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Nutritional profiling of Twenty-Five Genotypes of African Yam Bean (*Sphenostylis stenocarpa* Hochst. Ex A. Rich Herms) Grown in Humid Agroecology of Nigeria

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ABSTRACT

African yam bean (AYB) is a Sub-Saharan African stable food with high nutritional value. There is a lack of improved varieties of AYB that can adapt to varied agroecological conditions. This study aimed to determine the nutritional and anti-nutritional contents of AYB grown in humid agroecology of Nigeria. Twenty-five genotypes (G1 – G25) of AYB planted in a randomized complete block design in 3 replications and 25 treatments were grown in humid environment in the 2020 planting season. After harvesting, they were analyzed for their nutritional and anti-nutritional qualities. Twenty (20) genotypes were identified for selection based on high vitamins, minerals, nutrients and low anti-nutrient compositions. Genotype for vitamins study were G23-Orokam for retinol (493.67 µg/100g), G21-Ikom for thiamin (15.95 mg/100g), G24-Nsukka for riboflavin (6.18 mg/100g), G7-Dybw11 for niacin (9.22 mg/100g), G19-Ekureku for ascorbic acid (2.79 mg/100g), and G20-Ediba for alpha tocopherol (8.45 mg/100g), while genotypes for minerals study were G25-Abakaliki for phosphorus (231.50 mg/100g), G13-DybB17 for magnesium (16.22 mg/100g) and sodium (4.60 ppm), G18-Ugep for potassium (6.01 ppm), G24-Nsukka for calcium (19.90 ppm), G11-DybS14 for copper (0.29 ppm), G22-Onueke for iron (7.48 ppm), and G6-DybS10 for zinc (0.25 ppm). Genotypes for nutrients study were G10-DybB15 for carbohydrates (72.70%), G19-Ekureku for protein (24.95%), G2-DybS4 for fibre (3.75%), G11-DybS14 for fat (2.25%), Ediba and G19-Ekureku for ash (3.43%), and G8-DybS11 for moisture content (7.75%). Genotype G1-DybB with high mineral contents and low anti-nutritional content is safer for consumption, and is recommended for selection in quality breeding improvement study.

Keywords: African Yam Bean, Nutritional, Quality Breeding, Selection for Utilization, Genotype Improvement..

Introduction

Over the past few decades, enormous progress has been made in the tropics in the improvement and use of African Yam bean (AYB). Despite the over-reliance on planting materials from the wild, local farmers have used a few landraces from the Genetic Resource Centre of International Institute of Tropical Agriculture (GRC IITA). Despite remarkable improvement in the production of major food crops by global research bodies and institutions compared to minor crops like AYB, hunger and malnutrition in Sub-Saharan Africa (SSA) remain alarming. In Sub-Saharan Africa regions, billions of people are still suffering from acute malnutrition, inequality, poverty, unemployment, environmental degradation, diseases, displacement and immigration flows, etc. Hunger and malnutrition have remained global issues of concern as the Sub-Saharan African population is projected to rise to 2.5 billion people by 2050.[1] As a result, crop improvement to meet the nutritional needs of Sub-Saharan African population becomes imperative.

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Quality breeding concomitant with conventional approaches have been tailored to improve yield and address consumers' nutritional needs/preferences with associated health benefits. Meeting nutritional needs are quite challenging because farmers often find it difficult to compromise yield for quality. Yield and quality improvement are cost-intensive and time-consuming, and farmers often lack sponsors and collaboration in this regard. These challenges can be overcome by further exploring the potential and application of AYB in addressing National Food Security.

Despite the high nutritional value of AYB, its production level hardly meets the demand requirement due to a lack of improved varieties that can adapt to varied agroecological conditions, and farmers often rely on landraces and accessions with low productivity. Major quality breeding constraints such as longer cooking time, seed colour, seed size, aroma, as well as limited amino acids contents, and presence of anti-nutritional factors affect the acceptability and utilization of AYB compared to other major crops such as soybean, rice, cowpea, maize, sorghum, etc. Several studies have been conducted on the nutritional and anti-nutritional compositions of African Yam Bean in the tropics with emphasis on the seeds and tubers. Findings from these studies include moisture content of 9 - 12.04%, total ash content of 4.30 - 5.35%, crude fat of 2.5 - 5.12%, and crude fibre of 2.47 - 9.57%.[2-16] In addition, crude protein of 20-25%, carbohydrate content of 50-75%, minerals including calcium, magnesium, potassium, sodium, phosphorus, iron, and copper contents of 240 - 4,360 ppm, 4,320 - 5,810 ppm, 3,610 - 11,640 ppm, 42,130 ppm, 2,340 - 2,740 ppm, 100 -1,260 ppm, and 2,300 ppm, respectively have been reported.[17] Vitamins B2 and B3 contents of 0.19 mg/100 g and 0.53 mg/100g, respectively have also been reported.[18,19] However, limited studies on the nutritional potentials of other parts of the plant have been scarcely reported in the literature. According to the

European Food Safety Authority (EFSA)[20] recommendations, men require 30 – 35 g of fibre per day, while women require 25 – 35 g of fibre per day. AYB may have the potential to meet these recommendations and also meet livestock needs.

In Sub-Saharan African (SSA) regions, AYB seeds and tubers are staple food, and significant source of plant protein, especially for low-income earners. The cultivation of many landraces and accessions in these regions highlights the potential of AYB. However, the lack of recommended cultivar with high nutritional and low anti-nutritional value is a critical concern that necessitates further research and development to ensure food security in the region. This poses a challenge for AYB's quality breeding program, because farmers prioritize yield over quality in a relative term. Additionally, there are limited information on quality breeding programs, and available data have not adequately addressed consumer preference, especially the hard-to-cook nature of AYB. Secondly, research work conducted so far only focuses on the nutritional and anti-nutritional content of the seeds and tubers of AYB, and there is no quality breeding work on the discarded empty pod, leaves, and root for their nutrients and anti-nutrients properties. The discarded portion after processing might contain a high proportion of protein, carbohydrates, minerals, and vitamins that may serve as feed substitute in agro-allied industry.

This study was therefore designed to bridge nutritional gap by determining the nutritional and anti-nutritional content of African Yam Bean seed, tuber, pod and root present among the genotypes so as to recommend accessions/landraces with high nutritional value and low anti-nutrients for cultivation.

Materials and Methods

Source of planting materials

Twenty-five (25) genotypes of African Yam Bean (AYB), comprising 10 landraces and 15 accessions, were obtained from the Genetic Resource Centre, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and farmers' farms within Cross River, Ebonyi, Benue, and Enugu States (Table 1). The seeds of the 25 genotypes were planted in 2020 planting season. After harvesting, the AYB samples were analyzed for proximate, minerals, vitamins, and anti-nutrient content.

Table 1: List of 15 accessions and 10 landraces of African yam bean

S/No	Accessions	Place of Collection	S/No	Accessions	Place of Collection
1	DybB	GRC , IITA 2018	15	DybB21	GRC , IITA 2018
2	DybS4	GRC , IITA 2018	16	Abini	Abini, Biase LGA, CRS
3	DybS6	GRC , IITA 2018	17	Ogoja	Ogoja, Ogoja LGA, CRS
4	Dybw8	GRC , IITA 2018	18	Ugep	Ugep, Yakurr LGA, CRS
5	Dybw9	GRC , IITA 2018	19	Ekureku	Ekureku, Abi, LGA, CRS
6	DybS10	GRC , IITA 2018	20	Ediba	Ediba, Abi, LGA, CRS
7	Dybw11	GRC , IITA 2018	21	Ikom	Alok, Ikom LGA, CRS
8	DybS11	GRC , IITA 2018	22	Onueke	Onueke, Eza, LGA, EBS
9	Dybw12	GRC , IITA 2018	23	Orokam	Oturkpo, BS
10	DybB15	GRC , IITA 2018	24	Nsukka	Nsukka LGA, ES
11	DybS14	GRC , IITA 2018	25	Abakaliki	Kprikpiri, Abakalike LGA, EBS
12	Dybw15	GRC , IITA 2018			
13	DybB17	GRC , IITA 2018			
14	DybB18	GRC , IITA 2018			

CRS = Cross River state, EBS = Ebonyi state, BS = Benue state, ES = Enugu state

Agronomic practices

The 25 accessions and landraces were planted in Calabar in May 2020 in a Randomized Complete Block Design (RCBD), consisting of 3 replications and 25 treatments. The seeds of the 25 accessions and landraces sourced from Gene bank of International Institute of Tropical Agriculture, local farmers and markets from Ebonyi, Cross River, Benue and Enugu States were used as treatments. A plot size measuring 54 m x 24 m, to accommodate a plant population of 10,000 plant/ha was used for this study. After land preparation, planting of AYB seeds started after two weeks, NPK 15:15:15 fertilizer applications commenced immediately, staking using bamboo measuring 2.5 m in height were used, while weeding was done in June, August and November 2020. Four plant samples per plot were set aside for data collection in each plot that accommodated 10 plants/plot. At eight months (December 2020), harvested seeds were collected per accessions/landraces for nutritional and anti-nutritional analysis. Ekureku landrace (G19) had high yield in both tubers and seeds and were considered for nutritional and anti-nutrients contents analysis for tuber, root and dry empty pod.

Proximate analysis

After harvest, the seeds, tubers, roots and empty pods were collected from genotype bearing tubers and seeds only in Calabar for the 2020 season in a preliminary trial. The harvested seeds were collected from each plot in the 25 genotypes, while tubers, roots and dry empty pods were collected randomly from dual purpose genotype (Ekureku genotype - G19) only for nutritional and anti-nutritional analysis. The Ekureku genotype produced superior seeds and tubers only, while the other 24 genotypes were inconsistent in tuber production, though some genotypes produced higher seeds yield only but lack tubers for nutritional analysis. Seed samples (Figure 1) collected from the 25 accessions/landraces, and tuber, root, dry empty pods collected from Ekureku landrace were subjected to proximate analysis, including moisture, ash, crude fat, crude fibre, crude protein, and total carbohydrates analysis, as well as vitamins, minerals and anti-nutrients contents determination at the National Energy Research and Development Centre, University of Nigeria, Nsukka, using standard procedures.

Determination of moisture content

Moisture content (MC) was determined following the procedure outlined by AOAC.[21] Porcelain crucibles were cleaned and pre-dried in an oven at 100°C for 30 minutes, then cooled in a desiccator. Subsequently, one gram of each sample was accurately weighed into the crucibles and dried at 105°C for 4 h. After drying, the crucibles were cooled in a desiccator, and weighed. The drying and weighing process was repeated at intervals until a constant weight was observed, indicating complete moisture removal.

Figure 1: African yam bean parts used for the analysis and the experimental plots in which the samples were obtained

The moisture content was calculated using the following formula (Equation 1). `

$$\text{Moisture content (\%)} = \frac{A - B}{A} \times \frac{100}{1} \quad (1)$$

Where A is the weight of the crucible with the sample before drying, and B is the weight of the sample and crucible after drying.

Determination of total ash

Ash content was determined using the AOAC method.[21] Finely ground sample (1 g each) were weighed into pre-cleaned and dried porcelain crucibles of predetermined weights. The samples were placed in a muffle furnace and incinerated at 600°C for four hours. Upon completion, the crucibles were removed, cooled in a desiccator, and weighed again, and the ash content was calculated using the formula below (Equation 2).

$$\text{Ash content (\%)} = \frac{A - B}{C} \times \frac{100}{1} \quad (2)$$

Where; A = Weight of crucible + ash, B = Weight of crucible, and C = Weight of original sample

Determination of fat content

Fat content the samples was determined using the procedure described by Pearson.[22] In this method, approximately 2 grams of finely ground African yam bean flour were accurately weighed, wrapped in a folded filter paper, and placed in the extraction thimble. Before use, the extraction flasks were thoroughly cleaned, oven-dried, cooled in a desiccator, and weighed. The thimble was inserted into the Soxhlet extractor, and petroleum ether was added to the extraction flask to about three-quarters of its volume. The apparatus was assembled to ensure proper connection between the flask, extractor, and condenser. The setup was placed on a heating mantle, and continuous extraction was carried out for 4 hours. After the extraction, the solvent was recovered, and the residual oil collected in the flask was dried in an oven at 105°C. The flask was then reweighed, and the fat content was calculated using the formula shown in Equation 3:

$$\text{Fat content (\%)} = \frac{C - A}{B} \times \frac{100}{1} \quad (3)$$

Where; C = weight of flask + oil, A = weight of empty flask, B = weight of original sample.

Determination of crude fibre

The indigestible fraction of African yam bean flour, primarily cellulose and a minor amount of lignin, was isolated after removing organic matter under controlled conditions using organic solvents, dilute mineral acids, and alkali treatment. The fat content of the flour samples was determined based on the AOAC method.[21] For crude fibre estimation, 1 g of the sample (W_1) was accurately weighed into a 600 mL beaker, followed by adding 150 mL of preheated 0.128 M sulfuric acid (H_2SO_4). The mixture was heated for 30 minutes, after which it was filtered under suction and washed thoroughly with hot distilled water until the washing was free of acid. The retained residue was transferred into another clean beaker and boiled for 30 minutes with 150 mL of preheated 0.223 M potassium hydroxide (KOH). After this alkaline digestion, the residue was filtered and rinsed repeatedly with hot distilled water until no alkaline trace remained. It was washed three times with acetone, oven-dried at 105°C for 2 hours, cooled in a desiccator, and weighed (W_2). Subsequently, the sample was incinerated in a muffle furnace (Vecstar LF3, UK) at 500°C for 4 hours to obtain the ash. After cooling in a desiccator, the final weight (W_3) was recorded. Crude fibre content was calculated using the formula below (Equation 4).

$$\text{Crude fibre (\%)} = \frac{W_2 - W_3}{W_1} \times \frac{100}{1} \quad (4)$$

Where; W_1 = weight of sample, W_2 = Weight of dry residue, and W_3 = Weight of ash

Determination of crude protein

The crude protein was determined using the micro-Kjedahl method as described by [22] This method entails quantifying the sample's total nitrogen content and converting it to protein, based on the assumption that all nitrogen present originates from protein. The procedure includes;

Digestion: Approximately 1 g of finely ground sample was weighed and transferred into a Micro-Kjeldahl digestion flask, followed by the addition of 1 g catalyst mixture (consisting of 20 g potassium sulfate, 1 g copper sulfate, and 0.1 g selenium powder) and 15 mL of concentrated sulfuric acid. The mixture was gently heated on a digestion rack in a fume cupboard until the solution became transparent green, indicating complete digestion. Thereafter, the digest was left to settle for 30 minutes, reheated for 30 minutes, and then cooled. To prevent solidification (caking), 10 mL of distilled water was added. The entire digest was then quantitatively transferred into a 100 mL volumetric flask using multiple washings with distilled water, and the volume was brought up to the mark.

Distillation: A 10 mL aliquot of the digested sample was transferred to the distillation flask. A 100 mL conical receiver flask containing 5 mL of boric acid indicator solution was positioned beneath the condenser, ensuring that the condenser tip was submerged approximately 2 cm into the indicator solution. Using a funnel with a stopcock, 10 mL of 40% NaOH was carefully added to the digestion mixture to initiate the release of ammonia. Distillation was carried out by sealing the steam jet arm of the distillation unit. The liberated ammonia was collected in the receiver flask, with approximately 35 mL of distillate obtained for further analysis.

Titration: The distillate was titrated with 0.01 M HCl until the first pink colour was obtained. The percentage nitrogen content was calculated using the formula shown in equation 5 below.

$$\text{\% Nitrogen} = \frac{\text{Titration volume} \times 0.014 \times M}{W} \times \frac{50}{10} \times 100 \quad (5)$$

Where; M = molarity of the HCl solution, W = weight of sample used,

$\frac{50}{10}$ = Dilution factor and 0.014 = correction factor.

Using a standard nitrogen-to-protein conversion factor of 6.25, the percentage of crude protein in the sample was calculated as follows:

% crude protein = % Nitrogen × 6.25.

Determination of total carbohydrate
The carbohydrate content of the African yam bean flour samples was determined using the formula described by [23] The total carbohydrate was determined by subtracting measured protein, fat, fiber, ash, and moisture from 100 (Equation 6).

% carbohydrate = 100 - % (protein + fat + fibre + ash + moisture content (6)

Mineral analysis
Minerals such as P, Mg, Ca, Na, K, Cu, Fe and Zn were evaluated following standard procedures as described below:

Sample digestion:
Each sample (1 g) was weighed into a digestion flask, and 30 mL of aqua regia (prepared by mixing concentrated nitric acid and hydrochloric acid in a 1:3 ratio) was added and digested in a fume cupboard until a clear solution was obtained. The solution was cooled, filtered, and then made up to 50 mL in a standard volumetric flask with deionised water.

Preparation of standard calibration curve and determination of mineral concentration:
Standard solutions (2 ppm, 4 ppm and 6 ppm) were prepared from a 1000 ppm stock solution. of the metals. The minerals were atomized at high temperatures in the ignition chamber. All the standard solutions of the metals were analysed at their respective wavelength using atomic absorption spectrophotometer (AA-7000, Shimadzu, Japan), and the calibration curve was plotted automatically for the mineral of interest.

Determination of vitamins
Vitamins A, B_1, B_2, B_3, C and E were analyzed for the 25 AYB genotypes.

Determination of Retinol (vitamin A)
Vitamin A was determined according to the AOAC method.[21] A solution containing 1 g of the sample was weighed and extracted with 20 - 25% antimony trichloride in chloroform. Proteins were first precipitated with 3 mL of absolute ethanol before the extraction of vitamin A with 5 mL of heptane in a test tube, then shaken vigorously for 5 min. On standing, 3 mL of the heptane layer was placed into a cuvette and the absorbance was read at 450 nm against a blank solvent of heptane. Calibration curve of standard vitamin A was prepared and vitamin A content of the sample was estimated from the standard curve.

Determination of thiamine (vitamin B_1)
Thiamine complex was derived with dilute HCl, and the resultant solution was treated with phosphatase enzyme to liberate free thiamine following the method of [24] Briefly, 1 g of AYB flour was weighed into a flask and 100 mL of 0.2 N HCl was added. The solution was heated to boiling for 30 minutes on a water bath. After cooling, 5 mL of phosphatase enzyme was added, and then incubate at 37°C for 48 h. The solution was filtered followed by the addition of 2 g of anhydrous Na_2SO_4. To 5 mL of the resulting solution was added 3 mL of 15% NaOH in a stoppered flask. The absorbance of the final solution was measured at 435 nm using a UV-Visible spectrophotometer. The thiamin content was estimated using the formula below (Equation 7).

$$\text{Thiamin (Vitamin B1) content} = \frac{\text{Sample Abs}}{\text{Std Abs}} \times \frac{\text{Std conc}}{\text{weight used}} \quad (7)$$

Where; Sample Abs = absorbance of Sample, Std Abs = absorbance of standard, and Std Conc = Concentration of standard.

Determination of vitamin C
A 5 g sample of AYB was weighed into a 100 mL volumetric flask, and 2.5 mL of 20% metaphosphoric acid was added as a stabilizing agent, and was diluted to volume with distilled water. Then, 10 mL of the solution was pipetted into a flask and 2.5 mL of acetone was added. The solution was titrated with standardized indophenol solution until a faint pink colour persisted. The vitamin C content in the sample was estimated as mg/100 mL.

Determination of antinutritional factors
The antinutritional factors analyzed in the AYB seeds, tubers roots and dry empty pod were saponins, tannins, hydrogen cyanide, alkaloids, phenols, oxalates, steroids, trypsin inhibitors, and flavonoids.

Determination of saponin content
Saponin content was determined gravimetrically according to method described by AOAC (2023).[26] AYB flour (5.0 g) was placed in an extraction thimble and inserted into the Soxhlet extractor chamber fitted with a condenser and a round bottom flask. Acetone (50 mL) was poured into the flask, the set-up was heated on a hot plate for 3 hours to extract the fats and pigments from the sample. The extract was removed, the flask was dried and weighed. The defatted/depigmented AYB sample was thereafter extracted with 80% methanol in the Soxhlet apparatus for 3 hours. The methanol extract containing the saponins was dried. The saponin content was determined by the difference between the final and initial weights of the flask.

Determination of tannin content
The tannin content of AYB was determined according to the method described by [22] A 1 g sample of AYB was added to 10.0 mL of distilled water and shaken at 5-minute intervals for 30 minutes. The solution was centrifuged at 8,000 rpm for 15 min to get the extract. The supernatant (2.5 mL) was transferred into a 50 mL flask and 1.0 mL of Folin-Denis reagent was added to the flask, followed by 2.5 mL of saturated Na_2CO_3 solution. The solution was made up to the mark with distilled water, and incubated at room temperature for 90 minutes. A standard tannic acid solution (2.5 mL) was also treated with Folin-Denis reagent, and saturated Na_2CO_3 solution as described above. The absorbance of both standard and test sample was read at 280 nm. The tannin content of AYB sample was estimated using the formula below (Equation 8).

$$\text{Tannin content} = \frac{An}{As} \times C \times \frac{100}{w} \times \frac{Vf}{Va} \quad (8)$$

Where; An = absorbance of the test sample, As = absorbance of the standard solution, C = Conc of standard solution, W = weight of sample used, Vf = total volume of extract, Va = volume of extract analyzed.

Determination of hydrogen cyanide (HCN) content
HCN content was determined using the alkaline picrate colorimetric method as described by [27] AYB flour (1 g) was placed in a conical flask, and 200 mL of distilled water was added. The solution was mixed thoroughly. A rubber stopper was used to stripped off the alkaline picrate paper and the mixture was suspended in such a way that the alkaline picrate paper did not touch the surface of the mixture. The solution was incubated at room temperature for 18 hours. After incubation, the picrate paper was carefully removed and fixed in 60 mL of distilled water. At the same time, a standard cyanide solution was prepared and treated as illustrated above. The absorbance of the sample solution and standard was measured at 540 nm using a UV-Vis spectrophotometer. The hydrogen cyanide content was calculated using the formula below. The hydrogen cyanide content was expressed as mg/kg.

$$\text{HCN (mg/kg)} = (100/W) \times Au\,(As) \quad (9)$$

Where;
W = weight of sample analyzed (g), Au = Absorbance of sample (nm), As = Absorbance of the standard HCN solution (nm).

Determination of alkaloid content
Alkaloid content was determined by gravimetric method adopted by [28] AYB flour (5 g) was added to 50 mL of 10% acetic acid in ethanol. The mixture was carefully shaken and allowed to stand for 4 hours, and then filtered. The filtrate was evaporated to one quarter of its original volume. Concentrated NH_4OH was added drop-wise to precipitate the alkaloids. The precipitate was filtered, and washed with 1% NH_4OH solution. The precipitate was placed on a preweighed filter paper, dried in an oven at 60ºC for 30 mins and reweighed. The alkaloid content was calculated from the difference between the final and initial weights of the filter paper, and expressed as a percentage of the weight of AYM flour used as shown in the formula below:

$$\text{Alkaloid content (\%)} = \frac{w_2 - w_1}{w} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Where;
W = Weight of sample, W_1 = Weight of empty filter paper, W_2 = Weight of paper + precipitate.

Determination of phenol content
The total phenol content was determined according to the method described by [29] To 0.5 mL of AYB extract was added 25 mL of folin-ciocalteau reagent (previously diluted 10-fold with distilled water), followed by 2 mL of sodium bicarbonate (7.5% w/v), and the mixture was diluted to 100 mL with distilled water. thereafter, the solution was incubated at 45℃ for 40 min for colour development. The absorbance of the coloured complex was measured at 765 nm using a UV-Vis spectrophotometer. Gallic acid was used as the standard. The total phenol content was obtained from the gallic acid calibration curve, and expressed as milligram of gallic acid equivalent per gram of sample (mg GAE/g sample.

Determination of oxalate content
Oxalate content was determined using titrimetric method as previously described by [30] Five (5) grams of AYB flour was weighed into a 100 mL beaker, 20 mL of 0.3 N HCl was added and heated gently on a magnetic plate with stirring for 1 h. the extract was filtered immediately and transferred into a 100 mL volumetric flask and diluted to the 100 ml mark with distilled water. A 5 mL extract solution was pipetted into a conical flask, and 1.0 mL of 5 N ammonium hydroxide was added. The pH of the solution was tested using an indicator paper to ensure the solution was alkaline. Two (2) drops of phenolphthalein indicator, followed by 1 mL of glacial acetic acid were added. One millilitre of 5% $CaCI_2$ was then added, and the mixture was allowed to stand for a period of 3 h after which it was centrifuged at 3000 rpm for 15 min. The supernatant was discarded, and the precipitate was washed three times with hot water with thorough mixing and centrifugation each time. Two millilitre of 3 N H_2SO_4 was added to each tube, and the precipitates were dissolved by warming in water at 80ºC. The content of the tubes was carefully poured into a conical flask and titrated with freshly prepared 0.05 M $KMnO_4$ maintain at room temperature until the first pink colour occurred, and continued till the solution became colourless. The solution was then warmed at 80ºC and titrated again until a pink colour which was stable for at least 30 seconds appeared. Sodium oxalate was used as standard, and the oxalate content was estimated as sodium oxalate equivalent.

Determination of steroid content
Steroid content was determined using the spectrophotometric method as described by [31] One gram of AYB flour was macerated with 20 mL of ethanol. The solution was filtered with Whatman No 1 filter paper. The filtrate (2 mL) was pipetted into a test tube, and 2 mL of cholesterol colour reagent was added. The solution was left to stand for 35 min, after which the absorbance was measured at 550 nm. The steroid content was calculated using the formula below.

$$\text{Steroid content} = \frac{\text{Absorbance of sample}}{\text{Gradient Factor}} \times DF \quad (11)$$

Where; DF is the dilution factor

Determination of trypsin inhibitors
Preparation of sample: 1 g of finely ground AYB sample (100 mesh) was extracted with 50 mL of 0.01 N NaOH at room temperature for 1 hour. A longer time was required to extract the maximum amount of trypsin inhibitor from the heat-treated sample.

Substrate preparation: A substrate solution was prepared by dissolving 40 mg of benzoyl-DL-arginine-p-nitroanilide (BAPA) hydrochloride in 1 mL of dimethyl sulfoxide (DMSO), followed by dilution with Tris buffer (0.05 M, pH 8.2) (pre-warmed to 37°C) to a final volume of 100 mL. This BAPA solution was prepared daily and maintained at 37°C throughout the assay period.

Test procedure: Aliquots of the African yam bean (AYB) suspension (0.6 mL and 1.0 mL) were pipetted in duplicate into test tubes and made up to a volume of 2 mL with distilled water. Trypsin solution (2 mL of 0.4 mg/mL) was added to each tube and incubated in a water bath at 37°C. After 10 minutes of incubation, 5 mL of the pre-warmed BAPA solution was added to each tube. The enzymatic reaction was halted by adding 1 mL of 30% acetic acid. The contents were mixed thoroughly and filtered, after which the absorbance of the filtrate was measured at 410 nm using a spectrophotometer, with a reagent blank as the reference. The reagent blank was prepared by adding 1 mL of 30% acetic acid to a test tube containing 2 mL of distilled water and 2 mL of trypsin, followed by 5 mL of BAPA solution.
Tris-buffer (0.05 M, pH 8.2) containing 5 mM calcium chloride was prepared by dissolving 6.05 g of tris(hydroxymethyl)aminomethane and 3 g of $CaCl_2 \cdot 2H_2O$ in approximately 900 mL of distilled water. The pH was adjusted to 8.2, and the solution was made up to 1 L with distilled water.
Trypsin solution (0.4 mg/mL) was prepared in 100 mM Tris buffer (pH 8.2) containing 5 mM $CaCl_2$. The solution was first incubated at 50°C and then cooled to 37°C. AYB flour were dispersed in acetic acid solution (pH 3.3); poorly dispersible materials were homogenized for uniformity.

Determination of flavonoid content
Total flavonoid content was determined by a modified procedure described by [32] AYB flour extract (0.5 mL) was mixed with 0.5 mL methanol, 50 µL of 10% $ALCl_3$, 50 µL of 1 M potassium acetate, and 1.4 mL of distilled water. The reaction mixture was incubated at room temperature for 30 min. The absorbance was thereafter measured at 415 nm. Quercetin was used to prepare a standard calibration curve. The total flavonoid content was estimated as milligram quercetin equivalent per gram of extract (mg QE/g extract).

Statistical analysis
Were applicable, data were presented as mean ± standard deviation (SD) of four replicates. Data were analyzed by one-way analysis of variance (ANOVA). using Genstat software (18th edition) for Randomized Complete Block Design (RCBD). Significant differences between mean values were determined using Duncan multiple range test, and level of significance was set at $P < 0.05$, $P < 0.01$, and $P < 0.001$.

Results and Discussion

Phytochemical screening for secondary metabolites
Proximate composition
The proximate composition of the seeds from the 25 genotypes of AYB, and the dry empty pods, roots, and tubers from Ekureku landrace are presented in Table 2. The results showed significant differences ($P < 0.001$) in the proximate parameters, including moisture, crude ash, crude fat, crude protein, crude fibre, and carbohydrates contents among the various AYB genotypes
The moisture content (MC) ranged from 7.75% in the seeds of G8 to 12.85% in seeds of G6 (Dybs10). The dry empty pods from G19 produced a moisture content of 9.30%, which was lower than that of the dry roots (14.73%) and tubers (85.98%) (Table 2). The variation in the moisture content could be due to the differences among the AYB genotypes. However, five pairs of AYB accessions for the seeds had shown genetic resemblance in their MC as presented in Table 2.

Table 2: Proximate composition of Twenty-Five genotypes of African yam bean seed, pod, root, and tuber

GC	Genotype	Proximate composition					
		MC (%)	Ash (%)	Fat (%)	CF (%)	CP (%)	CHO (%)
G1	DybB	12.00±0.49^{f}	2.46±0.01^{de}	0.78±0.04^{a-f}	1.45±0.07^{f-i}	13.79±0.30^{d}	70.05±0.04^{jk}
G2	DybS4	12.05±0.08^{f}	2.78±0.04^{ghi}	0.42±0.04^{a-e}	3.75±0.07^{l}	15.05±0.08^{f}	65.44±0.64^{fg}
G3	DybS6	12.09±0.30^{fg}	2.71±0.06^{fgh}	0.35±0.07^{a-e}	2.19±0.05^{j}	14.48±0.04^{e}	68.53±0.68^{hij}
G4	Dybw8	8.40±0.14^{b}	2.58±0.04^{ef}	0.35±0.07^{a-e}	1.29±0.06^{e-h}	16.15±0.28^{h}	71.00±0.35^{kl}
G5	Dybw9	11.98±0.04^{f}	2.67±0.03^{fg}	0.25±0.07^{a-d}	1.30±0.01^{e-h}	14.04±0.04^{d}	68.99±1.26^{ijk}
G6	DybS10	12.85±0.21^{i}	3.22±0.10^{jk}	0.18±0.04^{abc}	1.32±0.04^{e-h}	20.96±0.08^{n}	60.97±1.09^{cd}
G7	Dybw11	11.85±0.07^{ef}	2.38±0.04^{cd}	0.89±0.02^{a-f}	1.45±0.07^{f-i}	14.48±0.04^{g}	68.75±0.35^{h-k}
G8	DybS11	7.75±0.07^{a}	2.46±0.01^{de}	0.18±0.04^{abc}	1.29±0.01^{e-h}	18.03±0.01^{k}	69.89±0.55^{jk}
G9	Dybw12	7.78±0.04^{a}	2.45±0.07^{de}	0.86±0.01^{a-f}	1.20±0.01^{def}	16.05±0.10^{h}	71.00±0.96^{kl}
G10	DybB15	8.48±0.04^{b}	2.35±0.07^{cd}	0.29±0.06^{a-e}	0.95±0.01^{bcd}	15.56±0.00^{g}	72.70±0.45^{l}
G11	DybS14	11.95±0.07^{f}	2.90±0.07^{i}	2.25±0.07^{g}	1.28±0.04^{efg}	17.57±0.08^{j}	63.60±0.83^{ef}
G12	Dybw15	12.53±0.11^{ghi}	3.23±0.11^{jk}	0.18±0.04^{abc}	1.58±0.04^{hi}	14.72±0.07^{e}	68.77±1.04^{h-k}
G13	DybB17	12.65±0.07^{hi}	2.88±0.04^{i}	0.08±0.04^{ab}	1.49±0.01^{f-i}	15.88±0.17^{h}	67.00±0.34^{ghi}
G14	DybB18	11.47±0.69^{de}	2.28±0.04^{c}	1.06±0.06^{c-f}	1.55±0.08^{ghi}	15.41±0.13^{f}	67.00±1.10^{ghi}
G15	DybB21	12.10±0.14^{fg}	3.08±0.04^{j}	1.00±0.00^{c-f}	0.80±0.01^{bc}	19.33±0.10^{m}	62.50±1.97^{de}
G16	Abini	11.17±0.02^{d}	2.67±0.02^{fg}	1.06±0.01^{c-f}	1.55±0.08^{ghi}	15.32±0.01^{fg}	69.00±1.09^{ijk}
G17	Ogoja	11.88±0.18^{ef}	2.51±0.06^{de}	1.06±0.06^{c-f}	2.68±0.04^{k}	15.88±0.17^{h}	65.45±1.05^{fg}
G18	Ugep	12.20±0.14^{fgh}	3.08±0.04^{j}	1.18±0.04^{ef}	0.70±0.01^{b}	14.48±0.04^{e}	68.78±0.32^{h-k}
G19	Ekureku	12.65±0.08^{hi}	3.43±0.11^{l}	0.08±0.04^{ab}	0.31±0.01^{a}	24.95±0.07^{o}	59.54±0.65^{c}
G20	Ediba	12.**70**±**0**.01^{i}	3.38±0.04^{kl}	1.10±0.01^{def}	1.49±0.02^{f-i}	18.40±0.01^{l}	61.05±2.70^{cd}
G21	Ikom	12.58±0.04^{hi}	2.85±0.07^{hi}	0.30±0.01^{a-e}	1.71±0.01^{i}	17.69±0.06^{j}	65.00±0.25^{fg}
G22	Onueke	11.95±0.07^{f}	3.29±0.06^{kl}	0.18±0.04^{abc}	1.08±0.04^{de}	16.82±0.25^{i}	67.00±0.01^{ghi}
G23	Orokam	12.65±0.07^{hi}	2.55±0.07^{ef}	0.29±0.01^{a-e}	2.30±0.01^{j}	17.05±0.03^{i}	65.00±0.18^{fg}
G24	Nsukka	11.98±0.04^{f}	2.83±0.04^{ghi}	0.92±0.02^{b-f}	0.99±0.01^{cd}	16.15±0.07^{h}	66.55±0.78^{gh}
G25	Abakaliki	12.05±0.07^{f}	2.75±0.07^{ghi}	0.00±0.00^{a}	2.20±0.14^{j}	13.50±0.10^{c}	70.00v0.66^{jk}
	Pod of G19	9.30±0.14^{c}	2.05±0.07^{b}	0.06±0.01^{ab}	49.77±0.49^{n}	6.79±0.30^{a}	32.08±0.69^{b}
	Root of G19	14.73±0.39^{j}	3.95±0.07^{m}	1.65±1.92^{fg}	35.25±0.36^{m}	13.50±0.10^{c}	32.14±1.36^{b}
	Tuber of G19	85.98±0.04^{k}	0.65±0.21^{a}	0.38±0.04^{a-e}	1.40±0.01^{fgh}	8.31±0.01^{b}	3.84±0.51^{a}

Data represent mean ± standard deviation. Means with different lower-case letter are significantly different at P < 0.001). GC = Genetic code, MC = Moisture Content, CF = Crude Fibre, CP = Crude Protein, CHO = Carbohydrate. G1 – G25 are for seed

Therefore, for quality breeding, study of moisture content among the genotype pairs for selection, one genotype in each pair is recommended while the others are eliminated. The pairs are as follows: First pair (genotypes 1, 2, 5, 11, 22, 24 and 24) had similar MC which ranged from 11.95 to 12.05%; second pair (genotypes 8 and 9) had a MC of 7.80%; third pair (genotypes 4 and 10) had MC which ranged from 8.4 to 8.5 %; fourth pair (genotypes 20 and 6) had MC ranging from 12.7 to 12.9%; and fifth pair (genotypes 13 and 19) had MC of 12.65% (Table 2). Moisture content among genotypes in the same pair for seeds was not significantly different, but differed among the different pairs. Low MC could extend longevity and lower the deterioration of the seed. A high MC of 85.98% for the tubers of AYB could be a reason for the under exploitation and utilization of this crop in Sub-Saharan African countries. This finding agrees with that of [3] who reported that seeds with high MC deteriorate significantly at higher rate than those with low MC. Moisture content influences maturity, longevity, and viability [2] recommended an optimum MC of 9 - 12% for pulses to avoid the production of mycotoxins and safe storage. The results of the present study showed that MC in the dry empty pod and seeds: 11.17% in G16, 11.47% in G14, 11.85% in G7, 11.88% in G17, 11.95% in G11 and G22, 11.98% in G5 and G24; and 12% in G1 are all within the recommended range. The seeds of genotypes 8 with 9, 4, and 10) had the lowest MC of 7.8%, 8.40%, and 8.5%, respectively, which were below the lower limit of the recommended range. Lower moisture content could indicate higher dry matter and respiratory activity of most storage grains may cease, leading to increased shelf-life. The higher the moisture content, the higher the rate of deterioration. This could account for the higher rate of deterioration, increased aflatoxins, and increased microbial growth among accessions of AYB with tuber, as it had the highest MC of 85.98%. [14] reported a high MC of 12.04% for Southwest Nigeria accessions. [7] finding corroborated the results of genotypes 2 and 25 with a similar MC of 12.05%. This result disagrees with [5] and [6], who reported the absence of moisture from Nsukka and Cross River accessions of AYB. All the Cross River State accessions and the Nsukka accession had a high MC of 11.17% for Abini, 11.88% for Ogoja, 12.20% for Ugep, 12.58% for Ikom, 12.65% for Ekureku, 12.70% for Ediba, and 11.98% for Nsukka. The MC falls within the recommended range of 1.93 - 13.30% for seeds.[2,4-8,13,15,18] Moisture content depends on postharvest drying, processing, handling and storage method.

Ash content ranged from 2.28% in the seeds of G14 to 3.43% in the seeds of G19 (Ekureku); 2.05% for dry empty pod; 0.65% for tuber, and

3.95% for dry root of AYB. There were highly significant ($p < 0.001$) differences in the ash content among the four parts assessed, as presented in Table 2, with the tuber producing the lowest ash content of 0.65%, and the dry root recording the highest ash content of 3.95%. Genetic similarities exist among AYB seeds for ash content, as G1, G8, and G17 had ash content of 2.50%; G5 with G16 had ash content of 2.67%; G15 with G18 had ash content of 3.08%, and G6 with G12 had ash content of 3.22%. The parts (seed, dry empty pod, tuber and dry root) assessed had relatively high ash content, this was lowest in the tubers, and highest in the roots and seeds. Higher concentration of minerals and abundance of micronutrients in the soil could account for the high rate of ash content present in the roots of AYB. Ash content of 1.86 - 5.35% has been reported for the seeds of AYB collected in Nsukka, Ekiti, Owerri, Southern Kaduna, Southwest Nigeria, Enugu, Institute of Agricultural Research and Training, National Centre for Genetic Resources and Biotechnology, International Institute of Tropical Agricultural, Ibadan, and Cross River.[2,4-8,13,15,18] The ash content for the seeds, roots, and dry empty pods of AYB in the present study agrees with these values, except for the tubers, which had the lowest ash content of 0.65%. The ash content of the AYB accessions studied was lower for the tuber, dry empty pod and seed, except for the root, which had the highest ash content (Table 2). The result for ash content for seed in Cross River genotypes ranged from 2.51% in Ogoja to 3.43% in the Ekureku genotype. These values differed from that obtained in the study of Anya and Ozung [6,] who reported ash contents of 5.35% for the seeds of Cross River State AYB accessions. The Nsukka genotype had an ash content of 2.83% in seeds, which differed from the value (4.55%) reported by [5] A high ash content indicates abundant minerals present in AYB and can assist in ameliorating microelement deficiencies in SSA regions.

Crude fat in AYB seeds ranged from 0.08 – 2.25%, except for the G25 (Abakaliki) accession, in which no crude fat was found (Table 2). Crude fat was highest in the seeds, with a value of 2.25% in G11. This value was significantly different ($P < 0.001$) from the values obtained for the other seed samples. On the other hand, lower crude fat content was recorded in the roots, tubers, and empty pods, with values of 1.65%, 0.38%, and 0.06%, respectively. Tuber and genotypes G3 (DybS6), and G4 (Dybw8) had similar crude fat content (0.38 and 0.35%). Hence, dual-purpose selection for quality breeding and fat content is possible. Negligible fat content of 0.08% was recorded for G19 and G13, with the dry empty pods of G19 also having negligible fat content of 0.06%. The four genotypes (G15, G14, G16, and G17) had similar fat content in the range of 1.00 -1.06%. This could be due to genetic similarity among these genotypes. Among the accessions evaluated for fat, it was present in 24 accessions for the seeds, tuber and root, except the Abakaliki accession, which had no fat content. These accessions could be recommended for quality breeding research for their fat content. Crude fat content of 2.5% for AYB seed has been reported in the literature.[10-12] The crude fat obtained from AYB accessions is lower than that reported in other legumes, such as soybean (28.2%),[33] and groundnut.[34] Fat and oil produced in legumes are healthy for human consumption due to their unsaturated nature. The low-fat content of AYB seed makes it a promising food crop for weight management, and as low-calory diet for diabetic patients. Cross River State accessions had a lower fat content (0.03 - 1.18%) than the Nsukka accession with a fat content of 0.92%. This finding is in contrast with the work of Nwokolo (1987)[5] and Anya and Ozung (2019)[6] who reported higher fat contents, ranging from 3.00% for the Nsukka accession to 5.12% for the Cross River accession.

For crude fibre, the value ranged from 0.31% in G19 (Ekureku) to 3.75% in G2 (DybS4) for seeds; 49.77% for the pod, 35.25% for the root, and 1.40% for the tuber (Table 2). The Ekureku accession had the least crude fibre content, while the G2 (Dybs4) genotype had the highest crude fibre for seeds, which differed significantly ($p < 0.001$) from the other accessions. parts such as dry empty pod, and root had the highest crude fibre of 49.77% and 35.25 %, respectively. Statistical analysis revealed a significant ($p < 0.001$) variation in the crude fibre content of the four parts assessed among the genotypes. Genotypes 1, 7, 13, and 20 had similar crude fibre content of ≈1.50%, while genotypes 4, 5, 6, and 8 had crude fibre content of ≈1.30%. Consumption of the seed and tuber of the 25 accessions can provide the daily fibre requirements as it falls within the current recommendations for dietary fibre intakes for adults in most European countries and the United States, which is between 30 – 35 g per day for men and 25 – 32 g per day for women.[17] Among the accessions studied, the Ekureku accession is recommended for cultivation due to a lower proportion of soluble and insoluble fibre content of 0.31%. The results of this study, however, differed from those reported in several studies, that reported crude fibre content ranging from 2.47 - 9.57%,[2,5-8,13-16] This variation could be accounted for by the difference in the varieties of AYB accessions. Apart from the seeds and tubers of AYB, the discarded portion, such as empty pods and roots, contain more polysaccharides, oligosaccharides, lignin, and other associated plant substances that are constituents of dietary fibre. The empty pod and root of AYB could serve as an alternative feed source to address farmers' and herders' crisis in SSA regions, aside cereals, nuts, fruits, and vegetables which are also for human consumption. Consumption of dietary fibre contained in grains, nuts, fruits and vegetables has been shown to have positive impact on health by decreasing the risk of several diseases, including diabetes, kidney disease, hypothyroidism, and cardiovascular diseases like atherosclerosis, myocardial infarction, heart attack, and stroke.[35]

The crude protein content ranged from 13.50% in G25 (Abakaliki) to 24.95% in G19 (Ekureku) for seeds, 6.97% in dry empty pod, 13.50% in root and 8.31% in tuber as presented in Table 2. There were highly significant differences ($p < 0.001$) among the accessions for crude protein content in the seeds, as genotypes 1 and 25 had the least crude protein content of 13.50%, compared to G19, which had the highest crude protein content of 24.95%. The seeds of genotype 25 had a similar protein content of 13.50% with that of the root of genotype 19. This implies that cultivar seeds display genetic similarities with dry root for crude protein content. The crude protein content recorded in this study, is however at variance with that reported by [19] who noted variation in crude protein content of 20 - 25% in AYB, and the results of [36] who noted higher contents of crude protein of 24.5%, 24.49% and 23.95% for AYB accessions TSs-446, TSs-13, and TSs-448, respectively, grown in Ethiopia. Ekureku accession of AYB seeds is recommended for selection for high crude protein, and further quality breeding research, and could also be exploited for crop improvement to address malnutrition in Sub-Saharan African countries.

Carbohydrate content (CHO) of AYB ranged from 59.54% in G19 (Ekureku) to 72.70% in G10 (DybB15) for the seeds, 32.08% in dry empty pods, 32.14% in roots, and 3.84% in the tuber. G10 had the highest CHO content of 72.70% in seeds, while G19 had the least CHO content of 59.54% in the seeds of AYB. There was a significant ($p < 0.0001$) variation in the CHO content between the seeds of AYB for the 25 accessions, and that of the tuber, dry empty pod, and the root. As shown in Table 2, genotypes 13, 14 and 22 had similar CHO content of 67.00%, while genotypes 4 and 9 had the same CHO content of 71.00%. The Ekureku genotype had the least CHO content of 59.54% for the seeds. The study of [8] noted CHO content of 59.85% in the seed of AYB collected in Southwest Nigeria, which was similar to the values reported in the present study. However, this result differed from the findings of [6] in Cross River accessions,[5] in Nsukka accession, and [4] in Northwest Nigeria accessions. AYB genotypes sourced from Cross River had CHO content of 59.54% in Ekureku, 61.05% in Ediba, 65.00% in Ikom, 65.45% in Ogoja and 69.00% in Abini genotypes, while the Nsukka genotypes had CHO content of 66.55%, and a total number of 15 genotypes sourced from Southwest Nigeria had CHO contents ranging from 62.50 - 72.70%. The results of CHO content for genotypes G6, G15, G19, and G20 agree with the findings of [39] who reported 49.88 - 63.51% CHO content in AYB. About 28.08% of CHO found in a bean seed is made up of slowly digestible starch. This benefits diabetic patients as it does not increase the glycemic index (GI) and blood glucose of individuals suffering from diabetes.[2,37] Apart from starch, other non-starch polysaccharide components present in the bean seed of AYB are cellulose, hemicellulose, and arabinose. This compound helps reduce the risk of various health conditions, including cardiovascular diseases, colorectal cancer, breast cancer, coronary heart disease (CHD), digestive issues, type 2 diabetes, and other diseases related to lifestyle.[38]Apart from seed and tuber of AYB, the discarded portion, such as empty pod and root, also contains a higher proportion of CHO that can serve as alternative sources of raw materials for agro-allied

industries in feed formulation for livestock. These underexploited potentials of AYB in the SSA can be harnessed.

Mineral composition

The results of this study, as presented in Table 3 has shown that the mineral content (phosphorus, magnesium, calcium, sodium, potassium, copper, iron, and zinc) in the 25 AYB accessions for seed, and the G19 accession for root, dry empty pod, and tuber differed highly significantly ($p < 0.001$). Phosphorus content ranged from 224.90 mg/100 g for G1-DybB to 231.50 mg/100 g for G24-Nsukka for the seeds, 212.55 mg/100 g for root, 225.50 mg/100 g for tuber, and 198.15 mg/100 g for dry empty pod. The discarded portion (dry empty pod) had the lowest phosphorus content, while G1-DybB had the highest phosphorus content among the parts analyzed (Seed, pod, root and tuber). The magnesium content of AYB accessions ranged from 8.90 mg/100 g for G14 (DybB18) to 16.22 mg/100 g for G13 (DybB17) for the seeds, for the other parts, the values are 14.41 mg/100 g for tubers, 16.09 mg/100 g for empty pods, and 18.47 mg/100 g for roots. The root had the highest magnesium content among the parts evaluated. The seeds of AYB accession G14 (Dybb18) had the least magnesium content among the parts evaluated.

Calcium content ranged from 6.00 ppm for G11- DybS14 to 19.90 ppm for G24-Nsukka for the seeds. Calcium content for the other parts were 17.12 ppm for tuber, 32.28 ppm for empty pod and 51.00 ppm for root. The root of AYB G19 accession had the highest calcium content, while the seed of accession G11- DybS14 had the lowest calcium content.

Sodium content ranged from 2.82 ppm for G14-DybB18 to 4.60 ppm for G13-DybB17 for the seeds, while the values were 4.41 ppm for tuber, 3.48 ppm for dry empty pod, and 39.85 ppm for the root

The root had the highest Na concentration, followed by the seed, tuber, and empty pod among the quantitative traits analyzed, while the seed of accession G14-DybB18 had the lowest concentration of sodium in AYB.

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Table 3: Mineral composition of Twenty-Five genotypes of African yam bean seed, pod, root, and tuber

GC	Genotype	Mineral content							
		P (mg/100g)	Mg (mg/100g)	Ca (ppm)	Na (ppm)	K (ppm)	Cu (ppm)	Fe (ppm)	Zn (ppm)
G1	DybB	224.9 ±0.14^{c}	15.41±8.76^{v}	9.67±2.35^{ab}	3.89±1.56^{a}	0.90±0.29^{ab}	0.00±0.00^{a}	0.73±0.01^{cd}	0.13±0.01^{hi}
G2	DybS4	225.15 ±0.07^{cd}	14.49±6.67^{s}	10.34±2.35^{ab}	4.12±0.57^{a}	2.34±0.03^{c-g}	0.07±0.01^{c}	0.37±0.01^{b}	0.14±0.01^{i}
G3	DybS6	225.25 ± 0.07^{cd}	11.73±3.78^{h}	8.67±0.94^{a}	4.14±1.60^{a}	5.13±0.25^{mno}	0.00±0.00^{a}	2.08±0.01^{j}	0.09±0.01^{fg}
G4	Dybw8	225.35 ± 0.07^{cd}	11.12±1.25^{f}	12.67±0.94^{ab}	4.29±1.48^{a}	4.83±0.38^{lmn}	0.03±0.01^{b}	1.47±0.01^{h}	0.08±0.01^{ef}
G5	Dybw9	225.6 ±0.00^{d}	11.77±3.73^{i}	7.34±4.72^{a}	4.10±1.54^{a}	5.08±0.06^{mno}	0.07±0.01^{c}	0.37±0.01^{b}	0.08±0.01^{ef}
G6	DybS10	226.15 ± 0.07^{e}	13.27±5.00^{l}	9.00±7.07^{ab}	4.16±1.30^{a}	4.70±0.41^{lmn}	0.03±0.01^{b}	0.61±0.01^{c}	0.25±0.01^{k}
G7	Dybw11	226.8 ± 0.28^{f}	10.33±2.36^{b}	11.34±0.94^{ab}	4.26±1.76^{a}	4.29±0.28^{k-n}	0.07±0.01^{c}	3.06±0.01^{k}	0.09±0.01^{fg}
G8	DybS11	226.75 ± 0.07^{f}	11.63±6.47^{g}	9.34±3.77^{ab}	3.44±1.58^{a}	2.85±0.52^{f-i}	0.07±0.01^{c}	0.73±0.01^{cd}	0.04±0.01^{bc}
G9	Dybw12	227.15 ± 0.07^{fg}	14.07±7.11^{o}	6.67±3.77^{a}	3.78±1.41^{a}	3.80±0.45^{i-l}	0.07±0.01^{c}	1.05±0.07^{fg}	0.13±0.01^{hi}
G10	DybB15	227.55 ± 0.07^{gh}	11.02±1.82^{e}	11.00±4.24^{ab}	3.76±1.06^{a}	5.15±1.36^{no}	0.03±0.01^{b}	2.08±0.01^{j}	0.08±0.04^{ef}
G11	DybS14	227.75 ± 0.07^{hi}	14.02±7.33^{mn}	6.00±2.83^{a}	3.37±0.18^{a}	3.65±0.35^{h-k}	0.29±0.01^{d}	1.95±0.01^{j}	0.05±0.01^{bc}
G12	Dybw15	228.05 ± 0.07^{ij}	10.58±5.41^{c}	8.00±0.00^{a}	3.93±0.65^{a}	3.17±0.87^{g-j}	0.03±0.01^{b}	0.72±0.02^{cd}	0.05±0.01^{bc}
G13	DybB17	228.45 ± 0.07^{jk}	16.22±11.01^{y}	10.67±3.77^{ab}	4.60±1.25^{a}	4.58±0.88^{k-n}	0.03±0.01^{b}	1.05±0.07^{fg}	0.10±0.00^{f}
G14	DybB18	228.6 ± 0.00^{kl}	8.90±4.39^{a}	7.34±4.72^{a}	2.82±0.06^{a}	1.48±0.57^{bc}	0.00±0.00^{a}	0.28±0.04^{b}	0.05±0.01^{bc}
G15	DybB21	228.95 ± 0.07^{lm}	10.68±5.26^{d}	8.00±0.00^{a}	3.43±0.27^{a}	1.55±0.33^{bcd}	0.00±0.00^{a}	0.61±0.01^{c}	0.04±0.01^{c}
G16	Abini	229.15 ± 0.07^{mn}	14.17±10.51^{p}	10.00±2.83^{ab}	3.17±0.54^{a}	1.64±0.03^{bcd}	0.00±0.00^{a}	0.86±0.01^{de}	0.05±0.01^{bc}
G17	Ogoja	229.4 ± 0.00^{n}	14.26±3.59^{q}	12.00±0.00^{ab}	3.97±1.36^{a}	4.80±0.44^{lmn}	0.00±0.00^{a}	1.78±0.07^{i}	0.11±0.01^{g}
G18	Ugep	229.45 ± 0.07^{n}	14.79±2.84^{u}	9.67±2.35^{ab}	4.00±0.75^{a}	6.01±0.29^{o}	0.00±0.00^{a}	0.12±0.01^{a}	0.08±0.01^{ef}
G19	Ekureku	230.08 ± 0.04^{o}	12.27±3.01^{j}	11.34±4.72^{ab}	3.50±2.00^{a}	1.55±0.10^{bcd}	0.07±0.01^{c}	3.25±0.07^{l}	0.07±0.01^{de}
G20	Ediba	230.35 ± 0.00^{op}	14.54±3.20^{t}	9.00±7.07^{ab}	4.07±0.84^{a}	2.55±0.23^{d-g}	0.00±0.00^{a}	1.05±0.07^{fg}	0.00±0.00^{a}
G21	Ikom	230.5 ± 0.00^{opq}	13.29±1.58^{m}	10.67±1.89^{ab}	3.90±0.93^{a}	1.77±0.21^{b-e}	0.00±0.00^{a}	0.98±0.01^{ef}	0.04±0.01^{bc}
G22	Onueke	230.55 ± 0.07^{pq}	12.96±2.04^{k}	11.34±4.72^{ab}	3.90±1.25^{a}	2.71±0.33^{e-h}	0.00±0.00^{a}	7.48±0.03^{m}	0.09±0.01^{fg}
G23	Orokam	230.85 ± 0.07^{q}	13.33±1.51^{m}	11.00±4.24^{ab}	3.61±1.17^{a}	3.21±0.27^{g-j}	0.03±0.01^{b}	0.25±0.00^{ab}	0.03±0.01^{b}
G24	Nsukka	231.50 ± 0.07^{r}	10.62±1.96^{c}	19.90±0.14^{c}	3.08±0.74^{a}	0.18±0.02^{a}	0.03±0.01^{b}	1.17±0.08^{g}	0.14±0.01^{i}
G25	Abakaliki	231.40 ± 0.07^{r}	15.97±4.57^{w}	12.34±0.47^{ab}	3.54±0.75^{a}	4.80±0.43^{lmn}	0.00±0.00^{a}	0.98±0.01^{ef}	0.06±0.01^{cd}
	Pod of G19	198.15 ± 0.07^{a}	16.09±4.40^{y}	32.28±1.49^{d}	3.48±0.98^{a}	4.06±0.05^{j-m}	0.00±0.00^{a}	1.38±0.04^{h}	0.07±0.01^{de}
	Root of G19	212.55 ± 0.07^{b}	18.47±6.70^{z}	51.00±2.36^{e}	39.85±8.44^{b}	1.45±0.08^{bc}	0.07±0.01^{c}	12.80±0.29^{n}	0.14±0.01^{i}
	Tuber of G19	225.50 ± 0.07^{d}	14.41±3.39^{r}	17.12±0.30^{bc}	4.41±0.93^{a}	2.07±0.19^{c-f}	0.03±0.01^{b}	0.83±0.05^{d}	0.19±0.01^{j}

Data represent mean ± standard deviation. Means with different lower-case letter are significantly different at $P < 0.001$). GC = Genetic code. G1 – G25 are for seed.

Potassium content ranged from 0.18 ppm for G24-Nsukka to 6.01 ppm for G18-Ugep for the seeds, while the values for other parts include 2.07 ppm for tubers, 1.45 ppm for the roots, and 4.06 ppm for dry empty pods. Copper concentration of the seed accessions of AYB ranged from 0.03 ppm for G4-Dybw8, G6DybS10, G10-DybB15, G12-Dybw15, G13-DybB17, G23-Oturkpo, and G24-Nsukka) to 0.29 ppm for G11-DybS14 for seeds. For the roots and tubers, copper contents were 0.07, and 0.03 ppm, respectively

Copper was absent in the empty pod, G25, G22, G21, G20, G18, G17, and G16. On the other hand, the Iron content ranged from 0.12 ppm for G18-Ugep to 7.48 ppm for G22-Onueke for the seeds. Iron content in the other parts were 1.38 ppm for empty pod, 0.83 ppm for tuber and 12.80 ppm for root in AYB accessions. From the results, the root had the highest iron content compared to the seed, tuber, and empty pod.

Zinc content ranged from 0.03 ppm for G23-Orokam to 0.25 ppm for G6-DybS10 for the seeds. Zinc content were 0.07 ppm for the empty pod, 0.19 ppm for the tuber, and 0.14 ppm for the root in AYB G19 accession. From the results, the concentration of zinc was highest in the seed compared to the tuber, empty pod, and root. Zinc was not identified in the G20–Ediba accession. The results showed genetic similarity among AYB accessions (G4Dybw8, G5-Dybw9, G18-Ugep), (G11-DybS14, G12-Dybw15, G14-DybB18, and G16-Abini) for the zinc content. The root also exhibited genetic similarity with accessions G24-Nsukka and G2-DybS4) for zinc content in AYB.

Vitamin content

The vitamin contents of 25 AYB accessions are presented in Table 4 for vitamins A, B_1, B_2, B_3, C, and E. Vitamin A concentration ranged from 411.93 µg/100 g for G13-DybB17 to 493.67 µg/100 g for G23-Orokam for the seeds. Vitamin A content in the pods, roots, and tubers were 2.45 µg/100 g, 4.30 µg/100 g, and 6.80 µg/100 g, respectively. G13 had the least vitamin A content, while G23-Orokam accession had the highest vitamin A content for seeds..

Table 4: Vitamins composition of Twenty-Five genotypes of African yam bean seed, pod, root, and tuber

		Vitamins content					
GC	Genotype	A (µg/100 g)	B1 (mg/100g)	B2 (mg/100g)	B3 (mg/100g)	C (mg/100g)	E (mg/100g)
G1	DybB	466.85±0.21g	14.99 ± 0.01o	2.48 ± 0.03c	2.00 ± 0.00m	1.49 ± 0.45cd	4.45 ± 0.07c
G2	DybS4	475.00±7.07i	7.75 ± 0.35d	4.58 ± 0.05o	1.89 ± 0.06l	2.15 ± 0.07jk	8.10 ± 0.14g
G3	DybS6	466.84±0.23h	10.7 ± 0.28j	3.39 ± 0.01i	1.90 ± 0.04l	1.98 ± 0.03f-j	6.05 ± 0.07f
G4	Dybw8	433.60±0.57e	9.1 ± 0.14f	2.56 ± 0.05d	2.21 ± 0.01o	2.05 ± 0.07hij	5.01 ± 0.01d
G5	Dybw9	479.50±0.71j	10.37 ± 0.09i	3.5 ± 0.06j	2.75 ± 0.01q	1.62 ± 0.03cde	5.99 ± 0.01f
G6	DybS10	479.00±1.41j	14.12 ± 0.01n	2.58 ± 0.05d	1.65 ± 0.01ij	1.77 ± 0.10e-h	4.45 ± 0.07c
G7	Dybw11	472.92±0.59i	6.78 ± 0.11c	5.34 ±0.06p	9.22 ± 0.01u	1.75 ± 0.07d-g	6.00 ± 0.00f
G8	DybS11	457.63±3.36g	7.56 ± 0.09d	3.28 ± 0.01h	2.90 ± 0.01r	1.35 ± 0.07bc	5.99 ± 0.01f
G9	Dybw12	422.68±0.45d	8.83 ± 0.10e	4.12 ± 0.01m	2.10 ± 0.01n	1.70 ± 0.00def	5.45 ± 0.07e
G10	DybB15	420.74±0.37d	9.9 ± 0.14h	3.12 ± 0.01f	3.66 ± 0.01t	2.15 ± 0.07jk	4.45 ± 0.07c
G11	DybS14	453.67±0.47f	14.12 ± 0.01n	2.58 ± 0.05d	2.58 ± 0.04p	1.18 ± 0.03b	6.00 ± 0.00f
G12	Dybw15	433.84±0.23e	11.36 ± 0.10k	3.22 ± 0.02g	1.41± 0.03f	1. 99 ± 0.01g-j	5.45 ± 0.07e
G13	DybB17	411.93±0.10c	9.17 ± 0.09f	4.01 ± 0.01l	1.51 ± 0.01g	2.06 ± 0.09ij	5.45 ± 0.07e
G14	DybB18	466.84±0.23g	14.12 ± 0.01n	2.58 ± 0.05d	1.83 ± 0.06kl	2.77 ± 0.10l	6.00 ± 0.00d
G15	DybB21	479.50±0.71j	11.95 ± 0.07l	3.09 ± 0.02f	1.75 ± 0.01jk	2.38 ± 0.03k	5.00 ± 0.00d
G16	Abini	486.84±0.23k	12.0 ± 0.00l	3.09 ± 0.02f	3.49 ± 0.01s	2.11 ± 0.01j	4.10 ± 0.14b
G17	Ogoja	479.50±0.71j	10.7 ± 0.28j	3.39 ± 0.00i	2.23 ± 0.11o	2.41 ± 0.04k	4.05 ± 0.07b
G18	Ugep	479.00±1.41j	9.95 ± 0.07h	3.70 ± 0.01k	1.68 ± 0.04ij	1.79 ± 0.01e-i	5.05 ± 0.07d
G19	Ekureku	453.50±0.71f	9.95 ± 0.07h	3.70 ± 0.01k	1.87 ± 0. 10 l	2.79 ± 0.06l	4.00 ± 0.00b
G20	Ediba	433.67±0.47e	13.28 ± 0.08m	2.79 ± 0.02c	1. 88 ± 0.01 l	1.82 ± 0.03 e-i	8.45 ± 0.07h
G21	Ikom	479.67±0.94j	15.95 ± 0.07p	2.30 ± 0.01b	1.75 ± 0.01jk	1.38 ± 0.03bc	5.99 ± 0.01f
G22	Onueke	466.84±0.23g	13.28 ± 0.08m	2.79 ± 0.03e	1.51 ± 0.01g	1.71 ± 0.01d-g	5.00 ± 0.00d
G23	Orokam	493.67±0.47l	14.12 ± 0.01n	2.58 ± 0.05d	1.29 ± 0.02e	1.12 ± 0.01b	5.99 ± 0.01f
G24	Nsukka	472.92±0.59i	6.05 ± 0.07b	6.18 ± 0.03q	1.19 ± 0.02d	1.22 ± 0.02b	6.00 ± 0.00f
G25	Abakaliki	433.67±0.47e	9.58 ± 0.04g	4.30 ± 0.01n	1.60 ± 0.00h	1.95 ± 0.07f-j	5.95 ± 0.07f
	Pod of G19	2.45±0.64a	0.08 ± 0.04a	0.02 ± 0.00a	0.20 ± 0.00a	0.33 ± 0.39a	0.04 ± 0.01a
	Root of G19	4.30±0.42a	0.07 ± 0.04a	0.02 ± 0.00a	0. 55 ± 0.01b	1.11 ± 0.01b	0.08 ± 0.01a
	Tuber of G19	6.80±0.28a	0.21 ± 0.01a	0.08 ± 0.01a	0.80 ± 0.00c	1.61 ± 0.01cde	0.12 ± 0.02a
	F – Value	16518.1***	2421.2***	4204.6***	2607.2***	38.2***	2343.3***

Data represent mean ± standard deviation. Means with different lower-case letter are significantly different at $P < 0.001$). GC = Genetic code. G1 – G25 are for seed.

Among the roots, tubers, and pods, the tubers had the highest vitamin content. Genotype G23-Orokam is recommended for selection for its high vitamin A content, as it showed more potential in nutrition and the fact that it can help build the body's immune system. Vitamin B_1 content ranged from 6.05 mg/100g for G24-Nsukka to 15.95 mg/100g for G21-Ikom for seeds, 0.08 mg/100g for the pods, 0.07 mg/100g for roots, and 0.21 mg/100g for the tubers. From the results, the Ikom accession had the highest vitamin B1 content among all the accessions. Among the characters analyzed for vit. B_1, the pod and root of Ekureku accession had the least vit. B1 content. This could be due to the varietal differences among the accessions of AYB

The present result for the Vit.B1 content of the seeds of AYB align with that reported by [40] who reported Vit. B_1 concentration of 0.12 mg/100 g for AYB seeds. Vitamin B_2 content ranged from 2.30 mg/100 g for G21-Ikom to 6.18 mg/100 g for G24-Nsukka for the seeds, while for the other parts, vitamin B_2 content were 0.02 mg/100 g for pod, 0.02 mg/100 g for root and 0.08 mg/100 g for tuber. For all the 25 accessions evaluated, the seeds generally had higher Vit. B_2 than the tubers, roots, and pods. This is in contrast with the findings of [40] who reported lower vitamin B_2 content of 0.19 ± 0.03 mg/100 g for AYB seeds. This could be attributed to the varietal difference among the accessions and landraces With its high vitamin B_2 content, the Nsukka genotype is recommended for selection and usage. Vitamin B_3 content ranged from 1.17 mg/100 g for G24-Nsukka landrace to 9.22 mg/100 g for G7-Dybw11 accession for seeds. For the pods, roots, and tubers of G19 accession, vitamin B_3 contents were 0.20 mg/100 g, 0.55 mg/100 g, and 0.80 mg/100 g, respectively.

Result of 1.17 - 9.22 mg/100 g for vitamins B_3 content for the seeds as presented in Table 4 did not align with the findings of [40] who reported Vit. B_3 content of 0.19 mg/100 g for AYB seeds. Vitamin C content ranged from 1.12 mg/100 g for G23-Orokam landrace to 2.79 mg/100 g for G19-Ekureku landrace for the seeds. For the other parts, vitamin C contents were 0.33 mg/100 g for pod, 1.11 mg/100 g for root, and 1.61 mg/100 g for tuber. However, [40] reported a higher content of vitamin C (12.94 mg/100 g) for AYB seed. In this study, the vitamin C content of AYB seed agree with the findings of [41] and [42,] who reported vitamin C content of 1.79 mg/100 g and 1.33 mg/100 g, respectively for bambara groundnut. Among all the genotypes, the G19-Ekureku landrace produced the highest vitamin C content. This demonstrated the potential of AYB as a source of Vitamin C to address vitamin C deficiency in the diet, especially in SSA.

Vitamin E content ranged from 4.00 mg/100 g for G19-Ekureku landrace to 8.45 mg/100 g for G20-Ediba landrace for the seeds. Vitamin E content of the pods, roots, and tubers of G19 landrace were 0.04 mg/100g, 0.08 mg/100 g, and 0.12 mg/100 g, respectively. This result disagrees with values reported in the literature for the vitamin E contents of AYB, soybean, and bambara groundnut seeds on a dry matter basis.[19,20,43] Based on the results obtained, the Ediba genotype is recommended for cultivation for its vitamin E content.

Anti-nutritional content

The results of anti-nutritional content for the 25 AYB accessions and landraces grown in the humid agroecology are presented in Table 5. The anti-nutritional compounds analyzed were saponins, tannins, hydrogen cyanide, alkaloids, phenols, oxalates, steroids, trypsin inhibitors, and flavonoids. The saponin content for the seeds ranged from 422.80 µg/100 g for G1-DybB to 732.80 µg/100 g for G7-Dybw11. For pods, roots, and tubers of G19 landrace, saponin content were 292.80 µg/100 g, 353.75 µg/100 g, and 386.15 µg/100 g, respectively.

Tannin content for AYB seeds ranged from 240.10 µg/100g for G1 to 256.15 µg/100g for G25. For the other parts, the tannin content were 172.50 µg/100 g (pod), 198.80 µg/100 g (root), and 220.50 µg/100 g (tuber). High tannin content could indicate low minerals and vitamins in the genotype. Among the traits assessed, the pod had the least tannin concentration. Tannins are low in pulses and roots, but higher in seeds and tubers, which could lead to higher levels of minerals and vitamins in pulses and roots, but lower levels in seeds and tubers. High tannin content among AYB genotypes could lead to a reduction in protein and mineral bioavailability and an increase in toxicity. Tannins also interfere with metabolic processes of other minerals like calcium, iron and zinc.

Hydrogen cyanide (HCN) content for seeds ranged from 15.15 mg/100 g for G1 to 22.35 mg/100 g for G24 and G25. The pods, roots, and tubers of G19 had hydrogen cyanide content of 15.35 mg/100 g, 17.00 mg/100 g, and 19.25 mg/100 g, respectively. Among the traits assessed, the pod had a higher concentration of HCN than that of G7, G8, G9, G10 and G11, while the HCN concentration for the tuber was equal to that of the G12 seed. Therefore, dual traits (seed and tuber) could be selected for quality breeding research for HCN in AYB.

Alkaloid concentration for seeds of AYB accessions and landraces ranged from 1.55 mg/100 g for G1 to 2.50 mg/100 g for G24 and G25. For the pod, root, and tuber, alkaloid contents were 1.35 mg/100 g, 1.55 mg/100 g, and 1.75 mg/100 g, respectively. Among the traits assessed for alkaloids, the tuber had the same alkaloid concentration (1.75 mg/100g) as that of G3, G4 and G5. A dual-purpose study (seed and tuber) on the concentration of alkaloids present in these AYB genotypes should be undertaken to improve quality breeding work. Alkaloids affect the nervous system and inhibit neurotransmitters. Consumption of crops with higher alkaloid concentration could reduce saliva production, vomiting, diarrhea, abdominal pain, convulsions and coma.

The phenolic concentration for seeds of AYB accessions ranged from 11.35 mg/100 g for G1 to 13.35 mg/100 g for G25, while for the pod, root, and tuber, phenolic contents were 9.55 mg/100 g, 10.75 mg/100 g, 12.00 mg/100 g, respectively. Among the traits assessed for phenols, the tuber had similar phenolic compound concentration of ≈12.00 mg/100 g with the G3 genotype of AYB. A dual-purpose study on seed and tuber for the concentration of phenolic compounds present in the G3 genotype of AYB should be exploited in quality breeding work for improvement.

The oxalate concentration for seeds of AYB accessions ranged from 82.00 mg/100 g for G1 to 86.25 mg/100 g for G25. Oxalate concentration in the pod, root, and tuber of G19 were 68.35 mg/100 g, 72.05 mg/100 g, and 83.55 mg/100 g, respectively. Among the traits assessed for oxalate, the tuber had the same oxalate concentration (83.6 mg/100 g) with that of G8 genotype of AYB seed.

These results agree with that of [36] who reported high oxalate content in TSs-47 and TSs-352 of AYB grown in Ethiopia. The pulses and roots were found to have lower oxalate concentrations than the seed and tuber.

The steroid content of the seed of AYB accession ranged from 0.025 mg/100 g for G1, G2, G3 and G4 to 0.065 mg/100 g for G25. The steroid content for other parts were recorded as 0.015 mg/100 g for the pod, 0.025 mg/100 g for the root, and 0.035 mg/100 g for the tuber of G19.

Trypsin inhibitors for the seeds of AYB accessions and landraces ranged from 6.15 mg/100 g for G1 and G2 to 8.05 mg/100 g for G20 - G25. Trypsin inhibitors for the pod, root, and tuber of G19 were 6.00 mg/100 g, 6.75 mg/100 g, and 8.15 mg/100 g, respectively. This result differed from that of et[44] who reported the absence of trypsin inhibitor and lectin in the tuber of some accessions of AYB. Genetic similarity between tuber and seed for the concentration of trypsin inhibitor was observed as stated above. However, reports from previous studies indicated the safety in consuming AYB seed and tuber in both humans and livestock.[44-47] Genotypes G1 and G2 are recommended for cultivation and quality improvement due to their low content of trypsin inhibitors.

Flavonoid content in the seeds AYB accessions and landraces ranged from 7.45 mg/100 g for G1 and G2 to 10.45 mg/100 g for G25. For the pod, root, and tuber of G19, flavonoid contents were found to be 6.55 mg/100 g, 7.35 mg/100 g, and 8.15 mg/100 g, respectively. G6 seed had the same flavonoid concentration as the tuber (8.15 mg/100 g), hence could be recommended for selection for dual-purpose cultivation to harness its flavonoids. Flavonoids are the largest group of secondary plant metabolites that contain isothiocyanates, which serve as antioxidants, scavenging free radicals and stable precursors of glucosinolates.

Table 5: Anti-nutrients compositions Twenty-Five genotypes of African yam bean seed, pod, root, and tuber

GC	Genotype	Anti-nutrient								
		Saponins (mg/100g)	Tannins (mg/100g	HCN (mg/kg)	Alkaloids (g/100)	Phenol (g/100)	Oxalates (mg/100)	Steroids (g/100)	Trypsin Inhibitors (mg/100)	Flavonoids (g/100)
G1	DybB	422.80d	240.10d	15.15a	1.55b	11.35c	82.00c	0.025ab	6.15c	7.45bc
G2	DybS4	426.50e	244.80e	15.90b	1.60b	11.75d	82.35d	0.025ab	6.15c	7.45bc
G3	DybS6	425.90e	246.00f	16.15c	1.75c	12.05ef	82.55e	0.025ab	6.35d	7.55c
G4	Dybw8	430.90f	246.35fg	16.80d	1.75c	12.15fg	82.95f	0.025ab	6.45d	7.75d
G5	Dybw9	431.35fg	246.90gh	16.95de	1.75c	12.25g	83.00fg	0.035bc	6.65e	8.00e
G6	DybS10	431.50fg	247.35h	17.15ef	1.90d	12.45h	83.15g	0.035bc	6.75e	8.15f
G7	Dybw11	732.80p	248.50i	17.35f	2.00de	12.45h	83.35h	0.035bc	7.00f	8.45g
G8	DybS11	432.00g	248.35i	17.75g	2.10ef	12.45h	83.55i	0.035bc	7.25g	8.65h
G9	Dybw12	433.15h	248.90ij	18.15h	2.05ef	12.55h	83.85j	0.035bc	7.45h	8.85i
G10	DybB15	433.20h	249.15j	18.65i	2.05ef	12.55h	84.15k	0.04cd	7.45h	9.15k
G11	DybS14	433.50h	249.90k	18.95j	2.05ef	12.55h	84.35l	0.04cd	5.35a	9.00j
G12	Dybw15	434.80i	250.35k	19.15jk	2.10ef	12.75i	84.75m	0.045cde	7.55hi	9.15k
G13	DybB17	435.10i	251.40l	19.35k	2.15fg	12.85ij	84.9m	0.045cde	7.55hi	9.15k
G14	DybB18	435.50ij	252.35m	19.75l	2.15fg	12.95jk	85.15n	0.045cde	7.55hi	9.25kl
G15	DybB21	436.35j	252.80mn	20.15m	2.15fg	12.95jk	85.30n	0.05def	7.60i	9.35l
G16	Abini	437.90k	253.15no	20.30m	2.15fg	12.95jk	85.55o	0.045cde	7.55hi	9.65m
G17	Ogoja	438.15k	253.55op	20.60n	2.15fg	13.05kl	85.55o	0.05def	7.75j	9.65m
G18	Ugep	438.80kl	254.15p	20.75no	2.25gh	13.15lm	85.55o	0.06fg	8.00k	9.65m
G19	Ekureku	439.2lm	254.80q	20.95op	2.25gh	13.15lm	85.75p	0.055efg	8.00k	9.80n
G20	Ediba	440.05mn	255.00q	21.10p	2.25gh	13.15lm	85.75p	0.055efg	8.05k	9.80n
G21	Ikom	440.90n	255.15q	21.35q	2.25gh	13.15lm	85.75p	0.055efg	8.05k	9.85n
G22	Onueke	440.95n	255.80r	21.75r	2.35h	13.25mn	85.95q	0.055efg	8.05k	10.15o
G23	Orokam	442.15o	255.90r	22.00s	2.35h	13.25mn	85.95q	0.06fg	8.05k	10.15o
G24	Nsukka	442.85o	256.15r	22.35t	2.50i	13.25mn	86.15r	0.06fg	8.05k	10.25o
G25	Abakaliki	442.90o	256.80a	22.35t	2.50i	13.35n	86.25r	0.065g	8.05k	10.45p
	Pod of G19	292.80a	172.50b	15.35a	1.35a	9.55a	68.35a	0.015a	6.00b	6.55a
	Root of G19	353.75b	198.80c	17.00de	1.55b	10.75b	72.05b	0.025ab	6.75e	7.35b
	Tuber of G19	386.15c	220.50cd	19.25k	1.75c	12.00e	83.55i	0.035bc	8.15k	8.15f

Data represent mean ± standard deviation. Means with different lower-case letter are significantly different at $P < 0.001$). GC = Genetic code. G1 – G25 are for seed.

Conclusion

Improvement of AYB for carbohydrates, protein, fibre, fat, ash and moisture content requires adequate quality breeding profiling to select a promising genotype. Hence, screening the 25 accessions and landraces becomes sacrosanct for quality breeding research. The results showed that G10 (DybB15) had the highest concentration of carbohydrates, G19 (Ekureku) had the highest crude protein and crude fibre, G11 (DybS14) had the highest crude fat, while G19 (Ekureku) and G20 (Ediba) had highest concentration of total ash, and are recommended for selection and quality improvement. Genotype 25 (Abakaliki) has been shown to be safe for consumption and is recommended for managing weight loss and inclusion in diabetic patient meals due to the absence of crude fat. Genotype 9 (Dybw12) had the least moisture content, and is recommended for the improvement of abiotic stress. Genotype G1 (DybB) with high minerals contents and low antinutritional content is safer for consumption, and is recommended for selection in quality breeding improvement study. Amongst the traits assessed for nutritional and anti-nutritional composition, the dry empty pod of AYB showed a high proportion of dietary fibre with micro and macro minerals composition, but had the lowest concentration of anti-nutrients. Hence, the dry empty pod of AYB could be recommended for animal feed formulation in agro-allied industries.

Conflict of interest

The author declare no conflicts of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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