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Nutritional and anti-nutritional components in *Pachyrhizus erosus* L. tuber

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Abstract

Tuber of *Pachyrhizus erosus* L., an underutilized crop, was analyzed to determine its proximate chemical composition, vitamin, mineral, and amino acid contents, and enzymatic activity. The anti-nutritional factors were also determined. The tuber had a high level of moisture, appreciable amounts of carbohydrate, crude fibre and protein and negligibly low amount of lipid. The total caloric value corresponded to 39 kcal/100 g. The amino acid profile was deficient compared to the [FAO/WHO (1973). *Energy and Protein Requirements*. Technical Report Series (Vol. 52, pp. 1–118). Switzerland, Geneva: WHO.] recommended pattern. The micro- and macro-nutrient analysis revealed the tuber to be potential source of potassium, sodium, phosphorus, calcium and magnesium. The tuber contained a significant amount of ascorbic acid. Thiamine, riboflavin, pyridoxine, niacin and folic acid were also detected. Very negligible contents of anti-nutrient components were observed. Comparison of these data to those of several other commonly consumed local tubers revealed that *P. erosus* tuber could be included in dietary formulae for man or monogastric animals, especially in those areas where carbohydrate is in short supply.

Keywords: *Pachyrhizus erosus* L.; Underutilized crop; Minerals; Anti-nutrients

1. Introduction

Malnutrition is rife in developing countries. To acquire the ability to reduce the adverse effect of hunger and or starvation, it is pertinent that some under-utilized crops should be investigated for their nutritive value and easy-cultivable characteristics. Thus, one such unprivileged crop that could be considered for the purpose is *Pachyrhizus erosus* L., a tuberous plant. Tubers are widely used as cheap sources of carbohydrates for man and livestock and they have been adjudged to be of good nutritional value (Nielsen, 1995). *P. erosus* originated in Mexico and Central America and is cultivated in Mexico, Guatemala, El Salvador and, to a limited extent, in Honduras. It has been introduced to different pan-tropical regions with notable success in southeast Asia, especially in the northern part of Bangladesh, and is named as ''Sakaloo'' or ''Kesor Aloo''. The tuber is consumed raw by the local people who consider it to be an energy-rich and easily digestible food. It is also believed to serve as a bulk food that helps to reduce the hyperactivity of the empty stomach. Despite its wide popularity and almost no adverse effect on health, no information on the nutritional or anti-nutritional compositions of this cultivar is available. In addition, lack of preservation and processing methods results in low market price. As a result, farmers are not cultivating the crop professionally, which is hindering the cultivar. Thus, this study was designed to provide some analytical information on the tuber after frozen storage with a view to increasing the interest of people such as farmers and to make the crop part of traditional farming systems in regions that offer great potential for the production of *P. erosus* L.

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2. Materials and methods

2.1. Tuber collection

The fresh tuber *Pachyrhizus erosos* L. was harvested from a traditional yard beside Bagha Mosque (Longitude 88°45′–88°55′, Latitude 24°05′–24°20′), Bagha, Rajshahi, Bangladesh, where they were not grown on a commercial basis. Thereafter, the outer skin was manually removed from the tuber and was kept in airtight containers and deep frozen prior to use.

2.2. Proximate chemical composition

Unless otherwise stated, all determinations were carried out in triplicate. The samples were analyzed by standard procedures (AOAC, 1990). Protein ($N \times 6.25$) was determined by the micro-Kjeldahl method (Wong, 1923). Ash content was determined by incineration of known weights of the samples in a muffle furnace. Lipid was extracted with a chloroform-ethanol mixture (bp 40–60 °C) in a Soxhlet extractor and the solvent was evaporated. The dried residue was quantified gravimetrically and expressed as percentage of lipid. Crude fibre was determined after digesting a known weight of fat-free sample in 1.25% sulfuric acid and refluxing in 1.25% sodium hydroxide. The total carbohydrate and starch were determined by the anthrone method (Morse, 1947). Total soluble sugar was determined by the method of Jayaraman (1981). Reducing sugar was determined by the Dinitrosalicylic acid method (Miller, 1972). Non-reducing sugar was determined by subtracting the reducing sugar from total sugar. Total caloric value (TCV) was determined against thermochemical-grade benzoic acid using a Gallenkamp Ballistic bomb calorimeter.

2.3. Estimation of vitamins

Ascorbic acid was determined by the titrimetric method, as described in AOAC (1990). The titrations were performed rapidly. Recovery experiments were performed by spiking standard ascorbic acids in the samples for extraction and titration. Other water-soluble vitamins were estimated by an HPLC system (Shimadzu SPD 10A VP and LC 10AT VP liquid chromatograph, Tokyo, Japan). Thiamine, riboflavin, pyridoxine and niacin were determined by using a 3.9×300 mm L1 column (octadeyl silane chemically bonded to porous silica or ceramic microparticles, 3–10 μm in diameter), eluted with a mixture of water, methanol, and glacial acetic acid (73:27:1) containing sodium 1-hexanesulfonate (1.4 mg/ml) at a flow rate of 1 ml/min and detected at 280 nm at 38 °C. Folic acid was determined by using a 4.6×250 mm column containing the same packing material as mentioned above and eluting with a mixture (0.4 ml of triethylamine, 15 ml of glacial acetic acid and 350 ml of methanol, diluted to 2000 ml with 8 mM sodium hexane sulfonate) at a flow rate of 2 ml/min and detected at 270 nm at 50 °C.

2.4. Determination of mineral elements

Minerals, such as Ca, Cu, Fe, Mg, Mn, P, K, Na, Zn and Se, were determined by the modified method of Enujiugha and Ayodele-Oni (2003). For micro- and macro-element determinations 25 and 10 g of the samples, respectively, were heated at 550 °C for 8 h in a muffle furnace and the resulting white ashes were dissolved in 2 ml portions of a mixture of nitric and perchloric acids (1:1 v/v). Lanthanum chloride was added to both the acid solutions of the ashes and to the standard solutions in a final proportion of 1% (w/v), to avoid possible interferences in the determination of Ca and Mg. The excess acid was evaporated off and the residues were dissolved in de-ionized water and adjusted to volumes of 50 and 100 ml, respectively. The Na and K were determined by flame photometry (Jenway Ltd., Dunmow, Essex, UK), and P by the vanado-molybdate method (AOAC, 1990). Other elements were determined by atomic absorption spectrometer (AAS), Pye Unicam model SP9, Cambridge, UK (Enujiugha & Ayodele-Oni, 2003).

2.5. Amino acid analysis

Amino acid analysis was performed using the Waters Associates PICO-TAG™ method, an integrated technique for pre-column derivatisation of amino acids using phenyl isothiocyanate (PITC). The amino acids in the protein hydrolyzate were separated by a reverse phase Pico-Tag C_{18} column (3.9×150 mm) with a linear gradient, starting with 10% and ending with 51% of 'B' (60% acetonitrile in water) in 'A' (an aqueous buffer), over 10 min at a flow rate of 2 ml/min and detected at 254 nm at 38 °C. A set of amino acid standards (Sigma Chemicals) was run in parallel with each set of samples. The chemical score was calculated as the content of essential amino acid in a food divided by that in whole egg proteins (Block & Mitchell, 1946).

2.6. Assay of enzyme activity

The cellulase and invertase activities of the sample were determined by the procedures of Mahadevan and Sridhar (1982) using carboxy methyl cellulose and sucrose as substrates, respectively. Amylase activity was determined by the procedures of Jayaraman (1981) using 1% starch solution as substrate. The activity was expressed as μkat/mg.

2.7. Analysis of anti-nutrients

Assays were carried out for phytin, phytin-phosphorus (phytin-P), tannins (as tannic acid), lectin (haemagglutinin) titres, trypsin inhibitor activity (TIA) and hydrogen cyanide (HCN) in the samples. Phytin-P was determined by the modified method of Reddy, Balakrishan, and Salunkhe (1978). Tannin content was determined by the modified vanillin–HCl method (Burns, 1971). Lectin (haemagglutinin) titres

of the extract were subsequently determined, using a 0.25% two-fold serial dilution technique (Liner & Hill, 1953). The trypsin inhibitor activity (TIA) was assayed in terms of the extent to which an extract of the defatted tuber inhibited the action of bovine trypsin (EC3. 4.2.1.4) on the substrate benzoyl-DL-arginine-*p*-nitroanilide (BAPNA) hydrochloride (Kakade, Simons, & Liener, 1969 as modified by Smith, Megen, Leendert, & Hitchcock (1980)). Hydrogen cyanide was determined by the method of Bradbury, Egan, and Lynch (1991). Potassium cyanide (KCN) was used to calibrate the standard curve from a stock solution containing 75 mg KCN/100 ml.

2.8. Statistical analysis

For all analyses, the mean and standard deviations were calculated.

3. Results and discussion

3.1. Proximate chemical composition

The proximate chemical composition of *P. erosus* tuber was determined by standard procedures and the data are presented in Table 1, along with the nutritional data of two other local tubers. The protein level in *P. erosus* tuber was estimated to be almost half that in potato but was more than double that in sweet pota. These differences in protein values were statistically significant at $p < 0.01$. The total lipid content in *the* tuber was found to be double that in potato which was statistically insignificant, but it was almost four times higher than that in sweet potato which was statistically significant at $p < 0.05$. The carbohydrate content in *P. erosus* tuber was found to be lower than that in potato, but was half that in sweet potato. The values were significant at $p < 0.01$. *P. erosus* contained a significantly high amount of moisture compared to that in potato and sweet potato. Consequently, the ash content was lower than those in potato and sweet potato. The crude fibre in *P. erosus* was almost 14 times higher than that in potato and 4 times higher than that in sweet potato. The total caloric value (TCV) of *P. erosus* tuber was around half that of potato and below 33% of that of sweet potato. Total soluble sugar in the tuber was significantly low compared to those in potato and sweet potato, but reducing sugar was 3 times higher in *P. erosus* than that in sweet potato. Sucrose content in *P. erosus* was half that in sweet potato.

3.2. Vitamin content

From the recovery experiments for analysis of ascorbic acid in the samples, the recoveries were found to be in

Table 1
Proximate chemical compositions (%) of *Pachyrhizus erosus*, potato and sweet potato

Composition (%)	Samples				
	P. erosus	Potato	Sweet potato	T static (*P. erosus* vs potato)	T static (*P. erosus* vs sweet potato)
Moisture	82.01 ± 2.24	77.26 ±0.15	68.72 ± 0.05	3.664*	6.849**
Ash	0.5 ± 0.12	0.65 ± 0.01	1.00 ± 0.02	2.157*	4.745**
Lipids	0.1 ± 0.04	0.04 ± 0.03	0.26 ± 0.05	2.078	2.885*
Protein	1.23 ± 0.13	2.73 ± 0.12	0.57 ± 0.15	14.685**	3.839**
Crude fibre	1.4 ± 0.14	0.13 ± 0.09	0.29 ± 0.12	11.876**	6.951**
Carbohydrate	14.9 ± 0.04	19.23 ± 0.12	29.14 ± 1.3	59.29**	12.642**
Total soluble sugar	2.13 ±0.11	4.8 ± 1.15	5.6 ± 0.75	4.003**	5.285**
Reducing sugar	1.83 ± 0.22	0.0	0.56 ± 0.05	14.407**	6.5**
Starch	9.04 ± 0.11	10.23 ± 3.45	12.45 ± 2.75	0.597	1.43
Sucrose	3.24 ± 0.13	4.56 ± 2.15	6.25 ± 1.56	1.061	2.22*
Energy (kcal)	39 ± 1.23	88 ± 0.15	121 ± 1.25	68.492**	53.992**

[a] Means ± SD Number of composite samples is three replicates each. Values are on wet basis.
* Significant at less than 0.05 level.
** Significant at less than 0.01 level.

Table 2
Vitamin contents of *Pachyrhizus erosus*, potato and sweet potato

Component (mg/100 g)	Samples				
	P. erosus	Potato	Sweet potato	T static (*P. erosus* vs potato)	T static (*P. erosus* vs sweet potato)
Ascorbic acid	14 ± 0.1	16.28 ± 1.45	28.75 ± 2.52	2.717*	6.753**
Thiamine	0.05 ± 0.001	0.03 ± 0.01	0.075 ± 0.02	3.446*	1.441
Riboflavin	0.02 ± 0.002	0.048 ± 0.03	0.2 ± 0.05	1.613	4.153**
Pyridoxine	0.25 ±0.01	0.35 ± 0.05	0.45 ± 0.07	3.396*	3.265*
Niacin	0.2 ± 0.01	1.56 ± 0.75	0.95 ± 0.35	3.140*	2.473*
Folic acid	0.001 ± 0.0002	0.005 ± 0.001	0.007 ± 0.002	6.793**	3.446*

[a] Means of three determinations ± standard deviation.
* Significant at less than 0.05 level.
** Significant at less than 0.01 level.

the range 90–100%; however, no comparison with other methods was made. The vitamin content in *P. erosus* tuber was compared to that in some locally consumed tubers (Table 2). It was found that vitamin C content in *P. erosus* was comparable to that in potato, but was half that in sweet potato. Other vitamins, such as thiamine, riboflavin, pyridoxine, niacin and folic acid, were determined by HPLC and the chromatograms are shown in Figs. 1 and 2. These values were compared to corresponding data for two other local tubers and are presented in Table 2. Thiamine level in *P. erosus* tuber is higher than that in potato but lower than that in sweet potato. The riboflavin and niacin content in *P. erosus* is lower than that in other tubers. The pyridoxine content in *P. erosus* is nearly equal to that in potato and sweet potato (Table 2). Folic acid was detected in a negligible amount in *P. erosus* tuber and the value is significantly low compared to that in potato and sweet potato (see Fig. 3).

3.3. Determination of micro- and macro-mineral elements

The data for minerals present in *P. erosus*, potato and sweet potato are presented in Table 3. It is evident from the data, that Na content in *P. erosus* is 8 and 5 times higher than that in potato and sweet potato, respectively, whereas Fe and Se contents in *P. erosus* were almost similar to those in potato and sweet potato (Table 3). Other minerals were also found in appreciable amounts, but were significantly lower than those present in other tubers.

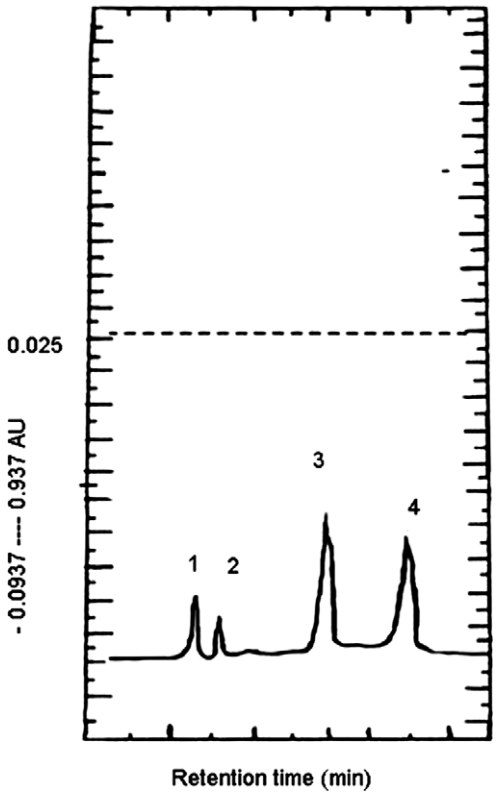

Fig. 2. HPLC chromatograph of thiamine, riboflovin, niacin and pyridoxine in *Pachyrhizus erosus* under conditions as given in the text (peak 1, thiamine; 2, riboflavin; 3, niacin; 4, pyridoxine).

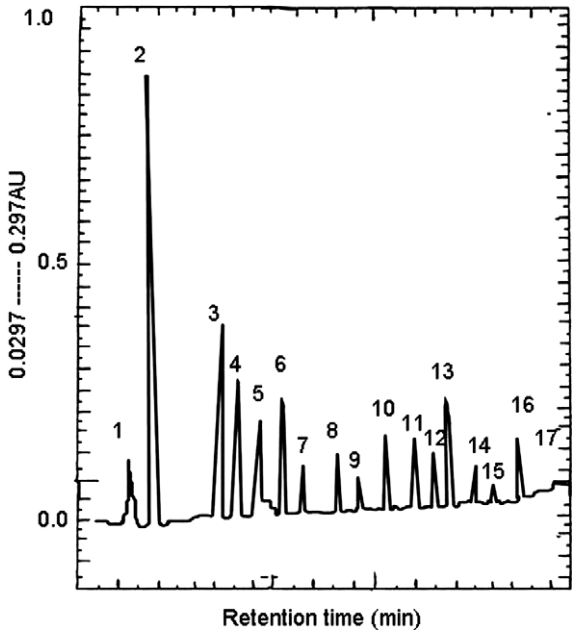

Fig. 1. Amino acid profile of *Pachyrhizus erosus* (peaks; 1, aspartate; 2, glutamate; 3, glycine; 4, histidine; 5, arginine; 6, threonine; 7, alanine;, 8, proline; 9, tyrosine; 10, valine; 11, methionine; 12, isoleucine; 13, leucine; 14, phenylalanine; 15, serine; 16, cysteine 17, lysine).

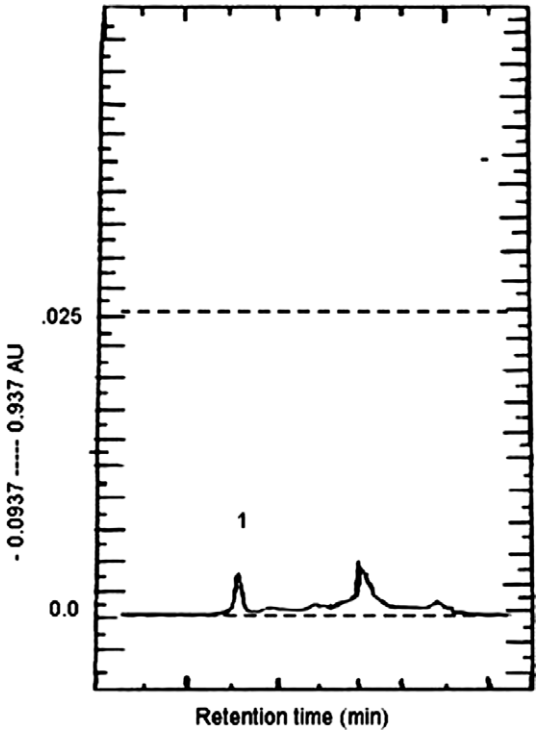

Fig. 3. HPLC chromatograph of folic acid in *Pachyrhizus erosus* under conditions as given in the text (peak 1, folic acid).

Table 3
Micro- and macro-mineral element contents of *Pachyrhizus erosus*, potato and sweet potato

Component (mg/100 g)	Samples				
	P. erosus	Potato	Sweet potato	T static (*P. erosus* vs potato)	T static (*P. erosus* vs sweet potato)
Ca	16 ± 0.45	27 ± 3.5	32 ± 0.88	5.399**	18.692**
Cu	0.048 ± 0.01	0.14 ± 0.05	0.169 ± 0.04	3.125*	3.388**
Fe	1.4 ± 0.03	1.08 ± 0.07	1.52 ± 0.07	2.277**	1.819
Mg	12.9 ± 1.05	51 ± 0.56	95 ± 0.24	55.454**	88.016**
Mn	0.06 ± 0.002	0.5 ± 0.1	0.45 ± 0.05	7.473**	8.362**
P	18 ± 1.02	31 ± 0.98	50 ± 0.43	15.918**	33.380**
K	172 ± 3.14	560 ± 2.14	232 ± 1.82	177.084**	19.248**
Na	35 ± 1.23	4.00 ± 0.32	7 ± 0.17	42.246**	26.038**
Zn	0.16 ± 0. 02	0.21 ± 0.01	0.11 ± 0.01	3.872**	2.581*
Se (μg)	0.7 ± 0.07	0.5 ± 0.05	0.7 ± 0.1	4.026**	0

[a]Means of three determinations ± standard deviation.
* Significant at less than 0.05 level.
** Significant at less than 0.01 level.

Table 4
Amino acid and total nitrogen contents of *Pachyrhizus erosus*, potato and sweet potato

Component (μmol/g)	Samples				
	P. erosus	Potato	Sweet potato	T static (*P. erosus* vs potato)	T static (*P. erosus* vs sweet potato)
Tryptophan	0.72 ± 0.23	0.85 ± 0.4	1.5 ± 0.2	0.488	2.954*
Threonine	1.42 ± 0.23	4.5 ± 1.35	7.75 ± 1.12	3.895**	6.392**
Isoleucine	1.75 ± 0.23	5.25 ± 0.5	6.75 ± 0.75	11.014**	7.359**
Leucine	2.13 ± 0.28	7.15 ± 1.1	10.15 ± 0.02	7.660**	32.989**
Lysine	0.19 ± 0.05	4.2 ± 1.14	4.98 ± 1.5	6.086**	3.685*
Methionine	1.88 ± 0.34	2.5 ± 0.45	3.12 ± 0.56	1.904	2.185*
Cysteine	0.57 ± 0.09	0.85 ± 0.15	1.85 ± 0.45	2.772*	3.220*
Phenylalanine	0.32 ± 0.03	4.52 ± 0.12	6.57 ± 1.05	58.811**	6.870**
Tyrosine	1.51 ± 0.02	6.23 ± 0.06	4.82 ± 0.14	129.263**	27.026**
Valine	1.11 ± 0.07	9.45 ± 1.5	11.25 ± 2.15	9.619**	5.443**
Arginine	1.26 ± 0.03	3.59 ± 0.09	4.47 ± 0.57	42.539**	6.493**
Histidine	2.58 ± 0.10	2.10 ± 0.15	3.25 ± 1.15	4.469**	0.669
Alanine	2.05 ± 0.04	7.56 ± 1.23	10.5 ± 2.16	7.754**	4.516**
Aspartic acid	1.57 ± 0.12	15.15 ± 1.15	23.25 ± 2.5	20.342**	10.002**
Glutamic acid	13.6 ± 0.08	13.6 ± 1.14	10.95 ± 2.54	0	1.204
Glycine	4.15 ± 0.07	5.15 ± 1.7	8.5 ± 0.3	1.017	16.305**
Proline	2.04 ± 0.04	5.5 ± 0.02	8.78 ± 0.5	134.005**	15.515**
Serine	2.13 ± 0.02	6.15 ± 1.2	8.55 ± 1.3	5.801**	5.701**
Total amino acids	40.98	104.3	136.99	#DIV/0!	#DIV/0!
EAA	12.14	48.24	61.71	#DIV/0!	#DIV/0!
Non-EAA	28.84	56.06	75.28	#DIV/0!	#DIV/0!
Total nitrogen (g/100 g dry wt)	0.09 ± 0.003	0.23 ± 0.001	0.30 ± 0.003	76.681**	57.154**

[a]Means of three determinations ± standard deviation.
* Significant at less than 0.05 level.
** Significant at less than 0.01 level.

3.4. Amino acid composition

Amino acids were quantitatively determined by HPLC and the amino acid profile is shown in the chromatogram (Fig. 1). Seventeen amino acids (10 essential and 7 non-essential) were detected in *P. erosus* tuber. Table 4 shows the amino acid concentration and total nitrogen content in *P. erosus* tuber, along with the data for potato and sweet potato. The ratio of essential amino acids to total amino acid is 0.3; i.e., almost one third of the amino acids in *P. erosus* consist of essential amino acids. The ratio of essential to non-essential amino acids is 0.4. *P. erosus* is rich in glutamic acid, glycine, histidine, leucine, serine, proline and alanine. Other amino acids are present in smaller amounts. Data on tryptophan are not included in this work since this amino acid is destroyed during acid hydrolysis. The determination of amino acid profile of *P. erosus* is of great value from a nutritional, chemical and biochemical point of view.

3.5. Nutritional evaluation

The nutritional value was determined by comparing the ratio of essential amino acids in *P. erosus* tuber to that in

hen egg. Table 7 shows comparative data on the essential amino acid in *P. erosus* and in hen egg reported by Sikka, Duggal, Singh, Guopta, and Joshi (1978). The chemical score of the essential amino acids in *P. erosus was* calculated according to the method of Meredith and Dull (1979). The protein quality is evaluated on the basis of 10 essential amino acids. Since cysteine and tryosine can replace methionine and phenylalanine, respectively, through a metabolic process, two amino acids are combined, namely, methionine with cysteine and phenylalanine with tyrosine, for the calculation of chemical score (Sikka et al., 1978). Table 7 shows that almost all of the essential amino acids studied in *P. erosus* have a low chemical score compared to the FAO/WHO recommended pattern which implies that dietary formulae based on the tuber will require amino acid supplementation, especially of the essential amino acids.

3.6. Enzyme activity

Activities of carbohydrate-splitting enzymes are presented in Table 5. The activities were compared to those for potato and sweet potato tuber. The results show that *P. erosus* possessed almost the same carbohydrate-splitting enzyme activity as do potato and sweet potato.

3.7. Anti-nutrient factors

The anti-nutrient factors in *P. erosus* were compared to corresponding data for *Caesalpinia pulcherima* seed flour

Table 5
Enzyme activities in *Pachyrhizus erosus*, potato and sweet potato

Activity (μkat/mg)	Samples				
	P. erosus	Potato	Sweet potato	T static (*P. erosus* vs potato)	T static (*P. erosus* vs sweet potato)
Amylase	65.8 ± 2.98	60.1 ± 3.98	80.6 ± 2.56	1.996	4.335**
Invertase	25 ± 1.23	21 ± 1.23	28.4 ± 1.75	3.950**	1.808
Cellulase	6.64 ± 0.43	5.98 ± 1.2	4.75 ± 1.5	0.896	1.398

[a]Means of three determinations ± standard deviation.
** Significant at less than 0.01 level.

Table 6
Anti-nutrient factors in *Pachyrhizus erosus*, potato and sweet potato

Component (mg/100 g)	Samples				
	P. erosus	Potato	Sweet potato	T statistic (*P. erosus* vs potato)	T statistic (*P. erosus* vs Sweet potato)
Phytin	0.004 ± 0.001	0.007 ± 0.002	0.005 ± 0.003	2.323*	1.825
Phytin-P	0.005 ± 0.002	0.008 ± 0.001	0.01 ± 0.15	2.323*	0.038
Lectin	0.0003 ± 0.0001	0.0008 ± 0.0002	0.001 ± 0.0005	3.872**	1.585
TIA	0.01 ± 0.003	0.01 ± 0.002	0.01 ± 0.001	0	0
HCN	0.0032 ± 0.0002	0.005 ± 0.001	0.004 ± 0.0005	3.057*	1.715
Tannic acid	0.001 ± 0.0005	0.003 ± 0.0015	0.005 ± 0.0005	2.190*	6.531**

[a]Means of three determinations ± standard deviation.
* Significant at less than 0.05 level.
** Significant at less than 0.01 level.

Table 7
Chemical score of the essential amino acids in *Pachyrhizus erosus*

Essential amino acids component	Amino acid concentration in g of amino acid/16 g of nitrogen			Chemical score (%) (egg ratio × 100)
	P. erosus	FAO/WHO (1973) recommended pattern[a]	Hen's eggs[b]	
Threonine	0.24	4	5.1	4.7
Arginine	0.31	6.1	6.1	5.08
Phenylalanine + tyrosine	0.414	3.2	10.3	4.0
Methionine + cysteine	0.15	1.8	5.4	2.7
Isoleucine	0.39	4	5.6	6.9
Leucine	0.48	7	8.3	5.7
Lysine	0.02	5.5	6.3	0.31
Phenylalanine	0.08	5.1	5.1	1.5
Tyrosine	0.31	6	4	7.75
Valine	0.22	5	7.6	2.89

[a] Source: FAO/WHO (1973). Technical Report Series.
[b] Source: Robinson (1987).

(Agbede, 2004) and are included in Table 6. The result of the present study shows no threat by anti-nutrients against bioavailability of nutrients in the tuber.

4. Conclusion

The study shows that the tuber of *P. erosus*, a neglected crop, could be used as food material for human or non-ruminant animals, judging from the high carbohydrate and energy content and adequate protein and low lipid content. Though low in mineral contents, its consumption with ingredients high in the micro- and macro-mineral elements would increase its utilization. The very low anti-nutritional factors in the tuber may not hamper its nutritional value. It is, therefore, suggested that unprocessed *P. erosus* tuber could be used for man and/or monogastric animals where malnutrition is prevalent.

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