions planted for two seasons (June to December 2011 and June to December 2012). Seeds of each accession were dusted with the macozeb fungicide and sown on a plot size of 5m x 1m with inter and intra row spacing of 1m x 1m. Three seeds were sown per hole and later thinned to one plant per stand two weeks after planting, to give a total of five plants per accession and a total of 200 plants in the total experimental area of 5m x 40m ($200m^2$). The experimental design used was a randomized complete block design with three replications. At three weeks after planting, the seedlings were staked. Manual weeding was carried out regularly to keep the field free of weeds. Insects were controlled with Cyperdiforce applied at the rate of 35-60ml in 20 liters of water at two weeks interval during the flowering period and subsequently for two-weeks for a total of three applications prior to harvesting. At maturity, three representative plants were sampled from each plot. The monthly rainfall, sunshine hours, temperature and relative humidity of the location (IAR&T) during the cropping seasons are presented in Table 2. The location received a total of 1246.15 mm rainfall (June to December 2011) and 1300.2 mm rainfall (June to December 2012). The total sunshine hours were 36.9 hrs (2011) and 34 hrs (2012). The minimum and maximum temperature ranged from 19.70 to 33.50 ^{o}C with an average temperature of 21.78 to 30.27 ^{o}C during the 2011 cropping season and ranged from 21.70 to 33.10 ^{o}C with an average of 21.97 to 29.87 ^{o}C during the 2012 cropping season. After 7 months of growth, AYB plants were uprooted and tubers if present were harvested.

Data Collection

Data were taken on number of tubers, tuber yield, tuber length, tuber width, tuber width/length ratio, tuber shape, tuber skin colour and tuber branching and extent of tuber branching using AYB descriptors (Adewale and Dumet, 2011). Tuber skin colour was determined using the Methuen handbook of colour (Kornerup and Wanscher, 1984).

Sample Preparation for anti-nutritional analysis of African yam bean seed and tuber

Tubers of four harvested 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, proximate and anti- nutritional analysis. The anti-nutritional factors; tannin, phytate, saponin, oxalate and lectin, were determined following the standard procedures of the Association of Analytical Chemists, (AOAC, 1984) Ojuederie, 2016). Trypsin inhibitor and cyanogenic glycosides were determined in accordance with the procedure of Edeogu et al. (2007).

Statistical analysis

Data were subjected to one-way analysis of variance and means compared using Student Newman Keuls test at 5% level of significance using SAS software 9.3 (SAS Institute, 2010) Paired T test was used to compare the mineral and anti-nutritional composition of the seeds and tubers of the four AYB accessions evaluated

Results and Discussion

Evaluation of AYB accessions for tuberization

Seventeen accessions of AYB (42.5%) produced tubers out of the forty accessions evaluated in 2012. Out of the accessions from IAR&T which were from South Western Nigeria, 76.9% were tuberous while only 18.52% of accessions obtained from IITA were tuberous. The quantitative and qualitative traits of tubers harvested from 17 AYB accessions evaluated in 2012 are presented (Table 3). In 2011, only one accession, AYB 70B produced tubers. Tuber yield (g) in 2012 ranged from 3.5g (AYB 56) to 600.0g (AYB 45). Accession AYB 45 had the highest tuber length (18.00cm) and width (22.90cm) while TSs 140 produced the highest number of tubers (6 tubers). Out of the 17 tuberous accessions, 15 produced two or more tubers (≥ Two Tubers), while two accessions produced only one tuber (AYB56 and AYB70B). Figure 1 shows the two common tuber shapes of some accessions evaluated in this study.

Accession TSs 5 had ovate shape, TSs140, TSs 148, TSs 157, TSs 107, AYB IFE, AYB 70B, AYB 61, AYB 23 AYB 56, and AYB 4 had spindle shape, while AYB 1 AYB 134, AYB 57, AYB 45, TSs 123 and TSs 134 had irregular tuber shapes. Based on Methuen handbook of colour , three tuber skin colours were observed (Fig. 2). Branched tubers occurred in 52.94% of accessions, 47.06% of accessions had unbranched tubers, 41.18% were slightly branched while 5.88% was highly branched (Table 3).

Proximate and mineral composition of some African yam bean tubers

The crude protein of the tubers of AYB was an average of 15.5 % with accession TSs 107 having the highest protein content (15.9 ± 0.2%). The moisture content (9.9 ± 0.8%) and the total ash (2.4 ± 0.2%) contents were also lowest in TSs 107. It however gave the highest calorific value (1469.3 ± 47.1). There was no significant difference in the carbohydrate composition among the accessions evaluated, which was an average of 68.30% (Table 4). The mineral composition of the tubers of the AYB accessions is presented in table 5. Magnesium (1.67 g/kg^{-1}) and potassium (10.09 g/kg^{-1}) were high in the tubers evaluated. TSs 107 had the highest magnesium (1.77 g/kg^{-1}) and iron (0.09g/kg^{-1}) contents respectively. The amount of calcium detected in the tubers of AYB was not significantly different in the four accessions evaluated.

Comparison of the mineral composition of AYB seeds and tubers

The use of paired t-test (Table 6) showed that both the seeds and tubers OF AYB did not differ significantly in the composition of their mineral contents (t= -0.21, Pr= 0.8368). Nevertheless, both products had high levels of potassium and magnesium.

Anti-nutritional composition of AYB seeds and tubers

Seven anti-nutritional factors were evaluated in the seed and tubers of 4 African yam bean accessions TSs 107, TSs 140, AYB 45 and AYB 57. These were trypsin inhibitors, tannins, phytate, oxalates, saponin, lectin and hydrogen cyanide. There was no trace of trypsin inhibitor and lectin in the tubers of TSs 107 and TSs 140. AYB 45 had the highest amount of hydrogen cyanide (64.0$mgkg^{-1}$), trypsin inhibitor (34.1$TIUmg^{-1}$) and lectin contents (57.2.$LUmg^{-1}$) respectively, compared to AYB 57 and the other accessions evaluated (Fig 3a).

The concentration of hydrogen cyanide was lower in the tubers of TSs 107 and TSs 140 compared to AYB 45 and AYB 57. TSs107 had the least amount of oxalate and phytate content in the seeds of AYB evaluated (0.80 gkg^{-1} and 2.10g kg^{-1}) respectively. Similar observation was made in the tubers of TSs 107 which had very low levels of oxalate (0.30gkg^{-1}) and phytate (17.5gkg^{-1}) compared to the tubers of AYB 45, AYB 57 and TSs140. However, TSs 107 had the highest amount of saponin (4.40gkg^{-1}) and tannin (6.60gkg^{-1}) in its seed (Fig 3b). Phytate was highest in AYB45 (2.75gkg^{-1}) and oxalate content highest in AYB57 (115.0$mg100g^{-1}$). Saponin content ranged from 3.0$mg100g^{-1}$ (TSs140) to 275.0$mg100g^{-1}$ (AYB45). Tannin content was more in the tubers of AYB 45 (4.80gkg^{-1}) and AYB 57 (5.40gkg^{-1}) compared to the seeds (1.89gkg^{-1} and 2.15gkg^{-1}) respectively. Highly significant differences ($P < 0.001$) were observed in the amount of phytate, saponin, hydrogen cyanide, trypsin inhibitor and lectin contents of the tubers evaluated. Accessions TSs 107 and TSs 140 had significantly lower levels of phytate (0.18 gkg^{-1} and 0.15 gkg^{-1}), saponin (0.05$gkg^{-1}$and 0.03g kg^{-1}), and hydrogen cyanide (8.7$mgkg^{-1}$ and 8.5 $mgkg^{-1}$) respectively.

Discussion

Forty (40) accessions of AYB were evaluated for tuberization in two seasons. The production of tubers in African yam bean was more in 2012 (42.5%) than 2011 (2.5%). The variation within *Sphenostylis stenocarpa* for tuber production had been speculated as an indicator for separating the species, classifying the crop into two ancestries as hypothesized by Potter and Doyle (1992): the single ancestry hypothesis which identified a single species indivisible by any form and the double hypothesis which recognized two different forms within the species (the tuberous and non-tuberous). Adewale (2010) morphologically placed the evolution of African yam bean into two groups, the tuber forming and the non-tuber forming. Not all accessions produced tubers as identified by Adewale (2011) who suggested that tuber production may not be solely under genetic control as the environment and/ or its interaction with the genotype may affect the physiological phenomenon of tuberization in the species. Few studies have been conducted on the influence of photoperiod and temperature on root tuber formation in legumes. Tuberization in *Pachyrhizus erosus* the Mexican yam bean (Paull et al., 1988) and *Pachyrhizus. tuberosus* the Amazonian yam bean (Alvarenga and Válio, 1989) are influenced by short daylength. Alvarenga and Válio (1989) observed that tuberization in *Pachyrhizus tuberosus* occurred only under photoperiods shorter than 16h and day/night temperature regimes of 25/20 °C and 20/15 °C. Schiavinato and Válio (1996) also made similar observation when they investigated *Psophocarpus tetragonolobus* (Winged bean) a tuberous legume common to Africa, by using different photoperiods and day/night temperatures. Unlike *Psophocarpus tetragonolobus* (Winged bean) and *Pachyrhizus erosus* (Mexican yam bean) which produce tubers under short day length, no research work has been done on the effects of photoperiod and temperature on tuberization in African yam bean. In potato, tuberization is also triggered by short day length which produces less heat and inhibited by long day length which produces more heat. Elevated temperatures inhibit Su synthase gene expression thereby preventing tuberization in potato. In this study, the sunshine hours were an average of 5.3 hrs (2011) and 4.9 hrs (2012). Sunshine hours were lower in 2012 in the months of June, August and September. This could be responsible for more accessions producing tubers in 2012. The average day/night temperatures were 30/22 °C which initiated tubers in 17 accessions of AYB in 2012. The three tuber shapes identified in this study, corroborates the report of (Adewale, 2011) that the tuber shapes in AYB could be round, ovate, spindle or irregular.

Ojuederie and Balogun (2017) highlighted the nutritional benefits of AYB tubers. TSs 107 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 (15.5% and 67.9%) respectively. Accession TSs 107 also had the highest calorific value (1469 Kjg^{-1}). With such high protein content (15.9%) in the tubers of AYB, it makes it a good source of alternative protein for human and livestock consumption. Additionally, the tubers were also found to be low in moisture content (10.3%) which indicates its ability to store for a longer time without spoilage from increased microbial action. The moisture content of the tubers was within the acceptable range (Ceirwyn, 1995). Minerals such as magnesium and potassium were also reported to be high in AYB tubers evaluated (Ojuederie and Balogun, 2017).

In the present study, the anti-nutritional composition of the tubers of four accessions of AYB were determined and compared to that of the seeds. Anti-nutritional factors in food legumes are chemical substances present in foods that cause adverse physiological responses in animals that consumes them (Adewale et al., 2013). These anti-nutritional factors in legumes decrease the overall nutritional quality of the seeds by impairing protein digestibility and mineral availability (Ndidi et al., 2014). Phytate which represents about 89.0% of the total phosphorous concentration is stored in cereal grains and other seeds and it is known to interact with both iron and proteins lowering the bioavailability of minerals and inhibits several proteolytic enzymes and amylases (Siegenberg et al., 1991). It chelates metals such as calcium, phosphorus, copper, magnesium and iron and forms complexes with proteins in legumes thereby reducing the nutritive value (Adeparusi, 2001). Phosphorus deficiency occurs in animals when phytate combines with phosphorus. Tannins affect the digestive tract and their metabolites are toxic (Ene-Obong and Carnovale, 1992). The precise toxic amount of tannin which causes depression in humans is yet to be identified. The amount of tannin obtained in the seed and tuber of AYB was slightly high but soaking overnight in water removes its content from seeds. This has been reported in sorghum (Nyachoti et al., 1997) and in African yam bean (Adeparusi, 2001). Trypsin inhibitor concentration in the seed (34.59 Tiu mg^{-1}) and tuber (33.96 Tiu mg^{-1}) of AYB obtained in this study were higher than that reported in soybean (12.0 Tiu mg^{-1}), bambara groundnut (22.6 Tiu mg^{-1}) (Ajayi et al., 2010) and in African yam bean seeds, an average of 29.44 Tiu mg^{-1}, but lower than that of TSs 133 (42.57Tiu mg^{-1}) reported by (Adesoye and Oluyede, 2015). The concentration of saponin analyzed in both seed and tuber of AYB were moderate. Significant reduction in phytate, tannins, saponin and trypsin inhibitor contents have been reported after cooking which makes it safe for human consumption (Nwosu, 2010; Ndidi et al., 2014). Oxalates are one of the major causes of renal failure as it complexes with calcium developing calcium crystals which get deposited as kidney stones (Banso and Adeyemo, 2007; Soetan, 2017). It also reduces the amount of soluble calcium available for the body's absorption due to the formation of insoluble calcium-oxalate complex (Adeniyi et al., 2009; Soetan, 2017). Oxalate levels were least in the seed and tuber of TSs 107. Therefore consumption of the cooked beans and the tubers of TSs 107 will increase absorption of calcium and other nutrients while keeping the kidneys healthy. The levels of hydrogen cyanide, trypsin inhibitor and lectin were about the same level in both seed and tuber of AYB 45 and AYB 57. The hydrogen cyanide concentration in both seed and tuber of AYB were above the permissible limit in food (50 mgkg^{-1}) as reported by Ndidi et al. (2014) except in the tubers of TSs 107 and TSs 140 which were relatively low (8.7 mgkg^{-1} and 8.5 mgkg^{-1}) respectively. Tubers of TSs 107 and TSs 140 had the least anti-nutritional factors in this study compared to the raw seeds and from the study of Ojuederie and Balogun (2017), they are also rich in phosphorous and magnesium as well as high in protein and carbohydrate contents. These accessions could be used as potential parents for breeding for varieties with low anti-nutritional factors. The anti-nutritional contents detected were found to be more in the seed than the tuber of AYB.

Conclusion

Tuberization occurred in 42.5% of AYB accessions investigated in this study. This could be due to the interaction of the genotype and the environment. However, further studies need to be carried out to ascertain if temperature regimes and photoperiod promotes tuberization in African yam bean which will enable scientist have more precise information on the nature of tuberization in the species. Antinutrients were less in the tubers of AYB evaluated compared to the seeds. TSs 107 and TSs 140 with low antinutrients could be considered in breeding programmes for improved varieties with low anti-nutritional factors. This indicates the usefulness of AYB as an alternative source of protein, energy requirements and food supplements for animal feed production as well as a staple food for man.

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Conflict of Interests

None

Tables, Figures and Charts

Table 1: List of accessions of African yam bean used in this study

S/N	Accession Code	Country	Region	Collection Sites	Collector
1	TSs5	Nigeria	NA	NA	C.N. Aniagu
2	TSs19	Nigeria	NA	NA	Kanti Rawal
3	TSs26	Nigeria	NA	NA	Kanti Rawal
4	TSs41	Nigeria	NA	NA	Kanti Rawal
5	TSs42	Nigeria	NA	NA	Kanti Rawal
6	TSs45	Nigeria	NA	NA	Kanti Rawal
7	TSs51	Nigeria	NA	NA	L. Igbokwe
8	TSs52	Nigeria	NA	NA	L. Igbokwe
9	TSs66	Bangladesh	NA	NA	Dr N. Haq
10	TSs68	Ghana	NA	NA	W.M. Steele
11	TSs78	Nigeria	NA	NA	Unknown
12	TSs88	Nigeria	NA	NA	Badra
13	TSs107	Nigeria	NA	NA	Dr. N. Q. Ng
14	TSs123	Ghana	NA	NA	Eastwood/Holloway
15	TSs133	Nigeria	NA	NA	Unknown
16	TSs134	Nigeria	NA	NA	Unknown
17	TSs137	Nigeria	NA	NA	Unknown
18	TSs138	Nigeria	NA	NA	Unknown
19	TSs139	Nigeria	NA	NA	Unknown
20	TSs140	Nigeria	South East	Agbani	Dr. J. Machuka
21	TSs148	Nigeria	South East	Enugu	Dr. J. Machuka
22	TSs150	Nigeria	South East	Enugu	Dr. J. Machuka
23	TSs152	Nigeria	South East	Enugu	Dr. J. Machuka
24	TSs153	Nigeria	South East	Enugu	Dr. J. Machuka
25	TSs154	Nigeria	South East	Enugu	Dr. J. Machuka
26	TSs156	Nigeria	South East	Umueze	Dr. J. Machuka
27	TSs157	Nigeria	South East	Umueze	Dr. J. Machuka
28	AYB1	Nigeria	NA	NA	Dr(Mrs.) S.R. Akande
29	AYB4	Nigeria	South West	Ado-Ekiti	Dr (Mrs.) S.R. Akande
30	AYB9	Nigeria	NA	NA	Dr (Mrs.) S.R. Akande
31	AYB23	Nigeria	South West	Ita-ogbolu	Dr (Mrs.) S.R. Akande
32	AYB26	Nigeria	South West	Ilesha	Dr (Mrs.) S.R. Akande
33	AYB34	Nigeria	North East	Kaduna	Dr (Mrs.) S.R. Akande
34	AYB45	Nigeria	South west	Ita-ogbolu	Dr (Mrs.) S.R. Akande
35	AYB50	Nigeria	South West	Omi-Adio	Dr (Mrs.) S.R. Akande
36	AYB56	Nigeria	South West	Ita-ogbolu	Dr (Mrs.) S.R. Akande
37	AYB57	Nigeria	South West	Akure	Dr (Mrs.) S.R. Akande
38	AYB61	Nigeria	South West	Serafu	Dr (Mrs.) S.R. Akande
39	AYB70B	Nigeria	NA	NA	Dr (Mrs.) S.R. Akande
40	AYBIFE	Nigeria	South West	Ife	Dr (Mrs.) S.R. Akande

TSs- Tropical (*Sphenostylis stenocarpa*), obtained from the Genetic Resources Centre, International Institute of Tropical Agriculture, Ibadan. AYB- African yam bean obtained from the Institute of Agricultural Research and Training, Obafemi Awolowo University

Table 2. Meteorological data on rainfall, sunshine hours, temperature and relative humidity at Institute of Agricultural Research and Training (IAR&T) in 2011 and 2012

2011	Rainfall	Sunshine Hour	Relative Humidity		Temperature	
Month	(mm)	(hrs)	Min (%)	Max (%)	Min (° C)	Max (° C)
Jun	224.4	5.6	61.0	97.0	22.5	30.5
Jul	156.4	3.2	68.0	93.0	21.8	28.1
Aug	314.9	2.9	69.0	96.0	21.7	27.8
Sep	280.9	4.2	63.0	96.0	22.2	29.6
Oct	262.4	5.1	61.0	97.0	21.7	30.0
Nov	8.0	7.9	40.0	95.0	22.9	32.4
Dec	0.0	8.0	19.0	92.0	19.7	33.5
Mean	178.14	5.3	54.43	95.14	21.79	30.27
2012						
Jun	182.7	4.9	62.0	97.0	22.0	29.6
Jul	279.7	3.3	69.0	96.0	21.9	28.1
Aug	428.5	2.4	70.0	95.0	21.3	27.1
Sep	204.4	2.9	65.0	98.0	21.7	28.9
Oct	187.4	5.9	60.0	97.0	21.9	30.2
Nov	17.5	6.9	51.0	96.0	22.9	32.1
Dec	0.0	7.7	33.0	90.0	22.1	33.1
Mean	185.74	4.9	58.57	95.57	21.97	29.87

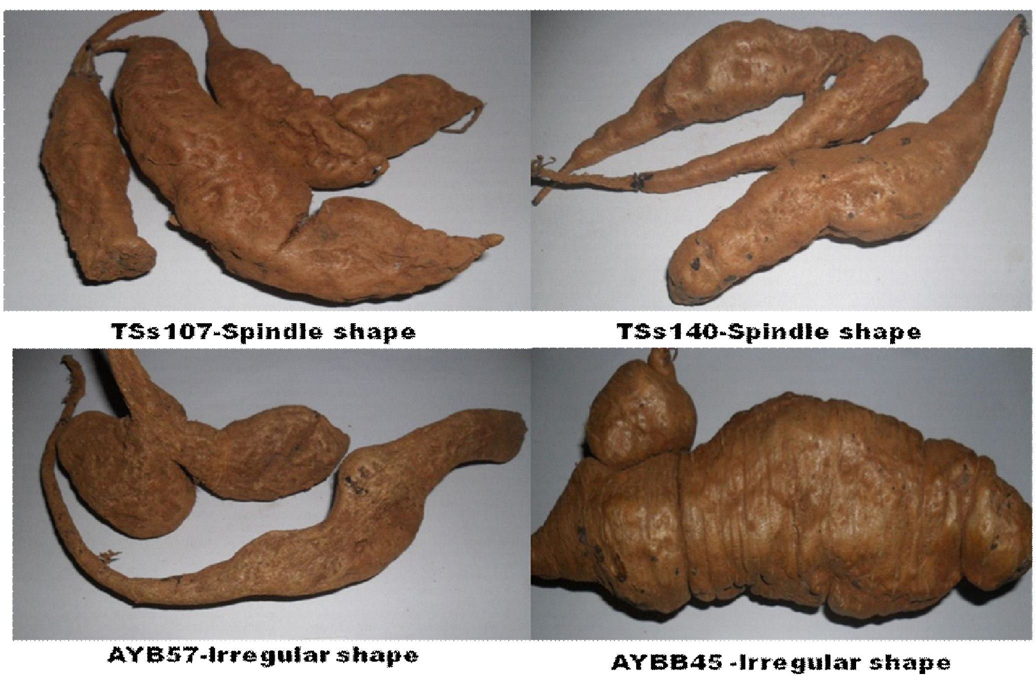

Figure 1. Different shapes of some harvested African yam bean tubers

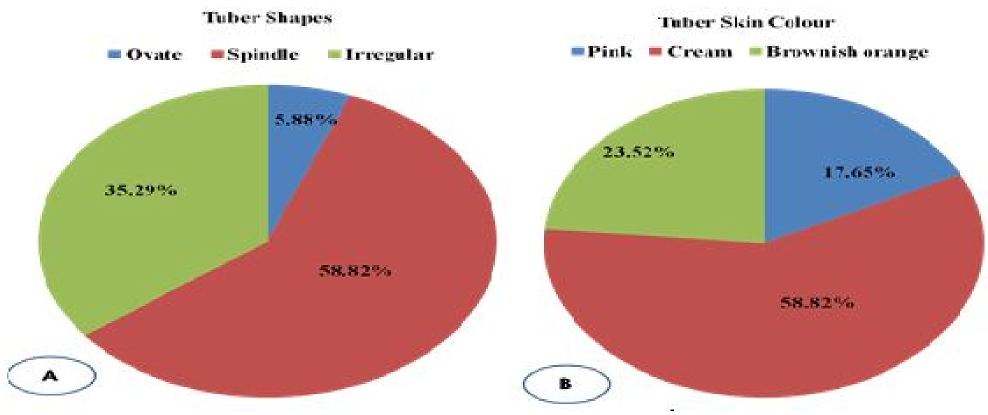

Fig. 2: Tuber (a) shapes and (b) skin colour of AYB accessions

Table 3: Quantitative and qualitative traits of African yam bean tubers evaluated in 2012

Accessions	NT	TL	TW	W/L Ratio	TY (g/plant	TP	TS	TSC	TB	ETB
AYB1	2	7.5	2.5	0.33	32.17	2	4	3	1	1
AYB4	2	12	6.5	0.54	19.25	2	3	1	0	0
AYB23	2	15	8.8	0.71	40.65	2	3	3	0	0
AYB34	5	16.8	14.5	0.86	29.48	2	4	1	1	1
AYB45	2	18	22.9	1.19	600	2	4	1	0	0
AYB56	1	10.5	4.5	0.41	3.53	1	3	2	0	0
AYB57	3	15.3	7.6	0.48	177.8	2	4	1	1	1
AYB61	4	15.3	5.7	0.38	71.73	2	3	1	1	1
AYB70B	2	16	5.5	0.34	178.2	2	3	1	0	0
AYBIFE	2	12	6.5	0.54	19.25	2	3	1	0	0
TSs5	2	23	8.3	0.36	87.71	2	2	3	0	0
TSs107	4	13.3	10.8	0.81	72.99	2	3	2	1	3
TSs123	5	11.4	9	0.79	117.6	2	4	1	1	1
TSs134	2	11.4	2.6	0.23	171.1	2	4	2	1	1
TSs140	5.5	10.1	2.6	0.26	194.7	2	3	1	1	1
TSs148	5	10.7	2.6	0.24	134.32	2	3	2	1	2
TSs157	2	16.8	15	0.86	176.9	2	3	1	0	0

NT-number of tubers, **TL**-tuber length, **TW**-tuber width, **W/L Ratio**-tuber weight to length ratio, **TY**-tuber yield, **TP**-tuber population (1 = One Tuber, 2 = ≥ Two Tubers) **TS**-tuber shape (1=Round, 2=Ovate, 3=Spindle, 4=Irregular) **TSC**-skin colour (1=Cream. 2=Brownish orange 3=Pink), **TB**-tuber branching, **ETB**-extent of tuber branching (1 = Slightly branched, 2 = Branched, 3 = Highly branched)

Table 4: Proximate analysis of African yam bean tubers

Accessions	Crude protein (%)	Moisture content (%)	Total ash (%)	Crude fiber (%)	Crude fat (%)	Carbohydrate content (%)	Calorific value (Kjg-1)
AYB57	15.1 ± 0.1[c]	10.4 ± 0.2[a]	3.4 ± 0.1[a]	1.5 ± 0.0[c]	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[b]	0.8 ± 0.0[c]	67.3 ± 1.9[a]	1457.4 ± 30.2[a]
TSs107	15.9 ± 0.2[a]	9.9 ± 0.8[a]	2.4 ± 0.2[b]	2.6 ± 0.0[b]	1.5 ± 0.0[b]	67.7 ± 2.6[a]	1469.3 ± 47.1[a]
TSs140	15.5 ± 0.2[b]	10.4 ± 0.2[a]	2.7 ± 0.0[b]	2.9 ± 0.1[a]	0.8 ± 0.0[c]	67.9 ± 0.4[a]	1423.3 ± 1.9[a]
Mean	15.5	10.3	2.90	2.40	1.30	68.30	1445.70

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 (Ojuederie and Balogun, 2017)

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

Accessions	Calcium	Phosphorous	Magnesium	Potassium	Iron
AYB45	0.51[a]	0.02[ab]	1.56[b]	10.95[a]	0.08[b]
AYB57	0.52[a]	0.02[ab]	1.69[d]	11.82[a]	0.08[b]
TSs107	0.48[a]	0.01[b]	1.77[a]	9.31[b]	0.09[a]
TSs140	0.49[a]	0.03[a]	1.66[c]	8.33[b]	0.07[c]
Mean	0.50	0.02	1.67	10.10	0.08

Means followed by the same letters down the columns are not significantly different ($P \leq 0.05$) using LSD (Ojuederie and Balogun, 2017)

Table 6. 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	0.0 9	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	10.95
AYB57	Potassium	2.60	11.83
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| 0.8368 (Ojuederie and Balogun, 2017)

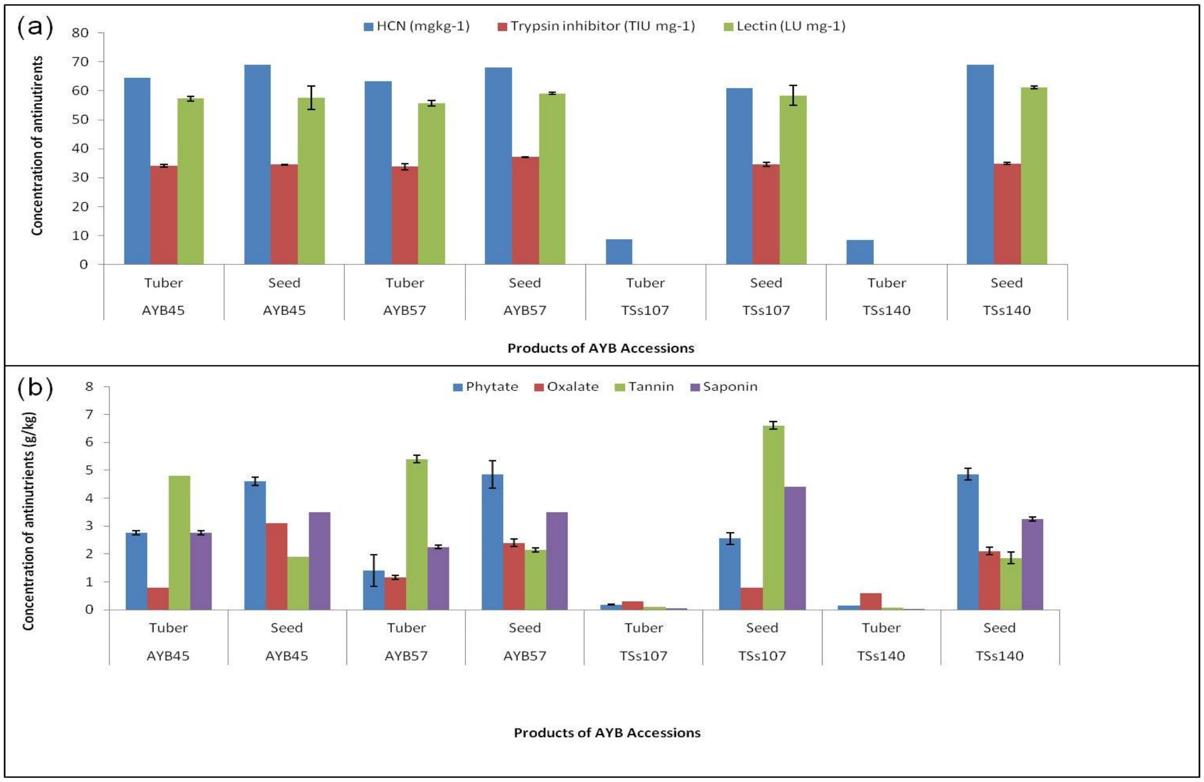

Fig 3 Antinutritional composition of African yam beans seeds and tubers. (a) HCN, Trypsin inhibitor and lectin contents in AYB seed and tubers (b) Phytate, oxalate, tannin and saponin contents in AYB seed and tubers

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