Chemical characterisation and nutrient evaluation of some Tanzanian plant protein feedstuffs

M. M. JAGADI*, M. RUNDGREN and R. B. OGLE
Department of Animal Nutrition and Management
Swedish University of Agricultural Sciences
S-750 07 Uppsala, Sweden

* Present address: Animal Diseases Research Institute, Temeke, P. 0. Box 9254, Dar-es-Salaam, Tanzania.

Summary

THE NUTRIENT *content of five Tanzanian plant protein feedstuffs was evaluated. Untoasted red beans (URB), cowpea seeds from Dar-es-Salaam (DSM-P) and Morogoro (MOR-P), kapok seed expeller cake (KC) and sunflower seed expeller cake (SFC) were analysed for crude fibre, crude protein, ether extract, minerals and amino acids. Their protein quality was evaluated and compared with soya bean meal (SBM) in an experiment with growing rats. Untoasted red beans were excluded from this experiment due to low feed consumption and occurrence of diarrhoea.*

The net protein utilisation (NPU) of the Tanzanian plant protein sources was inferior to that of SBM. The lower NPU of SFC and KC was mainly due to low lysine and high fibre contents, while that of the cowpea seed samples was due to a low content of methionine and cysteine, as well as a lower CP digestibility. The digestiblity of organic matter and digestible energy of SFC and KC were low compared with SBM and the cowpea seed samples.

Introduction

Information on the chemical and nutritive characteristics of Tanzanian feedstuffs is limited, particularly on variations due to differences in the origin of the material and processing conditions. Information given by Naik (1969) and French (1941) is limited, which is typical for many developing countries (Gohl, 1975; FAO, 1967). Mellon et al (1964) suggested using tables showing amino acid content of overseas feeds for similar tropical feeds, but this is of questionable value since differences occur in fibre, lignin, tannin and saponin contents and in the various antinutritional factors which affect the bioavailability of nutrients to the animal (FAO, 1967; Liener, 1975).

Accurate data on the nutritive value of locally available feedstuffs are essential for an effective least-cost feed formulation and the efficient use of feed resources (Gohl, 1975; Zainal et al, 1983). Often information regarding processing conditions is limited, and the products have ambiguous names. Such circumstances compel animal nutritionists and feed specialists to base feed formulations on estimates or on established analysis values of similar feeds produced in other countries.

This paper describes the chemical characteristics, protein quality, and energy evaluation of five Tanzanian plant protein sources. Comparisons were made with defatted soya bean meal using the nitrogen balance technique (NBT) with growing rats. This technique is widely accepted as a

valuable instrument to estimate the feeding properties of protein sources for non-ruminants (Austin, 1983; Batterham, 1979; Church, 1984; Eggum, 1973; McDonald et al, 1981).

Materials and methods

Materials

The plant protein sources studied included expeller-extracted seed cakes of kapok *(Ceiba pentandra)* (KC) and sunflower *(Helianthus annuus)* (SFC), seeds from cowpea *(Vigna sinensis)* grown in Dar-es-Salaam (DSM-P) and Morogoro (MOR-P), and untoasted red beans *(Phaseolus vulgaris)* from Morogoro (URB). The SFC and KC samples were obtained from the Morogoro multipurpose oil processing company, MOPROCO. Soya bean meal (SBM), which had been toasted to deactivate trypsin inhibitors, and non-protein feed ingredients (maize starch and soya bean oil), were of commercial quality and were supplied by the Department of Animal Nutrition and Management of the Swedish University of Agricultural Sciences, Uppsala.

The plant protein sources were ground in a Kamas mill to pass through a 1-mm screen. All samples were analysed for crude fibre, crude protein, ether extract, gross energy (GE), minerals (Ca, Mg, P, Co, Cu, Fe, Mn and Zn) and amino acids (AA).

Diets

Five diets, of which four were based on one of the test protein sources and one on SBM, were formulated to satisfy the energy, mineral and vitamin requirements of growing rats (Table 1). The diets were made isonitrogenous with maize starch as a basal ingredient to dilute the crude protein (CP) content to 1.5 g nitrogen (N) per 100 g diet, on a dry-matter (DM) basis. Appropriate amounts of soya bean oil were added to diets with an ether extract (EE) content of less than 3% dietary DM. A sixth diet was formulated with URB, but had to be excluded from the experiment because of poor feed consumption and diarrhoea in the rats fed the diet.

Table 1. *Experimental diet formulation and daily amounts of diet fed.*

	Diet with protein sources[1]				
	DSM-P	MOR-P	KC	SFC	SBM
Diet (% DM)					
Protein source	34.2	30.9	34.0	33.9	17.9
Soya bean oil	2.2	2.2	–	–	3.0
Mineral mixture [2]	4.5	4.5	4.5	4.5	4.5
Vitamin mixture[3]	1.0	1.0	1.0	1.0	1.0
Maize starch [4]	58.1	61.4	60.5	60.6	73.6
Composition					
Dry matter (%)	89.3	89.1	90.1	91.6	89.2
Ash (% DM)	5.3	4.9	6.3	4.9	5.3
Crude protein (%DM)	9.9	9.2	9.9	9.8	9.7
Diet fed per day (g DM)	10.0	10.1	10.0	10.2	10.1

[1] DSM-P = cowpea seeds from Dar-es-Salaam; MOR-P = cowpea seeds from Morogoro; KC = kapok expeller cake; SFC =sunflower expeller cake; SBM = Soya bean meal.
[2] Based on the manufacturer's formulation, mineral mixture provided 6.4 g Ca, 4.0 g Cl, 0.41 g Mg, 5.4g P, 4.65 g K, 2.09 g Na, 0.24 mg Co, 5.3 mg Cu, 15 mgI, 150 mg Fe, 54 mg Mn, 0.1 mg Se and 45 mg Zn per kg dietary DM.
[3] Based on the manufacturer's formulation, vitamin mixture provided 0.4 mg biotin, 2 g choline, 2 mg folic acid, 0.1 g inositol, 0.05 g menadione, 0.05 g niacin, 0.1 g para-aninobenzoic acid, 0.05 g pan- tothenic acid, 0.02 g riboflavin, 0.02 g thiamin, 0.01 g B6, 0.03 mg B12, 20 000 IU A, 0.2 g E, 2000 IU D_3.
[4] Maize starch = 88.2% DM; gross energy = 17.7 MJ/kg DM.

Animals and experimental technique

Twenty-five specific-pathogen-free Sprague Dawley male rats, initially aged 26 days, were kept individually in cylindrical, acrylic plastic metabolic cages in a room with controlled temperature (22°C) and humidity (60%). The cages were a modification of those used by Eggum (1973). Light was provided for 12 hours a day. The caged rats were divided into groups of five, such that the average group weights ranged between 70.7 and 71.1 g. Each group of rats was fed a diet based on a different plant protein source.

The 10-day experiment was divided into a preliminary period of 6 days, followed by a 4-day collection period. For the entire experiment each rat was allowed to eat daily an equivalent of 10 g dietary DM containing 150 mg N of the respective plant protein source. Individual diet consumption was recorded daily by weighing the residues. The rats were weighed on the first day of the experiment and on the first and last day of the collection period. Feed and water intake was stopped 2 hours before weighing.

The faeces of individual rats were collected once a day and stored in airtight plastic containers at –20°C. At the end of the collection period, faecal samples were freeze-dried, ground and subjected to chemical analysis. Urine was also collected daily and stored in 250 ml volumetric flasks containing 50 ml of 5% (v/v) H_2S0_4. During the collection period, surfaces below the cage mesh were sprayed once daily with 5% H_2S0_4 to minimise N losses from the urine by evaporation. At the end of the collection period all surfaces which were likely to have come in contact with urine were sprayed with acid which was collected in the flasks. The urine was diluted with distilled water to volume, sampled and stored in plastic bottles at –20°C. The faecal and urine samples were each analysed for N. Faecal samples pooled within diets were analysed for dry matter, ash and gross energy.

Analysis and computation

Crude protein, crude fibre and ether extract were determined according to AOAC (1980). Amino acids were analysed in a Durrum –500 AA analyser. Samples were hydrolysed with 3 M HCl according to Mattson (1978), and defatted to 3% EE (on a DM basis) by Soxhlet extraction. Gross energy was determined with a Gallenkamp adiabatic bomb calorimeter. Major elements were determined by atomic absorption of ash dissolved in HCI; trace elements were also determined by atomic absorption after wet aching. Both analyses were performed at the National Laboratory for Agricultural Chemistry, Uppsala.

The parameters used to express protein quality were:

- true digestibility of crude protein (TD);
- biological value (BV) – per cent of digested N retained;
- net protein utilisation (NPU) – retained
- N in percentage of consumed N, calculated as product of TD and BV; and
- utilisable crude protein (UCP) – the product of NPU and the percentage of CP of the protein source.

The parameters were calculated according to Eggum (1973). Metabolic and endogenous losses were corrected based on values from earlier experiments (Ahlstrom, 1983): metabolic faecal N (g) = 0.001 × g DM consumed, and endogenous N/day = 14.9 mg.

The apparent digestibility of organic matter (DOM) and digestible energy (DE) of the diets were estimated using difference calculations in which it was assumed that DOM (%) and DE (MJ/kg DM) were respectively 100 and 17.7 for maize starch, 95 and 37.8 for soya bean oil, 100 and 17.7 for vitamin mixture, and 0 and 0 for mineral mixture. All the calculations and statistical evaluations were performed using one-way analysis of variance in the generalised linear model (SAS, 1982).

Results and discussion

Chemical characteristics

The CP contents of the Tanzanian protein sources varied relatively little, but compared with that of SBM they were markedly lower. SFC and KC had a much higher crude fibre content than the other feedstuffs. The leguminous seeds (URB, DSM-P, and MOR-P) had higher NFE[1] values than SFC and KC. The comparatively high GE value for SBM seems to be related to its high CP

content. The Ca content varied between sources and was lowest in the cowpea seeds. Among trace elements, Cu content varied most (Table 2). The most important observation from the amino acid analysis was that SFC and KC had a very low level of lysine (Table 3).

[1] NFE = nitrogen-free extractives.

Table 2. *Proximate and chemical compositions of protein sources.*

	Cottonseed expeller cakes[1]						SBM[1]
	LGR	MLP	MHZ	MOR	SHY	UZG	
Proximate composition							
Dry matter (%)	92.0	91.9	92.2	93.1	92.6	93.6	88.8
Ash (% DM)	6.8	7.2	6.4	4.0	6.3	6.3	6.0
Crude fibre (% DM)	10.9	10.9	16.3	19.4	11.3	12.1	5.3
Crude protein (% DM)	46.7	48.2	40.9	24.1	45.8	42.9	52.4
Ether extract (% DM)	9.5	8.7	8.7	6.7	6.8	10.5	3.2
Nitrogen-free-extractives (% DM)	26.1	25.0	27.7	45.8	29.8	28.2	33.1
Gross energy (MJ/kg DM)	20.8	19.2	20.5	20.1	21.2	21.6	19.9
Major minerals[2] (g/kg DM)							
Ca	2.8	3.0	3.3	1.3	3.0	2.4	3.4
Mg	12.8	11.8	8.5	5.5	10.3	9.5	6.5
P	1.6	5.8	4.8	3.3	5.4	4.9	2.7
Trace elements[2] (mg/kg DM)							
Co	<1	<1	<1	<1	<1	<1	<1
Cu	21	29	25	28	26	26	20
Fe	174	185	282	172	248	171	225
Mn	22	22	23	27	25	21	53
Zn	77	81	68	68	77	72	64

[1] Cottonseed cake samples from Luguru (LGR), Malampaka (MLP), Mhunze (MHZ), Morogoro (MOR), Shinyanga (SHY) and Uzogore (UZG); SBM = Soya bean meal.
[2] The analyses were performed at the National Laboratory for Agricultural Chemistry, Uppsala, Sweden.

Table 3. *Amino acid composition (g per 16 g N) of protein sources.*

Amino acid[1]	EAARGR[2]	Protein source[3]					
		URB	DSM-P	MOR-P	KC	SFC	SBM
Alanine		3.8	3.7	3.5	3.9	3.5	3.7
Arginine	1.0	5.4	6.7	6.4	10.2	7.0	6.6
Asparagine		10.6	9.8	9.4	7.3	7.3	9.2
Cysteine		1.0	1.0	0.8	1.4	1.6	1.4
Glutamine		13.7	14.9	14.1	20.3	17.2	15.2
Glycine		3.7	3.7	3.4	4.1	4.7	3.7
Histidine	2.1	2.6	2.4	2.7	1.7	2.0	2.3
Isoleucine	3.9	4.0	3.7	3.5	3.1	3.5	3.9
Leucine	4.5	7.2	6.7	6.4	5.7	5.3	6.4
Lysine	5.4	6.2	5.9	5.6	3.9	2.7	5.3
Methionine	3.0	1.1	1.4	1.2	1.2	1.9	1.3
Phenylalanine	5.3	4.9	4.9	4.7	4.6	3.9	4.4
Prolene		3.4	3.7	3.5	3.9	4.0	4.5
Serine		5.8	4.8	4.5	5.1	3.9	4.8
Threonine	3.1	4.1	3.5	3.3	2.6	3.0	3.6
Tyrosine		2.5	2.4	2.3	2.2	1.6	2.9
Valine	3.1	4.7	4.4	4.1	4.7	4.6	4.2

[1] The analysis was performed at the Biomedical Centre, Uppsala University, Sweden.
[2] EAARGR = essential amino acid requirements for growing rats, taken from Maynard et al (1979).
[3] URB = untoasted red beans; DSM-P = cowpea seeds from Dar-es-Salaam; MOR-P = cowpea seeds from Morogoro; KC = kapok expeller cake; SFC = sunflower expeller cake; SBM = Soya bean meal.

Nutritional evaluation

Except for the diet based on URB, diet consumption was good, and no refusals were noted during the collection period. The nutritive values of the protein sources and the rat diets are given in Table 4. The DOM and DE values of both the diets and their protein sources were estimated using difference calculations.

Table 4. *Weight gain of rats, and nutritive values of entire diets and their protein sources.*

	Diet with protein source[1]					F-value [2]
	DSM-P	MOR-P	KC	SFC	SBM	
No. of animals	5	5	5	5	5	
Initial mean rat weight (g)	71.1	71.0	70.9	70.7	71.0	0.01 n.s
(± s.d.)[3]	(4.1)	(4.0)	(3.4)	(3.0)	(4.1)	
Weight gain in 10days (g)	9.1b	12.8b	9.8b	11.5b	19.7a	11.7***
Protein quality[4]						
TD	72.0c	74.6d	81.2b	82.6b	89.4a	79.8***
BV	60.7b	61.5b	58.8b	58.8b	70.6a	11.5***
NPU	43.7b	46.0b	47.8b	48.5b	63.1a	29.2***
UCP	12.0b	14.0b	13.2b	13.4b	33.1a	248.4***
Digestibility of entire diets						
Organic matter (%)	92.2c	93.1c	79.5b	79.9b	95.4a	812.2***
Energy (%)	91.0c	92.0c	78.4b	77.6b	94.8a	883.7***
Digestible energy						
(MJ/kgDM)	16.0c	16.2c	14.0b	14.1b	16.7a	688.2***
DOM[5] and DE[5] for protein source after difference calculation						
Organic matter (%)	78.0a	78.3a	41.8b	44.2b	75.6a	370.5***
(± s.d.)	(0.9)	(1.0)	(0.9)	(1.2)	(3.5)	
Digestible energy (MJ/kg DM)	13.7c	14.1c	9.5b	9.7b	12.9a	139.6***
(± s.d.)	(0.2)	(0.2)	(0.5)	(0.2)	(0.7)	

[1] DSM-P = cowpea seeds from Dar-es-Salaam; MOR-P = cowpea seeds from Morogoro; KC = kapok expeller cake; SFC = sunflower expeller cake; SBM = Soya bean meal.
[2] n.s. = not significant; *** = P<0.001. Means with different letters in the same row differ significantly (P<0.05).
[3] s.d. = standard deviation.
[4] TD = true digestibility of CP; BV = biological value; NPU = net protein utilisation; UCP = utilisable crude protein.
[5] DOM = digestibility of organic matter; DE = digestible energy.

The true digestibility (TD) of SBM was higher than that of the Tanzanian protein sources. No differences in TD were found between SFC and KC, but these feedstuffs had significantly higher TDs than the two batches of cowpea seeds.

The BV and, consequently, the NPU were highest for SBM, partly due to its better amino acid pattern, and probably partly due to the higher DE value of the diet in which it was incorporated, a result of the higher starch level. The differences in BV and NPU between the test protein sources were not significant. UCP values reflected the NPU values; however, the superior UCP value for SBM was due to its higher protein content.

Soya bean meal and the two batches of cowpea seeds had markedly higher DOM and DE than SFC and KC. The values estimated for SBM after difference calculations were less precise than those for the other protein sources, as illustrated by the higher standard deviations (Table 4). This was probably due to the lower level of SBM incorporation required (20%) compared with the other proteins (30%).

The weight gains of the rats reflected the NPU values, since the CP content of the diets was more limiting than the DE content.

The experiment demonstrated considerable differences between SBM and the Tanzanian plant protein sources in content, digestibility and quality of CP. This had also been reported, among others, by Muindi and Hansen (1981), Muindi and Rundgren (1981), Muindi et al (1981) and Gohl (1975). The lower TD of SFC and KC compared with SBM was probably due to their higher crude fibre content. The markedly lower TD of the cowpea seeds may have been caused by protein inhibitors (Liener, 1975) and/or other antinutritive substances often found in leguminous seeds (FAO, 1967).

The poor BV of SFC was due to the very low content of lysine, whereas for KC both the lysine and methionine and cysteine contents were limiting. The cowpea seeds had a rather high content of lysine and a poor methionine and cysteine content; a combination of SFC and cowpea seeds would therefore theoretically give a higher BV than the individual protein sources.

Experimenting with pigs, Just (1975; 1982a, b, c, d) concluded that a high CF content in a feedstuff is associated with lower digestibilities of organic matter and CP. The low DOM and DE values of SFC and KC were thus probably related to the high CF content of these feedstuffs. However, the GE values of KC and SFC would have been even lower if it had not been for their relatively high ether extract content.

The nutritive value of the leguminous seeds was superior to that of SFC and KC due to a higher digestibility of energy and a somewhat superior amino acid pattern, particularly lysine. It is also possible that the extremely high arginine content of KC could have been responsible for an

amino acid imbalance, which reduced its biological value. However, the TD of crude protein of leguminous seeds was limited, probably due to the occurrence of antinutritive substances. Although tannins were not determined, the dark colour of the cowpea hulls indicates a high content, which also probably affected the TD of the seeds. Similarly, the tannin-related polyphenolics in SFC and KC could have contributed to the lower digestibility of protein and energy in these feeds. The nutritive values of the Tanzanian protein sources were in almost all respects inferior to that of soya bean meal.

Acknowledgements

The authors are grateful to the staff of the Department of Animal Nutrition and Management of the Swedish University of Agricultural Sciences, the Uyole Agricultural Centre (Tanzania), the Department of Animal Science of the Sokoine University of Agriculture, the Tanzania Bureau of Standards and the Tanzania Animal Feed Company for their assistance. The authors also wish to extend their gratitude to TALIRO of Tanzania and SAREC of Sweden for supporting this project.

References

Ahlstrom B. 1983. Estimation of metabolic and endogenous losses by N-balance experiments with rats. Department of Animal Husbandry, Feed Science Division, Swedish University of Agricultural Sciences, Uppsala.

AOAC (Association of Official Analytical Chemists). 1980. *Official methods of analy*sis. AOAC, Washington D.C.

Austin R E. 1983. The availability of amino acids as an attribute of feeds. In: *Feed information and animal production.* Proceedings of the 2nd Symposium of INFIC, CAB, UK. p. 175.

Batterham E S. 1979. Amino acid availability in pig diets with special reference to natural proteins and synthetic amino acids. In: W Haresign and D Lewis (eds), *Recent advances in animal nutrition.*Butterworths, London. p. 11.

Church D C. 1984. *Livestock feeds and feeding.* 2nd ed. O & B Books Inc., Corvallis, Oregon.

Eggum B O. 1973. A study of certain factors influencing protein utilization in rats and pigs. Ph.D. thesis, University of Copenhagen, Denmark.

FAO (Food and Agriculture Organization). 1967. Poultry feeding in tropical and subtropical countries. FAO Agricultural Development Paper 82. FAO, Rome. 22 pp.

French M H. 1941. Tanganyika Territory: Annual Report, Department of Veterinary Science and Animal Husbandry, Part 11, Research. Dar-es-Salaam.

Gohl B. 1975. Tropical feeds. Animal Production and Health Division paper 98. FAO, Rome.

Just A. 1975. Feed evaluation in pigs. *World Rev. Anim. Prod.*11.

Just A. 1982a. The net energy value of balanced diets for growing pigs. *Livestock Prod. Sci.* 8: 541–545.

Just A. 1982b. The net energy value of crude (catabolized) protein for growth in pigs. *Livestock Prod.* Sci. 9: 349–360.

Just A. 1982c. The net energy value of crude fat for growth in pigs. *Livestock Prod. Sci.* 9: 501-509.

Just A. 1982d. The influence of crude fibre from cereals on the net energy value of diets for growth in pigs. *Livestock Prod. Sci.* 9: 569-580.

Liener I E. 1975. Endogenous toxic factors in oilseed residues. In: *Proceedings of the conference on products of subtropical origin.* Tropical Products Institute, London. p. 179.

Mattson P. 1978. *Crude protein determination in feedingstuffs: Some studies of extraction and hydrolysis methods.* Statens Lantbrukskemiska Laboratorium, Uppsala.

Maynard L A, Loosli J K, Hintz H F and Warner R G. 1979. *Animal nutrition.* 6th ed. McGraw-Hill Book Co., New York and London. 602 pp.

McDonald P, Edwards R A and Greenhalgh J F D. 1981. *Animal nutrition.* 3rd ed. Longman, London and New York.

Mellon T P A, Barnes B H and Greenwood-Barton L H. 1964. The importance of the amino acid content of feedingstuffs in East Africa. *East Afr. Agric. For. J.* 29: 237–242.

Muindi P J and Hansen J F. 1981. Protein enrichment of cassava root meal by *Trichoderma harzianum* for animal feed. *J. Sci. Food Agric.* 32: 655–661.

Muindi P J and Rundgren M. 1981. Investigation on the protein quality and alkaloid content of *Lupinus albus* cv. Kalina grown in Tanzania. *Nutr. Rep. Int.* 23: 391–399.

Muindi P J, Thomke S and Hansen J F. 1981. Protein quality studies on rats fed on cassava root meal enriched with *Cephalosporium eichhorniae* 152 or conventional plant protein supplements. *Anim. Feed Sci. Technol.* 6: 197–208.

Naik A H. 1969. Chemical composition of Tanzania feedstuffs. *East Afr. Agric. For. J.* 32: 201–205.

SAS (Statistical Analysis System) Institute Inc. 1982. *SAS User's Guide.* SAS Institute Inc., Cary, N.C., USA. 549 pp.

Zainal J, Jalaludin S, Vijchulata P, Mahyuddin M D and Hutagalung R I. 1983. Nutrient availability and utilization of feedstuffs for farm animals. In: *Feed Information and Animal Production.*Proceedings of the 2nd Symposium of INFIC, CAB, UK. p. 497.