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Proximate and antinutrient composition of selected West African Bambara groundnut (*Vigna subterranea* (L.) Verdc.) accessions

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Abstract

Underutilized legumes have gained recent prominence among various stakeholders globally, but particularly in the sub-Saharan African region. Among these is theBambara groundnut (*Vigna subterranea* (L.) Verdc); cultivated in several communities in Africa and Asia.In this study, five West African accessions obtained from the genebank at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria were compared for proximate and antinutrients. Analysis of variance showed statistically significant results (Significant level at$P < 0.0001$) for carbohydrates, protein, fat, crude, moisture, ash and crube fibre. The antinutrients analyzed(%) composed of flavonoids, alkaloids and saponin. The flavonoids ranged from 0.009 % to 0.005% in TVSU-1636 and TVSU-1649 respectively. The alkaloid varies from 0.182% in TVSU-1649 to 0.248% in TVSU-1636 while the saponin content varies from 0.333% in TVSU-1649 to 0.387% in TVSU-1636. The outcome of the study indicated variations in the trait measured and that the accessionscould be useful as legume supplements in animal and human foods. Bambara groundnut may also support low-cost protein and other beneficial nutrients required in sub-Saharan Africa.

Keywords: Bambara groundnut, nutrients, antinutrients, food and income security, sub-Saharan Africa

Introduction

Vigna subterranea (L.) Verdc popularly called Bambara groundnut (BG) is a member of the underutilized legumes positioned to support global food insecurity and malnutrition particularly in sub-Saharan Africa with the right awareness for its promotion and utilization (Mayes et al., 2019). The cultivation of underutilized legumes have good impacts for subsistence farmers in the area of revenue generation (Durst and Bayasgalanbat, 2014), limiting reliance on major staples for food and animal feed (Chivenge et al., 2015)with the addition of less farming inputs when compared to usual farming systems in regions where they are planted (Stamp et al., 2012). In this study,five accessions were selected from few West African states and analyzedfor variation in theirproximate and antinutrients composition. These accessions are conserved at the Genebank of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria with the sole purpose of breeding for nutritional high BG accessions in the on-going underutilized legumes crop improvement programme. The availability of data on the contribution this crop could make Bambara groundnut a valuable

source of nutrition in developing regions.BG like other known legumes have the capacity to fix atmospheric Nitrogen and nodulates very well(Gupta et al., 2015). In recent discussion, green bean (used as vegetables), soybean(used for oil extraction) and alfalfa (reputed for soil nutrition and animal feed) are regarded as pulses(Asif et al., 2013; Duranti and Gius, 1997).A very good and affordable means of obtaining protein is with the use of soybean (Considine et al., 2017; Foyer et al., 2016; Vollmann, 2016). Popular pulses referred to as orphan, neglected or underutilized legumes are Bambara groundnut, African yam bean, winged bean, adzuki, jack, Kersting's groundnut and marama beans amongst others(Cullis and Kunert, 2017; Padulosi et al., 2013).Due to reduced planting activities (Foyer et al., 2016) and global utilization(Miller et al., 2017), they do not make any significant impact to nationalnutrition intake when compared to staples such as rice(FAO, 2017) despite playing significant roles in rural populations where they provide income, affordable and nutritious meals(Asif et al., 2013; Graham and Vance, 2003; Heim et al., 2017; Mudryj et al., 2014). Various efforts are on-going to reverse these trends. They also support improvement in various human health status such as those who affected by high sugar level (Becerra-Tomás et al., 2018), hypertension (Polak et al., 2015), issues about obesity as well as diet and weight management (McCrory et al., 2010) to fat reductioninterventions(Bazzano et al., 2011). BG seeds have been used and processed in several ways for human and animal use as described byMubaiwa et al. (2017)in the arid area of Zimbabwe, Southern Africa. In many West African countries such as Benin Republic, freshly harvested BG seeds are boiled and consumed with or without pepper. Flour can also be produced from the seeds when milled and put to several uses (Kaptso et al., 2015). From the fresh seeds, delicious steamed-paste popularly called moi moi or okpa (sold as porridge in most communities in white polyethylene)are usually produced and widely common insome parts of Nigeria (Okpuzor et al., 2010). In Nigeria, especially in the East and some part of Northern Nigeria, BG isan important food crop and can be used in traditional preparationof various meals. The seeds are sometimes roasted, boiled or milled and used in preparing soup(Adu-Dapaah and Sangwan, 2004) or chewed with palm kernel. Animals also benefit by the use of BG seed for feeding of livestock and poultry(Anchirinah et al., 2001).

According to Mayes et al. (2019),flour from BG seeds can be used to make several confectionaries. BG derived milkcompetes well to that from soybean with BG milk containingmore than 19% protein compared with about less than 5% protein in the soy milk(Addo et al., 2016; Adu-Dapaah and Sangwan, 2004)and preferredby many due to its flavour andcolour (Goli et al., 1991). In Asia for instance and particularly in Indonesia, afried BG snack made from the immature seed is highlysought after. Known as 'Kacang Bogor', which are sold in high prices in supermarkets and even in specialistfood shops in Europe. In appearance, it is similar to dryroasted peanut, but is drier (less oil) and more strongly flavored. Nutritionistshave developed several recipesusing BG as substitutes for other ingredients inIndonesia, Malaysia(Crops For the Future) and recently at the Food and Nutrition Sciences Laboratory, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria(Feldman et al., 2019).Overall, the population need to be aware that adequate nutritional values are inherent in the consumption of the crop.

Materials and Methods

Materials

The BG accessions used for this study were obtained from the Genebank, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and grounded into flour before sample analysis. Samples were analyzed chemically according to the official methods of analysis described by the Association of Official Analytical Chemist (A.O.A.C., 18TH EDITION, 2005). All analysis was carried out in duplicate.

Proximate analysis:

Crude protein determination (AOAC Official Method 988.05)

The crude protein in the sample were determined by the routine semi-micro Kjeldahl, procedure/technique. This consists of three techniques of analysis namely Digestion, Distillation and Titration.

*Apparatus***:** Analytical Balance, Digestion tubes, Digestion Block Heaters, 50ml Burette, 5ml Pipette, 10ml Pipette, 10ml Measuring Cylinder, 100ml Beakers, Fume Cupboard.

*Reagents***:** ConC.H_2SO_4, 0.01NHCL, 40% (W/V) NaOH, 2% Boric Acid Solution, Methyl Red – Bromocresol green mixed indicator, Kjeldahl Catalyst tablet.

Digestion

Some 0.5g of each finely ground dried sample was weighed carefully into the Kjeldahl digestion tubes to ensure that all sample materials got to the bottom of the tubes. To this were added 1 Kjeldahl catalyst tablet and 10ml of ConC. H_2SO_4. These were set in the appropriate hole of the Digestion Block Heaters in a fume cupboard. The digestion was left on for 4 hours, after which a clear colourless solution was left in the tube. The digest was cooled and carefully transferred into 100ml volumetric flask, thoroughly rinsing the digestion tube with distilled water and the flask was made up to mark with distilled water.

Distillation

The 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 all 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.

Determination

Some 5ml portion of the digest above was pipetted into the body of the apparatus via the small funnel aperture. To this was added 5ml of 40% (W/V) NaOH through the same opening with the 5ml pipette. The mixture was steam-distilled for 2 minutes into a 50ml conical flask containing 10ml 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.

Titration

The green colour solution obtained was then titrated against 0.01N HCL contained in a 50ml 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 x Normality of HCL used x 4

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

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

Weight of sample digested in milligram x 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 x 6.25.

Crude fat or ether extract determination (AOAC official method 2003.06)

*Apparatus***:** Soxhlet apparatus and accessories, oven, desicator and analytical balance.

*Reagents***:** Petroleum spirit or Ether (40° – 60°C b.pt).

Determination: 1gm of each dried sample was weighed into fat free extraction thimble and pug lightly with cotton wool. The thimble was placed in the extractor and fitted up with reflux condenser and a 250ml soxhlet flask which has been previously dried in the oven, cooled in the desicator and weighed. The soxhlet flask is then filled to $^3/_4$ of its volume with petroleum ether (b.pt. 40º – 60ºC), and the soxhlet flask. Extractor plus condenser set was placed on the heater. The heater was put on for six hours with constant running water from the tap for condensation of ether vapour. The set is constantly watched for ether leaks and the heat source is adjusted appropriately for the ether to boil gently. The Ether is left to siphon over several times say over at least 10 – 12 times until it is short of siphoning. It is after this is noticed that any ether content of the extractor is carefully drained into the ether stock bottle. The thimble containing sample was then removed and dried on a clock glass on the bench top. The extractor, flask and condenser are replaced and the distillation continues until the flask is practically dry. The flask which now contains the fat or oil is detached, its exterior cleaned and dried to a constant weight in the oven. If the initial weight of dry soxhlet flask is Wo and the final weight of oven dried flask + oil/fat is W_1, percentage fat/oil is obtained by the formula:

$$\frac{W_1 - Wo}{\text{Wt. of Sample taken}} \times \frac{100}{1}$$

Dry matter and moisture determination (AOAC official method 967.08)

*Apparatus***:** Oven, crucibles, dessicator and balance.

*Reagents***:** Silical gel, grease.

*Determination***:** 2g of the sample was weighed into a previously weighed crucible. The crucible plus sample taken was then transferred into the oven set at 100C to dry to a constant weight for 24 hours overnight. At the end of the 24 hours, the crucible plus sample was removed from the oven and transferred to dessicator, cooled for ten minutes and weighed.

If the weight of empty crucible is Wo

weight of crucible plus sample is W_1

weight of crucible plus oven-dried sample W_3

$$\text{(\% DM) \% Dry Matter} = \frac{W_3 - Wo}{W_1 - Wo} \times \frac{100}{1}$$

$$\text{\% Moisture} = \frac{W_1 - W_3}{W_1 - Wo} \times \frac{100}{1}$$

or % Moisture = 100 – % DM.

Determination of ash (AOAC official method 942.05)

*Apparatus***:** Porcelain Crucibles, a Dessicator, Analytical Balances and a Furnace.

*Determination***:** 2.0gm of the sample were weighed into a porcelain crucible. This was transferred into the muffle furnace set at 550ºC and left for about 4 hours. About this time, it had turned to white ash. The crucible and its content were cooled to about 100ºC in air, then room temperature in a dessicator and weighed. This was done in duplicate. The percentage ash was calculated from the formula below:

$$\text{Ash content} = \text{wt. of ash} \times \frac{100}{\text{original wt of sample}}$$

Fibre determination (AOAC 958.06)

*Apparatus***:** Heating mantle, crucibles, furnace, sieve cloth, fibre flask, funnel, analytical weighing balance, a dessicator.

*Reagents***:** 0.255N H_2SO_4, 0.313N NaOH and Acetone.

*Determination***:** 2.0gm of the sample was accurately into the fibre flask and 100ml of 0.255N H_2SO_4 added. The mixture was heated under reflux for 1 hour with the heating mantle. The hot mixture was filtered through a fibre sieve cloth. The filterate obtained was thrown off and the residue was returned to the fibre flask to which 100ml of (0.313N NaOH) was added and heated under reflux for another 1 hour. The mixture was filtered through a fibre sieve cloth and 10ml of acetone added to dissolve any organic constituent. The residue was washed with about 50ml hot water on the sieve cloth before it was finally transferred into the crucible. The crucible and the residue were oven-dried at 105ºC overnight to drive off moisture. The oven-dried crucible containing the residue was cooled in a dessicator and later weighed to obtain the weight W_1. The crucible with weight W_1 was transferred to the muffle furnace for Ashing at 550°C for 4 hours.

The crucible containing white or grey ash (free of carbonaceous material) was cooled in the dessicator and weight to obtain W_2. The difference $W_1 - W_2$ gives the weight of fibre. The percentage fibre was obtained by the formula:

$$\% \text{ Fiber} = \frac{W_1 - W_2}{\text{wt. of sample}} \times 100$$

Carbohydrate by difference determination

The NFE determined by difference. This was done by subtracting SUM of (Moisture % + % Crude Protein + % Ether Extract + % Crude Fibre + % Ash) from 100 i.e. (100 – (% M + % CP + % EE + % CF + % Ash).

Antinutrient analysis: Spectrophotometric method as described by Arntfield et al. (1985)was used in determining the alkaloids while saponins and flavonoids were determined according to Association of Official Analytical Chemist standard referenced procedures(Chemists, 1990).

Statistical analysis: Statistical Analysis Software (SAS, 9.4)was used in data analysis. Result was recorded in duplicates for all determinations and the results expressed as mean± standard error (SE).Significance of the differences was defined as $p<0.05$ for ANOVA. Thedifferences in mean were compared using the Duncan's new Multiple Range test (Duncan, 1955).

Table 1: Passport data of selected BG accessions obtained from the IITA genebank

Accession name	No of seeds	Weight (g)	Accession number	Country of origin	Digital object identifier
TVSu-246	100	56.45	246	Gambia	10.18730/FN7J
TVSu-1518	100	60.62	1518	Not reported	10.18730/GSX8
TVSu-1570	100	53.98	1570	Not reported	10.18730/GVAG
TVSu-1630	100	72.37	1630	Togo	10.18730/GX51
TVSu-1649	100	50.67	1649	Senegal	10.18730/GXQK

Results

Proximate Composition

Tables 2 shows the results obtained from the present study which indicated highly significant ($P < 0.0001$) proximate composition which when compared to Table 3 also related BG's proximate composition with other known crops. Protein content varied from 21.13 % in TVSU-1518 to 19.75% in TVSU-1570. Crude fat content ranged from 5.91 (TVSU-1630) to 5.54 % (TVSU-1649); crude fibre contains 4.19 % in TVSU-1649 and 4.52 % in TVSU-1630. Ash values ranged from 3.81% in TVSU-1518 to 3.97% in both TVSU-1630 and TVSU-246; moisture content varies from 9.745% in TVSU-1630 to 9.93% in TVSU-1649, dry matter ranges from 90.12% in both TVSU-1570 and TVSU-246 to 90.25% in TVSU-1630 and carbohydrate varies from 45.05% in TVSU-1518 to 43.25%. The phytonutrients such as flavonoids, alkaloids and saponin. Flavonoids values varies from 0.0094% (TVSU-1630) to 0.00505 (TVSU-1649); alkaloids; 0.2135% (TVSU-1518) and 0.182% (TVSU-1649) and saponin 0.387% (TVSU-1630) to 0.3325 % (TVSU-1649) (Table 3).

Accession	CP ± SE	C fat ± SE	C fibre ± SE	Ash ± SE	M ± SE	DM ± SE	CHO ± SE
TVSU-1518	21.13 ± 0.0082^{b}	5.81 ± 0.0057^{b}	4.47 ± 0.008^{b}	3.81 ± 0.0035^{d}	9.82 ± 0.0065^{c}	90.185 ± 0.0065^{b}	45.05 ± 0.0083^{b}
TVSU-1570	19.93 ± 0.0082^{d}	5.69 ± 0.0057^{d}	4.25 ± 0.008^{d}	3.80 ± 0.0035^{e}	9.88 ± 0.0065^{b}	90.125 ± 0.0065^{c}	43.53 ± 0.0083^{d}
TVSU-1630	21.33 ± 0.0082^{a}	5.91 ± 0.0057^{a}	4.52 ± 0.008^{a}	3.97 ± 0.0035^{a}	9.75± 0.0065^{d}	90.255 ± 0.0065^{a}	45.47 ± 0.0083^{a}
TVSU-1649	19.74 ± 0.0082^{e}	5.54 ± 0.0057^{e}	4.19 ± 0.008^{e}	3.87 ± 0.0035^{c}	9.93 ± 0.0065^{a}	90.07 ± 0.0065^{d}	43.26 ± 0.0083^{e}
TVSU-246	20.12 ± 0.0082^{c}	5.77 ± 0.0057^{c}	4.30 ± 0.008^{c}	3.91 ± 0.0035^{b}	9.88 ± 0.0065^{b}	90.12 ± 0.0065^{c}	43.98 ± 0.0083^{c}
CV	0.05	0.14	0.27	0.12	0.09	0.01	0.02
F Value	<.0001*	<.0001*	<.0001*	<.0001*	<.0002*	<.0002*	<.0001*

Table 2: Proximate composition (%) of selected Bambara groundnut accessions

Key: CP= Crude protein; C fat=Crude fat; M=Moisture; DM= Dry matter; CHO=Carbohydrate; CV= Coefficient of variation, SE= Standard Error; TVSU=Tropical Vigna sub *Vigna subterranea* * Significant level at $P < 0.0001$. Means with the same subscript along the column are not significantly different (P<0.05).

Table 3: Reported ranges of proximate composition of BG seeds when compared with Soybean, Check pea, Cowpea and Mungbean.

Crop	Carbohydrate (%)	Protein (%)	Total fat (%)	Total dietary fibre (%)
Soybean	26.838	41.762	18.359	13.049
Chickpea	60.981	22.084	5.231	11.684
Cowpea	66.758	27.167	2.420	3.655
Mungbean	65.987	21.029	4.278	8.706
Bambara groundnut	64.433	23.589	6.510	5.495

Data adapted from Halimi et al. (2019)

Table 4: Means and Standard Error of selected BG anti-nutrients

Accession	Flavonoids ± SE	Alkaloids ± SE	Saponin ± SE
TVSU-1518	0.00825±0.00006124[b]	0.2135±0.00027386[b]	0.377±0.00035355[b]
TVSU-1570	0.0057±0.00006124[d]	0.1895±0.00027386[d]	0.3435±0.00035355[d]
TVSU-1630	0.0094±0.00006124[a]	0.248±0.00027386[a]	0.387±0.00035355[a]
TVSU-1649	0.00505±0.00006124[e]	0.182±0.00027386[e]	0.3325±0.00035355[e]
TVSU-246	0.00705±0.00006124[c]	0.1925±0.00027386[c]	0.3605±0.00035355[c]
CV	1.22	0.18	0.13
F Value	<.0001*	<.0001*	<.0001*

Discussion

Carbohydrates, proteins, fat and fibre are often regarded as proximate composition which typically describes the major constituents of any food products analysis(Finglas et al., 2014; Greenfield and Southgate, 2003). The proximate analysis also explained the moisture (or dry matter)as well as ash in a food product which further differs from the macro and micro elements found in any food products. In nature, pulses are reputed to have highlevels of protein (up to about 40 %) and fibre (20% less or more) than commonly consumed cereals and usually low levels of fat (usually less than 10%) when compared with oilseeds (Gepts et al., 2005). Consequently, the amount of proximate are different from pulses or within species due to several factors such as variation due to genetic and environmental interactions (Amarteifio et al., 2010; Medic et al., 2014).Studies have shown that BGcontain greater number of proximate though with low level of fibre(Halimi et al., 2019; Honi et al., 2018; Olaleye et al., 2013; Oyeyinka et al., 2018; Qaku et al., 2020).The proximate composition in BG is close to what has been previously reported for cowpea, mungbean (Table 3). These legumes have benefitted from several crop improvements programmes which BG is still tailed towardsnutritional and food quality improvements (Boukar et al., 2016; Ebert, 2014; Kim et al., 2015; Muñoz-Amatriaín et al., 2017; Shanmugasundaram et al., 2009).

Carbohydrate composition

Carbohydrates play very significant role in human and animal nutrition as a major supplier of energy (Calories) providing mutual support to improve health (Chibbar et al., 2010), and the management of common diseases (Smith et al., 2012; Tosh and Yada, 2010). In this study, the carbohydrate composition ranges from 43.53 % in TVSU-1570 to 45.47 % in TVSU-1630. This is lower when compared to the values of 63.37 % reported by Alhassan et al. (2015); 67.55 % by Tchiotsa et al. (2004)with estimated high proportion of starch proportion up to 60% in BG seeds(Yao et al., 2015).However, the outcome of this study is similar to other previous results (Adebowale et al., 2011; Amarteifio and Moholo, 1998; Annan et al., 2003; Ijarotimi and Olopade, 2009).

Protein

Studies have reported legume seeds considerable less than 40% protein, (Pandey et al., 2016), a multiple of what is obtainable in cereals (Asif et al., 2013).For BG, several research reports indicates its position as a protein rich crop due to the amount (Goudoum et al., 2016; Hillocks et al., 2012; Massawe et al., 2002), above 20% protein level (Boateng et al., 2013; Mubaiwa et al., 2017; Mwale et al., 2007). The result from this current study also corroborates these claims. BG is reported to have huge crude protein unlike other pulses. Globally, BG protein varies from 9.6 % to 30.7 % providing an avenue for crop improvement to a carefully structured breeding system. Should this be successful, the journey to the agricultural transformationof the crop which have started with sole aim of making substantial contribution to reducing malnutrition andfood security(Mayes et al., 2019).In other related studies, the protein composition was higher to those of Abu-Salem and Abou-Arab (2011), 17.70%; Tchiotsa et al. (2004) 18.83 % and Alhassan et al. (2015)18.83%. However, the results obtained in this study is similar to the report by Olaleye et al. (2013)15.2-22.2 %; Amarteifio and Moholo (1998) on BG seedsas well as Chinedu and Nwinyi (2012); Soetan (2017)(26.60%). and Adegboyega et al. (2020)on African yam bean (32.40%) and Adegboyega et al. (2019)on winged bean (31.13-28.43%).

Fatty acids

BG is highly reputed for low level in the amount of fat when compared with soybean and groundnut(Mudryj et al., 2014), and essentially not too suitable for oil production (Asif et al., 2013; Vollmann, 2016). According to Mayes et al. (2019)due to BG's relative similarity in fatty acid structure with cowpea and related family member, there could be an opportunity to change the related vigna family in areas where BG is cultivated.

Crude Fibre

Crude fibre contains 4.19 % in TVSU-1649 and 4.52 % in TVSU-1630 and similar to other previous studies on Bambara groundnut crude fibre constituents(Alhassan et al., 2015; Alozie et al., 2009; Amarteifio and Moholo, 1998; Rocha-Guzmán et al., 2006).

Moisture Content

For most pulses, moisture content ranges between 9-12 % which assures reduction of mkcrobial attack and storage safety thereby improving germplasm shelf life (Sujeetha et al., 2014). In the current study,the moisture content of the BG accessions analyzed were less than 10% and fellwithin the recommended values which implies the seeds can be stored at room temperaturewithout microbial attack for a number of months (Baiyeri et al., 2018). The valuesobtained in this study were less than the results reported byOjuederie and Balogun (2017)for African yam bean (11.3 to 12.6%). Other similar studies on BG confirmed outcome of this current report (Adebowale et al., 2011; Annan et al., 2003; Ijarotimi, 2008; Koné et al., 2011)

Antinutrients composition

Antinutritional factorsin pulses includes but not limited to tannins, phytic acid and saponins(Rochfort and Panozzo, 2007)which reduces premium placed on orphan legume utilization(Soetan and Oyewole, 2009). The antinutrients can reduce protein bioavailability and digestion by over 45 % (Gilani et al., 2012), as well as lowering circulation ofother nutrients (Sandberg, 2002). Their removal is considered abreeding target for most pulses(Wang et al., 2003). The results antinutrientsof the five accessions were shown in figure 1. Flavonoids

ranges from 0.006 % in TVSU-1570 to 0.009 % in TVSU-1630. Alkaloids varies from 0.190 % in TVSU-1570 to 0.248 % in TVSU-1630. Saponins ranges also varies from 0.333 % in TVSU-1649 to 0.387 % in TVSU-1630. These results are similar to the works of Soetan (2017)andMubaiwa et al. (2018). Additional, the accessions had comparable results with previous results on African yam bean byAjibola and Olapade (2016)and were lower than those obtained from (Nwosu, 2013)and these values fall within the permissible limitbased on (Halimi et al., 2019; Ndidi et al., 2014).

Conclusion

BG contains desirable nutritional properties that could support human and animal consumption and may support global dietary diversification, infant weaning and other levels of utilization. Concerted efforts must be made to increase awareness on its nutritional importance for food and income security. Targeted breeding programmes could further assist to eliminate identified antinutrients and increase consumption strategies.

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None

Conflict of Interests

There is no conflict of interest.

References

Abu-Salem, F. M., and Abou-Arab, A. A. (2011). Effect of supplementation of Bambara groundnut (Vigna subterranean L.) flour on the quality of biscuits. *African Journal of Food Science***5**, 376-383.

Addo, J., Amoah, S., Boateng, A., Okyere, H., Adu-Dapaah, H., and Amoa-Owusu, A. (2016). Physical, functional and cooking characteristics of six newly released cowpea (< i> Vignaunguiculata [L] Walp) varieties in Ghana. *Agricultural and Food Science Journal of Ghana***9**, 742-753.

Adebowale, A., Awolala, F., Fetuga, G., Sanni, S., and Adegunwa, M. (2011). Effect of soaking pre-treatments on nutritional composition and functional properties of bambara groundnut (vigna subterranea) flour. *In* "II International Symposium on Underutilized Plant Species: Crops for the Future-Beyond Food Security 979", pp. 139-146.

Adegboyega, T. T., Abberton, M. T., AbdelGadir, A. H., Dianda, M., Maziya-Dixon, B., Oyatomi, O. A., Ofodile, S., and Babalola, O. O. (2019). Nutrient and antinutrient composition of winged bean (Psophocarpus tetragonolobus (L.) DC.) seeds and tubers. *Journal of Food Quality***2019**.

Adegboyega, T. T., Abberton, M. T., AbdelGadir, A. H., Dianda, M., Maziya-Dixon, B., Oyatomi, O. A., Ofodile, S., and Babalola, O. O. (2020). Evaluation of Nutritional and Antinutritional Properties of African Yam Bean (Sphenostylis stenocarpa (Hochst ex. A. Rich.) Harms.) Seeds. *Journal of Food Quality***2020**.

Adu-Dapaah, H., and Sangwan, R. (2004). Improving bambara groundnut productivity using gamma irradiation and in vitro techniques. *African Journal of Biotechnology***3**, 260-265.

Ajibola, G. O., and Olapade, A. A. (2016). Physical, proximate and anti-nutritional composition of African yam bean (Sphenostylis stenocarpa) seeds varieties. *Journal of Food Research***5**, 67.

Alhassan, A., Dangambo, M., and Abdulmumin, T. (2015). Evaluation of the Proximate Contents of Bambara Groundnut Vigna subterranean (L.) Verdc Grown in MadobiLGA, Kano State, Nigeria. *Current Journal of Applied Science and Technology,* 361-365.

Alozie, Y. E., Iyam, M. A., Lawal, O., Udofia, U., and Ani, I. F. (2009). Utilization of Bambara Groundnut Flour blends in bread production. *Journal of Food technology***7**, 111-114.

Amarteifio, J., and Moholo, D. (1998). The chemical composition of four legumes consumed in Botswana. *Journal of Food Composition and Analysis***11**, 329-332.

Amarteifio, J., Tibe, O., and Njogu, R. (2010). The Nutrient Composition Of Bambara Groundnut Landraces (Vigna Subterreanea,(L.) Verdc.) Cultivated In Southern Africa.

Anchirinah, V. M., Yiridoe, E. K., and Bennett-Lartey, S. (2001). Enhancing sustainable production and genetic resource conservation of bambara groundnut: a survey of indigenous agricultural knowledge systems. *Outlook on AGRICULTURE***30**, 281-288.

Annan, N., Plahar, W., and Nti, C. (2003). Dessemination of improved bambara groundnut processing technologies through a new coalition arrangement to enhance rural livelihoods in Northen Ghana. *Tamale Ghana*.

Arntfield, S., Ismond, M., and Murray, E. (1985). The fate of antinutritional factors during the preparation of a fababean protein isolate using a micellization technique. *Canadian Institute of food science and technology journal***18**, 137-143.

Asif, M., Rooney, L. W., Ali, R., and Riaz, M. N. (2013). Application and opportunities of pulses in food system: a review. *Critical reviews in food science and nutrition***53**, 1168-1179.

Baiyeri, S., Uguru, M., Ogbonna, P., Samuel-Baiyeri, C., Okechukwu, R., Kumaga, F., and Amoatey, C. (2018). Evaluation of the nutritional composition ofthe seeds of some selected African yam bean (Sphenostylis stenocarpa Hochst Ex. A. Rich (Harms)) accessions. *Agro-Science***17**, 37-44.

Bazzano, L. A., Thompson, A. M., Tees, M. T., Nguyen, C. H., and Winham, D. M. (2011). Non-soy legume consumption lowers cholesterol levels: a meta-analysis of randomized controlled trials. *Nutrition, metabolism and cardiovascular diseases***21**, 94-103.

Becerra-Tomás, N., Díaz-López, A., Rosique-Esteban, N., Ros, E., Buil-Cosiales, P., Corella, D., Estruch, R., Fitó, M., Serra-Majem, L., and Arós, F. (2018). Legume consumption is inversely associated with type 2 diabetes incidence in adults: A prospective assessment from the PREDIMED study. *Clinical nutrition***37**, 906-913.

Boateng, M., Addo, J., Okyere, H., Berchie, J., and Tetteh, A. (2013). Physicochemical and functional properties of proteinates of two bambara groundnut (Vigna subterranea (L) Verdc.) landraces. *Afr J Food Sci Technol***4**, 64-70.

Boukar, O., Fatokun, C. A., Huynh, B.-L., Roberts, P. A., and Close, T. J. (2016). Genomic tools in cowpea breeding programs: status and perspectives. *Frontiers in plant science***7**, 757.

Chemists, A. o. O. A. (1990). "Official Methods of Analysis: Changes in Official Methods of Analysis Made at the Annual Meeting. Supplement," Association of Official Analytical Chemists.

Chibbar, R. N., Ambigaipalan, P., and Hoover, R. (2010). Molecular diversity in pulse seed starch and complex carbohydrates and its role in human nutrition and health. *Cereal Chemistry***87**, 342-352.

Chinedu, S. N., and Nwinyi, C. O. (2012). Proximate analysis of Sphenostylis stenocarpa and Voadzeia subterranean consumed in South-Eastern Nigeria. *Journal of Agricultural Biotechnology and Sustainable Development***4**, 1-6.

Chivenge, P., Mabhaudhi, T., Modi, A. T., and Mafongoya, P. (2015). The potential role of neglected and underutilised crop species as future crops under water scarce conditions in Sub-Saharan Africa. *International journal of environmental research and public health***12**, 5685-5711.

Considine, M. J., Siddique, K. H., and Foyer, C. H. (2017). Nature's pulse power: legumes, food security and climate change. *Journal of Experimental Botany***68**, 1815-1818.

Cullis, C., and Kunert, K. J. (2017). Unlocking the potential of orphan legumes. *Journal of experimental botany***68**, 1895-1903.

Duncan, D. B. (1955). Multiple range and multiple F tests. *Biometrics***11**, 1-42.

Duranti, M., and Gius, C. (1997). Legume seeds: protein content and nutritional value. *Field Crops Research***53**, 31-45.

Durst, P., and Bayasgalanbat, N. (2014). Promotion of underutilized indigenous food resources for food security and nutrition in Asia and the Pacific. *RAP Publication (FAO) eng no*. *2014/07*.

Ebert, A. W. (2014). Potential of underutilized traditional vegetables and legume crops to contribute to food and nutritional security, income and more sustainable production systems. *Sustainability***6**, 319-335.

FAO (2017). FAOSTAT. Food and Agriculture Data. Food Balance: Food Balance Sheets

Retrieved Date from. http://www.fao.org/faostat/

en/#compare.

Feldman, A., Ho, W. K., Massawe, F., and Mayes, S. (2019). Bambara Groundnut is a Climate-Resilient Crop: How Could a Drought-Tolerant and Nutritious Legume Improve Community Resilience in the Face of Climate Change? *In* "Sustainable Solutions for Food Security", pp. 151-167. Springer.

Finglas, P. M., Berry, R., and Astley, S. (2014). Assessing and improving the quality of food composition databases for nutrition and health applications in Europe: the contribution of EuroFIR. *Advances in Nutrition***5**, 608S-614S.

Foyer, C. H., Lam, H.-M., Nguyen, H. T., Siddique, K. H., Varshney, R. K., Colmer, T. D., Cowling, W., Bramley, H., Mori, T. A., and Hodgson, J. M. (2016). Neglecting legumes has compromised human health and sustainable food production. *Nature plants***2**, 1-10.

Gepts, P., Beavis, W. D., Brummer, E. C., Shoemaker, R. C., Stalker, H. T., Weeden, N. F., and Young, N. D. (2005). Legumes as a model plant family. Genomics for food and feed report of the cross-legume advances through genomics conference. Am Soc Plant Biol.

Gilani, G. S., Xiao, C. W., and Cockell, K. A. (2012). Impact of antinutritional factors in food proteins on the digestibility of protein and the bioavailability of amino acids and on protein quality. *British Journal of Nutrition***108**, S315-S332.

Goli, A., Begemann, F., and Ng, N. (1991). Germplasm diversity in bambara groundnut and prospects for crop improvement. *In* "Crop Genetic Resources of Africa ", pp. pp. 195-202. IITA, IBPGR, UNEP, CNR.

Goudoum, A., NGAMO TINKEU, L. S., Madou, C., Djakissam, W., and Mbofung, C. M. (2016). Variation of some chemical and functional properties of Bambara groundnut (Voandzeia Subterranean L. Thouars) during sort time storage. *Food Science and Technology***36**, 290-295.

Graham, P. H., and Vance, C. P. (2003). Legumes: importance and constraints to greater use. *Plant physiology***131**, 872-877.

Greenfield, H., and Southgate, D. A. (2003). "Food composition data: production, management, and use," Food & Agriculture Org.

Gupta, R. K., Gangoliya, S. S., and Singh, N. K. (2015). Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains. *Journal of food science and technology***52**, 676-684.

Halimi, R. A., Barkla, B. J., Mayes, S., and King, G. J. (2019). The potential of the underutilized pulse bambara groundnut (Vigna subterranea (L.) Verdc.) for nutritional food security. *Journal of Food Composition and Analysis***77**, 47-59.

Heim, H., Vieira, E., Polo, L., Lima, N., Silva, G., Linde, G., Colauto, N., and Schuster, I. (2017). Internal amplification control of PCR for the Glu1-Dx5 allele in wheat. *Genetics and Molecular Research***16**.

Hillocks, R., Bennett, C., and Mponda, O. (2012). Bambara nut: A review of utilisation, market potential and crop improvement. *African Crop Science Journal***20**.

Honi, B., Mukisa, I. M., and Mongi, R. J. (2018). Proximate composition, provitamin A retention, and shelf life of extruded orange□fleshed sweet potato and bambara groundnut□based snacks. *Journal of Food Processing and Preservation***42**, e13415.

Ijarotimi, O. (2008). Nutritional composition, microbial status, functional and sensory properties of infant diets formulated from cooking banana fruits (Musa spp, ABB genome) and fermented bambara groundnut (Vigna subterranean L. Verdc) seeds. *Nutrition & Food Science*.

Ijarotimi, O., and Olopade, A. (2009). Determination of amino Acid content and protein quality of complementary food produced from locally available food materials in ondo state, Nigeria. *Malaysian Journal of Nutrition***15**.

Kaptso, K. G., Njintang, Y. N., Nguemtchouin, M. M. G., Scher, J., Hounhouigan, J., and Mbofung, C. M. (2015). Physicochemical and micro-structural properties of flours, starch and proteins from two varieties of legumes: bambara groundnut (Vigna subterranea). *Journal of food science and technology***52**, 4915-4924.

Kim, S. K., Nair, R. M., Lee, J., and Lee, S.-H. (2015). Genomic resources in mungbean for future breeding programs. *Frontiers in plant science***6**, 626.

Koné, M., Paice, A. G., and Touré, Y. (2011). Bambara groundnut [Vigna subterranea (L.) Verdc.(Fabaceae)] usage in human health. *In* "Nuts and Seeds in Health and Disease Prevention", pp. 189-196. Elsevier.

Massawe, F., Dickinson, M., Roberts, J., and Azam-Ali, S. (2002). Genetic diversity in bambara groundnut (Vigna subterranea (L.) Verdc) landraces revealed by AFLP markers. *Genome***45**, 1175-1180.

Mayes, S., Ho, W. K., Chai, H. H., Gao, X., Kundy, A. C., Mateva, K. I., Zahrulakmal, M., Hahiree, M. K. I. M., Kendabie, P., and Licea, L. C. (2019). Bambara groundnut: an exemplar underutilised legume for resilience under climate change. *Planta*, 1-18.

McCrory, M. A., Hamaker, B. R., Lovejoy, J. C., and Eichelsdoerfer, P. E. (2010). Pulse consumption, satiety, and weight management. *Advances in Nutrition***1**, 17-30.

Medic, J., Atkinson, C., and Hurburgh, C. R. (2014). Current knowledge in soybean composition. *Journal of the American oil chemists' society***91**, 363-384.

Miller, V., Mente, A., Dehghan, M., Rangarajan, S., Zhang, X., Swaminathan, S., Dagenais, G., Gupta, R., Mohan, V., and Lear, S. (2017). Fruit, vegetable, and legume intake, and cardiovascular disease and deaths in 18 countries (PURE): a prospective cohort study. *The Lancet***390**, 2037-2049.

Mubaiwa, J., Fogliano, V., Chidewe, C., and Linnemann, A. R. (2017). Hard-to-cook phenomenon in bambara groundnut (Vigna subterranea (L.) Verdc.) processing: Options to improve its role in providing food security. *Food Reviews International***33**, 167-194.

Mubaiwa, J., Fogliano, V., Chidewe, C., and Linnemann, A. R. (2018). Bambara groundnut (Vigna subterranea (L.) Verdc.) flour: A functional ingredient to favour the use of an unexploited sustainable protein source. *PloS one***13**, e0205776.

Mudryj, A. N., Yu, N., and Aukema, H. M. (2014). Nutritional and health benefits of pulses. *Applied Physiology, Nutrition, and Metabolism***39**, 1197-1204.

Muñoz□Amatriaín, M., Mirebrahim, H., Xu, P., Wanamaker, S. I., Luo, M., Alhakami, H., Alpert, M., Atokple, I., Batieno, B. J., and Boukar, O. (2017). Genome resources for climate□resilient cowpea, an essential crop for food security. *The Plant Journal***89**, 1042-1054.

Mwale, S., Azam-Ali, S., and Massawe, F. (2007). Growth and development of bambara groundnut (Vigna subterranea) in response to soil moisture: 1. Dry matter and yield. *European journal of agronomy***26**, 345-353.

Ndidi, U. S., Ndidi, C. U., Olagunju, A., Muhammad, A., Billy, F. G., and Okpe, O. (2014). Proximate, antinutrients and mineral composition of raw and processed (Boiled and Roasted) Sphenostylis stenocarpa seeds from Southern Kaduna, Northwest Nigeria. *International Scholarly Research Notices***2014**.

Nwosu, J. N. (2013). Evaluation of the proximate composition and antinutritional properties of African yam bean (Sphenostylis sternocarpa) using malting treatment. *International Journal of Basic and Applied Sciences***2**, 157-169.

Ojuederie, O., and Balogun, M. (2017). Genetic variation in nutritional properties of

African yam bean Sphenostylis stenocarps

(Hochst ex. A. Rich. Harms) accessions. *Nigerian Journal of Agriculture, Food and Environment***13**, 180-187.

Okpuzor, J., Ogbunugafor, H., Okafor, U., and Sofidiya, M. (2010). Identification of protein types in bambara nut seeds: perspectives for dietary protein supply in developing countries. *Excli Journal***9**, 17.

Olaleye, A., Adeyeye, E., and Adesina, A. (2013). Chemical composition of bambara groundnut (V. subterranea L. Verdc) seed parts. *Bangladesh Journal of Scientific and Industrial Research***48**, 167-178.

Oyeyinka, S. A., Tijani, T. S., Oyeyinka, A. T., Arise, A. K., Balogun, M. A., Kolawole, F. L., Obalowu, M. A., and Joseph, J. K. (2018). Value added snacks produced from Bambara groundnut (Vigna subterranea) paste or flour. *LWT***88**, 126-131.

Padulosi, S., Thompson, J., and Rudebjer, P. (2013). Fighting poverty, hunger and malnutrition with neglected and underutilized species: needs, challenges and the way forward. Bioversity International.

Pandey, M. K., Roorkiwal, M., Singh, V. K., Ramalingam, A., Kudapa, H., Thudi, M., Chitikineni, A., Rathore, A., and Varshney, R. K. (2016). Emerging genomic tools for legume breeding: current status and future prospects. *Frontiers in Plant Science***7**, 455.

Polak, R., Phillips, E. M., and Campbell, A. (2015). Legumes: Health benefits and culinary approaches to increase intake. *Clinical Diabetes***33**, 198-205.

Qaku, X. W., Adetunji, A., and Dlamini, B. C. (2020). Fermentability and nutritional characteristics of sorghum Mahewu supplemented with Bambara groundnut. *Journal of Food Science***85**, 1661-1667.

Rocha-Guzmán, N., Gallegos-Infante, J., González-Laredo, R., Castillo-Antonio, P., Delgado-Licon, E., and Ibarra-Perez, F. (2006). Functional properties of three common bean (Phaseolus vulgaris) cultivars stored under accelerated conditions followed by extrusion. *LWT-Food science and technology***39**, 6-10.

Rochfort, S., and Panozzo, J. (2007). Phytochemicals for health, the role of pulses. *Journal of agricultural and food chemistry***55**, 7981-7994.

Sandberg, A.-S. (2002). Bioavailability of minerals in legumes. *British Journal of Nutrition***88**, 281-285.

Shanmugasundaram, S., Keatinge, J., and Hughes, J. d. A. (2009). The mungbean transformation: Diversifying crops, defeating malnutrition. *Proven Successes in Agricultural Development*, 381.

Smith, C. E., Mollard, R. C., Luhovyy, B. L., and Anderson, G. H. (2012). The effect of yellow pea protein and fibre on short-term food intake, subjective appetite and glycaemic response in healthy young men. *British Journal of Nutrition***108**, S74-S80.

Soetan, K., and Oyewole, O. (2009). The need for adequate processing to reduce the anti-nutritional factors in plants used as human foods and animal feeds: A review. *African Journal of food science***3**, 223-232.

Soetan, K. O. (2017). Preliminary studies on the nutritional and antinutritional constituents of six accessions od African yam bean (Sphenostylis stenocarpa), an underutilized legueme *Journal of Applied Research on Children***8**, 1-7.

Stamp, P., Messmer, R., and Walter, A. (2012). Competitive underutilized crops will depend on the state funding of breeding programmes: an opinion on the example of Europe. *Plant breeding***131**, 461-464.

Sujeetha, J. A. R., Abirami, C. K., and Alagusundaram, K. (2014). Biointensive safe storage methods for pulses. *Journal of Biopesticides***7**, 98.

Tchiotsa, D. T., Fokou, E., Kansci, G., and Mbiapo, F. (2004). Chemical composition and functional properties of flours of four cultivars of bambara groundnut (Vigna subterranean L. Verdc). *Journal of the Cameroon Academy of Sciences***4**, 345-352.

Tosh, S. M., and Yada, S. (2010). Dietary fibres in pulse seeds and fractions: Characterization, functional attributes, and applications. *Food Research International***43**, 450-460.

Vollmann, J. (2016). Soybean versus other food grain legumes: A critical appraisal of the United Nations International Year of Pulses 2016: Sojabohne versus Körnerleguminosen: Eine kritische Würdigung des Internationalen Jahres der Körnerleguminosen 2016 der Vereinten Nationen. *Die Bodenkultur: Journal of Land Management, Food and Environment***67**, 17-24.

Wang, T. L., Domoney, C., Hedley, C. L., Casey, R., and Grusak, M. A. (2003). Can we improve the nutritional quality of legume seeds? *Plant Physiology***131**, 886-891.

Yao, D. N., Kouassi, K. N., Erba, D., Scazzina, F., Pellegrini, N., and Casiraghi, M. C. (2015). Nutritive evaluation of the bambara groundnut Ci12 landrace [Vigna subterranea (L.) Verdc.(Fabaceae)] produced in côte d'Ivoire. *International Journal of Molecular Sciences***16**, 21428-21441.