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Updates on Nutritional Diversity in *Sphenostylis stenocarpa* (Hoechst ex. A. Rich.) Harms. for Food Security and Conservation

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Abstract: Neglected and underutilized plant genetic resources constitute opportunity for diversification of food and environmental services globally, particularly within communities in developing country. They can provide, in some cases, higher nutrient content than traditional globally accepted staples commonly consumed. Currently, with climate uncertainty and the desire and challenge for sustainably produced food, there is an urgent need to promote crop diversity. Benefits are also likely to come from the greater resilience to environmental stress and the lower resource demand associated with growing these neglected crops. This study aims at quantifying the nutritional variety in 34 accessions of *Sphenostylis stenocarpa* (African yam bean) sourced from farmers, marketers and consumers for food and nutrient security. The accessions were evaluated for variability in their nutritional components based on proximate and vitamin values using Multidimensional Analysis (MDA), Principal Component Analysis (PCA) and cluster analysis. Highly diversity were observed among these accessions in most of the traits measured. The MDA analysis showed that accessions AB2, AB4, AB3, EB5, AB1 and EB6 ranked 1st to 6th, respectively. The PCA revealed that PCA 1, 2, 3, 4 and 5 loaded the most significant variables which contributed more in discriminating the accessions examined. PC1 and PC3 gave the maximum variability for two traits each while PC2, PC4 and PC5 loaded 1 each. The cluster analysis highlighted three distinct clads. Group I clades with 19 accessions, group II, with 3 accessions and group III clustered 12 accessions. MDA and Principal Component Analysis (PCA) were highly concordant. They serve as robust tools for enhancing breeding program for genetic improvement and germplasm conservation.

Keywords: Malnutrition, Underutilized Species, Nutritional Composition, African Yam Bean, *Sphenostylis stenocarpa*

Introduction

Food and nutrient security have become major challenge for both the rich and poor, given the increasing population, changes in dietary consumption patterns and effect of climate variability and change on natural resources (Porter *et al*., 2014). The focus on a few widely used, but heavily exploited species has helped to sustain population growth and human wellbeing over the last two decades. However, reliance on few crops has inherent conservation, agronomic, ecological, nutritional and economic risks (Andreas, 2014). Moreover, declining agro-biodiversity both between and within specific crops highlights the increasing vulnerability among resource poor communities for which diversity provides means of survival (FOA, 2011). Lin (2011) also noted that climate change affect both biotic (pest, pathogens) and a biotic (e.g., temperature, water and solar radiation) factors and thus threaten species productivity and sustainability.

Currently, adaptation has shifted from focusing on ‘effects’ to include those strategies, which enable practical approaches for adaptation, participation and individual inclusiveness (Noble *et al*., 2014). They further stressed that it is crucial now, that responses to climate change impacts, should be appropriate, enhancing adaptive capacity and must be location-specific by maximizing the use of local resources through diversification to enhance resilience.

Many countries have experienced persistent food crisis both in terms of quantity and quality. A cursory analysis shows that most countries in Africa have high indexes of the extremely poor and hungry populations. Cases of malnutrition and under nutrition are widespread and the food intake of most people is below the international standard (Otaha, 2013). This calls for urgent need to promote crop diversification to include Neglected and Underutilized Species (NUS). These species can potentially play vital roles in sustainable livelihoods ensuring food and nutrient security, leading to poverty reduction. NUS are readily affordable and accessible to the rural and semi-urban dwellers and can withstand the stresses linked to climate change, as they already show partial and local adaptation to growing in stressed environments (Durst and Bayasgalanbat, 2014; Nnamani *et al*., 2009). Aside from being more easily accessible than conventional major crops, they can be robust point for conventional breeding programs and germplasm conservation (Arora, 2014).

African Yam Bean (AYB), is a NUS, belonging to the Fabaceae. Its nutritional potential is derived from both its seeds and underground tubers with amino acid (lysine and methionine) content higher than those of pigeon pea, cowpea and bambara groundnut (Uguru and Madukaife, 2001). Notable studies have been carried out on the nutritional values of AYB (Ekpo, 2006; Norman and Cunningham, 2006; Ameh, 2007; Adebowale and Sanni, 2009; Emiola, 2011; Kiin-Kabari and Giami, 2015; Banigo and Kiin-Kabari, 2016). However, little or no attention has been given to ranking the nutritional values within these accessions in order to highlight those with the most desirable nutrient contents. Such data could enhance breeding program for genetic improvement and germplasm conservation.

The overall aim of this study was to evaluate the nutritional contents of 34 accessions of AYB using multidimensional analysis (MDA) based on their weighed factors (WF), relating this to principal component analysis (PCA).Specifically, the study proposes to: (1) Determine the proximate and vitamin compositions of the 34 accessions by identifying those accessions with the most desirable nutrients using MDA; 2) access the similarities and distance among these accessions based on their nutritional variability using principal component analysis.

Materials and Methods

Study Area and Sample Collection

The study area was Southeastern Nigeria, comprising of Abia, Anambra, Ebonyi, Enugu and Imo States. This region (Fig. 1) lies within latitudes 4°30' to 7°00'N and longitudes 5°30' to 9°30'E, occupying 75,488 km^2 (Ofomata, 1975). Thirty four African yam bean accessions were collected from different AYB stakeholders (farmers’ gene bank and vendors) in the five states of Southeastern Nigeria (Table 1). Sorted seeds of each accession were stored freezer (-20°C) before use. Seed of each accession were ground into paste with distilled water and stored in plastic containers.

Chemical Analyses

Samples were analyzed chemically according to the official methods of analysis described by the Association of Official Analytical Chemist (AOAC, 2005).

Determination of Total Protein

The crude protein in the sample was determined by the routine semi-micro Kjeldahl, procedure consisting of three techniques of digestion, distillation and titration. For this 0.5 g of each finely ground dried sample was weighed carefully into the Kjeldahl digestion tubes to which 1 Kjeldahl catalyst tablet and 10 mL of ConC. H_2SO_4 were added, allowed to stand for 4 h, after which a clear colourless solution was left in the tube. The digest was cooled and carefully transferred into 100ml volumetric flask.

Distillation was done with Markham Distillation Apparatus which allows volatile substances such as ammonia to be steam distilled with complete collection of the distillate. The apparatus was steamed out for about ten minutes. The steam generator is then removed from the heat source to allow the developing vacuum to remove condensed water. The steam generator is then placed on the heat source (i.e., heating mantle) and each component of the apparatus was fixed up appropriately. 5 mL portion of the digest was pipetted into the body of the apparatus via the small funnel aperture. To this was added 5 mL of 40% (W/V) NaOH through the same opening with the 5 mL pipette.

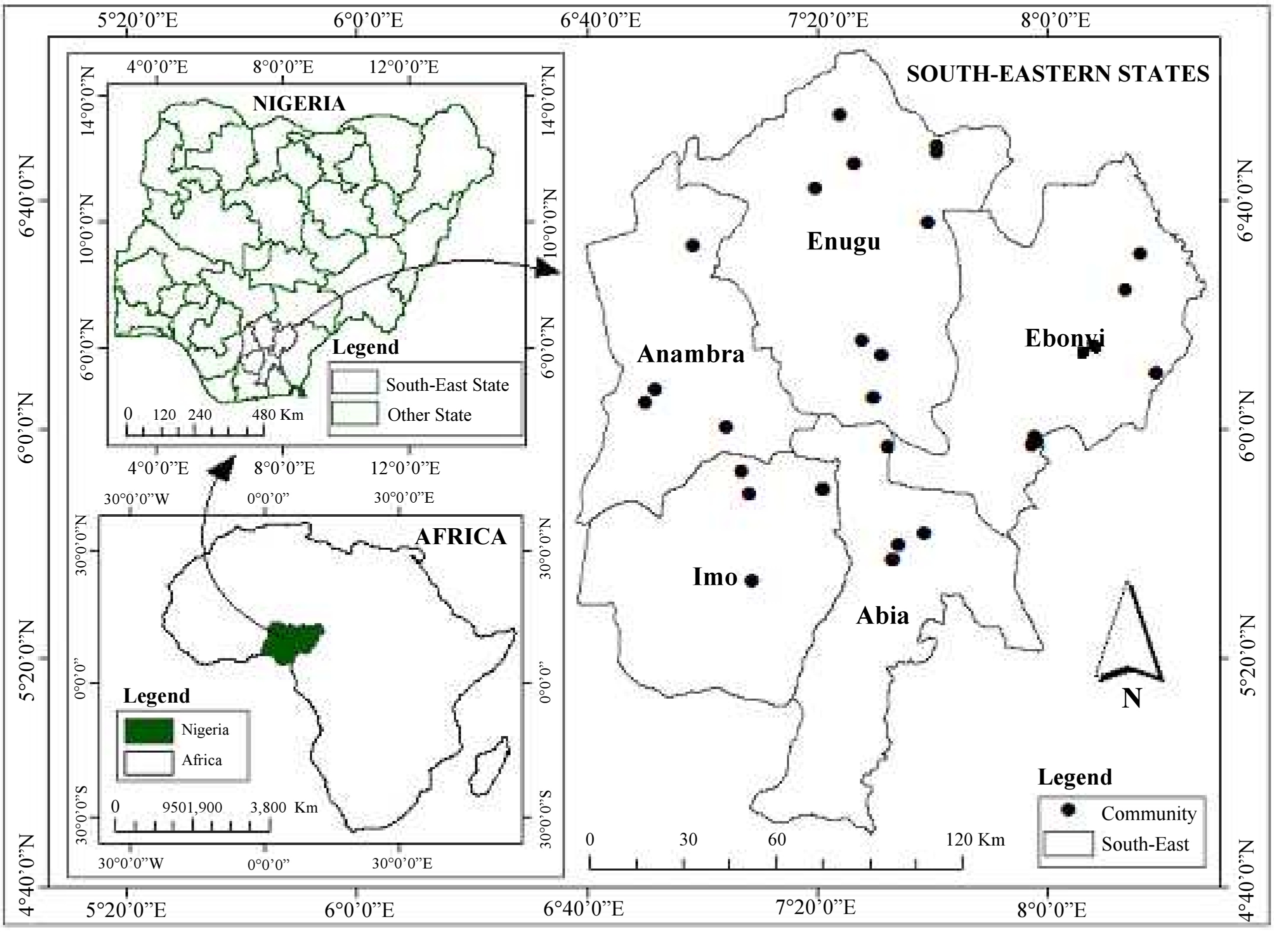

Fig. 1: Southeastern States of Nigeria where samples of African yam bean accessions were collected

The mixture was steam-distilled for 2 min into a 50 mL conical flask containing 10 mL of 2% Boric Acid plus mixed indicator solution placed at the receiving tip of the condenser. The Boric Acid plus indicator solution changes colour from red to green showing that all the ammonia liberated have been trapped.

The green colour solution obtained was then titrated against 0.01N HCL contained in a 50 mL Burette. At the end point or equivalent point, the green colour turns to wine colour which indicates that all the Nitrogen trapped as Ammonium Borate [$(NH_4)_2BO_3$] have been removed as Ammonium chloride (NH_4CL).

The percentage nitrogen in this analysis was calculated using the formula:

% N = Titre value x Atomic mass of Nitrogen × Normality of HCL used x 4
or % N = Titre value x Normality/Molarity of HCL used x Atomic mass of

N × Volume of flask containing the digest × $\frac{100}{1}$

Weight of sample digested in milligram × Vol. of digest for steam distillation. The crude protein content is determined by multiplying percentage Nitrogen by a constant factor of 6.25 i.e., % CP = % N ×6.25.

Determination of Fat

One (1g) of each of ground paste was weighed into fat free extraction thimble and plugged lightly with cotton wool. The thimble was placed in the extractor and fitted with reflux condenser and a 250 cm^{-3} Soxhlet flask and desiccators cooled and weighed. The Soxhlet flask was $^3/_4$ filled with petroleum ether (b.pt. 40-60°C). Seed dry matter and moisture content were determined by weighing 2 g of sample dried into a previously weighed crucible. The crucible and dried sample was then transferred to an oven set at 100°C and the sample dried until constant weight. At the end of the drying the crucible and sample was transferred to desiccator, cooled and reweighed (AOAC, 2005).

Table 1: Passport information of the collected Africa yam bean accessions in south-eastern, Nigeria

S/N	Sample Code	State	LGA	Community	Longitude	Latitude	Source	Seed colour
1	ABBEuz	ABIA	Bende	Ngwu Uzoakoli	7°55.07"E	5°62.02"N	Farmer	BV
2	ABBEuz 1	ABIA	Bende	Ngwu Uzoakoli	7°55.23"E	5°62.22"N	Farmer	BV
3	ABUNum 2	ABIA	Umuahia North	Ubani Makt	7°56.78"E	5°66.23"N	Vendor	BV
4	ABBEng	ABIA	Bende	Ngwu	7°55.08"E	5°62.02"N	Farmer	BV
5	ABBEnu 1	ABIA	Bende	Court	7°64.26"E	5°69.57"N	Farmer	BV
6	ANAGan	ANAMBRA	Aghamelum	Anaku	-	-	Vendor	BV
7	ANAGug	ANAMBRA	Aguata	Uga	-	-	Farmer	BV
8	ANINum	ANAMBRA	Idemili North	Umuoji	-	-	Farmer	BV
9	ANISnn	ANAMBRA	Idemili South	Nnobi	-	-	Market	BV
10	EBANam	EBONYI	Afipko North	Amata	7°97.1"E	5°96.57"N	Farmer	Milky
11	EBANao 1	EBONYI	Afipko North	Apku Oha	7°96.34"E	5°97. 97"N	Farmer	Milky
12	EBANau	EBONYI	Afipko North	Apku Ugo	7°95.47"E	5°95.47"N	Farmer	Milky
13	EBIKea	EBONYI	Ikwo	Eleke Achara	8°13.56"E	6°24.33"N	Farmer	Milky
14	EBIKok	EBONYI	Ikwo	Okputomo	8°10.43"E	6°22.13"N	Farmer	Milky
15	EBISlo	EBONYI	Ishielu	Labassa Okpoto	7°51.82"E	6°21.69"N	Farmer	Milky
16	EBIZib	EBONYI	Izzi	Iboko	8°22.59"E	6°40.68"N	Farmer	Milky
17	EBIZig	EBONYI	Izzi	Igboagu	-	-	Farmer	Milky
18	EBIZwa	EBONYI	Izzi	Waka	8°31.5"E	6°16.44"N	Farmer	Milky
19	ENAGag	ENUGU	Agwu	Agbaogugu	7°46.07"E	6°25.72"N	Farmer	Brown
20	ENAGmg 1	ENUGU	Agwu	Mgbowo	7°49.57"E	6°09.46"N	Farmer	Brown
21	ENAGmg 2	ENUGU	Agwu	Mgbowo	7°49.57"E	6°09.46"N	Farmer	Brown
22	ENANam 2	ENUGU	Aninri	Amoro	7°53.7"E	5°95.1"N	Farmer	Brown
23	ENISib	ENUGU	Igboeze South	Ibagwa	7°39.84"E	6°91.63"N	Farmer	Brown
24	ENIWea	ENUGU	Igbetiti West	Eke Aku	7°32.68"E	6°70.29"N	Farmer	Brown
25	ENNEub	ENUGU	Nkanu East	Ubahu	7°67.93"E	6°80.52"N	Vendor	Brown
26	ENNKob	ENUGU	Nkanu East	Obe	7°67.94"E	6°82.56"N	Farmer	Brown
27	ENNSeh	ENUGU	Nsukka	Ehandagu	7°65.24"E	6°59.90"N	Farmer	Brown
28	ENNSog	ENUGU	Nsukka	Ogbaozara	7°43.96"E	6°77.26"N	Farmer	Brown
29	IMIKum	IMO	Ikeduru	Umudi	-	-	Vendor	BV
30	IMINak	IMO	Ideato North	Akuokwa	-	Farmer	Farmer	BV
31	IMISis	IMO	Ideato South	Isiekenesi	-	-	Vendor	BV
32	IMOKeo 1	IMO	Okigwe	Eke Okigwe	7°34.95"E	5°82.56"N	Farmer	BV
33	IMOKeo 2	IMO	Okigwe	Eke Okigwe	7°34.96"E	5°82.57"N	Farmer	BV
34	IMOKeo 3	IMO	Okigwe	Eke Okigwe	7°34.96"E	5°82.57"N	Farmer	BV

Source: Field Survey, 2016. Legend: – Data not available, BV= Black variegated

Determination of Ash and Fibre

Seed ash content, was determined by weighing 2 g of dried sampleinto a porcelain crucible. This was transferred into the muffle furnace set at 550°C and left for around 4 h. Once ashed the crucible was cooled to about 100°C in air, then left at room temperature in a desiccator until weighing. Seed fibre content was determined by weighing 2 g of sample into a fibre flask containing 100 cm^{-3} of 0.25N H_2SO_4. The mixture was heated with an electrical mantle under reflux for 1 h. The hot mixture was filtered through a fibre sieve cloth with the filtrate discarded and the residue returned to the fibre flask, to which was added 100 cm^{-3} of NaOH (0.3 N) followed by heating under reflux for a further hour. The mixture was again filtered through a fibre sieve cloth and 10 cm^{-3} of acetone added to dissolve any organic constituents. The residue was washed with about 50 cm^{-3} of hot distilled water while on the sieve cloth, before being finally transferred into a crucible. The residue was oven-dried at 105°C overnight. After cooling in a desiccator, the weight of fibre was determined after ashing at 550°C for 4 h.

Chemical Analyses Methods

Determination of Vitamin C

A sample of 0.5 g was weighed into a crucible to which was added 30 cm^3 dichloroethane and 30 cm^3 of 30% HCl (ratio1:1 v/v) and 50 cm^3 ammonium hydroxide solution. The resultant mixture was filtered. The absorbance of the mixture was measured with a spectrophotometer (Spectronic 20 model) at 415 nm. A standard curve over the range of 0.1 to 0.5 ppm μmol (cm^3) solution was prepared using a stock solution of riboflavin. The standard curve was used to determine the ascorbic acid concentrations present in sample of each accession.

Determination of vitamin B1

One gram of sample paste was weighed, added into a conical flask 50 cm^3 of 50% methanol and 50 cm^3 of a

17% solution of sodium carbonate (ratio 1:1, w/v).The mixture was filtered and the filtrate was diluted with 50□mL of pure deionized water and was allowed to stand until it gave a bluish colour. The absorbance of the cooled solution was determined with a spectrophotometer at a wavelength of 415 nm.

Determination of Vitamin B2

Half gram of the ground sample was weighed into 200 mL flask then 5 mL of dichloromethane and 90 mL of deionized water were added. The set up was put on the steam bath for 20 min to allow all the vitamins go into solution. This was cooled and made up with water. Five ml of this was pipetted into hot 250 mL volumetric flask and made up to mark with water. Standard solution was prepared by dissolving 50 g of vitamin B2 into 500 mL of distilled water and further dilution of 2ppm, 4ppm, 6ppm, 8ppm and 10 ppm. These were read on spectrophotometer at 520 nm wavelength. Calculations were done using the formula: Meter reading × Dilution factor × Standard reading.

Multidimensional Analysis (MDA)

Multidimensional Analysis (MDA) was used to generate the most desirable nutrient compilation in all the 34 accessions based on their Weighed Factors (WF). This analysis was carried out using data generated from the 6 proximate values and 4 vitamin parameters. Data obtained were transformed using $\log_{10} = 1$ according to McDonald (2014). The transformed values were used to determine the MDA for the accession with the highest value for the desirable traits (Akoroda, 2004). According to Akoroda (2004), nothing is fixed in a multidimensional analysis, rather standards are set. Here all variables were coded so that at the end, the best desirable becomes a unity. Thus, any potential accession with the highest protein content was used as a standard to determine the MDA for other accessions. This highest value would be divided by itself to get the WF unity of 1. Subsequently, the standard was used to determine the WF of other accessions for protein. However, for parameter such as lipid content, the most desirable becomes the accession with the lowest lipid value. These values constituted the WFs, which were summed together to generate their hierarchical positions and then ranked systematically accordingly.

Statistical Analysis

Data generated from these analyses were transformed using $\log_{10}$according to McDonald (2014). Analysis of Variance (ANOVA) was carried out on the data to determine significant differences among the accessions for the traits evaluated using the Statistical Analysis System (SAS 9.2, what version?), SAS Institute (2000). Means were compared using the Least Significant Difference (LSD) at 5%. Principal Component Analysis (PCA) was performed following the approach of Manly (1994), to characterize the accessions in relation to the most discriminating nutrient traits. Variability and relatedness of these accessions were determined using Ward's minimum variance cluster method.

Results

The salient variability from proximate and vitamin parameters recorded in the 34 accessions of AYB, as transformed, are summarized in Table 2. The highest ash content of 9.64% was observed in EB5 with the least of 2.03% found in AB5. Highest dry matter and crude fiber contents of 92.5% and 5.5% were recorded in accessions EB4 and IM1 respectively, while the lowest were EB9 and AB3(Table 2). A total protein value of 30.3% was recorded from accession EN4, followed by EB1 at 30.2% and AB5 at 28.9% with the least in AN3 at 16.7%. A carbohydrate content of 68.3% was recorded for AN3 with least for AB1, at 42.5% (Table 2).

Physiochemical Analysis

The physiochemical analyses showed that AN4 recorded the highest vitamin C value of 15.7 mg/100g, while both AB4 and EN1 accessions had 15.5 mg/100g each. The lowest value of 10.2 mg/100g was recorded for both EN8 and IM1 accessions. The vitamin B1 content of the accession EB9 was the highest value i.e., 1.01 mg/100g with the least 0.04 mg/100g for the accession EN2, while accession EN6 showed the highest vitamin B2 and B3 values of 0.91 and 0.68 mg/100g respectively (Table 2).

Using the MDA with respect to their weighed factors, to compile all the desirable nutrients levels together, showed that AB2 had the best nutritional traits with a WF of 7.02 followed by AB4 recording 6.86, while IM1 and EB9 scored the least values of 4.82 and 4.77, respectively (Table 3). Of all the six proximate and four vitamin parameters evaluated, accessions with the lowest nutritional values were EB9, IM1, IM4, IM6 and IM5 (Table 3).

Ranking of the Desirable Nutrients based on Multidimensional Analysis

Multidimensional Analysis (MDA) based on their Weighed Factors (WF) pooled all the desirable nutrients in all accessions and it showed that AB2, AB4, AB3, EB5, AB1 and EB6 ranked 1^{st} to 6^{th}, with WF values of 7.02, 6.86, 6.77, 6.76, 6.71 and 6.63, respectively (Table 3 and Fig. 2). The MDA results equally showed that IM3, IM2, IM5, IM6, IM1 and EB9 ranked 28 to 34 respectively in regard to the possession of the least desirable nutritional accession traits.

Table 2: Proximate and Vitamin compositions of 34 African yam bean accessions collected from Southeast, Nigeria

Accession code number	Ash (%)	Dry Matter (%)	Crude Fibre (%)	Total Protein (%)	Total lipids (%)	Carbo-hydrate (%)	Vitamin C (mg/100g)	Vitamin B1 (mg/100g)	Vitamin B2 (mg/100g)	Vitamin B3 (mg/100g)
AB1	3.97	91.69	5.07	23.48	7.22	42.49	10.76	0.08	0.17	0.56
AB2	3.78	92.05	4.90	25.40	7.51	59.54	12.30	0.36	0.65	0.57
AB3	4.31	91.80	4.33	26.33	7.40	57.62	12.14	0.09	0.16	0.58
AB4	5.14	92.13	4.67	27.77	7.17	55.28	15.45	0.11	0.11	0.56
AB5	2.03	91.62	4.90	28.86	7.20	57.01	13.70	0.07	0.12	0.55
AN1	4.30	91.63	5.17	26.63	6.72	55.78	13.23	0.07	0.15	0.53
AN2	3.45	92.66	4.96	24.29	6.46	60.89	13.05	0.09	0.15	0.42
AN3	3.67	91.62	4.87	16.72	6.46	68.29	11.37	0.05	0.11	0.46
AN4	4.80	92.42	4.51	24.17	10.31	56.15	15.73	0.08	0.14	0.65
EB1	3.86	91.51	4.94	30.20	9.40	51.65	12.39	0.11	0.94	0.55
EB2	4.10	91.56	4.90	20.82	7.87	62.18	13.92	0.11	0.16	0.57
EB3	3.54	92.32	4.66	18.13	7.64	65.78	14.37	0.08	0.15	0.59
EB4	4.39	92.47	4.65	23.25	7.40	61.08	14.76	0.09	0.15	0.64
EB5	9.64	92.00	4.70	22.80	8.07	62.90	13.33	0.08	0.14	0.54
EB6	2.40	92.03	4.83	25.17	12.51	54.47	12.25	0.10	0.13	0.58
EB7	4.10	91.76	4.60	19.08	6.67	65.66	11.73	0.06	0.13	0.48
EB8	4.53	91.53	5.27	24.73	7.47	60.46	13.30	0.08	0.13	0.58
EB9	3.01	64.60	5.53	22.87	6.43	62.38	15.03	1.01	0.15	0.52
EN1	4.28	91.66	4.77	27.23	6.75	55.83	15.45	0.11	0.11	0.56
EN2	4.16	92.23	4.77	23.72	8.17	59.53	10.53	0.04	0.11	0.38
EN3	3.57	91.90	4.47	23.99	6.43	61.96	10.93	0.10	0.11	0.58
EN4	3.86	91.50	4.93	30.28	9.40	51.72	11.04	0.10	0.11	0.63
EN5	4.35	91.56	4.87	20.66	7.67	61.77	12.49	0.11	0.15	0.57
EN6	4.66	91.27	4.52	22.67	7.05	61.17	12.78	0.10	0.91	0.68
EN7	4.56	92.51	4.52	24.58	7.33	55.83	12.59	0.07	0.15	0.63
EN8	5.30	90.83	4.72	20.97	6.87	62.14	10.17	0.04	0.11	0.35
EN9	4.44	91.50	4.68	24.94	8.50	59.32	13.57	0.08	0.13	0.56
EN10	4.00	92.13	4.52	27.23	9.20	54.94	12.99	0.09	0.12	0.43
IM1	3.35	93.31	4.69	22.07	7.33	62.46	10.17	0.06	0.11	0.37
IM2	3.54	91.77	4.91	24.95	6.50	60.15	14.57	0.12	0.15	0.58
IM3	4.10	92.16	4.99	22.79	6.99	61.85	12.67	0.28	0.12	0.53
IM4	3.65	92.31	4.80	26.40	7.57	56.91	15.10	0.13	0.16	0.60
IM5	3.52	91.92	5.12	22.17	8.22	61.34	13.95	0.09	0.15	0.65
IM6	5.21	91.22	4.94	23.26	7.26	59.56	13.11	0.10	0.14	0.57
Mean	4.16	91.09	4.81	24.08	7.68	59.00	12.97	0.13	0.20	0.07

Principal Components Analysis

The PCA analysis showed a high discrimination capacity for the variables measured. The results of the five principal component axes accounted for 71% of the total variation among the 34 accessions (Table 4). On the first Principal Component axis (PC1), the parameters for total protein and lipids showed positively high loadings of 0.523 and 0.545(Table 4). Similarly, vitamin B1 alone had high loading of 0.564 on the PC2 axis indicating its secondary importance when quantifying variation among these AYB accessions. Vitamin C and vitamin B3 had high eigenvector loadings with PC3 axis of 0.526, while vitamin B2 was highly loaded on PC4with a value of 0.883, with ash content at 0.930 on the PC5 axis (Table 4).

Relatedness among the 34 Accessions of AYB from Southeast, Nigeria

The intra-specific variability within the 34 accessions studied was further accessed using the Ward's minimum variance clustering system (Fig. 3) based on the proximate and mineral traits. Inferring from similarity for the ten parameters investigated, three distinct clusters were evident at the modulation point of 0.5% in the dendrogram (Fig. 3). The dendrogram grouped these accessions into three clusters. Clusters I had the highest affiliation for nineteen AYB accessions, cluster II had the least membership, with three accessions, while twelve accessions featured in cluster III. From reference to the verified parameters the most similar accessions were EN1, EN2 and EN3 (Fig. 3).

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Table 3: Weighed factors of the 34 African yam bean accessions from southeastern, Nigeria

Accession code	Ash	Dry matter	Crude Fibre	Total protein	Lipids	Carbohydrate	Vitamin C	Vitaminz B_1	Vitamin B_2	Vitamin B_3	Total
AB1	0.41	0.98	0.92	0.78	0.12	0.62	0.95	1.00	0.15	0.76	6.71
AB2	0.39	0.98	0.88	0.84	0.16	0.87	0.81	0.10	0.96	1.00	7.02
AB3	0.44	0.98	0.78	0.81	0.15	0.84	0.77	0.10	1.00	0.80	6.76
AB4	0.53	0.98	0.84	0.92	0.12	0.81	0.78	0.35	0.68	0.83	6.86
AB5	0.21	0.98	0.88	0.95	0.12	0.84	1.00	0.08	0.15	0.95	6.17
AN1	0.44	0.98	0.94	0.88	0.04	0.82	0.96	0.14	0.17	0.88	6.24
AN2	0.35	0.99	0.89	0.80	0.01	0.89	0.93	0.08	0.16	0.94	6.07
AN3	0.38	0.98	0.88	0.55	0.01	1.00	0.88	0.08	0.16	0.95	5.89
AN4	0.49	0.99	0.82	0.79	0.60	0.82	0.92	0.12	0.15	0.84	6.57
EB1	0.41	0.98	0.89	0.99	0.46	0.75	0.98	0.11	0.11	0.82	6.52
EB2	0.43	0.98	0.89	0.68	0.22	0.91	0.98	0.11	0.11	0.82	6.14
EB3	0.36	0.98	0.84	0.59	0.18	0.96	0.91	0.08	0.15	0.86	5.95
EB4	0.45	0.99	0.84	0.76	0.15	0.89	0.88	0.11	0.16	0.84	6.09
EB5	1.00	0.98	0.85	0.75	0.25	0.92	0.81	0.27	0.13	0.78	6.76
EB6	0.24	0.98	0.87	0.83	0.95	0.79	0.8	0.07	0.15	0.93	6.63
EB7	0.42	0.98	0.83	0.63	0.03	0.96	0.83	0.09	0.14	0.84	5.78
EB8	0.46	0.98	0.95	0.82	0.16	0.88	0.88	0.08	0.13	0.85	5.33
EB9	0.31	0.69	1.00	0.75	0.04	0.91	0.80	0.11	0.16	0.83	4.77
EN10	0.44	0.98	0.86	0.89	0.05	0.82	0.80	0.07	0.13	0.82	5.08
EN1	0.41	0.98	0.82	0.89	0.43	0.81	0.95	0.06	0.13	0.81	5.36
EN2	0.43	0.98	0.86	0.78	0.27	0.87	0.94	0.09	0.16	0.84	5.31
EN3	0.37	0.98	0.81	0.79	1.00	0.91	0.88	0.08	0.14	0.78	5.87
EN4	0.41	0.98	0.89	1.00	0.46	0.75	0.92	0.09	0.13	0.84	5.57
EN5	0.45	0.98	0.88	0.68	0.19	0.90	0.97	0.06	0.15	0.78	5.10
EN6	0.48	0.97	0.81	0.75	0.09	0.89	0.98	0.10	0.12	0.92	5.16
EN7	0.47	0.99	0.81	0.81	0.14	0.82	0.91	0.10	0.12	0.85	5.13
EN8	0.55	0.97	0.85	0.69	0.06	0.91	0.88	0.07	0.17	0.83	5.12
EN9	0.46	0.98	0.84	0.82	0.32	0.86	0.88	0.09	0.16	0.62	5.18
IM1	0.35	1.00	0.85	0.71	0.14	0.92	0.80	0.08	0.12	0.63	4.82
IM2	0.37	0.98	0.88	0.82	0.01	0.88	0.80	0.05	0.13	0.70	4.84
IM3	0.43	0.98	0.90	0.75	0.08	0.91	0.95	0.05	0.11	0.68	4.91
IM4	0.38	0.98	0.86	0.87	0.17	0.83	0.93	0.04	0.12	0. 55	4.83
IM5	0.37	0.98	0.92	0.73	0.27	0.89	0.88	0.05	0.12	0.54	4.91
IM6	0.54	0.97	0.89	0.76	0.13	0.87	0.93	0.0 4	0.11	0.51	4.85

Table 4: Principal component analysis for proximate and vitamin contents of 34accessions of African yam bean from Southeast, Nigeria

Eigenvectors	PC1	PC2	PC3	PC4	PC5
Ash	-0.019	-0.088	0.333	-0.003	0.930
Dry matter	0.212	-0.473	0.192	-0.050	-0.153
Crude fibre	-0.135	0.430	-0.281	-0.148	0.185
Total protein	0.523	0.153	-0.237	-0.102	0.077
Lipid EE	0.545	-0.056	-0.098	-0.123	0.007
Carbohydrate	-0.474	-0.063	0.379	0.206	-0.178
Vitamin C	0.154	0.403	0.526	-0.313	-0.121
Vitamin B1	-0.184	0.564	-0.079	0.126	-0.022
Vitamin B2	0.253	0.097	-0.039	0.883	0.057
Vitamin B3	0.356	0.250	0.529	0.120	-0.148
Proportion	0.200	0.190	0.120	0.100	0.100
Cumulative	0.200	0.390	0.520	0.620	0.710
Eigenvalue	1.998	1.899	1.243	1.007	0.970

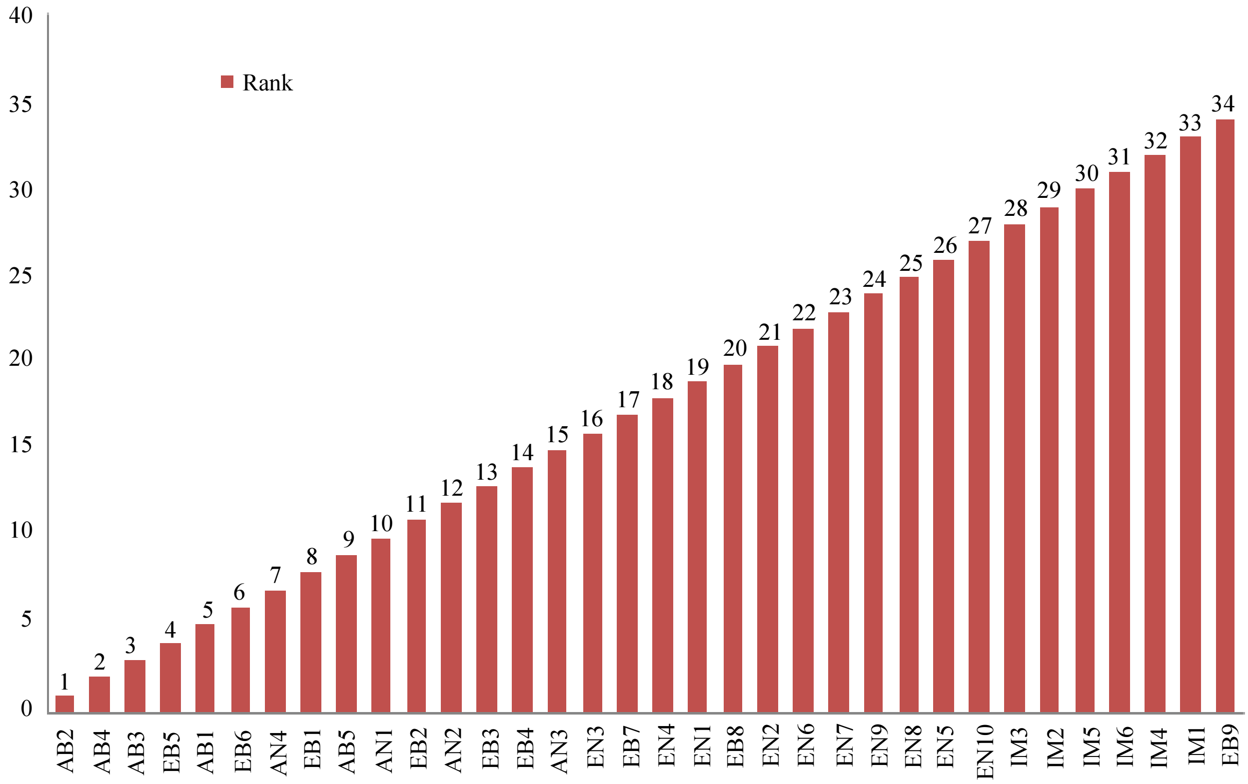

Fig. 2: African yam been accessions ranked with respect to desirable nutrient content based on Multidimensional Analysis (MDA)

Discussion

The high contents of ash, dry matter and crude fiber recorded in some of these African yam bean accessions were indicative of their rich nutritional composition. This shows that accessions EB9, EB8 and IM5 at a 5.53% level of crude fibre, are good dietary sources relative to the other accessions. At a fibre content of 5.53% the EB9 accession exceeded the fibre content of *Talenium triangulare* (2.0%) *Telferia occidentalis* (1.7%) and *Celosia argentea* (1.8%) (Akachukwu and Fawusi, 1995).

Dhingra *et al.* (2012) reported that a fibre-rich diet is lower in energy density and fat content, but higher and richer in micronutrients. They suggested that the bulk mass of this type of food takes longer to eat and as such gives a better feeling of satisfaction sooner to the consumer. There is good evidence supporting the notion that dietary satisfaction can help in dietary management, particularly with respect to weight reduction and diabetic health control (Bello *et al*., 2008). Available data suggests that decreased consumption of fats and an increased consumption of dietary fibre from fruits, vegetables and whole grains could be implicated in the reduction of some types of cancer (Valvi and Rathod, 2011).

The total protein values of 30.3% (Table 2) may be capable of supplementing the 27g of protein which satisfies the recommended daily allowance of protein for children (FAO, 1986). This is in concordance with the remarks by Emelike *et al*. (2015) who reported that the 34% protein from the defatted cashew kernel flour could be a useful source of raw material to help in fortifying foods (as meat analogues) and that plants with such potential include whole-grains, legumes and nuts (Pasiakos *et al*., 2015).

Total protein values of 30.3% as recorded in this study were higher than the 22% reported by Uguru and Madukaife (2001), suggesting that protein content may be influenced by factors other than genetics.Such variance may be due to different analytical methods as reported by (Azeke *et al*., 2005), environmental conditions and age of plant at harvest (Tesfaye *et al*., 2017).

MDA provided a clearer picture on the nutritional variability of these 34 AYB accessions with respect to those with more desirable nutrient contents. Those accessions which ranked 1st to 6th (Table 3 and Fig. 2) imply to be nutritional better than other accessions. These inferences were not captured at this level of compositionally comparative analyses. This is in line with the report of (Oku, 2009) who noted that enhanced crop yield performance cannot simply be achieved from knowledge derived from a statistical analysis of limiting parameters. This work however, noted that multidimensional analysis was able to identify and factorize the contributions of all variables to enable the most appropriate accession to be identified.

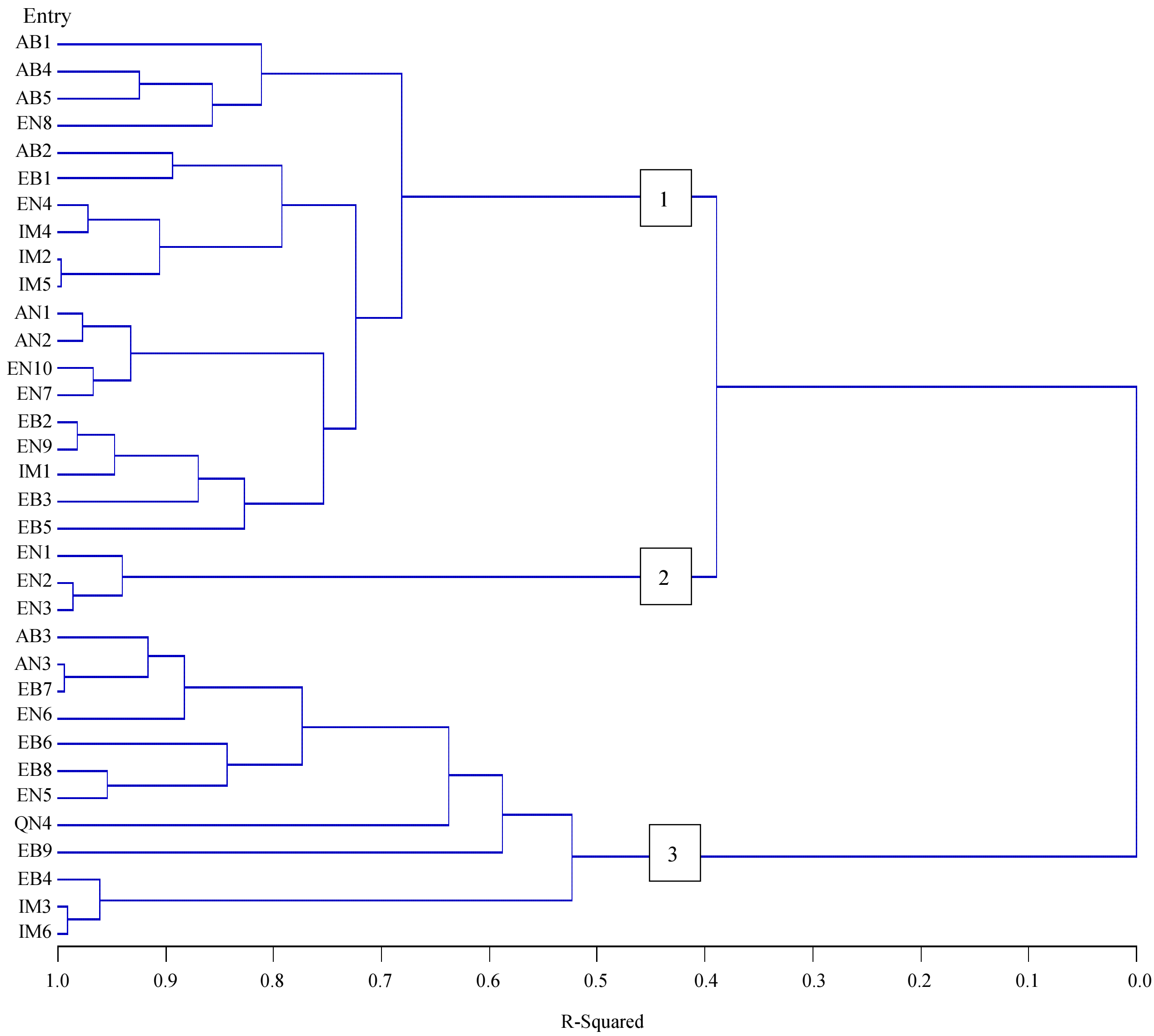

Fig. 3: Dendrogram showing the similarity among the 34 accessions of African yam bean

These accessions highlighted by the MDA tool were either black variegated, brown, or where black seed coated accessions. The whitish or milky seed coat accessions were absence from this group. This agrees with the report by Hacisalihoglu and Settles (2013) who noted that there were substantial variations in nutrient composition in seeds in relation to their seed coat colours. They reported that 91 common beans (*Phaseolus vulgaris* L.) genotypes, whose seeds were black, had higher concentration of nutrients more than white, or milky coloured seed coated genotypes.

The PCA results showed that five principal component axes accounted for 71% variability in these accessions with PC1 and PC3 having the greater portion indicating that these two traits were of primary importance in discriminating variations among the 34 accessions. The traits contributing to variability in this study were in order of importance of, total protein > lipids > vitamin B1 > vitamin B3 > and vitamin C concentrations. Principal component analysis revealed that greater variability was accounted for by the first and three axes. However maximum variability was observed in PC1 with a high concentration of total protein and low lipid related traits, while PC3 weighed heavily on vitamin C and vitamin B2 concentrations. Machuka and Okeola (2000) noted that intra-specific diversity within African yam bean provides necessary pre-requisites for its subsequent genetic improvement.

A good combination of these nutritional traits could be vital in mitigating malnutrition and achieving enhanced Biohappiness within these resources poor communities. The conservation and management of these genetic resources assures plant breeders of possibilities for improvement and to conservation biologists' insight into seasoned conservation strategies.

Values on the dendrogram collaborated with MDA ranking as the accessions in cluster 1 contained all the accessions hierarchically positioned from 1 to 6. These two tools were highly effective in discriminating nutritional similarity of these accessions. The close linkage among these accessions (Fig. 3) at 50% scale is particularly apparent, suggesting that these samples were distinctively related nutritionally more than others. Additionally, this cluster is dominated by accessions with brown to black variegated seed coated patterns.

The second cluster was very distinctive too and closely linked, consisting of three accessions from one state comprising of mainly brown seed coat, making the cluster genetically discrete from others. This high level variability observed in these accessions is a reflection adequate genetic diversity suitable for enhance breeding program for genetic improvement and germplasm conservation.

Conclusions and Recommendation

Poor communities with their low income capacity will continue to be vulnerable to malnutrition and food insecurity, if nothing is done to scale up their food and dietary menu. Neglected and underutilized plant genetic resources of high nutritional values such as African yam bean, could be exploited. MDA and principal component analysis were highly robust in discriminating among these accessions. They revealed the genetic diversity and relationships within these accessions and showed that these tools could be exploited in assessing variability in AYB species.

The range of variations observed was highly significant; showing that these accessions have diverse genetic variability. This can provide sufficient scope for genotype selection by breeders, ecologist and biologist for germplasm conservation to avoid genetic erosion. These facts can further be engaged to guide future studies, germplasm collection, characterization, documentation, utilization and safeguarding of AYB to boost knowledge and awareness on the genetic diversity and utility of the species.

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Author's Contribution

Catherine Veronica Nnamani: Conceived and wrote the proposal, designed, performed the experiments and prepared the manuscript.

Sunday Adesola Ajayi: Designed the experiment and proof read the article.

Christopher John Atkinson: Participated in planning the research experiments, the analysis of the results and proofing of the article.

Benard Adewale: Interpreted the data and proof read the manuscript.

David O. Igwe and Richard O. Akinwale: Performed the data analysis.

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Sources of Figures:

Fig. 1: Source Nnamani *et al*. (2009)