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Chemical Composition, Amino Acid Content and Protein Quality of *Canavalia* spp. Seeds

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ABSTRACT

Canavalia ensiformis *is a grain legume that offers good possibilities for its use, but reports on its chemical composition and nutritive quality are not readily available. This study presents chemical and nutritional data on* C. ensiformis, C. gladiata *and* C. maritima *grains. The three species varied in protein content mainly because of differences in crude fibre content. Protein varied from 26·9 to 22·4%, and crude fibre varied from 8·5 to 17·3%. This was due to differences in seed-coat percentage. The amino acid content in* C. ensiformis *and* C. gladiata *was essentially the same, and both were deficient in sulphur-containing amino acids but rich in lysine. Pressure cooking and roasting reduced lysine levels. Mineral content in the three species was essentially the same, with high potassium levels as is the case with most food legumes. Feeding trials indicated low nutritional quality for the raw grain, which was significantly improved by pressure cooking and roasting. Protein digestibility was 47·9%, and cooked and roasted samples had 76·4 and 78·7%, respectively. Both* C. ensiformis *and* C. gladiata *had the same protein quality (PER=1·24), and it was significantly improved with methionine supplementation.*

Keywords: Canavalia, chemical composition, protein quality.

1 INTRODUCTION

Protein sources are in demand by the poultry, swine and ruminant mixed-feed industry in Central America due to a significant decrease in the production of cotton, on the one hand, and the economic situation which restricts purchase of soya bean meal, on the other. Alternatives to such a situation are not easily found; however, one possibility is provided by utilisation of non-conventional grain legumes, which are not used to an important extent by the human population. Among these, one that offers good possibilities is the seed of *Canavalia*. This seed may contain up to 32% protein and its production may be as high as 4600 kg ha^{-1}, with an average yield ranging from 800 to 1000 kg ha^{-1}.[1] The yield of grain from *Canavalia ensiformis* produced for the purposes of the present report and other studies was between 2400 and 3400 kg ha^{-1} from 11 individual experimental plots. These yields compare well with yields of common beans (*Phaseolus vulgaris*) of 500–700 g ha^{-1} and with those of soya beans of 600–1000 kg ha^{-1}. The plant is bushy, with a tendency to climb, and is mainly used as a cover crop, although it may also be used as forage. It flowers from 55 to 80 days depending on date of planting, and pods are ready to be harvested in approximately 160 days. The plant has low susceptibility to pests and diseases, although fieldmice eat the seeds from pods that are close to the ground. At present, *Canavalia* is used mainly as a cover crop, and seeds are roasted and ground to prepare a coffee-like drink.

Information on chemical composition is not readily available, nor are results of studies on feeding trials. *Canavalia* seeds are known to contain the usual anti-physiological substances of food grain legumes and they contain canavanine which interferes with arginine.[2,3] Therefore, to be used as animal feed, *Canavalia* seeds would have to be thermally processed since moist heat is known to destroy anti-physiological substances in food legumes.[4,5]

Because of the potential agronomic characteristics of *Canavalia* spp, their protein content and the interest in using such material in animal diets, this paper provides basic information derived from recent studies.

2 EXPERIMENTAL

Seeds from three *Canavalia* species (*Canavalia ensiformis*, *C. gladiata* and *C. maritima*) were collected and planted to obtain enough seeds for chemical analysis and determination of amino acid content.

Lots of 25 seeds from each species were weighed and hand-dissected to calculate seed-coat percentage. The pool cotyledons and seed coats were then ground together with a Wiley mill to pass 40 mesh for proximate chemical analysis applying the AOAC methods.[6] A 1-g sample was hydrolysed under vacuum with 6N HCl for amino acid analysis using a Technicon Amino Acid Analyzer; hydrolysis was conducted for a fixed 4-h period in an oven at 140°C. Tryptophan content was estimated colorimetrically.[7] About 2 kg of *C. ensiformis* were cooked under 1050 g cm^{-2} (15 psi) pressure for 45 min in water using a 3:1 water to seed ratio. The cooking liquid was separated and the cooked seeds were dehydrated with hot air at 60°C and then ground. Approximately the same amount of *C. ensiformis* was roasted at 200°C for 10 min, allowed to cool, and then ground for the feeding tests.

A batch of *C. gladiata* was also pressure-cooked as described above for *C.*

ensiformis; however, since not enough sample was available, it did not undergo a roasting process.

These samples were used for biological testing using weanling rats and the Protein Efficiency Ratio (PER) assay. Three studies were carried out, one on the effect of processing; a second to compare protein quality of two species, and the third on methionine supplementation of cooked *C. ensiformis*. Diets were prepared with *Canavalia* as the sole protein source to provide 10% protein. It was supplemented with 5% refined cottonseed oil, 1% cod liver oil, 4% mineral mixture,[8] and corn starch to adjust to 100%. All diets were further supplemented with a complete vitamin solution,[9] In all studies, eight rats, 21–22 days old, of the Wistar strain of the INCAP colony were used per experimental group. They were placed in individual all-wire screen cages with raised screen bottoms. Feed and water were supplied *ad libitum*. Changes in weight and amount of food consumed were determined every 7 days for a total experimental period of 28 days unless otherwise indicated. Protein digestibility was carried out on a 7-day collection of faeces.

3 RESULTS AND DISCUSSION

A physical description of the three *Canavalia* species studied is presented in Table 1. Average seed weight of *C. ensiformis* was 1·84 g, whereas that of *C. gladiata* and *C. maritima* was 4·87 and 0·71 g seed^{-1}, respectively. These figures indicate that *Canavalia* seeds are very large as compared with most food legumes, including faba beans. Seed-coat percentage with respect to seed weight in *C. ensiformis* is 10·8%, similar to that found in common beans;[4] however, in *C. gladiata* and *C. maritima*, seed-coat weight is much higher, 20·3 and 29·6%, respectively. Cotyledon weight for *C. ensiformis, C. gladiata* and *C. maritima* represents 89·1, 79·7 and 70·4% of seed weight, respectively. Table 2 summarises the proximate composition of the three *Canavalia* species. Ether extract and ash contents are similar among the three. However, crude fibre and protein are different, with *C. ensiformis* having less fibre and more protein than the other two species. This, of course, is a reflection of the amount of seed coat present in each of the three species. With the exception of *C. maritima*, the amount of protein in the other two species is higher than that usually reported for common beans. The amino acid content of raw *C. ensiformis* and *C. gladiata* and of processed *C. ensiformis* is presented in Table 3. The table also presents the FAO/WHO reference amino acid pattern.[10] The amino acid content is similar to that previously reported.[11,12]

TABLE 1
Some Physical Charcteristics of Three *Canavalia* Species

Physical characteristics	C. ensiformis	C. gladiata	C. maritima
Average seed weight, g	1·84±0·33	4·87±0·41	0.71±0·12
Seed-coat weight, g	0·20 (10·9%)	0·99 (20·3%)	0·21 (29·6%)
Cotyledon weight, g	1·64 (89·1%)	3·88 (79·7%)	0·50 (70·4%)

TABLE 2
Proximate Chemical Composition of Three *Canavalia* Species (%)

Component	C. ensiformis	C. gladiata	C. maritima
Moisture	13·5	11·2	10·6
Ether extract	1·8	1·4	1·6
Crude fibre	8·5	12·8	17·3
Protein (N×6·25)	26·9	25·6	22·4
Ash	3·2	3·9	3·2
Carbohydrate	46·1	45·1	44·9

TABLE 3
Amino Acid Content of Raw *C. gladiata* and of Raw and Processed *C. ensiformis*, g g^{-1} N

Amino acid	C. gladiata *Raw*	C. ensiformis		*Roasted*	*FAO pattern*
		Raw	*Pressure-cooked*		
Lysine	0·429	0·457	0·375	0·376	0·340
Histidine	0·260	0·227	0·179	0·221	
Arginine	0·376	0·342	0·346	0·321	
Aspartic acid	0·597	0·643	0·262	0·644	
Threonine	0·240	0·257	0·275	0·23	0·250
Serine	0·221	0·300	0·292	0·305	
Glutamic acid	0·632	0·650	0·660		
Proline	0·251	0·254	0·234	0·250	
Glycine	0·220	0·260	0·218	0·235	
Alanine	0·251	0·266	0·230	0·248	
Valine	0·370	0·339	0·302	0·348	0·310
Methionine	0·040	0·057	–	–	0·220
Isoleucine	0·403	0·393	0·432	0·441	0·250
Leucine	0·454	0·434	0·469	0·479	0·440
Tyrosine	0·219	0·212	0·197	0·200	0·380
Phenylalanine	0·246	0·256	0·265	0·264	0·380
Tryptophan	0·040	0·050	ND	ND	0·060

ND: Not determined.

TABLE 4
Mineral Content of Three *Canavalia* Species

Mineral	C. ensiformis	C. gladiata	C. maritima
P (g 100 g^{-1})	0·36	0·40	0·33
K (g 100 g^{-1})	0·72	0·79	0·80
Ca (g 100 g^{-1})	0·17	0·20	0·29
Mg (g 100 g^{-1})	0·17	0·13	0·16
Fe	Trace	Trace	Trace
Cu (mg 100 g^{-1})	1·22	1·49	1·16
Mn (mg 100 g^{-1})	0·87	0·87	0·87
Zn (mg 100 g^{-1})	2·87	3·17	3·85

As with all food legumes, *Canavalia* is a good source of lysine. Likewise, as in other food legumes,[4] it is deficient in the sulphur-containing amino acids.

Thermal processing of *C. ensiformis* decreased the concentration of some amino acids, particularly lysine and methionine. The latter was not detected in the acid hydrolysates of pressure-cooked and roasted *C. ensiformis,* and cystine was not detected in any of the samples, probably due to its destruction during the acid hydrolysis step. Because of its nutritional importance, as is the case with methionine, its concentration in *Canavalia* protein should be established.

Table 4 presents mineral content. Differences among the three species are small, and, as in most food legumes,[13] potassium content is found in concentrations higher than that of other minerals. However, the amount of all minerals found in *Canavalia* (shown in the table) are lower than concentrations reported for other food legumes.[13]

Results on protein quality of *Canavalia ensiformis* are shown in Table 5. Two processes were tested. One consisted of a pressure-cooking operation as carried out for food legumes to inactivate the anti-physiological factors; the other was a dry high-temperature cooking process. The protein quality of the raw seed is very low, probably due to the presence of anti-physiological substances such as trypsin inhibitors and lectins besides the known substances in *Canavalia,* such as urease[5] and canavanine,[2,3] In this study these substances were not analysed. It is of interest to point out that there were no cases of mortality. The protein digestibility of the raw seed was very low. Both types of processes, wet and dry thermic treatment, resulted in a beneficial effect on the protein quality, with PER increasing to 1·21 and 1·18 for wet and dry cooking, respectively. Protein digestibility also increased. Protein quality of *C. ensiformis* was 41·5% as compared with casein. This value is similar to that of common food legumes.[4]

Further studies should be carried out to determine the best processing conditions to attain optimum nutritional quality. On the assumption that 45-min pressure cooking at 1050 g cm^{-2} (15 psi) was adequate, both *C. ensiformis* and *C. gladiata* were processed in this way for protein quality evaluation. The results are presented in Table 5. As shown, the protein quality of both products is similar, and, as before, it is 45·2% as compared with that of casein. As previously

TABLE 5
Protein Quality of Heat-processed *Canavalia ensiformis* and *C. gladiata*

Species	*Process*	*Protein in diet (%)*	*Av. wt gain (g)*	*Av. food intake (g)*	*PER*	*Protein digestibility (%)*
C. ensiformis	Raw	9·5	2±1.9[a]	170±15·4	0·10±0·05	47·9±4·8
C. ensiformis	Pressure-cooked	11·0	28±5.6[a]	208±24·7	1·21±0·17	76·4±3·5
C. ensiformis	Roasted	11·7	28±4·2[a]	205±16·3	1·18±0·19	78·7±4·7
Casein		10·1	129±17·4[a]	441±41·8	2·89±0·15	91·2±2·1
C. ensiformis	Pressure-cooked	10·2	28±7·3[b]	225±35·4	1·24±0·19	—
C. gladiata	Pressure-cooked	10·4	32±11·2[b]	244±47·0	1·24±0·24	—
Casein		10·2	110±15·3[b]	393±28·5	2·74±0·32	—

[a] Average initial weight: 47 g.
[b] Average initial weight: 45 g.

TABLE 6
Effect of Methionine Supplementation

Diet	*Protein in diet (%)*	*Av. wt gain (g)*	*Av. food intake (g)*	*PER*
Canavalia[a]	10·5	12±6·0	164±27·7	0·70±0·23
Canavalia+methionine	10·6	52±11·5	251±25·9	1·94±0·30
Casein	10·0	42±6·25	151±117·0	2·79[b]±0·19

[a] *Canavalia ensiformis.*
[b] 14 days.

indicated, common beans and other edible legume proteins give similar PER values as those reported in this paper for *Canavalia.* This low value is due to the deficiency of sulphur-containing amino acids. To prove this, results are presented in Table 6. In this experiment pressure-cooked *Canavalia ensiformis* was used. The resulting flour added at a level to give 10% protein was supplemented with 0·3% DL-methionine. As shown by the outcomes, methionine supplementation increased protein quality from a PER of 0·70 to a value of 1·94, the latter being 69·5% of the value of casein. This increase is comparable to that observed with common beans.[14] Future studies should investigate if that level of methionine addition is sufficient, and whether other amino acids, including cystine, should be added together with methionine. Based on the amino acid scores calculated from the data in Table 3, it would seem that tryptophan is also a deficient amino acid. This is not surprising, since food legumes such as pigeon peas respond in protein quality when supplemented with both methionine and tryptophan.[15]

The results of this study suggest that chemical differences between *Canavalia* species are small, and where they exist are caused by the seed coat. On the other hand, their protein is deficient in sulphur-containing amino acids; furthermore. *Canavalia* has a protein quality similar to that of most edible food legumes. Another fact that is of interest is that apparently a simple dry cooking process can improve its nutritional quality; thus, the use of the processed seeds in animal feeding, particularly for swine and poultry, is a possibility.

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