Chemical composition and protein quality of Tanzanian cottonseed expeller cakes

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Summary

SAMPLES OF *cottonseed expeller cake (CSC) from six different commercial oil mills in Tanzania were analysed for their crude protein, crude fibre, ether extract, minerals and amino acids. The biological value of the feeds was determined in an experiment with rats, using soya bean meal as a reference.*

The crude protein of the samples varied between 24 and 48%, crude fibre was 11 to 19% and ether extract 7 to 10%. The difference in amino acid composition per 16 g nitrogen was negligible, except for the sample from Morogoro which had low arginine, histidine and lysine contents. Rats fed a diet based on this protein retained nitrogen poorly and gained significantly less weight than rats in the other treatment groups. The protein quality of the cottonseed cakes was generally inferior to that of the soya bean meal.

The experiment with rats demonstrated significant differences in the true digestibility, biological value, net protein utilisation and the utilisable crude protein of the CSC protein sources. These could be traced to differences in their amino acid profile. There were also noticeable differences in energy digestibility due to differences in the crude fibre content.

Introduction

The major raw materials used as protein sources in the Tanzanian animal feed industry are the oilseed residues of cotton, kapok, simsim, soya bean and sunflower. The cotton plant is grown mainly for cotton linters, while the others are grown primarily to produce oil for human consumption. The use of the oilseed residues as animal feed is incidental (Breslin, 1974; Church, 1984; Eggum, 1973; McDonald et al, 1981). Any expansion in CSC production will depend on the country's need for the primary products. At present, the Tanzanian Government favours increasing production of oil for human use and raw cotton for the domestic and export markets.

The Tanzania Cotton Authority (TCA, 1985) reported that the country's production of seed cotton (consisting on average of 36% linters and 64% cottonseed by weight) in 1978/79, 1982/83, 1983/84, and 1984 to early 1985 was 176, 128, 140 and 151 thousand tonnes respectively. TCA (1985) estimated that the cottonseed contained 40 to 50% of cottonseed hull and 8 to 10% of cottonseed oil. Using these proportions, the content of cottonseed residues has been estimated to be between 40 and 50%.

If properly utilised, cottonseed residues could support a significant number of livestock in Tanzania. However, more information is needed on the nutritive value of cottonseed cake, which is affected by plant variety, geographical source, weather, processing conditions and levels of endogenous substances (Stansbury et al, 1956).

The objective of this work was to determine the effects of area of origin and processing method on the chemical composition and protein quality of Tanzanian cottonseed expeller cakes. The cottonseed protein was determined using the nitrogen balance technique with growing rats.

Materials and methods

Materials

Six samples of cottonseed (*Gossypium spp*) from which the oil was removed by expeller extraction were evaluated. The samples were obtained from six commercial oil mills in Tanzania: Luguru (LGR), Malampaka (MLP), Mhunze (MHZ), the Morogoro multipurpose oil processing company (MOR), Shinyanga (SHY) and Uzogore (UZG).

Defatted soya bean meal (SBM) (*Glycine max* L.) was used as a reference. Starch, mineral and vitamin mixtures and soya bean oil were supplied by the Department of Animal Nutrition and Management of the Swedish University of Agricultural Sciences, Uppsala. The samples were ground in a Kamas mill to pass through a 1-mm screen.

Diets

Six diets, each containing one of the test protein sources, were formulated (Table 1; Jagadi et al, 1987). A seventh diet based on SBM was used as reference.

Table 1. *Formulation of experimental diets and daily amounts fed.*

	Diet with cottonseed cakes[1]						Diet with SBM[1]
	LGR	MLP	MHZ	MOR	SHY	UZG	
Diet (% DM)							
Protein source	20.1	19.5	22.9	38.9	20.5	21.9	17.9
Soya bean oil	1.1	1.4	1.0	1.1	1.6	1.0	3.0
Mineral mixture[2]	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Vitamin mixture [3]	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Maize starch [4]	73.6	73.6	70.6	54.5	73.4	71.6	73.6
Composition							
Dry matter(%)	89.1	88.6	88.8	90.4	89.0	89.2	89.2
Ash (% of DM)	5.1	4.9	4.7	5.0	4.9	5.0	5.3
Diet fed per day (g DM)	11.2	11.2	11.2	11.1	11.2	11.2	10.1

[1] Cottonseed cake samples from Luguru (LGR), Malampaka (MLP), Mhunze (MHZ), Morogoro (MOR), Shinyanga (SHY) and Uzogore (UZG); 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, 5.4 g P, 4.65 g K, 2.0 g Na, 0.24 mg Co, 5.3 mg Cu, 15 mg I, 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 para-aminobenzoic acid, 0.5 g pantothenic acid, 0.02 g riboflavin, 0.02 g thiamin, 0.01 g B6, 0.03 mg B12, 20 000 IU A, 0.01 g E and 2000 IU D3 per kg dietary DM.
[4] Maize starch = 88.2% DM; gross energy = 17.7 MJ/kg DM.

Animals and experimental technique

Thirty-three specific-pathogen-free Sprague Dawley male rats were used to determine the biological value of the feeds. Each of the CSC treatment groups was five rats, while the control diet was fed to only three rats. The animals were 26 days old at the beginning of the experiment and their weights did not differ significantly. The experimental technique used was described by Jagadi et al (1987).

Results

Chemical characterisation

Except for the sample from Morogoro, the test protein sources had crude protein (CP) content exceeding 40% (Table 2). The low CP content (24%) of the MOR sample was due to its high crude fibre (CF) content. The MOR and SHY samples were considered to have been extracted more efficiently (ether extract of about 7%) than the other CSC samples which had ether extract values in the range of 8 to 10% (Table 2). The MOR sample had the lowest content of major elements, but trace elements did not differ markedly between samples (Table 2). Lysine and arginine varied greatly between samples and were the only limiting amino acids; the MOR sample had the lowest values (Table 3).

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

	Protein source[1]					
	URB	DSM-P	MOR-P	KC	SFC	SBM
Proximate composition						
Dry matter (%)	89.6	89.7	88.9	93.1	93.3	88.8
Ash (% DM)	3.9	4.4	3.8	6.5	3.7	5.3
Crude fibre (% DM)	4.3	5.7	6.0	24.6	35.2	6.3
Crude protein (% DM)	25.8	27.4	30.4	27.6	27.6	52.4
Ether extract (% DM)	2.6	2.4	2.6	12.7	9.4	3.2
Nitrogen-free extractives (% DM)	63.4	60.1	57.2	28.6	24.1	32.8
Gross energy (MJ/kg DM)	17.5	17.7	17.5	17.6	17.6	19.9
Major minerals (g/kg DM)						
Ca	1.7	1.1	1.1	4.5	2.3	3.4
Mg	1.8	2.2	2.1	4.7	3.2	2.7
P	4.6	4.9	4.7	8.6	6.2	6.5
Trace elements (mg/kg DM)						

Co	<1	<1	<1	<1	<1	<1
Cu	9	7	7	33	24	20
Fe	89	123	96	408	361	225
Mn	16	14	18	18	30	53
Zn	36	37	39	50	64	64

[1]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.

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

Amino acid	AA[1] requirements of growing rat		Cottonseed cake[2] acid						
	EAARGR[3]	BB[4]	LGR	MLP	MHZ	MOR	SHY	UZG	SBM[2]
Alanine			3.8	3.6	3.7	3.7	3.6	3.8	3.7
Arginine	1.0	11.1	11.2	10.7	10.8	8.1	10.7	10.8	6.6
Asparagine			8.9	7.8	8.7	7.8	8.1	8.5	9.2
Cysteine		2.2	1.7	1.7	1.6	1.6	1.7	1.8	1.4
Glutamine			17.8	16.9	17.6	17.6	17.3	18.0	15.2
Glycine		6.1	4.1	3.9	4.0	4.0	3.9	4.2	3.7
Histidine	2.1	2.7	2.7	2.6	2.6	1.9	2.6	2.7	2.9
Isoleucine	3.9	4.2	3.0	2.8	3.0	3.6	2.9	3.0	3.9
Leucine	4.5	6.2	5.6	5.2	5.4	6.4	5.3	5.6	6.4
Lysine	5.4	4.2	4.2	3.9	4.9	2.8	3.9	4.3	5.3
Methionine	3.0	1.5	1.5	1.4	1.5	1.6	1.4	1.5	1.3
Phenylalanine	5.3	5.3	5.1	4.9	5.0	3.9	4.9	5.2	4.4

Prolene			3.8	3.5	3.7	3.6	3.5	3.9	4.5
Serine			4.6	4.3	4.S	4.9	4.5	4.7	4.8
Threonine	3.1	3.5	3.3	3.1	3.2	3.3	3.1	3.3	3.6
Tyrosine		3.2	2.6	2.5	2.5	2.4	2.4	2.7	2.9
Valine	3.1	5.0	4.3	4.1	4.2	4.8	4.1	4.3	4.2

[1] AA =amino acid.
[2] Cottonseed cake samples from Luguru (LGR), Malampaka (MLP), Mhunze (MHZ), Morogoro (MOR), Shinyanga (SHY) and Uzogore (UZG); SBM = soya bean meal.
[3] EAARGR = essential amino acid requirements of growing rats, taken from Maynard et al (1979).
[4] Calculated from data of Bolton and Blair (1977).

Nutritive values

The parameters used to express protein quality were true digestibility (TD) of crude protein, biological value (BV), net protein utilisation (NPU) and utilisable crude protein (UCP). The results of the experiment show that SBM had the highest nutritive values and the MOR sample the lowest (Table 4). TD differed significantly (P<0.001) between samples; the MOR sample had the lowest and the LGR sample the highest value. BV and, consequently, NPU also differed significantly (P<0.001); the MOR sample had the lowest and the LGR and UZG samples the highest values. The digestibility of organic matter of the samples varied between 55% (MOR) and 67% (LGR).

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

	Diet with cottonseed cake						Diet with SBM[1]	F-value[2]
	LGR	MLP	MHZ	MOR	SHY	UZG		
No. of animals	5	5	5	5	5	5	3	
Initial weight (g) of rats	69.6	69.4	69.5	69.4	68.3	69.7	70.1	0.1 n.s.
(± s.d.[3])	(2.0)	(2.5)	(2.1)	(3.1)	(4.6)	(4.3)	(6.9)	
Weight gain (g) in 10 days	16.9cd	15.4c	14.1c	8.8a	18.4d	17.3cd	19.8b	18.9* * *
Protein quality[4]								

TD	87.1cd	84.4d	80.1a	75.4b	86.3cd	86.6cd	89.2c	20.0***
(± s.d.)	(1.4)	(1.5)	(3.4)	(1.2)	(3.4)	(1.4)	(1.4)	
BV	73.2bc	68.0b	70.9bc	58.3a	72.6bc	76.7c	79.7c	6.3***
NPU	63.7bc	57.4d	56.7d	44.0a	62.5cd	66.5bc	71.1b	12.8***
UCP	29.8d	27.7d	23.2a	10.6b	28.6d	28.5d	37.2c	56.3***
Digestibility of entire diets								
Organic matter (%)	93.1e	92.4de	88.6a	81.5b	92.5de	92.2d	95.7c	363.1***
Energy(%)	92.2d	91.3c	87.7a	80.0b	90.8c	90.7c		284.2***
Digestible energy (MJ/kg DM)	16.3d	16.1c	15.4a	14.3b	16.4cd	16.2cd		256.0***
DOM[5] and DE[5] of protein sources after difference calculation								
Organic matter (%)	67.0de	62.0d	52.0a	55.0b	65.0e	66.0e	77.0c	46.8***
Digestible energy (MJ/kg DM)	14.0c	12.7b	10.8a	10.8a	12.9b	14.0c		42.3***

[1] Cottonseed cake samples from Luguru (LGR), Malampaka (MLP), Mhunze (MHZ), Morogoro (MOR), Shinyanga (SHY) and Uzogore (UZG); SBM = soya bean meal.
[2] *** = P<0.001; n.s. = not significant.
Means with different letters in the same row differ significantly (P<0.05).
[3] s.d. = standard deviation.
[4] TD = true digestibility; B V = biological value; NPU = net protein utilisation; UCP = utilisable crude protein.
[5] DOM = digestible organic matter; DE = digestible energy.

Rats fed a diet based on the MOR sample gained significantly less than those in the other treatment groups. The very low nutritive value of this diet was probably due to very low lysine and high fibre contents.

Discussion

Composition

The CP content of the samples did not differ markedly, except for the MOR sample (Table 2). The relatively high CF content of this sample was probably due to mechanical problems in the Morogoro processing plant. The revolving blades that remove the short-fibre lint adhering to the seeds after ginning were old and wornout and left a high proportion of fibrous linters. Also, the pneumatic hull removal system in the decortication plant was not functioning properly, which could also have contributed to the high CF content in addition to leaving high levels of gossypol in the seed.

Nutritive value

The dietary energy digestibility of the different CSC samples appeared to be related to their CF content (Table 2). The high ranking of SBM was probably due to its better amino acid composition (Table 3). The low weight gain of rats fed MOR-CSC was probably due to a high CF and low lysine content (Table 4). A gossypol-lysine complex is known to form if excessive heat is applied to decorticated seed prior to oil extraction. Higher than normal temperatures from a malfunctioning steam cooker, which preheats the decorticated seeds to facilitate mechanical expression of the oil, could have caused the complex to form. The damage caused to the protein would have affected energy digestibility, which, in turn, could have further limited nitrogen retention by the rats.

Since the analysed and calculated nutritive values of the MOR sample were considerably lower than those for the other samples, it may be worth investigating further whether this was due to an abnormally poor quality of a single batch, or whether the processing technique used in Morogoro consistently results in a low-quality product.

Conclusion

Tanzanian cottonseed expeller cakes differ significantly in protein quality; this can be traced to differences in amino acid composition. There were also noticeable differences in energy digestibility due to differences in crude fibre content. It was concluded that more information is needed on the effects of processing on the composition of these feedstuffs. A reliable method is also needed to determine their nutritive value for compound animal feeds.

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