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Nutritional potential of nine underexploited legumes in Southwest Nigeria

[123*]Ade-Omowaye, B.I.O,, [1]Tucker, G.A. and [3]Smetanska, I.

[1]*Division of Nutritional Sciences, School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough, Leics LE12 5RD, UK*
[2]*Department of Food Science and Engineering, Ladoke Akintola University of Technology, PMB 4000, Ogbomoso, Nigeria*
[3]*Department of Plant Food Processing, University of Applied Science Weihenstephan- Triesdorf, Steingruber Str. 2, Weidenbach 91746, Germany*

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Abstract

There is increasing interest in finding new food sources to alleviate malnutrition in developing countries. Nine little known legumes (*Mallotus subulatus* (white variety), *Cassia hirsutta*, *Canavalia ensiformis*, *Vignea subterranean* (checkered variety), *Vigna racemosa*, *Mallotus subulatus* (red variety), *Vignea subterranean* (cream variety), *Sphenostylis sterocarpa* and *Cajanus cajan* in the South western Nigeria were studied to highlight their nutritional significance. The proximate composition, fatty acid composition, total phenolic content, antioxidant activity and amino acid profile of the legumes were evaluated using standard methods in the literature. Significant ($p<0.05$) variations existed among the legumes with respect to their proximate composition, fatty acid profile, total phenolic content, antioxidant activity and amino acid composition. *Mallotus subulatus* (red variety) rated highest in protein, *Vigna racemosa* and *Sphenostylis sterocarpa* had high starch contents, while *Cajanus cajan* rated best in dietary fibre (non starch polysaccharides) among the legumes tested. The total unsaturated fatty acids were much higher than the total saturated fatty acids in all the legumes. Linoleic acid (C18:2) was the most abundant polyunsaturated fatty acid (PUFA) identified, at varying levels, in all the legumes studied. All the legumes had varying levels of linolenic acid (C18:3). *Sphenostylis sterocarpa* had the least essential fatty acid contents (32.73%) and the highest (57.25%) was found in *Cassia hirsutta*. *Cajanus cajan* had the highest total phenolic content (293.23 mg/100g) and also rated best in its antioxidant activity. The percentage total essential amino acids were between 45.53 and 48.44 which are considered adequate for ideal protein foods. All the legumes were good sources of total phenolics and possess moderate to high antioxidant activities suggesting that these lesser known legumes are promising commodities in combating food and nutrition insecurity in Nigeria and other countries where they are known and consumed.

Introduction

The nutritional value of legumes is gaining considerable interest globally because of the demand for healthy foods. Consumed regularly, legumes contribute to a healthy diet, and would help to control metabolic diseases such as diabetes mellitus (Nestel *et al*., 2004). In general, legumes are sources of complex carbohydrates, protein and dietary fibre, have significant amounts of vitamins and minerals, and high energetic value (Almeida- Costa *et al*., 2006). Legumes are an affordable source of protein and have the advantage of having low glycemic index, and significant antioxidant activity (Granito *et al.*, 2008). Legumes have been demonstrated to help manage both cholesterol and blood glucose (Olmedilla-Alonso *et al*., 2013). Legume consumption has been associated with a lower risk of developing several chronic diseases, mainly cardiovascular diseases, but also obesity and type 2 diabetes (Schröder, 2007; Sievenpiper *et al*., 2009). Legumes contain a range of nutrients and bioactive components that may explain their protective effect. Legumes are an important food crop in Nigeria and all over the world because they provide a vast number of the population with a cheap alternate source of protein. Cowpea, groundnut and soybeans are the major legumes consumed in Nigeria. Bean production increased from 2.14 million hectares in 1994/1995 to 3.47 million hectares in 2005/2006 (Akinyele, 2009). In order to secure food supply for the Nigerian population, research efforts are being directed towards the study of underexploited legumes that are well adapted to adverse environmental conditions and highly resistant to disease and pests. For instance, Fasoyiro *et al.* (2006) evaluated and reported the proximate, mineral and anti-nutritional

*Corresponding author.
Email: *adeomowaye@yahoo.com, bioade-omowaye@lautech.edu.ng*
Tel: 00234-8034-947-340

factors found in four minor grain legumes found in Nigeria. The crude protein contents in the legumes was found to range between 22 and 37 % suggesting the potentials of these underutilized legumes as protein sources for the Nigerian populace. Oboh (2006) also evaluated the antioxidant properties of some commonly consumed and underutilized tropical legumes in Nigeria. It is documented that there are thousands of underutilized crops which have desirable nutritional profiles compared to major crops and have the potential to alleviate 'hidden hunger' of the poor communities (Nah and Chau, 2010). The aim of this present study was to evaluate the nutritional profile of some underutilized legumes in Nigeria to provide enlightenment on their potential as food sources for a wider populace in the country.

Materials And Methods

Materials

Freshly harvested whole legume seeds were purchased from peasant farmers in Atisbo and Saki West Local Government areas of Oyo State in Nigeria. The nine (9) legume seed samples studied in this work were: *Mallotus subulatus* (white variety); *Cassia hirsutta*; *Canavalia ensiformis*; *Vignea subterranean* (checkered variety); *Vigna racemosa*; *Mallotus subulatus* (red variety); *Vignea subterranean* (cream variety); *Sphenostylis sterocarpa* and *Cajanus cajan.*

Sample preparation

The legumes were manually cleaned to remove foreign material, immature and damaged seeds. The legumes were milled using a coffee grinder and sieved to obtain a flour fraction of less than 699 µm. The milled samples were sealed in polyethylene bags and stored at -14^{0}C for two months.

Proximate composition

Chemical analysis to determine proximate composition of each sample was carried out using standard procedures. A Thermo Flash Nitrogen Analyser (Flash EA1112 Nitrogen Analyzer) was used to determine the protein content of the samples according to the Dumas method (AOAC, 1990). A 50 mg sample was sealed in a tin capsule and combusted at approximately 1800°C. Combustion gases were passed into a reduction reactor (at 680°C containing reduced copper) where nitrogen oxides are converted to elemental nitrogen. Carbon dioxide, sulphur dioxide and water were removed via filters of soda lime, magnesium perchlorate and a molecular sieve. The effluent stream was passed through a nitrogen separation column (50°C) and into a thermal conductivity detector. Quantitation was achieved with Eager 300 software using an L-aspartic acid standard. Total protein was determined using the N*6.25 conversion factor (Igbal *et al.*, 2006). The fat content was determined using a Soxtherm Gerhardt rapid Soxhlet extraction system. The extraction was performed using the Soxhlet method with petroleum ether (AOAC, 1990). Moisture was determined from sample weight loss after oven drying at 105 °C for 5 h (AOAC 1990). Non-starch polysaccharides (NSP) were determined by the method of Englyst and Cummings (1988). Starch was measured using a starch Assay kit- HK (SA-20) following the manufacturer's protocol (Sigma-Aldrich, St. Louis, MO, USA).

Preparation of fatty acid methyl ester (FAMEs)

Oil extracted with soxhlet extractor using petroleum ether was dissolved in chloroform to a concentration of 10 mg/mL (i.e. 0.01 g lipid mixed with 1.0 ml chloroform). For every 1.0 ml of sample, 200 µL of trimethylsulfonium hydroxide (TMSH) was added. After waiting for at least 10 min (to allow the fatty acids to convert to methyl esters), 2.0 µL was injected into the GC/MS for analysis.

Determination of fatty acid composition

Fatty acid analysis on GC/MS was performed using a CTS Analytics PAL system auto sampler and a DSQ and TRACE GC Ultra (Thermo Electron Corporation). The sample was injected into the SSL injector (split flow 50 mL min^{-1}) at a temperature of 250˚C. Compounds were separated using a polyethylene glycol (BP20 ID 0.22 mm × 25 m) gas chromatography column (Milton Keynes, UK) with 30 mL min-1 nitrogen. Oven temperatures were controlled at 120˚C (1 min) then ramped (5˚C min-1) to 260˚C. Identification of chromatographic peaks was carried out by comparison of their retention times using appropriate fatty acid methyl esters standards (Merck, Sigma) (Carvalho and Malcata, 2005).

Determination of total phenolic content and antioxidant capacity

0ne gram of the legume flour sample was homogenized with 50 mL acetone and then centrifuged for 10 min at 2,000×g. Supernatant was collected and kept in an ice bath. Total phenolic content was assayed using the method described by Slinkard and Singleton (1977). Total phenolic content was expressed in terms of milligrammes of gallic acid per 100 g of dry weight (mg gallic acid 100 g^{-1} DW). Antioxidant capacity of the sample was determined using ferric reducing antioxidant potential

(FRAP) assay according to the method described by Benzie and Strain (1996). Antioxidant capacity was expressed as millimoles of Trolox equivalents per gram of dry weight (millimoles TE g^{-1} DW).

Statistical analysis

Statistical analysis of all data of the two replicates was done with Statistical Analysis System (SAS) (version 9.2). Analysis of variance (ANOVA) procedure was used to determine statistical significant difference ($p<0.05$) in all data. Means were separated with least significant difference using Fisher's procedure.

Results and Discussion

Proximate composition of the legumes

The proximate composition of all the studied legumes is summarized in Table 1.

Table 1. Proximate composition (%, dry basis) of the underutilized legumes[a]

Sample code	Protein	Starch	NSP	Fat	MC
A	21.05c	23.70bcd	19.08cd	0.46f	11.33de
B	21.30c	25.24bc	20.20c	1.25e	12.23abc
C	20.82c	28.41ab	13.11e	2.20d	11.88abcd
D	18.26f	13.02f	12.96e	6.14c	11.66bcd
E	19.84d	29.06a	19.05cd	1.36e	12.64a
F	23.86a	16.62e	24.70b	0.39f	12.35ab
G	18.94e	13.26f	12.76e	6.67b	11.73bcd
H	19.53d	28.08ab	14.70e	1.39e	12.04abcd
I	22.06b	23.66bcd	37.24a	1.08e	12.73a

[a] Each value is an average of two replications
Means with the same letter along the same column are not significantly different ($p>0.05$).
A=*Mallotus subulatus* (white variety); B= *Cassia hirsutta*; C= *Canavalia ensiformis*; D= *Vignea subterranean* (checkered variety); E= *Vigna racemosa*; F= *Mallotus subulatus* (red variety); G= *Vignea subterranean* (cream variety); H= *Sphenostylis sterocarpa*; I= *Cajanus cajan*

Crude protein content in the underutilized legumes ranged between 18.3 and 24% in sample D, *Vignea subterranean* (checkered variety) and sample F, *Mallotus subulatus* (red variety) respectively. The lowest protein contents corresponded to the two varieties of *Vignea subterranean* (D, G) whilst *Mallotus subulatus* (red variety) had the highest protein value, close to 24% of dry matter which was significantly different ($p<0.05$) from other samples. Significant differences were not observed among samples A, B and C. In the same vein, the difference in the protein values between samples E and H was not significant. Legumes are known to be good sources of protein which this study has also confirmed. This observation agrees with the findings of Almeida Costa *et al.* (2006) who reported protein in pea, common bean, chickpea and lentil to be in the range of 18.5 to 24%. The results are also close to those reported by Bravo *et al.* (1999) for lesser known pulses in India which were in the range of 20.7 to 25%. Mamiro *et al*. (2011) reported protein contents in local and improved cowpea varieties (a legume widely consumed in Nigeria and several other parts of the world) to be in the range of 22-26% suggesting the potential of these lesser known legumes as alternative sources of protein for the seemingly increasing population in Nigeria. The similar protein content might suggest a comparable nutritional value for these underexploited legumes in terms of protein digestibility, in-depth studies of this are underway.

Starch content varied between 13.02 and 29.06%. *Vigna racemosa* (E), *Canavalia ensiformis* (C), and *Sphenostylis sterocarpa* (H) had the highest starch contents of all the nine legumes studied (around 29%) reflecting no significant difference ($p<0.05$) among the samples. The two varieties of the *Vignea subterranean* (D, G) had the least starch content of around 13 % which were not different statistically. All others were above 23% except for *Mallotus subulatus* (red variety, F). Total starch has been reported to be 31.8% in chickpeas and 39.9% in green gram (Bravo *et al.* 1999). A range of 24 to 37% starch was reported for wrinkled pea and 32 to 48% in cowpea indicating these underexploited legumes as promising commodities in the human diet (Zhou *et al*., 2013). Siddhuraju and Becker (2005) reported 28% starch content in mucuna beans. Extremely low starch values in the range of 0.2 to 3.9% have been reported for some legumes such as soybean and lupine seed.

The non-starch polysaccharides (NSP) constituents of the legume seeds varied significantly ($p<0.05$) from 12.8 to 32.7%. *Canavalia ensiformis* was the richest source of NSP, followed by *Mallotus subulatus* (red variety, F), *Cassia hirsutta*, *Mallotus subulatus* (white variety) and *Sphenostylis sterocarpa*. *Vignea subterranean* (checkered variety), *Vignea subterranean* (cream variety) and *Canavalia ensiformis* were significant sources of NSP as they contained more than 12 %. Fibre contents of 10.4 to 17.2 % has been reported for different varieties of cowpeas (Mamiro *et al*., 2011), while total dietary fibre in some legumes in India ranged between 18.5 and 30.9% and a range of 1.2 to 25.6% was reported elsewhere for various legumes (Bravo *et al.* 1999; Zhou *et al.,* 2013). Growing evidence indicates the potential health benefits of legume bean fiber and

Table 2. Fatty acids compositions (g/kg) of the nine underutilized legumes in Nigeria

	Sample code								
Fatty acids	A	B	C	D	E	F	G	H	I
C14:0	0.52a	0.27bc	0.45ab	0.17c	0.40ab	0.36abc	0.27bc	0.40ab	0.30bc
C16:0	24.61a	22.14b	19.54d	22.23b	19.87cd	24.90a	21.09bc	9.89cd	21.59b
C18:0	6.33bcd	5.57d	2.98e	7.51ab	3.21e	5.69cd	7.80a	3.85e	5.88cd
C18:1	13.17cd	9.96d	35.01a	19.26b	34.59a	9.67d	17.01bc	34.40a	10.21d
C18:2	33.48c	50.11a	29.81cd	40.34b	29.62cd	31.72c	43.06b	27.04d	49.69a
C20:0	1.00d	1.29bc	1.07d	1.95a	1.03d	1.26c	2.04a	1.23c	1.43b
C20:1	0.31cd	0.22de	1.17ab	0.36c	1.15b	0.30cd	0.31cd	1.27a	0.25de
C18:3	13.26b	5.50c	5.04cd	3.06de	4.92cd	15.70a	2.61e	4.84cde	4.66cde
C22:0	1.42d	1.17d	1.95c	3.53a	1.73c	2.37b	3.30a	2.22b	1.26d
C24:0	2.11bc	0.92e	1.98c	1.24d	1.87c	3.48a	1.03de	2.27b	0.94e
% TSFA	37.40	32.27	28.24	36.75	28.56	39.87	36.06	30.65	32.63
%TUFA	62.60	67.73	71.76	63.25	71.44	60.13	63.94	69.35	67.37
%MUFA	13.69	10.25	35.37	19.33	35.16	10.13	17.27	35.32	10.61
%PUFA	48.59	57.25	35.21	43.56	35.11	49.69	46.36	32.73	56.49

Means with the same letter along the same row are not significantly different ($p>0.05$). A=*Mallotus subulatus* (white variety); B= *Cassia hirsutta*; C= *Canavalia ensiformis*; D= *Vignea subterranean* (checkered variety); E= *Vigna racemosa*; F= *Mallotus subulatus* (red variety); G= *Vignea subterranean* (cream variety); H= *Sphenostylis sterocarpa*; I= *Cajanus cajan*.

other dietary fibers. These advantageous effects may include, but are not limited to, an increase in fecal bulk and fecal moisture, reduction of plasma cholesterol level, improved GI, and reduced risk of colon cancer (Nwokolo, 1996). This observation further suggests the potential food value of these lesser known legumes which if included in the diet could lower the risk of certain diseases and minimize food insecurity rampart in developing nations as Nigeria.

There were significant ($p<0.05$) variations in the fat contents of the legume samples. Generally the samples had very low fat, less than 2% of the dry matter, except for the two varieties of *Vignea subterranean* that were comparatively rich in fat (6 - 7% d.m.). Samples B, E, H and I were not significantly different ($p<0.05$) in their fat contents. This agrees with previous reports that legumes are not good sources of fat except the oilseeds such as groundnut and soybean (Iqbal *et al*., 2006; Bravo *et al*., 1999).

The moisture contents were in the range of 11.3 to 12.7%, typical of dry seeds. No much difference ($p<0.05$) was observed in the moisture contents of the legumes. For instance, samples B, C, E, F, H and I were not significantly different from one another. The generally low moisture content of the legumes suggests relatively long shelf life of the commodities. Based on the components of the legumes the following classifications could be deduced: high protein/high fibre (samples A, B, E, F and I); high protein/low fibre (samples C, D, G and H); high fat/low starch (samples D and F); low fat/high starch (samples A, B, C, E, H and I) and low fat/low starch (F).

Fatty acid composition of the legumes

There were significant ($p<0.05$) variations in the fatty acid profile of all the legumes studied (Table 2). It was evident that the total saturated fatty acids were lower than the total unsaturated fatty acids in all the legumes. The total saturated fatty acids were observed to range from 28.24 to 39.87% in *Canavalia ensiformis* and *Mallotus subulatus* (red variety), respectively. *Mallotus subulatus* (red variety), *Mallotus subulatus* (white variety), *Vignea subterranean* (checkered variety) and *Vignea subterranean* (cream variety) were found to have the greatest total saturated fatty acids (39.87, 37.40, 36.75 and 36.06%, respectively). The levels of total unsaturated fatty acids ranged from 60.13% in *Mallotus subulatus* (red variety) to 71.76% in *Canavalia ensiformis.* The major monounsaturated fatty acid (MUFA) present in all the legumes was oleic acid (C18:1) which was particularly high in *Canavalia ensiformis, Vigna racemosa* and *Sphenostylis sterocarpa.* The most abundant polyunsaturated fatty acid (PUFA) identified in all the legumes studied was linoleic acid (C18:2). It was noticeably higher in *Cassia hirsutta, Cajanus cajan* and the two varieties of *Vignea subterranean,* cream and checkered, (50.11, 49.69, 43.06, 40.34 g/kg, respectively). The differences ($p<0.05$) between samples I and B, A and F, C and E, D and G were not significant. Interestingly, all the legumes had varying levels of linolenic acid (C18:3). The two varieties of *Mallotus subulatus* were exceptionally rich in this fatty acid with the red variety having

15.70 while the white variety had 13.26 g/kg. All other legumes had concentrations between 2.61 in *Vignea subterranean* (cream variety) and 5.04 g/kg in *Canavalia ensiformis.* The information contained in Table 2 shows that *Sphenostylis sterocarpa* had the least total essential fatty acids (PUFA) at 32.73% and the highest was 57.25% found in *Cassia hirsutta.* All other legumes studied had their PUFA above 40% except *Canavalia ensiformis* and *Vigna racemosa* with around 35%. The results are similar to those observed in some legumes by Ryan *et al.* (2007).

The literature provides compelling evidence for the health benefit of n-3 PUFA consumption not only on the metabolic syndrome, cardiovascular risks, and associated comorbidities but also on other conditions such as neuroinflammatory and neurodegenerative diseases (Molendi-Coste *et al.*, 2011). PUFA (n-3) has been reported to be the most potent anti-inflammatory effector and inflammation is at the base of many chronic diseases, including coronary heart disease, diabetes, arthritis, cancer and mental health, indicating that dietary intake of omega-3 fatty acids may prevent the development of many diseases (Hussein, 2013). Linoleic and α–linolenic acids are the most important essential fatty acids needed for physiological functions, growth, and body maintenance (Singh, 2005). These underutilized legumes if consumed in substantial quantity will participate well in these functions. The considerably lower total saturated fatty acids than PUFA in all the lesser known legumes studied in this work points to the health significance of these legumes in the human diet.

Total phenolic content and the antioxidant activities of the legumes

Variations in the levels of the total phenolics and the antioxidant activities in all the nine underutilized legumes studied (Table 3). The result revealed that *Cajanus cajan* had the highest total phenolic content (293.23 mg/100g), while the lowest content was exhibited by *Vignea subterranean* (cream variety) (68 mg/100g). Other legume samples with relatively high contents were *Sphenostylis sterocarpa*, *Canavalia ensiformis*, *Mallotus subulatus* (red variety) and *Vignea subterranean* (checkered variety) with 288.68, 281.64, 255.27 and 170.95 mg/100g, respectively. These values are lower than those reported (3.12–6.69 g/100 g DM) for some wild Indian legumes (Vadivel and Biesalski, 2012). The values are however higher than those reported (9.7 to 12.6 mg/100g) by Gharachorloo *et al*. (2013) for four pulses. The values are also higher than total phenolics (100-200 mg/100 g) reported for some vegetables grouped

Table 3. Total polyphenolics and antioxidant activities of the nine underutilized legumes

Sample	Total Polyphenols (mg/100g)	Antioxidant activity mmolTE/100g
A	70.95g	0.55g
B	91.64f	0.39i
C	281.64c	0.70c
D	170.95e	0.88b
E	80.05g	0.45h
F	255.27d	0.66e
G	68.00h	0.56f
H	288.68b	0.67d
I	293.23a	1.00a

Means with the same letter along the same column are not significantly different (p>0.05).
A=*Mallotus subulatus* (white variety); B= *Cassia hirsutta*; C= *Canavalia ensiformis*; D= *Vignea subterranean* (checkered variety); E= *Vigna racemosa*; F= *Mallotus subulatus* (red variety); G= *Vignea subterranean* (cream variety); H= *Sphenostylis sterocarpa*; I= *Cajanus cajan*

under medium antioxidant activity commodities (Kaur and Kapoor, 2002). Oboh (2006) reported a similar observation for *Cajanus cajan* (brown) with a high total phenol content of 120 mg/100g and 70 mg/100g for *Sphenostylis sterocarpa.* Various reports have shown that the quantity of phenolic compounds in seed samples is influenced by soil, environmental conditions, genotype (cultivar/variety), agronomic practices (irrigation, fertilization and pest management), maturity level at harvest and post-harvest storage, which might explain the differences in the values obtained for similar legumes studied elsewhere (Vadivel *et al.*, 2011). Evidence abounds that plant phenolics are highly effective free radical scavengers and antioxidants signifying the potential of these underutilized legumes as promising food commodities in human diet. Epidemiological studies revealed a strong correlation between the consumption of natural food products high in phenols with low incidence of cancer, coronary heart disease and atherosclerosis (Randhir *et al*. 2004; Alothman *et al.* 2009).

The antioxidant activity ranged between 0.39 and 1.00 mmolTE/100g in *Cassia hirsutta* and *Cajanus cajan*, respectively. Interestingly the sample with the highest total phenolic content had the highest antioxidant power but the sample with the lowest phenolic content had 0.45 mmolTE/100g. All the legumes generally exhibited relatively high antioxidant power as reflected in the values of their antioxidant activities. However, it was observed that *Vignea subterranean* (checkered variety), *Canavalia ensiformis*, *Sphenostylis sterocarpa* and *Mallotus subulatus* (red variety) had relatively higher activities (0.88, 0.70, 0.67 and 0.66 mmolTE/100g, respectively) than the remaining evaluated legume

Table 4. Amino acid composition (g/kg) of the nine underutilized legumes

Amino Acid	A	B	C	D	E	F	G	H	I
Cyst	4.26i	5.06g	6.78a	4.73h	6.29c	5.21f	5.43e	6.43b	5.47d
Asp	26.29b	20.85i	23.49c	21.13h	22.17e	27.78a	22.13f	21.75g	22.55d
Meth[a]	2.54g	2.63c	2.74a	2.58d	2.56f	2.57e	2.57e	2.46h	2.65b
Thr[a]	9.29b	7.70f	8.59c	6.62h	8.12e	9.72a	7.26g	8.12e	8.25d
Ser	13.70b	10.31h	12.72c	10.04i	11.86e	14.78a	11.00g	12.05d	11.42f
Glu	27.32i	40.07b	29.57e	30.62d	28.30f	27.87g	31.98c	27.46h	43.31a
Gly	8.35e	7.53g	9.24a	7.05i	8.79b	8.49d	7.37h	8.55c	7.85f
Ala	9.35d	9.46c	9.51b	8.15h	8.97e	9.46c	8.52g	8.75f	9.72a
Val[a]	11.63a	9.52e	11.38c	9.04f	10.31d	11.60b	8.45i	8.96g	8.67h
Ile[a]	11.05b	8.27e	9.76c	7.97f	8.85d	11.07a	7.36i	7.72g	7.71h
Leu[a]	17.90b	16.08e	17.06c	14.96i	15.90f	18.24a	15.21g	15.07h	16.48d
Tyr	6.87e	5.20h	8.10a	5.45g	7.85c	7.67d	4.99i	7.90b	5.52f
Phe[a]	13.09d	20.88b	12.94e	10.79h	12.14f	13.41c	10.73i	11.33g	22.19a
Lys[a]	14.33g	14.46f	17.40a	13.41i	16.22b	14.56e	13.77h	15.31c	14.77d
His[a]	6.14g	8.08d	8.56b	5.95i	8.92a	6.44f	6.10h	8.49c	7.93e
Arg[a]	12.71f	13.18d	11.83g	12.96e	10.46h	14.40a	13.19c	9.74i	13.51b
Pro	8.89g	9.34f	10.05c	8.65h	9.59e	9.34f	9.85d	10.09b	11.44a

[a] Essential Amino Acids; Means with the same letter along the same row are not significantly different ($p>0.05$). A=*Mallotus subulatus* (white variety); B= *Cassia hirsutta*; C= *Canavalia ensiformis*; D= *Vignea subterranean* (checkered variety); E= *Vigna racemosa*; F= *Mallotus subulatus* (red variety); G= *Vignea subterranean* (cream variety); H= *Sphenostylis sterocarpa*; I= *Cajanus cajan*

samples. The result corresponds with previous studies that legumes are good sources of total phenolics and possess considerable antioxidant activity (Xu and Chang, 2008; Oboh, 2006). The result shows low correlation (r = 0.690) between total phenolics and antioxidant activity which agrees with previous observations by different researchers. No correlation was found between scavenging activity and total phenolic content in lupin genotypes and cocoa beans (Oomah *et al*., 2006; Othman *et al*., 2007). Maheshu *et al*. (2013) also noted low correlation between total phenols and the antioxidative activity in seeds of field bean stating that the major antioxidant compounds may be tannins. The trends of relationships between the antioxidant activity and the total phenolics may be explained as the total phenolics content does not incorporate all the antioxidants. In addition, the synergism between the antioxidants in the mixture makes the antioxidant activity not only dependent on the concentration, but also on the structure and the interaction between the antioxidants (Djeridane *et al*., 2006).

Amino acid composition of the legumes

There were significant ($p<0.05$) variations in the amino acid composition of the nine legumes (Table 4). Glutamic acid was the most abundant amino acid in all the legumes evaluated. The values were between 27.32 and 43.31 g/kg with the lowest value in *Mallotus subulatus*, white variety (sample A) and highest value in *Cajanus cajan* (sample I). The second most abundant amino acid in all the legumes was aspartic acid ranging from 20.85 to 27.78 g/kg in *Cassia hirsutta* (B) and *Mallotus subulatus*, red variety (sample F), respectively. Vadivel and Janardhanan (2005) reported similar observation for the amino acids of seven south Indian wild legumes.

The most concentrated essential amino acid in all the legumes studied was leucine with values ranging from 14.96 to 17.90 g/kg (*Vignea subterranean*, checkered variety, sample D and *Mallotus subulatus*, white variety, sample A, respectively). Ogunbusola *et al.* (2010) noted similar observation for *Lagenaria siceraria* seed flour and its protein fractions. All the legumes are rich in lysine, phenylalanine and arginine but deficient in sulphur containing amino acids (methionine and cystine). *Canavalia ensiformis* (C) however rated best in terms of the cystine and methionine contents among all the legumes evaluated. Generally, sulphur-rich amino acids (methionine and cystine) are limiting in legumes. Commonly consumed food pulses such as chickpea, field pea, green pea, lentils and common beans have about 11 g/kg protein of methionine and cysteine (Wang and Daun, 2004), the exceptions being cowpea, which has about 22 g/kg protein of methionine, and green pea, which has about 18 g/kg protein of cysteine (Iqbal *et al*., 2006). Amino acid deficiencies in the little known legumes could be complemented by eating cereals, which are rich in amino acids containing sulphur (Jukanti *et al*., 2012). Legumes are usually consumed along with cereals, especially in Nigeria, thereby allowing the daily dietary amino acid requirements to be met. Tryptophan was not determined.

The total amino acid contents (Table 5) were between 180 in *Vignea subterranean* (D) and 213 g/kg in *Mallotus subulatus* (F). The total essential amino acids of the legumes ranged between 84 and

Table 5. Summary of amino acid composition (g/kg protein) of the nine underutilized legumes

	Sample code								
	A	B	C	D	E	F	G	H	I
Total amino acids (TAA)	203.71	208.61	209.70	180.09	197.31	212.59	185.90	190.17	219.43
Total essential amino acids (TEAA)	98.68	100.80	100.25	84.28	93.48	102.00	84.64	87.19	102.15
% TEAA	48.44	48.32	47.80	46.80	47.38	47.98	45.53	45.85	46.55
Total non essential amino acids (TNEAA)	105.03	107.81	109.45	95.81	103.83	110.59	101.26	102.99	117.28
%TNEAA	51.56	51.68	52.20	53.20	52.62	52.02	54.47	54.15	53.45
Total sulphur amino acids (TSAA)	6.80	7.70	9.51	7.31	8.86	7.79	8.00	8.89	8.12
Cystine (%) in TSAA	62.65	65.79	71.24	64.67	71.07	66.96	67.89	72.35	67.34
Ratio of TEAA:TNEAA	0.94	0.93	0.92	0.88	0.90	0.92	0.84	0.85	0.87
Total aromatic essential amino acids phe.+tyr. (ArEAA)	19.96	26.08	21.04	16.24	19.98	21.08	15.73	19.22	27.71
Total acidic amino acids (TAAA)% Glu. + Asp.	26.32	29.20	25.30	28.73	25.58	26.17	29.10	25.88	30.02
Total basic amino acids (TBAA)% Lys. + Arg. + His.	16.29	17.13	18.02	17.95	18.05	16.65	17.78	17.63	16.50
Total neutral amino acids (TNAA)%	57.40	53.67	56.68	53.32	56.37	57.18	53.11	56.49	53.49

A=*Mallotus subulatus* (white variety); B= *Cassia hirsutta*; C= *Canavalia ensiformis*; D= *Vignea subterranean* (checkered variety); E= *Vigna racemosa*; F= *Mallotus subulatus* (red variety); G= *Vignea subterranean (*cream variety); H= *Sphenostylis sterocarpa*; I= *Cajanus cajan*

102 g/kg in *Vignea subterranean* (D) and *Mallotus subulatus* (F), respectively. This is within the range of total essential amino acids without tryptophan, 89 to 236 g/kg edible portion reported for seven important food legumes (Zhou *et al*., 2013). The range of percentage total essential amino acid (45.53-48.44) obtained for the nine little known legumes is well above 36%, which is considered adequate for an ideal protein (FAO/WHO, 1973). This indicates the potentials of these legumes in contributing to solving the food and nutrition insecurity in the country and beyond. *Mallotus subulatus* (white variety, A) had the highest percentage of total essential amino acid and the lowest was found in *Vignea subterranean* (cream variety, G). The values of total amino acids containing sulphur ranged from 6.80 to 9.51 g/kg with cystine ranging from 62.65 to 72.35%. The range of total neutral, acidic and basic amino acids were 53.11–57.18%, 25.30–30.02% and 16.29-18.05%, respectively, which suggests that the protein in the legumes may be acidic in nature. Ogunbusola *et al*. (2010) and Aremu et al. (2006) noted similar observations for some Nigerian underutilized oilseeds.

Conclusion

The proximate components of the underutilized legumes were comparable to common beans and some other legumes. Summarily, all the legumes are good sources of protein, starch and dietary fibre. Although, generally low in fat, unsaturated fatty acids (MUFA and PUFA) were the most highly represented among the fatty acids with values higher than 50% of the total fat. All the legumes have relatively high contents of total phenolics and antioxidant activity pointing to the potentials of these legumes as promising food crops for the tropics. The fatty acid profile, dietary fibre, total phenolic content and antioxidant capacity of these legumes may contribute to reducing the risk of cardiovascular disease and other degenerative diseases associated with free radical damage. The proportions of the total essential amino acids in the legumes are considered adequate for ideal protein foods. With their protein, fiber and antioxidant capacity, these underutilized legumes would offer good nutrition to a wider community if promoted and adopted.

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