Studies on the nutritive value of cowpeas (*Vigna unguiculata*)

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Samples of 150 different cowpea cultivars, used in the breeding trials of the Summer Grain Institute at Potchefstroom, were analysed and found to have an average crude protein content of 28.4 ± 1.8% (range 24.5 to 33.9%). From these samples, five high- and five low-protein cowpea samples as well as a composite sample of the remaining 140 cowpea cultivars, were selected. Part of the composite sample was autoclaved for 15 min at 121 °C. Only small differences were observed in the chemical composition of the experimental cowpea meals. No significant ($P > 0.05$) differences were found between raw and autoclaved cowpea meal either in relative nutritional value (RNV) and true protein digestibility (PTD) determined with rats, or in amino acid availability (AAA) determined with roosters. Autoclaving resulted in significant ($P < 0.05$) improvements in digestible energy (DE) and true metabolizable energy (TME) when determined in pigs and poultry respectively.

Monsters van 150 verskillende akkerboonkultivars, afkomstig van die kultivarstudies van die Somergraan Instituut by Potchefstroom, is ontleed en het 'n gemiddelde ruproteïen-inhoud van 28.4 ± 1.8% (24.5 tot 33.9%) gehad. Vyf hoë- en vyf laeproteïen-akkerboonmonsters en 'n monster, saamgestel uit die oorblywende 140 kultivarmonsters, is geselekteer. 'n Gedeelte van die saamgestelde monster is vir 15 min met stoom teen 121 °C behandel. Slegs klein verskille in die chemiese samestelling van die eksperimentele akkerboonmele is gevind. Geen betekenisvolle ($P > 0.05$) verskille is gevind tussen rou en stoombehandelde akkerbone in relatiewe voedingswaarde en ware proteïenverteerbaarheid, soos met rotte bepaal, en aminosuurbeskikbaarheid, soos met pluimvee bepaal nie. Stoombehandeling het 'n betekenisvolle ($P < 0.05$) verbetering in verteerbare energie by varke en ware metaboliseerbare energie by pluimvee tot gevolg gehad.

Keywords: Amino acid availability, cowpea meal, digestible energy, pigs, poultry, rats, relative nutritive value, true metabolizable energy, true protein digestibility.

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Introduction

Cowpeas are heat and drought tolerant (Sellschop, 1962). It is also a low-input crop (Coetzee, J.J., 1991, personal communication), which makes it a tough grain legume well adapted to the arid agronomic areas in South Africa. Even though an average of 5 000 t are presently being produced per annum (Dept. Agriculture, 1991), cowpea meal is not readily used in mixed diets for animal feed in South Africa. A better knowledge of the nutritional value of cowpeas for monogastric animals may increase the demand and therefore the production of cowpeas for the animal feed market. Cowpeas could make a valuable contribution to the supply of proteins for animal feed in South Africa, particularly if it is kept in mind that by the year 2 000 a predicted deficit of 1 000 000 t oilcake equivalent can be expected (Cloete, 1990).

The Oil and Protein Seeds Centre evaluated different cowpea cultivars agronomically and the seeds produced in these trials were made available for this study. The aim of this study was therefore to determine the nutritional value of the cowpea cultivars for monogastric animals to be used as selection criteria to assist in the cultivar breeding programme.

Cowpeas, like most other grain legumes, contain anti-nutritional factors (ANFs) such as trypsin inhibitors, lectins and tannins, which decrease protein digestibility and reduce protein quality (Gatehouse & Boulter, 1983; Price *et al.*, 1980;

Bressani, 1985). In order to counter the effects of the ANFs, it was necessary to apply heat treatment to the raw cowpea meal.

To assess the nutritional value of the raw and autoclaved cowpea meals, the chemical composition, including the amino acid composition and availability, was determined. Relative nutritive value was measured in order to determine the protein quality of the cowpea meals as well as the effect of heat treatment on the ANFs.

Materials and Methods

Chemical composition

The crude protein content of 150 small (*ca.* 50 g) samples of different South African cowpea cultivars was determined using the Kjeldahl procedure on a Büchi system (AOAC, 1984). This was done to determine the variability between cultivars and as an aid to the cultivar breeding programme. Two composite samples (with a high and a low protein content respectively), consisting of five cultivars each, were subsequently composed to determine the effect of protein content on the chemical composition of cowpea meal. The remaining cultivar samples were blended to obtain a cowpea meal (CPM) that was representative of the 150 cowpea cultivars used in this study.

The samples were analysed for dry matter, ash, ether extract, crude fibre, crude protein, amino acid composition, phosphorus and calcium content according to the methods

Table 1 Composition of the experimental diets used to determine relative nutritional values and true protein digestibility with rats (% air dry)

Component	Control	Lactalbumin				Cowpea meal				Autoclaved cowpea meal			
CP[a] content	0	2	4	6	8	2	4	6	8	2	4	6	8
Maize starch	90.0	87.5	85.0	82.5	80.0	82.3	74.5	66.8	59.1	82.3	74.6	67.0	59.3
Sunflower oil	5	5	5	5	5	5	5	5	5	5	5	5	5
Mineral & vitamin premix[b]	5	5	5	5	5	5	5	5	5	5	5	5	5
Lactalbumin	–	2.5	5.0	7.5	10.0	–	–	–	–	–	–	–	–
Cowpea meal	–	–	–	–	–	7.7	15.5	23.2	30.9	–	–	–	–
Autoclaved cowpea meal	–	–	–	–	–	–	–	–	–	7.7	15.4	23.0	30.7

[a] Crude protein.
[b] Supplied per kg feed: Vitamin A, 2000 IU; Vitamin D, 1000 IU; Vitamin E, 35 mg; Vitamin K, 50 µg; Thiamin hydrochloride, 1.25 mg; Riboflavin, 2.5 mg; Vitamin B12, 5 µg; Calcium pantothenate, 8 mg; Niacin, 15 mg; Choline chloride, 750 mg; Cu, 5 mg; Mn, 50 mg; Zn, 12 mg; I, 0.15 mg; Fe, 35 mg; Se, 0.04 mg; Mg, 0.4 g; P, 4.0 g; K, 1.8 g; Na, 0.5 g; Ca, 5.0 g.

used by Nell et al. (1992a). Total sugars (reducing and non-reducing) as well as starch content was determined according to the AOAC (1984) methods. The Fibertec system (Robertson & Van Soest, 1981) was used to determine neutral detergent fibre.

Determination of antinutritional factors (ANFs)

The CPM was autoclaved for 15 min at 121°C (Elías et al., 1976) in order to counter the effect of the ANFs. Urease activity (AACC, 1983), trypsin inhibitor activity (Smith et al., 1980) and tannins (Daiber, 1975) were determined.

Protein quality and digestibility using a rat assay

The protein quality was determined by means of a multi-point slope ratio assay as developed by Hegsted et al. (1968) and adapted by Nell et al. (1992a). Protein quality was expressed as relative nutritive value (RNV).

CPM and autoclaved CPM (ACPM) were used as experimental protein sources, while lactalbumin was used as reference protein. Sixty-three male Wistar rats were divided into 14 groups of equal live mass at 27 days of age and fasted for 24 h. The initial slaughter group (n = 9) was then asphyxiated, and protein content was determined according to the method described by Nell et al. (1992a). One group (n = 6) received a protein-free diet whilst the remaining 12 groups of four rats each were randomly allocated to the other treatments shown in Table 1.

True protein digestibility (PTD) was estimated by the method described by Nell et al. (1992a).

The data used to calculate the regression equations were subjected to an analysis of covariance (Snedecor & Cochran, 1980), in order to determine whether the regression equations differed significantly.

Bioavailable energy

Digestible energy for pigs was determined with the mobile nylon bag technique (MNBT) described by Sauer & Ozimek (1985) and adapted by Brand et al. (1989a).

The true metabolizable energy method for poultry of Sibbald (1976) adapted by McNab & Fisher (1984) was used to determine metabolizable energy content. Nitrogen retention corrections were made on the TME values as proposed by Wolynetz & Sibbald (1984) to determine TME_n.

Amino acid availability

Available amino acids for poultry were determined by the method of Likuski & Dorrell (1978) as adapted by McNab & Fisher (1984).

Results and Discussion

Chemical composition

The average crude protein content of the 150 cowpea cultivar samples was 28.4 ± 1.8% (DM) and varied between 24.5 and 33.9%. Evans & Boulter (1974) found that the range of crude protein of 79 cowpea varieties was 21 to 34%, and stated that due to the wide range, screening programmes for higher protein-containing cowpea varieties were likely to be successful.

Apart from the difference in protein content between the high (30.2%) and the low (27.4%) composite meals, differences in the chemical composition of the cowpea meals used in this study (Table 2), were small.

Table 2 Chemical composition of the experimental cowpea meals (%DM)

Component	Cowpea meal			
	High[a]	Low[b]	CPM[c]	ACPM[d]
Dry matter	90.6	90.4	91.1	90.1
Crude protein (N × 6.25)	30.2	27.4	28.4	28.9
Ash	3.8	3.5	3.4	3.3
Ether extract	1.3	1.1	1.2	1.4
Crude fibre	5.0	5.6	5.2	5.3
Neutral detergent fibre	20.1	21.9	21.2	21.3
Starch	40.1	41.7	41.3	40.6
Sugars[e]	0.34	0.41	0.36	0.39
Calcium	0.13	0.10	0.13	0.12
Phosphorus	0.49	0.52	0.50	0.51

[a] Cowpea meal with a high protein content; [b] Cowpea meal with a low protein content; [c] Raw cowpea meal; [d] Autoclaved cowpea meal; [e] Reducing and non-reducing.

Antinutritional factors

The trypsin inhibitor activity (TIA) of CPM was 9.7 mg trypsin inhibited per g sample. By autoclaving the CPM, this value was reduced by 79% to 2.0 mg/g. This is in accordance with the results of Akinyele (1989). He observed a decrease of 82% from 15.1 mg/g to 2.7 mg/g in TIA, when CPM was heated using steam. The urease activity method was not sensitive enough to estimate the reduction in TIA, resulting from the autoclaving of CPM; the difference in pH units being 0.13 for both CPM and ACPM.

Autoclaving the CPM also resulted in a reduction of the tannin content from 0.32% to 0.24%. The tannin content, and the reduction in tannin content, due to treatment are low when these values are compared to the values derived by Brand *et al.* (1989b). They treated bird proof grain sorghum (1.24% tannin) with NH_3 and heat, which reduced tannin content to 0.55%. However, the tannin content of the cowpeas used in the present study is relatively high when compared to the average value of 0.16% tannin (Price *et al.*, 1980) in 10 varieties of cowpea.

Protein quality

Experimental cowpea meals had RNVs of 51 and 59% (see Table 3) which compares favourably with the RNV of sunflower oilcake meal of 43% (Nell *et al.*, 1992b), but not with the RNV of full fat soyabean meal of 65% (Hegsted *et al.*, 1968). It was expected that the removal of ANFs by autoclaving would improve amino acid availability and therefore the protein quality for rats, but there was no significant difference ($P > 0.05$) in RNV between CPM and ACPM (Table 3). The reason could be that the rat is not a suitable experimental animal to use in determining the effect of ANFs. According to Huisman & Van der Poel (1988), ANFs had a greater negative effect on weight gain in piglets than weight gain in rats. They suggested that the nutritional effects of ANFs should be studied in different target animals.

Table 3 The relative nutritional values (RNVs) of the experimental cowpea meals with body protein accretion as response to protein intake (Common Intercept = −5.17)

Protein source	Slope ± SE^1	RNV ± SE
Lactalbumin	0.69[a] ± 0.015	1.00
Cowpea meal	0.38[b] ± 0.015	0.51 ± 0.051
Autoclaved cowpea meal	0.41[b] ± 0.022	0.59 ± 0.057

[a,b] Slopes with different superscripts differ significantly ($P \leqslant 0.05$).

[1] Standard error of the estimate.

Protein digestibility

The true protein digestibility (PTD) values, together with the slopes of the equations used to calculate PTD, are listed in Table 4. Autoclaved cowpea meal had a PTD of 76 ± 2.2% and did not differ significantly from the PTD (73 ± 2.2) of untreated cowpea meal. Elías *et al.* (1976) found that the protein digestibility of raw and autoclaved cowpeas were 73.2 and 77.4% respectively. These digestibilities are low relative to those of other plant proteins, and it is one of the problems

Table 4 True protein digestibilty (PTD) of the experimental diets containing lactalbumin and cowpea meal

Protein source	Slope ± SE^1	PTD ± SE
Lactalbumin	0.08[a] ± 0.01	92 ± 0.9%
Cowpea meal	0.27[b] ± 0.02	73 ± 2.2%
Autoclaved cowpea meal	0.24[b] ± 0.02	76 ± 2.2%

[a,b] Slopes with different superscripts differ significantly ($P \leqslant 0.05$).

[1] Standard error of the estimate.

associated with feed legumes, including cowpeas (Bressani, 1985). Although not significant, small improvements in both RNV and PTD were observed with heat treatment.

Bioavailable energy (BE)

Pig DE and poultry TME and TME_n values for autoclaved cowpeas were significantly ($P < 0.05$) higher than the corresponding values for raw cowpeas (Table 5). Negative effects of the ANFs present in the meal cannot be detected when using the MNBT method to determine DE. The ANF concentration in the gut would be very low, as only 0.5 g of feed is placed in the nylon bag. The difference in DE values may well be due to an improved digestibility of the autoclaved meal. The improved TME and TME_n values are in accordance with the results of Nwokolo & Oji (1985), who found a significant ($P < 0.05$) improvement in apparent metabolizable energy of autoclaved cowpeas, from 11.4 to 12.4 MJ/kg. The TME technique is effective in estimating the effect of ANFs on the BE for poultry. This was shown by Gous *et al.* (1982) in a study on the relationship between tannic acid content and TME of sorghum cultivars.

Table 5 Bioavailable energy of the experimental cowpea meals, for pigs and poultry (MJ/kg air dry)

Method	n	Cowpea meal (CPM)	Autoclaved CPM
TME^1	6	12.34[a] ± 0.27	12.98[b] ± 0.34
$TME_n{}^2$	6	11.79[a] ± 0.23	12.34[b] ± 0.30
DE^3	6	13.50[a] ± 0.53	14.18[b] ± 0.38

[a,b] Means in the same row with a different superscript, differ significantly ($P < 0.05$).

[1] True metabolizable energy.

[2] True metabolizable energy with nitrogen retention correction.

[3] Digestible energy (pigs).

Amino acid composition and availability

In Table 6, amino acid composition is expressed as g amino acid per 100 g of protein (N × 6.25). The composition of the four experimental cowpea meals used was quite similar. This is a clear indication that protein content had no effect on the protein quality of the meals.

Although the amino acid availabilities of ACPM were higher than CPM for the majority of the amino acids, no significant differences ($P > 0.05$) could be found.

Conclusions

Cowpea meal is a valuable protein source which can contribute towards overcoming the predicted protein shortage by

Table 6 Amino acid composition (g/100 g N × 6.25) and availability (% air dry) of the experimental cowpea meals

	g Amino acid/100 g N × 6.25				Availability %	
	High[a]	Low[b]	CPM[c]	ACPM[d]	CPM	ACPM
VAL	3.3	3.4	3.4	3.4	73 ± 9	76 ± 7
TRE	2.9	3.0	3.0	2.9	77 ± 7	80 ± 7
SER	4.2	4.3	4.4	4.3	79 ± 7	83 ± 4
PRO	4.6	4.9	4.8	4.9	85 ± 6	86 ± 2
PHE	4.2	4.2	4.4	4.1	75 ± 8	74 ± 6
MET	1.2	1.1	1.2	1.1	81 ± 5	85 ± 4
LYS	5.0	5.2	5.2	4.9	78 ± 8	78 ± 3
LEU	5.7	5.1	5.8	5.8	77 ± 9	81 ± 5
ILE	2.8	2.8	2.8	2.7	74 ± 9	77 ± 6
HIS	2.4	2.3	2.4	2.3	78 ± 7	78 ± 5
GLY	3.0	3.1	3.1	3.1	68 ± 8	66 ± 5
GLU	14.3	14.2	14.1	14.1	83 ± 6	85 ± 3
CYS	1.1	1.1	1.1	1.1	65 ± 5	67 ± 6
ASP	9.5	9.5	9.4	9.6	79 ± 8	82 ± 3
ARG	5.1	4.8	5.0	4.6	83 ± 9	86 ± 3
ALA	3.3	3.4	3.4	3.4	72 ± 7	73 ± 6

[a] Cowpea meal with a high protein content.

[b] Cowpea meal with a low protein content.

[c] Raw cowpea meal.

[d] Autoclaved cowpea meal.

supplying protein, produced in the arid agronomical areas of South Africa, to the animal feed industry. Cowpeas have the disadvantage that they contain ANFs which must be removed by expensive heat treatment in order to make the meal acceptable for use in the diets of monogastric animals.

Protein contents had no effect on the protein quality of the meals. This suggests that the selection for better cowpea cultivars, from a nutritional point of view, can be done on protein content alone. There were no significant ($P > 0.05$) differences between raw and autoclaved cowpea meal either in relative nutritional value (RNV) and true protein digestibility (PTD) determined with rats, or in amino acid availability (AAA) determined with roosters. Autoclaving gave significant ($P < 0.05$) improvements in digestible energy (DE) when determined with pigs and true metabolizable energy (TME) determined with poultry.

Further research on target animals is necessary to determine the nutritional value of cowpea meal and to find the best treatment method for the removal of antinutritional factors.

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