PRELIMINARY STUDIES ON THE NUTRITIONAL AND ANTINUTRITIONAL CONSTITUENTS OF SIX ACCESSIONS OF AFRICAN YAM BEAN (*SPHENOSTYLIS STENOCARPA*), AN UNDERUTILIZED LEGUME

Kehinde O. Soetan
Department of Veterinary Physiology and Biochemistry, Faculty of Veterinary Medicine,
University of Ibadan, Ibadan, Nigeria
E-mail: kehinde.soetan@gmail.com

Abstract
African Yam Bean (AYB) (Sphenostylis stenocarpa) is an underutilized legume in Nigeria and Africa. This study evaluates the proximate analysis, mineral constituents, and antinutritional factors (ANFs) of six accessions of AYB, (TSS 10, TSS 57, TSS 84, TSS 95, TSS 96 and TSS 111) from the International Institute of Tropical Agriculture (I.I.T.A), Ibadan, Nigeria. All the analyses were done using standard methods. Statistical analysis was done using one-way ANOVA. Results of proximate analysis show that the following AYB accessions had the highest data; crude protein 26.60±0.14% (TSS 95), crude fat 3.10±0.14% (TSS 96), crude fibre 4.40±0.00% (TSS 10), ash 3.10±0.14% (TSS 95), gross energy 4.558±0.01Kcal/g (TSS 95), dry matter 94.75±0.7 (TSS 57) and moisture 6.36±0.61(TSS 10). Minerals results show that the following AYB accessions had the highest figures: calcium 0.289±0.00% (TSS 96); magnesium 0.161±0.00% (TSS 10); potassium 0.720±0.00% (TSS 95); phosphorus 0.206 ± 0.00% (TSS 95); sodium 591.88±0.00mg/g (TSS 57); iron 89.98±0.00mg/g (TSS 84) and copper 16.10±0.00mg/g (TSS 84). The following accessions recorded the highest values of ANFs: tannin 0.009±0.00% (TSS 84); saponin 0.139±0.01% (TSS 84); oxalate 0.116±0.00% (TSS 84); trypsin inhibitor 15.92±0.26% (TSS 57); phytate 0.2000±0.00% (TSS 111) and alkaloids 15.015±0.01% (TSS 57). This study concludes that AYB is rich in crude protein and crude fibre, however, the ANFs need adequate processing for adequate utilization as human foods and animal feeds.

Keywords: African yam bean, nutrition, anti-nutritional factors, animal feeds

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1. INTRODUCTION

African yam bean (AYB) (*Sphenostylis stenocarpa)* is an underutilized legume grown in West Africa and it belongs to the Family *Fabaceae* (Oshodi *et al*. 1997). AYB is a tuberous legume producing both tubers and seeds (Adewale and Aremu, 2013; Adewale, 2014) and it is reported to be the most important and prominently used tuberous legume in Africa (Adewale, 2010; Adewale and Odoh, 2013). AYB can thrive under different climatic, geographical and edaphic ecologies and Nigeria holds a prominent position for AYB production in Africa (Adewale and Odoh, 2013).
African yam bean is well ranked among the neglected crops and it can reduce the problem of food insecurity in Nigeria and Africa (Adewale *et al*. 2012). AYB is classified as an underutilized legume because of lack of adequate information on its nutritional components (Adebowale *et al*. 2009). Balogun and Fetuga, (1986) reported that the lack of information on the composition and utilization of tropical plants is the major problem limiting their utilization rather than shortage. There are varying cultural and regional preferences to AYB consumption. Rural producers of bean pudding (moinmoin) and bean cake (akara) sometimes replace cowpea with African yam bean (Enujiugha *et al*. 2012). The nutritional, genetic, medicinal and other potentials of AYB have been recognized but it has not received adequate research attention. Proteins from other plants are often neglected, apart from the use of soybeans. Adewale (2010) reported that AYB would be a good alternative source of protein for livestocks and poultry feeds. Underutilized legumes contribute immensely to food security in a many ways, due to increasing demand for plant proteins in lieu of expensive animal protein (Adebowale *et al*. 2009). There is the need to intensify research efforts aimed

at propagation and utilization of AYB, an underutilized and underexploited legume, so as to enhance food security because of the continous competitions between humans and animals for plant protein sources. The aim of this study is to evaluate some basic nutritional and antinutritional constituents of African yam bean, an important but under-utilized legume of Africa.

2. MATERIALS AND METHODS

Source of the African Yam Beans

The source of the African yam beans (*Sphenostylis stenocarpa*) is the Genetic Resources Unit of the International Institute of Tropical Agriculture (I.I.T.A.), Ibadan, Oyo State, Nigeria.

Proximate Analysis: %Ash, % Crude Fibre, % Crude Protein, % Crude Fat, % Dry Matter, % Moisture and Gross Energy (Kcal/g) were determined according to (AOAC, 2000).

Minerals Constituents: %K, %Ca and Na (mg/g) were determined by flame photometry. %Mg, %P, Fe (mg/g), Cu (mg/g) were determined using atomic absorption spectroscopy.

Quantification of the Antinutritional Factors

Trypsin inhibitor activity of the samples were analysed by the method of Liener (1979). The total oxalates were quantified according to the procedure of Fasset (1996). Phytates were determined based on the method of Maga (1983). Tannins were analysed using the method of Dawra *et al*. (1988). Saponins were quantified according to the procedure of Brunner (1984). Alkaloids were determined using the procedure of Henry (1973). The detailed procedures for the antinutritional factors have been reported by (Soetan, 2012).

Statistical Analysis

Statistical differences among mean values were determined using one-way ANOVA and pairwise comparison was done between means using Turkey's Multiple Comparisons Test.

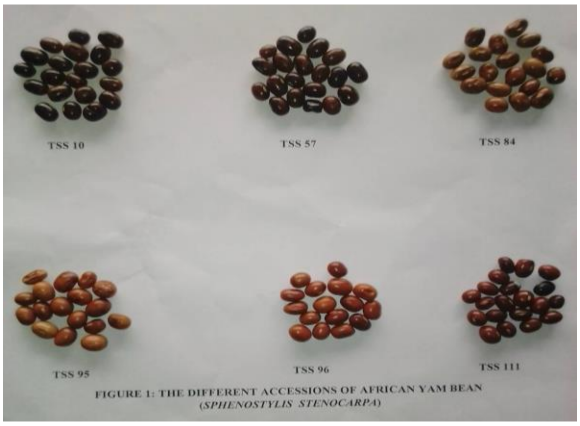

FIGURE 1: THE DIFFERENT ACCESSIONS OF AFRICAN YAM BEAN (*SPHENOSTYLIS STENOCARPA*)

3. RESULTS AND DISCUSSION

The results for the proximate analysis, minerals constituents and the antinutritional factors are shown in Tables 1, 2 and 3 respectively.

The crude protein of the six accessions of African yam bean in this study ranged from 23.00 ± 0.14% (TSS 111) to 26.15 ± 0.21% (TSS 10). This result is similar to that of Kay, (1987) who reported crude protein of (24-28%) for AYB seeds, and of Adeyeye *et al*. (1999), who reported the crude protein values ranging from 20.18 ± 0.02% to 25.78 ± 0.05% for the AYB cultivars they studied. Proteins play a vital role in organoleptic properties of foods/feeds (Aremu *et al*. 2006). Proteins boost immune system and play a key role in cell division and growth (Okeke and Elekwa, 2006; Okeke *et al*. 2008). The crude fat of the six accessions of African yam bean under study ranged from 1.91 ± 0.12% (TSS 10) to 3.10 ± 0.14% (TSS 96). Kay, (1987) reported crude fat of (1.5–2%) for AYB while Adeyeye *et al*. (1999) recorded crude fat values ranging from 1.93 ± 0.05% to 10.18 ± 0.04%. These values were within the range reported for the six accessions of AYB in this study.

Table 1: PROXIMATE ANALYSIS OF SIX ACCESIONS OF AFRICAN YAM BEAN (*Sphenostylis stenocarpa*)

AYB Accession	% Crude Protein	% Crude Fat	% Crude Fibre	% Ash	Gross Energy Kcal/g	% Dry Matter	% Moisture
TSS 10	26.15 ± 0.212[ef]	1.91 ± 0.127[cef]	4.40 ± 0.000[cd]	2.50 ± 0.141	4.508 ± 0.000[c]	93.64 ± 0.615	6.36±0.615
TSS 57	23.75 ± 0.354[def]	2.40 ± 0.1141[d]	3.05 ± 0.071[abc]	2.75 ± 0.071[c]	4.517 ± 0.021	94.75 ± 0.778	5.25±0.778
TSS 84	24.63 ± 0.672	2.60 ± 0.141[f]	3.98 ± 0.035[ad]	2.40 ± 0.000[bc]	4.532 ± 0.000[b]	94.63 ± 0.240	5.37±0.240
TSS 95	26.60 ± 0.141[ad]	3.00 ± 0.141[ac]	3.70 ± 0.000[b]	3.10 ± 0.141[ab]	4.558 ± 0.014[ac]	94.25 ± 0.488	5.75±0.488
TSS 96	25.98 ± 0.601[be]	3.10 ± 0.141[bde]	3.38 ± 0.067	2.45 ± 0.212	4.541 ± 0.028	93.82 ± 0.240	6.18±0.240
TSS 111	23.00 ± 0.141[abc]	2.10 ± 0.141[ab]	3.30 ± 0.000	2.45 ± 0.071	4.495 ± 0.007[ab]	94.20 ± 0.141	5.80±0.141

Values recorded as mean ± SD (standard deviation)
Any two mean values with similar alphabetical letters (a-f) as superscript are significantly different at $p<0.05$.

Table 2: MINERAL CONSTITUENTS OF SIX ACCESIONS OF AFRICAN YAM BEAN (*Sphenostylis stenocarpa*)

AYB Accession	Calcium %	Magnesium %	Potassium %	Phosphorus %	Sodium Mg/g	Iron Mg/g	Copper Mg/g
TSS 10	0.212 ± 0.0007[ad]	0.1611 ± 0.0002[a]	0.3216 ± 0.0001[a]	0.1839 ± 0.0000[ce]	451.91 ± 0.0002[a]	56.99 ± 0.0000[a]	9.90 ± 0.0028[a]
TSS 57	0.237 ± 0.0005[bd]	0.1219 ± 0.0002[a]	0.5436 ± 0.0001[a]	0.1751 ± 0.0001[bg]	591.88 ± 0.0004[a]	60.99 ± 0.0007[a]	10.10 ± 0.0000[a]
TSS 84	0.274 ± 0.0001[cd]	0.1518 ± 0.0001[a]	0.6926 ± 0.0000[a]	0.1902 ± 0.0000[fg]	482.90 ± 0.0001[a]	89.98 ± 0.0014[a]	16.10 ± 0.0000[a]
TSS 95	0.233 ± 0.0003[ac]	0.1559 ± 0.0002[a]	0.7207 ± 0.0004[a]	0.2062 ± 0.0001[abcd]	355.93 ± 0.0006[a]	80.98 ± 0.0007[a]	14.10 ± 0.0007[a]
TSS 96	0.289 ± 0.0002[ad]	0.1444 ±0.0000[a]	0.6284 ± 0.0006[a]	0.1698 ± 0.0001[aef]	531.89 ± 0.0001[a]	57.99 ± 0.0028[a]	9.70 ± 0.0000[a]
TSS 111	0.264 ± 0.0005[ab]	0.1307 ± 0.0001[a]	0.5894 ± 0.0002[a]	0.1819 ± 0.0001[a]	545.89 ± 0.0001[a]	67.78 ± 0.2871[a]	9.99 ± 0.0057[a]

Values recorded as mean ± SD (standard deviation)
Any two mean values with similar alphabetical letters (a-g) as superscript are significantly different at $p<0.05$

Table 3: ANTINUTRITIONAL FACTORS OF SIX ACCESIONS OF AFRICAN YAM BEAN (*Sphenostylis stenocarpa*)

AYB Accession	Tannin %	Saponin %	Oxalate %	Trypsin inhibitor mg/g	Phytate %	Alkaloids %
TSS 10	0.0061 ± 0.0004[b]	0.1195 ± 0.0021[cgh]	0.0885 ± 0.0021[bcg]	11.9205 ± 0.5586[bde]	0.1420 ± 0.0042[bef]	13.71 ± 0.0191[a]
TSS 57	0.0079 ± 0.0010	0.1315 ± 0.0021[dg]	0.1105 ± 0.0021[ce]	15.9210 ± 0.2673[ae]	0.1895 ± 0.0050[ef]	15.015 ± 0.0099[a]
TSS 84	0.0096 ± 0.0006[ab]	0.1390 ± 0.0014[efh]	0.1160 ± 0.0028[dfg]	9.8360 ± 0.1188[cde]	0.1995 ± 0.0035[de]	12.581 ± 0.0226[a]
TSS 95	0.0063 ± 0.0004[a]	0.1190 ± 0.0028[ade]	0.0785 ± 0.0007[acd]	12.0110 ± 0.0297[ac]	0.1385 ± 0.0021[acd]	13.8675 ± 0.0842[a]
TSS 96	0.0074 ± 0.0008	0.1250 ± 0.0014[bf]	0.0920 ± 0.0042[aef]	13.7470 ± 0.0791[ad]	0.1740 ± 0.0057[ae]	13.3125 ± 0.0205[a]
TSS 111	0.0084 ± 0.0001	0.1345 ± 0.0021[abc]	0.1150 ± 0.0014[ab]	10.1460 ± 0.0763[ab]	0.2000 ± 0.0014[ab]	12.0595 ± 0.0148[a]

Values recorded as mean ± SD (standard deviation)
Any two mean values with similar alphabetical letters (a-f) as superscript are significantly different at $p<0.05$.

Fats are needed for insulation and protection of vital organs and for hormone production. Lipids provide very good sources of energy and aids in transport of fat soluble vitamin, insulates and protects internal tissue and contribute to important cell processes (Pamela *et al.* 2005).
The crude fibre ranged from 3.05 ± 0.07% (TSS 57) to 4.40 ± 0.00% (TSS 10). This result is lower than that of Kay, (1987), who recorded crude fibre ranges of (5.2-5.7%) and higher than that of Adeyeye *et al*. (1999), who reported crude fibre values from 1.61 ± 0.02% to 2.38 ± 0.00%. Dietary fibres slow down rate of glucose absorption into bloodstream and reduce risk of hyperglycemia (Okeke and Adaku, 2009). Dietary fibres stimulate normal gastric mobility, increases digestibility and prevents constipation. Dietary fibres has numerous medical importance like lowering blood cholesterol, maintain blood sugar level and helps in reducing body weight (Soetan and Olaiya, 2013).
The ash content of the different accessions of AYB in this work ranged from 2.40 ± 0.00% (TSS 84) to 3.10 ± 0.14% (TSS 95). This result is similar to that of Kay, (1987) who reported ash ranging from (2.8-3.2%) in AYB, and that of Adeyeye *et al*. (1999), recording ash ranging from 2.06 ± 0.03% to 2.36 ± 0.05% for AYB. Ash content of legumes is an indication of their mineral content (Musa *et al*. 2010). Dietary ash is useful in maintaining acid-base balance of the body system. The gross energy ranged from 4.495 ± 0.00 Kcal/g (TSS 111) to 4.558 ± 0.01 Kcal/g (TSS 95). Kcal: Measure of the energy content of food/feeds. This shows that AYB is a good source of energy for foods/feeds and is needed for oxidation of fats (Omoyeni and Adeyeye, 2009). Carbohydrates are major source of energy for man/animals (Okeke *et al.* 2008). The dry matter content of the AYB accessions ranged from 93.64 ± 0.61% (TSS 10) to 94.75 ± 0.77% (TSS 57). Dry matter is important in nutritional analysis because it gives the amount of nutrients available to an animal for production and health (NASEM, 2001).
The moisture content of the AYB accessions in this study ranged from 5.25 ± 0.77% (TSS 57) to 6.36 ± 0.61% (TSS 10). These moisture values were within the ranges reported by Adeyeye *et al*. (1999), 3.20 ± 0.03% to 7.10 ± 0.02% for the AYB they studied. Moisture (Water) is a universal solvent that dissolves other substances, carries nutrients and various materials round the body for optimal function of organs (Okeke and Adaku, 2009). Moisture contents are valuable in preservation of food materials. The lower the moisture contents of food material, the higher is its keeping quality (Ajayi and Adedire, 2007).
Calcium ranged from 0.212 ± 0.00% (TSS 10) to 0.289 ± 0.00% (TSS 96). Calcium functions in bone formation and blood coagulation (Seidu *et al*. 2014). Magnesium ranged from 0.1219 ± 0.00% (TSS 57) to 0.1611 ± 0.00% (TSS 10). Magnesium is an active component of several enzymes and thymine pyrophosphate is a cofactor (Murray *et al*. 2000). Magnesium regulates diverse biochemical reactions in the body, including protein synthesis, muscle and nerve functions, blood glucose control and blood pressure regulation. It also keeps bones strong and heart rhythm steady (Murray *et al*. 2000). Potassium ranged from 0.3216 ± 0.00% (TSS 10) to 0.7207 ± 0.00% (TSS 95). Potassium is the principal cation in intracellular fluid. It functions in acid-base balance, regulation of osmotic pressure, conduction of nerve impulse, muscle contraction particularly the cardiac muscle, and cell membrane function (Murray *et al*. 2000). Potassium is a building block of body tissue.
Phosphorus ranged from 0.1698 ± 0.00% (TSS 96) to 0.2062 ± 0.00% (TSS 95). Phosphorus regulates essential biochemical processes like regulation of enzyme activity, formation skeletal structures (bones and teeth) and in neuromuscular irritability (Kalita *et al*. 2007). Sodium ranged from 355.93 ± 0.00 mg/g (TSS 95) to 591.88 ± 0.00 mg/g (TSS 57). Sodium is the principal extracellular cation and is used for acid-base balance and osmoregulation (Crook, 2006). Sodium stimulates cell proliferation, protein synthesis and increase cell mass. (Twum *et al*. 2015). Iron ranged from 56.99 ±

0.00 mg/g (TSS 10) to 89.98 ± 0.00 mg/g (TSS 84). Iron aids in transport of oxygen in red blood cells and in muscles. It is an important constituent of succinate dehydrogenase and is also a part of the haeme of haemoglobin (Hb), myoglobin and the cytochromes (Antia *et al.* 2006). Copper ranged from 9.70 ± 0.00 mg/g (TSS 96) to 16.10 ± 0.00 mg/g (TSS 84). Copper acts as an antioxidant by protecting the brain and nervous system. Although, copper is an essential metal, it can also produce toxic effects when the metal intake is excessively high (Murray *et al*. 2000).

Tannins ranged from 0.0061 ± 0.00% (TSS 10) to 0.0096 ± 0.00% (TSS 84). Tannins form insoluble (inactive complexes) with dietary proteins and reduces their biological value, causing reduced weight gain, reduced palatability and poor feed efficiency (Emiola *et al*. 2007; Omoyeni and Adeyeye, 2009; Akande *et al*. 2010). Saponins ranged from 0.1190 ± 0.00% (TSS 95) to 0.1390 ± 0.00% (TSS 84). Saponins reduce uptake of certain nutrients (cholesterol) in the gut causing hypocholesterolaemia (Umaru *et al.* 2007). It causes haemolysis of red blood cells of rats (Akande *et al*. 2010).

Oxalates ranged from 0.0785 ± 0.00% (TSS 95) to 0.1160 ± 0.00% (TSS 84). Oxalates complex with calcium forming calcium crystals which get deposited as stones and are associated with blockage of renal tubules (Banso and Adeyemo, 2007). Oxalates also prevent the body's absorption of calcium ions by forming insoluble calcium-oxalate complex (Adeniyi *et al*. 2009). Phytates ranged from 0.1385 ± 0.00% (TSS 95) to 0.2000 ± 0.00% (TSS 111). Phytates form stable complexes with mineral ions like Ca, Fe, Mg and Zn and lower their bioavailability for intestinal absorption (Walter *et al*. 2002; Banso and Adeyemo, 2007).

Trypsin inhibitors ranged from 9.8360 ± 0.118 mg/g (TSS 84) to 15.9210 ± 0.267 mg/g (TSS 57). TI in large quantities disrupt digestive process and may lead to undesirable physiological reactions. Trypsin inhibitors cause hypertrophy and hyperplasia of the pancreas (Ologhobo *et al*. 2003). Alkaloids ranged from 12.0595 ± 0.01% (TSS 111) to 15.015 ± 0.00% (TSS 57). Alkaloids can cause gastrointestinal and neuronal disorders (Tadele, 2015).

There are limitations to the full utilization of AYB. Some of them are the hard seed coat (Adewale, 2014), presence of anti-nutritional factors (ANFs) in the grains which reduce AYB digestibility (Emiola, 2011). The Antinutritional Factors (ANFs) in AYB cause flatulence, especially when AYB is not well cooked (Azeke *et al*. 2005). Stomach cramps, diarrhea and dizziness are caused as a result of improperly processed AYB (Azeke *et al*. 2005). However, there are methods for processing AYB so as to reduce the ANFs. They are breeding of AYB with thinner seed coat and less ANF (Adewale, 2014), adequate pre-cooking treatments such as lactic-acid fermentation (Azeke *et al*. 2005; Betche *et al.* 2005), soaking, boiling/cooking, baking, autoclaving, dehulling, germination, alkaline treatment reduces or eliminates ANFs (Rehman and Shah, 2005; Udensi *et al*. 2005; Soetan and Oyewole, 2009). Heat processing, aqeous and dry heating (toasting) increases the digestible nutrients in AYB available to young chicks (Emiola, 2011). Phytate-degrading enzymes also reduce phytic acid content and increase bioavailability of minerals (Hidvegi and Lasztity, 2003).

4. CONCLUSIONS

The study concluded that all the accessions of African Yam Beans (AYB) are rich in crude proteins, crude fibres and some minerals like potassium, sodium, iron and copper. However, the antinutritional factors in AYB should be adequately processed to reduce their levels for optimization of the AYB as human foods and as sources of animal feeds.

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