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Variability in the physicochemical, nutritional and antinutritional attributes of six *Mucuna* species

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Abstract

Six *Mucuna* species (*M. pruriens*, *M. cochinchinensis*, *M. rajada*, *M. veracruz* white, *M. veracruz* mottle and *M. deeringeana*) have been subjected to standard analytical techniques in order to evaluate their in physicochemical, nutritional and antinutritional properties.

Physicochemical characterization indicated that *M. veracruz* white and *M. veracruz* mottle had the lowest hydration capacities and indices, and swelling capacities and indices.

Proximate analysis showed that they had low moisture and ash contents (3.65–5.88% and 2.74–3.41%, respectively). The carbohydrate content was fairly high (43.7–49.7%). Starch constituted the dominant carbohydrate while some reducing and non-reducing sugars were also found in the seeds. The crude protein content in the seeds varied from 33.2% to 38.4%. In all, 18 amino acids were detected in the protein. *M. pruriens* had the highest total essential amino acids TEAA (555) mg g^{-1} protein, while *M. veracruz* mottle had the lowest (500 mg g^{-1} protein). Methionine and cysteine were the limiting amino acid in the seeds. Protein digestibilities of the seeds were high (81.3–85.5%). Results on the valuable nutritional minerals and trace elements indicated that potassium was the most abundant mineral present in the seeds (356–433 mg 100 g^{-1}). In addition, the seeds also had a high content of calcium and phosphorus.

The antinutritional factors estimated in the seeds included total polyphenolic substances, protease inhibitor, saponins, phytic acid, L-dopa and flatulence sugars. The concentration of phenolic substances ranged from 4.34% to 7.75%, while the concentration of protease inhibitor, TIA, ranged from 18.5 to 23.1 mg g^{-1} sample. Saponin concentration ranged from 0.52% to 3.01% while the phytic acid concentration in the seeds was between 1.23% and 2.56%. L-dopa concentration ranged from 3.87% to 7.12%. Out of the three flatulence sugars estimated in the seeds, verbascose showed the highest value.

Keywords: *Mucuna* species; Nutrients; Antinutritional factors; Physicochemical properties

1. Introduction

The wide prevalence of protein-calorie-malnutrition in developing countries is of great importance, not only for agricultural scientists but also for concerned governments (Olsen, 1975). The continuous increase in population and inadequate supply of protein have in advertently increased the occurrence of malnutrition in developing countries (Siddhuraju, Vijayakumari, & Janardhanan, 1996). Recent studies have shown that malnutrition among children in developing countries is mainly due to the consumption of cereal-based porridge which is bulky, with low energy, low nutrient density and high antinutrient content (Michaelsen & Henrik, 1998). To meet the protein demands in developing countries, where animal protein is also grossly inadequate and relatively expensive, intensive research effort is geared at finding alternative sources of protein from under-utilized grain legume seeds. In the developed

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countries, plant proteins are now regarded either as versatile functional ingredients or as biologically active components more than as essential nutrients (Marcello & Gius, 1997). This evolution towards health and functionality is mainly driven by the demands of consumers and health professionals (the partial replacement of animal foods with legumes is claimed to improve overall nutritional status (Guillon & Champ, 1996)) and the needs of the food industry, respectively. The world production of legume seeds "the poor man's meat" as developed producers call them, was about 58 million tons in 1994 by FAO estimations. Of this, the major part, 40 million tons, was produced by developing countries. Only 8.5% of this amount was consumed outside its production area (Heiser, 1996). This renewed awareness, in developing and developed countries alike, of the potential of legume seeds has provoked new research approaches to the exploitation of legume seeds.

These legumes, which are not only rich in proteins, but also carbohydrates, fats, minerals and other nutrients are limited by the presence of antimetabolic/antiphysiological substances, such as protease inhibitors, phenolic substances, non-protein amino acids, lecithins, saponins, flatulence produces and non-starch polysaccharides (Olguin et al., 2003; Siddhuraju & Becker, 2001; Siddhuraju, Becker, & Makkar, 2000; Vidivel & Janardhanen, 2001). The polyphenols are known, to decrease protein digestibility, either by binding with digestive enzymes or direct action on dietary proteins (Jambunathan & Singh, 1981). Phytic acid lowers the bioavailability of minerals and inhibits proteases and amylases (Sharma & Sehgal, 1992). Oligosaccharides are involved in the production of flatulence, characterized by the production of CO_2, H_2 and small amounts of CH_4, which leads to abdominal rumbling, cramps, diarrhea and nausea (Vijayakumari, Siddhuraju, & Janardhanan, 1997).

There is a dearth of information on the variability in the nutritional and antinutritional aspects of *Mucuna* species. The aim of this article, therefore, was to consider, the physicochemical and nutritional properties and antinutrients of six varieties of *Mucuna* spp. (*M. rajada*, *M. pruriens*, *M. varacruz* mottle, *M. veracruz* white, *M. cochinchinensis* and *M. deeringeana*). The work also includes the determination of the amino acid spectrum and in vitro protein digestibility, as well as the determination of the valuable nutritional minerals in the seeds. It is hoped that the work will generate baseline data which will not only be useful' in determining the severity of processing but also in providing effective utilization of these lesser-known and underutilized seeds.

2. Materials and methods

2.1. Materials

Seeds of *M. rajada*, *M. pruriens*, *M. varacruz* mottle, *M. veracruz* white, *M. cochinchinensis* and *M. deeringeana*, were provided by Dr. Shirley Tarawali of the International Institute of tropical Agriculture/International Livestock Research Institute IITA/ILRI, Ibadan-Nigeria. The seeds were air-dried for 48 h. After removal of the immature seeds and unwanted materials, the seeds were stored in plastic containers at room temperature (30 ± 2 °C). Thereafter the samples were pulverised using a WARING blender (Braun Multimix de luxe MX40, type 2291). They were sieved to pass through a 0.5 mm mesh sieve and kept in airtight plastic containers at 4 °C prior to use.

2.2. Physicochemical analysis

2.2.1. Density

Seeds (100 g) were weighed accurately and transferred to a 200 ml measuring cylinder, where 100 ml deionised water were added. The seeds were placed in water to sink them and the volume of the displaced water was recorded.

2.2.2. Hydration capacity

Seeds, weighing 100 g, were counted and transferred to a measuring cylinder, along with 100 ml of water. The cylinder was covered with aluminium foil and left overnight at room temperature (30 ± 2 °C). After 24 h, the seeds were drained; superfluous water was removed with filter paper and swollen seeds separated and reweighed.

$$\text{Hydration capacity per seed} = \frac{\text{Weight of soaked seeds} - \text{Weight of seeds before soaking}}{\text{Number of seeds}}$$

Hydration index was calculated as follows:

$$\text{Hydration index} = \frac{\text{Hydration capacity per seed}}{\text{Weight of one seed}}$$

2.2.3. Swelling capacity

Seeds, weighing 100 g, were counted, their volume noted and soaked overnight. The volume of soaked seeds was noted in a graduated cylinder. Swelling capacity per seed was determined as follows:

$$\text{Swelling capacity} = \frac{\text{Volume after soaking} - \text{Volume before soaking}}{\text{Number of seeds}}$$

$$\text{Swelling index} = \frac{\text{Swelling capacity of seed}}{\text{Volume of one seed}}$$

The colour of the seeds was determined subjectively. The proportions of seed coat + endosperm and cotyledon in the different seeds were determined by taking the average measure of 100 g weight.

2.3. Seed composition

2.3.1. General analysis

The contents of moisture, crude protein, lipid, ash and crude fibre in the samples were determined by the standard methods already described in the AOAC (1990). The carbohydrate content was determined as the weight difference using moisture, crude protein, lipid and ash content data.

Soluble sugars were extracted into 80% (v/v) ethanol according to the procedure of McCready, Guggolz, Silviera, and Owens (1950). The residue after the extraction of the soluble sugars was used for the determination of the insoluble sugars. Quantitative determination of starch was carried out by the method described by McCready et al. (1950).

$$\text{Starch} = \text{Glucose} \times 0.9.$$

The reducing sugars were determined (after separation), using the phenol–sulphuric acid method described by Dubois, Gilles, Hamilton, Rebers, and Smith (1950). The amount of non-reducing sugars was calculated as the difference between the total soluble sugars and reducing sugars.

Gross energy was determined with a bomb calorimeter (IKA C7000), using a benzoic acid standard.

2.3.2. Total phenolics (tannins)

The phenolics in the sample were isolated according to the method of Shahidi and Naczk (1989). One gramme, of the sample was extracted thrice with 10 ml of 70% (v/v) aqueous acetone at room temperature (30 ± 2 °C). This was centrifuged at 10,000*g* for 10 min. The supernatant was collected, combined and evaporated to dryness at 30 °C under vacuum. The extracted phenolics were then dissolved in 25 ml methanol and re-centrifuged. To 0.5 ml of the methanolic solution was added 0.5 ml of Folin–Denis reagent [Folin–Denis reagent: To 750 ml water, 100 g sodium tungstate and 20 g phosphomolybdic acid were added in a 2 l standard flask. Thereafter, 50 ml orthophosphoric acid was added and the mixture refluxed for 2 h. The mixture was allowed to stand and made up to 1 l. The solution is stored in the dark prior to use] followed by the addition of 1 ml sodium carbonate and 8 ml of deionised water. The mixture was gently swirled and the mixture allowed to stand for 45 min to allow for colour development. The absorbance was measured in a colorimeter at 725 nm, using the method of Swain and Hillis (1959). *Trans*-sipanic acid was used to prepare the standard calibration curve where the concentration was extrapolated.

2.3.3. Phytic acid

Phytic acid in the sample was determined by a procedure described by Vaintraub and Lapteva (1988). Ground samples (0.5 g each) were stirred using a magnetic stirrer in 10 ml of 3.5% HCl for 1 h. The contents were centrifuged at 3000*g* for 10 min to obtain supernatants. A suitable aliquot of the supernatant was diluted with 3.5% HCl to make up to the 3 ml mark. One millitre of Wade reagent (0.03% solution of $FeCl_3 \cdot 6H_2O$ containing 0.3% sulphosalicylic acid) was added and it was centrifuged again. The absorbance was measured a 500 nm using a colorimeter. Phytic acid was used as the standard.

2.3.4. Trypsin inhibitor

Trypsin inhibitor activity was determined by the method of Smith, Van Megan, Twaalhoven, and Hitchcook (1980). Deffated ground seed samples (0.25 g) were extracted for 5 min in 12.5 ml of 0.01 M NaOH at pH 9.5 in a macerator. The contents were centrifuged at 3800*g* for 15 min and the supernatants were collected. The supernatants was further centrifuged at 3800*g*, following which the supernatants were collected by slowly pipetting between the residue at the bottom and the fatty later on top.

2.3.5. Estimation of total saponins

The total saponin content was determined using the spectrophotometric procedure described by Baccou, Lambert, and Samvaire (1977). To 0.5 g defatted ground seed samples, in a screw-capped centrifuge tube were added 10 ml of 80% aqueous methanol. The tubes were tightly capped and the contents were stirred overnight using a magnetic stirrer. The tubes were centrifuged at 3000*g* for 10 min at room temperature and the supernatants were collected in 25 ml volumetric flasks. The residue were washed thrice with 5 ml of 80% aqueous methanol. Aliquots of the samples from the flasks were used for saponin determination. Diosgenin was used as the standard.

2.3.6. Determination of oligosaccharide content

The oligosaccharide were first extracted from the samples by treating 5 g of each sample with 25 ml of 80% ethanol at room temperature (30 ± 2 °C) by repeated shaking. The extraction was repeated thrice. The extracts were pooled and concentrated using a rotary evapotor under vacuum. The residue was made up to 5 ml with deionised water and the sugars were separated using a descending paper chromatography technique with Whatman No. 1 chromatographic paper and the solvent mixture, prgpanol:ethanol:water in a ratio 7:1:2

(v/v) (Vijayakumari et al., 1997). A standard sugar, mixture containing raffinose, stachyose and verbascose (SIGMA-ALDRICH chemical company, St. Louis, MO, USA), was run simultaneously. After development, *p*-anisidine hydrochloride reagent was sprayed on the papers to reveal the sugar spots. For quantitation, the paper (of area 2×2 cm) corresponding to each oligosaccharide spot was cut from unsprayed papers and eluted with 3 ml of deionised water. Then the eluted individual sugars were estimated by the phenol–sulphuric acid method described by Dubois et al. (1950).

2.3.7. Extraction and determination of L-dopa

3,4-Dihydroxy-L-phenylalanine (L-dopa) was determined using the method described by Myhrrman (2002). Five millilitres of distilled-deionised water were added to 2 g of the flour in a 16 mm (OD) × 100 mm glass culture tube (screw-cap style), and the tube was vortexed briefly to mix the contents and then placed in a boiling water bath for 6 min. The tube was centrifuged for 2 min at 3000*g*. The extraction was repeated three times. The combined supernatants were diluted to 100 ml with dionised water, filtered through a 0.45 mm nylon membrane and cooled to ≈15 °C. The concentration of L-dopa in the extract of the samples was determined by HPLC with UV detection at 279 nm on a SB-C18 column (4.6×150 mm, 3μ particles). Two mobile phases were used at 1 ml min^{-1} and 30 °C. Mobile phase A consisted of buffer [0.1 M phosphoric acid, 1 mM 1-octanesulphonic acid, 2 mM EDTA–Na_2 adjusted to pH 3 with 20% (w/v) NaOH] and mobile phase B consisted of HPLC-grade methanol. Elution was carried out using nine parts of A, one part of B at 10 ml min^{-1} for 15–20 min. Injection volume was 40 μl. Quantitation of L-dopa was based on a standard curve developed, using 1.00 mM standard L-dopa dissolved in water.

2.3.8. Total amino acids

Total amino acids were determined as described by Shahidi, Naczk, and Synoweicki (1992). Samples were freeze-dried and then hydrolysed for 24 h at 110 °C in 6 M HCl (Bishnoi & Khetarpaul, 1993). The HCl was removed in vacuo and dried samples were reconstituted using lithium citrate buffer at pH 2.2. The hydrolysed amino acids were then determined using a Beckman 121 MB amino acid analyzer (Beckmann Instruments Inc., Palo Alto CA).

2.3.9. In vitro protein enzyme digestibility

In vitro was carried out by the method of Hsu, Vavak, Satterlee, and Miller (1977). Fifty millilitres of an aqueous suspension of the samples (6.25 mg sample per ml) in distilled water was adjusted to pH 8.0 with 0.1 M HCl and/or 0.1 M NaOH, while stirring on a water bath maintained at 37 °C. The multienzyme solution, containing 1.6 mg trypsin, 3.1 mg chymotrypsin and 1.3 mg peptidase, was maintained in an ice bath and adjusted to pH 8.0 with 0.1 M HCl and/or 0.1 M NaOH. The enzymes were purchased from SIGMA Chem. Company (St Louis, MO, USA). A 5 ml sample multienzyme solution was added to the sample suspension with constant stirring at 37 ± 2 °C. The pH of the suspension was recorded 15 min after the addition of the multienzyme solution. In vitro digestibility was calculated using a regression equation of Hsu et al. (1977).

$Y = 210.46 - 18.10X$,

Y = in vitro digestibility (%),

X = pH of the sample after 15 min of digestion with multienzyme solution.

Enzyme activity was determined using casein of known in vivo apparent digestibility.

2.3.10. Minerals

Dried and ground samples (1–2 g) were pre-ashed on a bunsen flame for 20 min. Thereafter, the samples were then subjected to dry-ashing in well cleaned porcelain crucibles at 550 °C in a muffle furnace. The resultant greyish-white ash was dissolved in 5 ml HNO_3/HCl (1:1) while heating on a hot plate at the boiling temperature of the solution until brown fumes disappeared. To the residue, in each crucible, 5 ml of distilled-deionised water were added and the mixture heated until a colourless solution was obtained. The mineral solution in each crucible was transferred into a 100 ml volumetric flask by filtering through a Whatman No. 42 filter paper and the volume made up to the mark distilled-deionised water.The metals were determined using a Perkin–Elmer 8650 atomic absorption spectrophotometer. Phosphorus content of the digest was determined colorimetrically, according to the method described by Nahapetian and Bassiri (1975). To 0.5 ml of the digest, 4 ml of deionised water, 3 ml of 0.75 M H_2SO_4, 0.4 ml of 10% (w/v) $(NH_4)6Mo_7O_24 \cdot 4H_2O$ and 0.4 ml of 2% ascorbic acid were added and mixed. The solution was allowed to stand for 20 min, and the absorbance reading was recorded at 660 nm. KH_2PO_4 was used as the standard.

2.4. Statistical analysis

All results in this study are reported as means of three replicate analyses. One-way analysis of variance (ANOVA) were carried out to compare between the mean values of different species of the seeds. Differences in the mean values were determined at $p < 0.05$ (SAS, 1990).

3. Results and discussion

3.1. Physicochemical properties of the Mucuna seeds

In order to compare the morphological characteristics of the *Mucuna* species, their physicochemical prop-

Table 1
Physicochemical properties of the *Mucuna* species

Parameter	*Mucuna* species					
	M. pruriens	*M. cochinchnensis*	*M. rajada*	*M. veracruz* (W)[A]	*M. veracruz* (M)[B]	*M. deeringeana*
Colour	Black	Brown	Dark brown	White	Brown	Brown with white spots
Grain weight (average of 100 seeds)	0.92 ± 0.02^{a}	0.98 ± 0.04^{a}	0.59 ± 0.01^{b}	0.86 ± 0.02^{ab}	0.88 ± 0.02^{ab}	0.78 ± 0.02^{a}
% Seed coat	11.05 ± 0.04^{b}	12.03 ± 0.03^{b}	13.08 ± 0.05^{b}	12.09 ± 0.03^{b}	14.02 ± 0.03^{c}	12.67 ± 0.02^{b}
Cotyledon (% whole seed)	88.85 ± 0.05^{c}	87.97 ± 0.04^{c}	86.82 ± 0.04^{c}	87.81 ± 0.02^{c}	85.88 ± 0.04^{d}	87.33 ± 0.05^{c}
Density ($g\,ml^{-1}$)	0.89 ± 0.01^{d}	0.95 ± 0.02^{e}	0.65 ± 0.01^{f}	0.78 ± 0.01^{f}	0.82 ± 0.01^{d}	0.70 ± 0.02^{f}
Hydration capacity (g/seed)	0.28 ± 0.01^{e}	0.41 ± 0.01^{f}	0.20 ± 0.01^{e}	0.20 ± 0.01^{e}	0.25 ± 0.01^{e}	0.34 ± 0.01^{ef}
Hydration index	0.30 ± 0.02^{a}	0.42 ± 0.01^{b}	0.34 ± 0.02^{a}	0.23 ± 0.02^{a}	0.28 ± 0.01^{a}	0.43 ± 0.02^{b}
Swelling capacity (ml/seed)	0.31 ± 0.03^{b}	0.43 ± 0.02^{c}	0.31 ± 0.03^{b}	0.26 ± 0.02^{b}	0.30 ± 0.02^{b}	0.49 ± 0.01^{c}
Swelling index	0.30 ± 0.02^{c}	0.42 ± 0.03^{d}	0.48 ± 0.01^{d}	0.24 ± 0.01^{c}	0.29 ± 0.02^{c}	0.44 ± 0.01^{d}

Results are expressed as means of triplicate determinations ± SD.
Means followed by different superscript in each row indicates significant differences at $P < 0.05$.
[A] *M. veracruz* (M) – mottle.
[B] *M. veracruz* (W) – white.

erties were evaluated and the results are presented in Table 1. *M. cochichinensis* and *M. veracruz* mottle were brown in colour; *M. rajada* and *M. deeringeana* had a darker shade of brown, in addition to some white spots as were located on *M. deeringeana* seeds. *M. veracruz* white as the name implies, is white in colour while *M. pruriens* is black. The average weight of the seeds ranged from 0.59 to 0.98 g and the percentage seed coats in the whole seed was between 11.05% and 14.02%. The density ($g\,ml^{-1}$) of the different seeds ranged from 0.65 to 0.89. *M. veracruz* white had the lowest hydration capacity, hydration index, swelling capacity and index. This might be a reflection of the relative hardness and impermeability of the seed coat compared to other seeds. The hardness and impermeability follow the order:

M. veracruz white > *M. veracruz* mottle > *M. pruriens* > *M. rajada* > *M. cochinchinensis* > *M. deeringeana*

M. veracruz white and *M. veracruz* mottle may therefore require a longer time in order to germinate or cook and this could also influence the preference of consumers and processors of the seeds (Akinyele, Onigbinde, Hussain, & Omololu, 1986; Bishnoi & Khetarpaul, 1993).

3.2. Proximate chemical composition

The summary of the proximate chemical composition of *Mucuna* species is presented in Table 2. The moisture content of the whole seed is quite low (3.65–4.64%). The values are comparable to the moisture content of the cotyledon. However, slightly higher values were recorded in the seed coat (4.65–5.88%). Generally, the moisture values of these seeds are lower than those of similar legumes: *Cassia floribunda*, 6.0% (Vidivel & Janardhanen, 2001); *Lathyrus martimus*, 9.7% (Chavan, Shahidi, Bal, & McKenzie, 1999); *Lupin* species, 6.6% (Ruiz-Lopez et al., 2000); *Vigna unguiculata*, 8.9% (Aletor & Aladetimi, 1989). This might be advantageous in terms of the shelf life and keeping qualities of the seeds.

The ash content of the whole seeds ranged from 2.74% to 3.41%. The cotyledon showed a much lower value. Ash content is significant in food for various reasons. Among others it is an index for of the quality of feeding materials used for poultry and cattle feeding already established by Pomeranz and Clifton (1981). The seeds could be as for compounding of feed.

The carbohydrate contents of the seeds are fairly high. *M. cochinchinensis* had the highest carbohydrate content (49.7 ± 0.23%). Others ranged from 43.7% to 47.4% in both the whole seeds and cotyledon. Starch constituted the major carbohydrate (>40% in most of the varieties). Reducing and non-reducing sugars were also estimated in the carbohydrate fraction. *M. rajada* had the highest level of reducing sugars (554 mg 100 g^{-1}). The crude fibre content ranged from 5.79% to 7.91% in the whole seed. This is higher than those reported for commonly cultivated pulses, such as chick pea and horse gram (Premakumari, Fathima, & Saraswati, 1984). The presence of high crude fibre in food materials is reported to decrease the dry matter digestibility in animals. The high crude fibre content therefore provides a good indication of nutritive value of feed materials (Devendra, 1995). Lower values were recorded in the cotyledon (0.79–1.91%). However, the crude fibre values in the seed coat ranged from 39.9% to 46.5%. The differences originate from the testa structure and the thick leathery skins of tine seeds as was also noted by

Table 2
Chemical composition of the *Mucuna* species[A]

Parameter (%)	*Mucuna* species					
	M. pruriens	*M. cochinchinensis*	*M. rajada*	*M. veracruz* (W)[D]	*M. veracruz* (M)[E]	*M. deeringeana*
(a) Whole seed						
Moisture	4.64 ± 0.10^{a}	3.82 ± 0.24^{a}	3.65 ± 0.12^{b}	3.88 ± 0.26^{a}	3.74 ± 0.38^{a}	4.46 ± 0.31^{a}
Dry matter	95.36 ± 0.56^{b}	96.18 ± 0.11^{b}	96.35 ± 0.13^{b}	96.12 ± 0.13^{b}	96.26 ± 0.14^{b}	95.54 ± 0.32^{b}
Protein	37.5 ± 0.27^{c}	38.4 ± 0.36^{c}	33.2 ± 0.16^{b}	37.8 ± 0.33^{c}	37.9 ± 0.24^{c}	38.2 ± 0.18^{c}
Lipid	9.65 ± 0.16^{b}	9.69 ± 0.47^{b}	10.19 ± 0.47^{b}	9.05 ± 0.20^{b}	10.03 ± 0.27^{b}	8.72 ± 0.41^{a}
Ash	3.24 ± 0.16^{e}	3.36 ± 0.06^{e}	3.32 ± 0.12^{e}	2.91 ± 0.31^{d}	2.74 ± 0.17^{d}	3.41 ± 0.10^{e}
Crude fibre	7.91 ± 0.16^{a}	6.89 ± 0.02^{a}	$6.8Z \pm 0.05^{a}$	6.12 ± 0.13^{a}	6.86;t0.08[a]	5.79 ± 0.03^{b}
Carbohydrates[B]	44.9 ± 0.25^{b}	44.8 ± 0.35^{b}	49.7 ± 0.23^{c}	46.4 ± 0.34^{b}	45.6 ± 0.18^{b}	45.2 ± 0.20^{b}
Reducing sugars[C]	334 ± 3.61^{e}	430 ± 4.04^{f}	554 ± 4.85^{fg}	480 ± 4.56^{f}	301 ± 3.60^{e}	550 ± 3.20^{fg}
Non-reducing sugars	2.56 ± 0.34^{a}	3.78 ± 0.45^{b}	4.01 ± 0.48^{bc}	2.65 ± 0.06^{a}	4.14 ± 0.10^{bc}	3.30 ± 0.27^{b}
Starch	37.5 ± 0.31^{c}	36.8 ± 0.23^{c}	40.1 ± 0.34^{d}	39.0 ± 0.29^{cd}	37.0 ± 0.22^{cd}	37.5 ± 0.26^{cd}
Gross energy (MJ/kg)	22.7 ± 0.23^{e}	21.8 ± 0.45^{e}	22.9 ± 0.35^{e}	23.1 ± 0.39^{e}	22.9 ± 0.29^{e}	24.7 ± 0.12^{f}
(b) Cotyledon						
Moisture	3.17 ± 0.12^{a}	2.82 ± 0.20^{a}	2.65 ± 0.11^{a}	2.88 ± 0.20^{a}	2.74 ± 0.18^{a}	3.46 ± 0.24^{a}
Dry matter	96.83 ± 0.36^{b}	97.18 ± 0.09^{b}	97.35 ± 0.06^{b}	97.12 ± 0.10^{b}	97.26 ± 0.09^{b}	96.54 ± 0.22^{b}
Protein	41.2 ± 0.25^{d}	38.6 ± 0.30^{e}	38.3 ± 0.16^{e}	$38.7^{c} \pm 0.13^{e}$	39.4 ± 0.44^{e}	39.4 ± 0.40^{e}
Lipid	9.80 ± 0.11^{c}	9.63 ± 0.32^{c}	10.00 ± 0.33^{c}	9.15 ± 0.21^{c}	10.43 ± 0.22^{e}	8.04 ± 0.48^{cd}
Ash	2.14 ± 0.16^{b}	2.32 ± 0.06^{b}	2.03 ± 0.12^{b}	1.92 ± 0.11^{c}	1.94 ± 0.27^{bc}	2.32 ± 0.11^{b}
Crude fibre	1.91 ± 0.02^{f}	1.89 ± 0.02^{f}	1.87 ± 0.05^{f}	1.12 ± 0.02^{fg}	1.86 ± 0.01^{f}	0.79 ± 0.03^{h}
Carbohydrates[B]	43.7 ± 0.21^{a}	46.6 ± 0.24^{b}	47.0 ± 0.13^{b}	47.4 ± 0.24^{b}	45.5 ± 0.15^{b}	46.8 ± 0.13^{b}
Reducing sugars[C]	454 ± 4.81^{c}	615 ± 5.06^{d}	754 ± 3.87^{e}	680 ± 5.59^{de}	501 ± 5.61^{c}	850 ± 3.20^{ef}
Non-reducing sugars	4.56 ± 0.34^{e}	5.78 ± 0.45^{e}	6.01 ± 0.48^{e}	4.65 ± 0.06^{e}	5.14 ± 0.10^{e}	6.30 ± 0.27^{ef}
Starch	40.6 ± 0.51^{a}	$39.0\text{-} \pm 0.43^{b}$	44.78 ± 0.44^{a}	46.0 ± 0.39^{a}	41.3 ± 0.42^{a}	40.6 ± 0.36^{a}
Gross energy (MJ/kg)	24.9 ± 0.24^{b}	24.8 ± 0.47^{b}	22.9 ± 0.25^{c}	23.1 ± 0.29^{bc}	22.9 ± 0.19^{c}	24.7 ± 0.23^{b}
(c) Seed coat						
Moisture	5.17 ± 0.08^{a}	4.82 ± 0.15^{a}	4.65 ± 0.15^{a}	5.88 ± 0.15^{a}	4.74 ± 0.08^{a}	5.46 ± 0.12^{a}
Dry matter	96.83 ± 0.16	97.18 ± 0.08	97.35 ± 0.03	97.12 ± 0.13	97.26 ± 0.04	96.54 ± 0.34
Protein	8.14 ± 0.13	7.11 ± 0.21	6.92 ± 0.11	7.64 ± 0.17	7.03 ± 0.35	7.17 ± 0.29
Lipid	3.07 ± 0.07	4.74 ± 0.21	2.07 ± 0.37	3.23 ± 0.14	1.12 ± 0.12	3.05 ± 0.36
Ash	4.17 ± 0.13	3.17 ± 0.02	2.84 ± 0.19	2.35 ± 0.05	2.84 ± 0.18	3.26 ± 0.09
Crude fibre	42.4 ± 0.12	43.4 ± 0.13	46.5 ± 0.20	43.3 ± 0.19	39.3 ± 0.19	39.9 ± 0.07

Results other than moisture are on dry weight basis.

Means followed by different superscript in each row indicates significant differences at $P < 0.05$.

[A] Results are means ± SD of triplicate analyses.

[B] Carbohydrates by difference as 100–(moisture + crude protein + lipid + ash).

[C] Results expressed as mg/100 g.

[D] *M. veracruz* (M) – mottle.

[E] *M. vera* (W) – white.

Ene-Obong and Carnovale (1992) for other legumes. Soxhlet extraction of the seeds lipids with petroleum ether (40–60 °C) gave a brown oil with strong beany aroma. The lipid content varied from 8.72% to 10.19%. The oil has excellent keeping properties, as the colour was intact for several months. Work is already in progress on the physicochemical, lipid classes, fatty acids and triacylglycerol contents of the oil, the results of which will be published in the near future. Due to the high lipid and protein contents of the seeds, total gross energy values seem to be higher than similar seeds (Siddhuraju et al., 1996, 2000).

The crude protein in the whole, seed of the *Mucuna* species varied from 33.2% to 38.4%. *M. cochinchinensis* had the highest value. A slightly higher value was recorded in the cotyledon samples. The value is higher than those recorded for similar seeds: *Mucuna*, (*M. monosperma)*, 25.4% (Vijayakumari et al., 1997); cowpea, (*Vigna sinensis*), 24.1%; pigeon pea (*Cajanus cajan)*, 19.2%; chick pea (*C. arietinum*), 18.2%; Faba beans (*V. faba*), 24.0%; soy bean (*Glycine max*), 33.4%; peanuts (*A. hypogea*) 26.7% (Bressani, 2002). Therefore, based on the recommended average human protein intake of 23–50 g by the National Research Council (1974), the *Mucuna* spp. could contribute significantly to alleviating the problem of protein malnutrition in the third world and developing countries. The amino acid composition of the seeds is shown in Table 3. *M. pruriens* had the highest total essential amino acids TEAA (555 mg g^{-1} protein) while *M. veracruz* mottle had the lowest TEAA (500 mg g^{-1} protein). In comparison with the results of amino acid content of soybean and beach pea displayed

Table 3
Amino acid composition of *Mucuna* species (mg g^{-1} crude protein)[A]

Amino acid	*Mucuna* species						Soy beans [E]	Beach pea[F]
	M. pruriens	*M. cochinchinensis*	*M. rajada*	*M. veracruz* (M)[G]	*M. veracruz* (W)[H]	*M. deeringeana*		
ALA	67.4[a]	74.5[b]	66.9[a]	77.6[ab]	65.9[a]	80.5[c]	42.3	20.3
ARG[B]	89.8[b]	80.5[b]	77.9[c]	60.6[d]	78.5[c]	89.5[c]	71.3	91.9
ASP + ASPG	167	136[e]	101	122[g]	88.7[h]	123[eg]	113	124
CYS	Trace	10.4[a]	Trace	Trace	Trace	12.3[a]	17.0	15.5
GLU + GLUM	158	168	156	179[d]	124	179	169	115
GLY	56.7[a]	54.3[a]	34.6[b]	56.9	44.6[b]	47.9[b]	40.1	20.9
HIS	36.7[b]	23.6[c]	35.7[b]	37.9[b]	45.9[d]	44.9[d]	25.0	11.6
ISOLEU[B]	96.7[e]	90.8[e]	88.7[e]	89.5[e]	88.6[e]	98.5[e]	46.2	5.1
LEU[B]	77.8[d]	72.7[d]	67.8[e]	70.7[d]	75.8[d]	80.4[d]	77.2	8.9
LYS[B]	78.5[b]	67.8[c]	56.7[c]	80.4[d]	74.5[b]	79.5[b]	60.8	12.7
MET[B]	Trace	13.2[a]	12.6[a]	Trace	Trace	19.7[b]	12.2	30.5
PHE[B]	70.9[a]	76.9[a]	75.6[a]	67.8[a]	56.7[b]	50.5[b]	48.4	4.2
PRO	125[b]	1345	131[b]	113[c]	131[b]	146[cd]	48.6	44.4
SER	43.2[e]	34.5[ef]	25.7[g]	50.6[h]	54.3[h]	65.4[h]	56.7	20.7
THR[B]	46.7[a]	50.4[a]	54.4[a]	65.3[b]	67.4[b]	60.8[b]	37.6	6.5
TRY	20.9[b]	23.4[b]	34.3[c]	23.4[b]	21.3[b]	21.2[b]	33.9	6.4
TYRO	60.9[c]	54.6[d]	55.7[d]	60.7[c]	64.5[c]	76.4[cd]	12.4	6.1
VAL^{+}	57.8[e]	69.8[f]	69.4[f]	65.8[f]	62.2[f]	76.4[g]	45.9	6.1
TEAA	518	522	503	500	504	555	400	166
TNEAA	736	713	639	720.1	639.5	797.3	558	385
%TEAA	41.3	42.3	44.0	41.0	44.1	41.1	41.7	30.1
% TNEAA	58.7	57.7	56.0	59.0	55.9	58.9	58.3	69.9
In vitro PD[C]	84.6	85.5	84.6	83.7	83.1	84.2	NA[D]	NA[D]

ALA – alanine; ARG – arginine; ASP – aspartic acid; ASPG – asparigine; CYS – cysteine; GLU – glutamic acid; GLUM – glutamine; GLY – glycine; HIS – histidine; ISOLEU – isoleucine; LEU – leucine; LYS – lysine; MET – methionine; PHE – phenylalanine; PRO – proline; SER – serine; THR – threonine; TRY – tryptophan; TYR – tyrosine; VAL – valine.

Results other than moisture are on dry weight basis.

Means followed by different superscript in each row indicates significant differences at $P < 0.05$.

[A] Results presented as means ± SD of triplicate analyses.

[B] Essential amino acids.

[C] In vitro, protein digestibility (digestibility of casein, standard protein is 94.3%).

[D] ND Not detectable (below detection limit).

[E] Data from Bau et al. (1994).

[F] Data from Chavan et al. (1999).

[G] *M. veracruz* (M) – mottle.

[H] *M. veracruz* (W) – white.

longside, all the *Mucuna* species had higher TEAA than both these samples. The nutritive value of proteins depends primarily on the capacity to satisfy the needs of nitrogen and essential amino acids (Pellet & Young, 1980). Comparison of the amino acid composition in the *Mucuna* species with FAO/WHO reference values (FAO/WHO, 1985), indicates that the values obtained from this study are higher that the values recommended for pre-school and school children. This implies that the samples would be a good source of essential amino acids and could be used for the fortification of cereal-based foods which are particularly deficient in lysine (Lys). The quality of dietary proteins can be measured in many ways. There is general acceptance that this value is a ratio of the available amino acids in the food or diet compared with the daily requirements. According to the provisional amino acid scoring pattern and amino acid scores reported in Table 4, the amino acid score compared favourably with the suggested reference standard. In fact, in most cases, values obtained from this study were almost double the suggested levels. However, methionine and cysteine were the limiting amino acids in this study. The relatively low levels of methionine and cysteine in legumes have been reported by other investigators (Apata & Ologhobo, 1994). However, the high lysine content of the *Mucuna* protein is a very important nutritional attribute and probably more important than the protein content because it makes this legume a significant supplementary protein to cereal-based diets known to be deficient in lysine. The bio-availability of the protein was also examined and the result is presented, a long with the composition of the amino acids in Table 3. Digestibility of a protein and bio-availability of its constituent amino acids, is an important factor which determines the protein quality (Hsu et al., 1977; Suman, Monterio, Ramanchandra, & Sudharshana,

Table 4
Provisional amino acid scoring pattern and amino acid scores of *Mucuna* spp.

Amino acid	Amino acid content							Amino acid score[B]					
	Suggested level[A]	Present work						Present work					
ILE	40	96.7[C]	90.8[D]	88.7[E]	89.5[F]	88.6[G]	98.5[H]	2.42 [C]	2.27[D]	2.21[E]	2.24[F]	2.22[G]	2.46[H]
LEU	70	77.8	72.7	67.8	70.7	75.8	80.4	1.11	1.04	0.97	1.01	1.08	1.15
LYS	55	78.5	67.8	56.7	80.4	74.5	79.5	1.43	1.23	1.03	1.46	1.35	1.45
MET + CYS	35	trace	23.6	12.6	trace	trace	32.0	–	0.67	0.36	–	–	0.91
PHE + TRY	60	91.8	100	110	90.2	78.0	71.7	1.53	1.67	1.83	1.50	1.30	1.20
THR	40	46.7	50.4	54.4	65.3	67.4	60.8	1.17	1.26	1.36	1.63	1.69	1.52
VAL	50	57.8	69.8	69.4	65.8	62.2	76.4	1.16	1.40	1.39	1.32	1.24	1.53

ILE – isoleucine; LEU – leucine; LYS – lysine; MET – methionine; CYS – cystine; PHE – phenylalanine; TRY – tryptophan; THR – threonine; VAL – valine.
[A] Suggested levels (FAO/WHO, 1985).
[B] Amino acid score = mg of amino acid per g test protein/mg amino acid per reference protein.
[C] *M. pruriens*.
[D] *M. cochichinensis*.
[E] *M. rajada*.
[F] *M. veravruz* mottle.
[G] *M. veracruz* white.
[H] *M. deeringeana*.

1992). This is true because not all proteins are digested, absorbed and utilized to the same extent. Difference in the protein digestibility may arise from inherent differences in the nature of food protein constituents which may modify digestion as a result of anti-physiological factors or processing conditions that alter the enzymatic processes. The multienzyme in vitro procedure has shown good correlation with in vivo methods. In the results, protein digestibility of the samples ranged from 83.1% in *M. veracruz* mottle to 85.5% in *M. cochinchinensis*. These values are higher that those already reported for legumes and animal protein sources (*P. vulgarus*, 78.5%; *Lentil esculenta*, 80.3%; *Cajanus cajan*, 59.9%; *Carnavalia einseformis*, 78.8%) (Hsu et al., 1977; Mba, 1980; Oshodi, Ipinmoroti, Adeyeye, & Hall, 1995).

3.3. Antinutritional factors (ANFs)

Although legumes are important sources of dietary protein for both humans and animals, their acceptability and utilization has been limited due to some ANFs, such as protein inhibitors, lectins and cyanogens that constitute the heat-labile ANFs, whereas toxic amino acids, phenolics, tannins, saponins are heat resistant ANFs (Linier, 1994). The data on the ANFs of the *Mucuna* species are presented in Table 5. Polyphenols and tannins in legumes are known to inhibit the activities of

Table 5
Antinutritional factors in six *Mucuna* species (g 100 g^{-1} dry matter unless otherwise stated)[A]

Antinutritional factors	*Mucuna* species					
	M. pruriens	*M. cochinchnensis*	*M. rajada*	*M. veracruz* (M)[C]	*M. veracruz* (W)[D]	*M. deeringeana*
Total phenolics	7.75 ± 0.02^{a}	6.53 ± 0.02^{b}	6.23 ± 0.01^{b}	9.23 ± 0.03^{ac}	5.24 ± 0.03^{d}	4.34 ± 0.02^{d}
Trypsin inhibitor[B]	24.2 ± 0.08^{b}	23.6 ± 0.06^{b}	26.1 ± 0.08^{c}	20.2 ± 0.04^{d}	21.2 ± 0.05^{d}	18.5 ± 0.06^{e}
Saponnins	1.46 ± 0.01^{e}	2.07 ± 0.01^{f}	1.99 ± 0.01^{e}	3.01 ± 0.02^{g}	1.45 ± 0.01^{e}	0.52 ± 0.01^{h}
Phytic acid	1.97 ± 0.01^{a}	1.50 ± 0.02^{b}	1.23 ± 0.02^{ab}	2.56 ± 0.03^{c}	1.77 ± 0.01^{a}	1.42 ± 0.02^{b}
L-Dopa	4.99 ± 0.02^{c}	6.11 ± 0.01^{d}	5.35 ± 0.03^{e}	7.12 ± 0.03^{df}	6.35 ± 0.01^{d}	3.87 ± 0.02^{g}
Raffinose	1.65 ± 0.01^{b}	1.45 ± 0.02^{b}	1.87 ± 0.01^{b}	1.76 ± 0.02^{b}	1.21 ± 0.01^{c}	1.10 ± 0.02^{bc}
Stachyose	1.23 ± 0.02^{d}	1.05 ± 0.01^{e}	1.34 ± 0.02^{b}	1.12 ± 0.01^{de}	1.10 ± 0.01^{e}	1.29 ± 0.02^{d}
Verbascose	0.93 ± 0.01^{a}	1.03 ± 0.01^{a}	0.78 ± 0.01^{b}	0.87 ± 0.01^{a}	1.06 ± 0.02^{a}	0.65 ± 0.01^{ac}

Results other than moisture are on dry weight basis.
Means followed by different superscript in each row indicates significant differences at $P < 0.05$.
[A] Results presented as means ± SD of triplicate analyses.
[B] mg pure trypsin inhibited per g of sample.
[C] *M. veracruz* (M) – mottle.
[D] *M. veracruz* (W) – white.

digestive enzymes (Jambunathan & Singh, 1981) and nutritional effects are mainly related to their interaction with proteins and minerals. They also reduce the absorption of nutrients such as vitamin B_{12} (Linier, 1989). Tannin–protein complexes are insoluble and this decreases the protein digestibility (Carnovale, Lugaro, & Marconi, 1991). The concentration of phenols in the *Mucuna* species ranges from 4.34% to 7.75%. This value is higher than those reported for conventional legumes such as *Vigna radiate* (1.45%). The result is comparable to the work of Josephine and Janardhanan (1992). In their work on three germplasms of *M. pruriens*, up to 9% of total free phenols was reported. Siddhuraju et al. (2000) have reported that up to 80% of the total phenol constituents could be removed by either dehulling of the seed coat or by soaking, followed by irradiation.

Protease inhibitors are widespread antinutrient substances which block either trypsin or chymotrypsin, thereby reducing digestibility. The concentration of protease inhibitor (TIA) estimated in the six species of *Mucuna* ranged from 18.5 to 23.1 mg g^{-1} sample. It is very difficult to compare the enzyme inhibitory activities of legumes, as reported by different authors, primarily because of differences in methods and units used. Smith et al. (1980) reported trypsin inhibitor values (using the same method as used in this work) of 16.6–30 mg trypsin inhibited per gramme of raw soy bean meal. Kochhar, Walker, and Pike (1988) also reported trypsin inhibitor activity of 4.6–13.9 mg g^{-1} seed in *Vigna unguiculata*. Moist heat treatment, by autoclaving for 15–30 min, has been recommended as a means of reducing the levels of TIA below critical levels (Norton, 1991).

Other antinutrients, saponins, are a diverse group of compounds containing an aglycone moiety linked to one or more sugar or oligosaccharide residues. Some of the biological effects in animals include erythrocyte haemolysis, depressed growth, reduced feed intake, and effects on nutrient absorption and bile acid metabolism (Cheeke, 1996). The total saponin estimated in the *Mucuna* seeds ranges from 0.52% to 3.01%. Hossain and Becker (2001) reported lower values of saponin in sesbania seeds (0.50–1.46%). Fenwick, Price, Tsukamoto, and Okubo (1991) reported a saponin in value of 0.23% in chickpeas. In another earlier report, Fenwick and Oakenfull (1983) reported higher values for chickpeas (5.7%). Dehulled soy to seeds are reported to contain between 0.08% and 0.25% saponin (Dandanell, Aman, Betz, & Obermeyer, 1995). Due to the high solubility of saponins in water, aqueous extraction is recommended for the complete removal of saponin. In our studies it appeared that a large variation occurred in the saponin contents of the six species.

Phytates (hexaphosphates of myo-inositol) are common antinutrients in plant seeds. They chelate di- and trivalent mineral ions, such as Ca^{2+}, Mg^{2+}, Zn^{2+}, and Fe^{3+}, resulting in reduced bioavailability of trace minerals to consumers (Duffus & Duffus, 1991). Phytates were estimated as phytic acid in this study. Phytic acid concentration ranged from 1.23% to 2.56%. Hossain and Becker (2001) have reported phytic acid content of 1.89–2.37% in Sesbania seeds. The phytic acid can be reduced or substantially eliminated by processing methods such as soaking and cooking (Reddy, Sathe, & Salunkhe, 1982).

A non-protein antinutritional factor, L-dopa, was also determined. The concentration ranged from 3.87% to 7.12% in the seeds. Earlier, Josephine and Janardhanan (1992) reported a higher value of L-dopa for some germplasms of *Mucuna pruriens* (6.97–9.16%). Significant reductions in the level of L-dopa, have been demonstrated by dry heat treatment (Siddhuraju et al., 1996). Oligosaccharides of the raffinose family and

Table 6
Nutritionally valuable and trace metals (mg $100g^{-1}$) of *Mucuna* spp.[A]

Metals	Composition					
	M. pruriens	*M. cochinchinesis*	*M. rajada*	*M. veracruz* (W)[C]	*M. veracruz* (M)[D]	*M. deeringeeana*
Sodium	2.87 ± 0.02^{a}	2.24 ± 0.01^{a}	2.40 ± 0.01^{a}	3.78 ± 0.04^{b}	3.06 ± 0.01^{b}	3.86 ± 0.02^{b}
Potassium	389 ± 0.30^{b}	407 ± 0.20^{b}	410 ± 0.35^{b}	433 ± 0.45^{c}	356 ± 0.56^{bc}	361 ± 0.65^{bc}
Calcium	262 ± 0.78^{c}	293 ± 0.68^{d}	258 ± 0.55^{c}	359 ± 0.56^{d}	308 ± 0.40^{c}	408 ± 0.54^{e}
Magnesium	52.8 ± 0.05^{e}	50.0 ± 0.10^{e}	59.6 ± 0.04^{e}	69.6 ± 0.03^{f}	58.5 ± 0.02^{e}	72.6 ± 0.06^{ef}
Phosphorus	457 ± 0.94^{a}	568 ± 0.86^{b}	601 ± 0.53^{c}	459 ± 0.41^{a}	564 ± 0.39^{b}	607 ± 0.58^{c}
Iron	14.9 ± 0.04^{b}	14.7 ± 0.04^{b}	8.62 ± 0.03^{c}	14.3 ± 0.03^{b}	19.6 ± 0.04^{b}	17.6 ± 0.02^{b}
Copper	0.57 ± 0.01^{d}	0.78 ± 0.02^{e}	0.95 ± 0.02^{ef}	0.32 ± 0.01^{g}	0.43 ± 0.01^{g}	0.98 ± 0.03^{ef}
Zinc	3.76 ± 0.01^{e}	2.11 ± 0.01^{f}	2.18 ± 0.01^{f}	3.65 ± 0.02^{e}	4.40 ± 0.03^{g}	6.08 ± 0.02^{h}
Manganese	0.30 ± 0.01^{a}	0.26 ± 0.02^{a}	0.43 ± 0.02^{b}	0.11 ± 0.02^{ab}	0.38 ± 0.01^{a}	0.35 ± 0.01^{a}
Lead	ND[B]	ND	ND	ND	ND	ND
Nickel	ND	ND	ND	ND	ND	ND

Means followed by different superscript in each row indicates significant differences at $P < 0.05$.
[A] Results presented as means ± SD of three replicate analyses.
[B] ND – not detectable (below detection limit).
[C] *M. veracruz* (M) – mottle.
[D] *M. veracruz* (W) – white.

non-starch polysaccharides, known as flatulence factors, are also antinutritional factors present in legumes. Three flatulence factors were estimated in the *Mucuna* samples. They include, raffinose, stachyose and verbascose. Verbascose was the highest of flatulence factors in the *Mucuna* samples.

3.4. Mineral composition

The results of the nutritionally valuable minerals and trace metals are presented in Table 6. Potassium was the most abundant mineral present in the in the *Mucuna* species. The value varied from 356 to 433 mg 100 g^{-1}. In addition, the seeds also contained high contents of phosphorus and calcium (457–607 mg 100 $g^{-1}$and 258–408 mg 100 g^{-1}, respectively). This trend is similar to those reported by other authors. Ravindran and Ravindran (1988) and Rajaram and Janardhanan (1991) reported the mineral content of *Mucuna utilis*: (potassium, 1110 mg 100 g^{-1}; phosphorus, 220 mg 100 g^{-1}; calcium, 250.0 mg 100 g^{-1}) and *Mucuna gigantean*: (potassium, 229 6 mg 100 g^{-1}; phosphorus, 194 mg 100 g^{-1}; calcium, 518 mg 100 g^{-1}).

4. Conclusions

Most tropical legumes contain varieties of antinutritional factors with capacity to cause adverse effects on consumers. Nevertheless, on the whole, these antinutritional factors exert only minor effects on food and feeding values of tropical pulses and legumes. Apparent overexploitation of the conventional legumes by humans and livestock in developing countries has forced nutritionists and planners to look for unconventional and under-utilized sources with less competition.

In this study, the six *Mucuna* species are a good source of protein (33.2–38.4%). Besides, they have higher levels of amino acids and minerals than the recommended levels. In vitro protein digestibility is higher than most common legumes. The presence of antinutritional factors identified in this paper should not pose a problem to humans if the seeds are properly processed. In view of the overall nutrient and proximate chemical composition, these *Mucuna* species may be an economic and alternative protein source that could alleviate protein malnutrition in developing countries and improve overall nutritional status of functional food in the developed countries.

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