ELSEVIER

Food Chemistry 66 (1999) 115–119

Food Chemistry

Analytical, Nutritional and Clinical Methods Section

Proximate composition, mineral and amino acid content of mature *Canavalia gladiata* seeds

Sagarika Eknayake[a,b,*], Errol R. Jansz[b], Baboo M. Nair[a]

[a]*Department of Applied Nutrition and Food Chemistry, Chemical Centre, University of Lund, PO Box 124, S 221 00 Lund, Sweden*
[b]*Department of Biochemistry, Faculty of Medical Sciences, University of Sri Jayawardenapura, Nugegoda, Sri Lanka*

Received 24 September 1998; received in revised form and accepted 29 December 1998

Abstract

The chemical composition and the nutritional quality of protein and carbohydrates of mature seeds of *Canavalia gladiata* (L.) were investigated. The whole and cotyledon flour of mature seeds contained; crude protein 26.8 and 29.2%; fat 2.8 and 3.1%; fibre 33.2 and 10.2%; ash 3.9 and 4.3%; carbohydrate 33.3 and 53.2% on dry matter basis respectively. The carbohydrate fractions have starch contents of 30.7 and 39.6% and 27.7 and 34.6 mg g^{-1} low molecular weight carbohydrates on dry matter basis. The energy content of whole seed and cotyledon flour was 11,082 and 14,923 kJ kg^{-1}. Sucrose represents the highest fraction of low molecular weight carbohydrates with fructose being the lowest. The mineral analysis showed K, Mg, Ca, P and S to be present in high quantities. The essential amino acid profile compared well with FAO/WHO recommended pattern except for sulphur containing amino acids, cysteine and methionine. Therefore the chemical composition of the raw mature seeds of *Canavalia gladiata* (kernel) indicates the bean to be a good supplement to cereal-based diets.

1. Introduction

With the high rate at which the world population is growing, the world food supply should grow at the same rate if not faster. The most affected from these will be the people in the so-called third world countries. Therefore it is essential that cheaper sources of protein and other nutrients be found. This could be obtained from the plant materials in abundance, most of that are under-utilised. Leguminous seeds, which are said to have as much good quality protein as animal proteins, should be given priority in this quest.

The bean of leguminous plant *Canavalia gladiata* is consumed as a vegetable when the pod is tender or the mature seed is utilised in a variety of ways but not frequently. The mature dry beans may be cooked and eaten as food, but requires careful preparation because of the anti-nutritional factors present (Purseglove, 1968). In Indonesia the seeds are usually boiled twice, washed in clean water, the seed coat is removed, soaked in water for 2 days, drained and then fermented for 3 to 4 days. In other parts of Asia beans are often soaked in water overnight, boiled in water to which a small quantity of sodium bicarbonate has been added, rinsed, boiled, pounded and used in curries, or as a substitute for mashed potato.

The plant has originated in the Asian continent and now is widespread throughout the tropics (Purseglove, 1968). Sometimes it is grown as a cover, green manure and as a feed. It has agronomic features desirable for growth in tropics such as high cultivation temperatures (15–30°C), moderately high evenly distributed rainfall (99–1500 mm/annum), but some cultivars can be drought resistant and susceptible to water logging. Average yield is about 720–1500 kg ha^{-1} comparable with that of soya bean. It is relatively resistant to attack from pests and diseases (Smartt, 1976). Bressani and coworkers (1987), stated that the protein quality of these seeds to be similar to most edible food legumes and therefore advocated to be a good source for extending protein.

Despite these desirable features the seeds are not extensively utilised as a food. In a study with an aim to develop a starch to be used in food preparation from mature seeds of *C. gladiata* the preliminary step was to study the chemical composition and the nutritional quality of raw whole seed and cotyledon flour of the red

* Corresponding author at: Department of Biochemistry, Faculty of Medical Sciences, University of Sir Jayawardenapura, Nugegoda, Sri Lanka.

0308-8146/99/$—see front matter
PII: S0308-8146(99)00041-2

seeded white flowered variety (*rathu awara*). The parameters will reflect the quantity of different nutrients present and the nutritional quality of the seed with and without the seed coat.

2. Materials and methods

Mature sword beans (*C. gladiata*; *awara* in Sinhala) originally obtained from Galle, in south of Sri Lanka, where the red seeded white flowered variety known as *rathu awara*, is more common, cultivated in an experimental plot in Kandy, Sri Lanka harvested at full maturity were used to determine the proximate composition, mineral content and amino acid content.

The seeds were removed from the mature pods, air dried and stored at 4°C until required for analysis. Before analyses seeds were washed with tap water, rinsed with distilled water and oven dried at 50°C overnight (12 h).

The whole seeds and cotyledons were ground to a flour of particle size 40–60 mesh using a standard mill (Cyclotec 1093, Tecator, Sweden). Flour samples were stored in a desiccator until required for analyses.

2.1. Proximate composition

Moisture, ash and fat contents were assayed by the Association of the Official Analytical Chemists (AOAC, 1984) methods 14004 (1984), 14009 (1984) and 14006 (1984) respectively.

Nitrogen was determined using the Kjeldahl method (Kjeltec, Tecator AB, Höganäs, Sweden). The quantity of protein was calculated as 6.25×N (method 7015, AOAC, 1984).

The energy value of the seeds were estimated in kilojoules by multiplying the protein, fat and carbohydrate percentages by the factors 16.7, 37.7 and 16.7, respectively.

2.2. Starch

Starch determination was by the method of Holm and co-workers (1986). Following incubation with Termamyl (Novo A/S, Copenhagen, Denmark) and Amyloglucosidase (Boehringer No. 1202367 3500U) the released glucose was measured using an enzymatic colourimetric method described by the above authors. The starch content was calculated as glucose×0.9.

2.3. Dietary fibre

Soluble and insoluble dietary fibre content was determined gravimetrically as described by Asp and co-workers (1983). The dietary fibre values were corrected for protein (N×6.25) and ash that could be associated with fibre by subjecting the fibre and celite to ashing and Kjeldahl method.

2.4. Low molecular weight carbohydrates

The low molecular weight carbohydrate content was quantified by using high performance anion exchange (HPAE) chromatography [CarboPac PA 10 Analytical (4×250 mm) and guard (4×50 mm)] with pulsed amperometric detection (gold working electrode standard carbohydrate settings). The low molecular weight carbohydrate was determined by suspending samples of cotyledon and whole seed flour (1 g) in distilled water (80 ml) and incubating at 100°C for 30 min. The samples were then diluted (100 ml) and an aliquot (5 ml) diluted (25 ml) again with the internal standard (arabinose; 1000 mg/l). This was centrifuged (4000 rpm: 5 min) and filtered through Millex-HV (0.45 μm) and OnGuard-A filter and injected to HPAE.

2.5. Mineral content

Mineral content of *C. gladiata* cotyledon flour was analysed with a Perkin–Elmer (optima) 3000 DV analyser with induction coupled plasma atomic emission (ICPAES) spectroscopy. The sample was (2 g) digested with 20 ml concentrated nitric acid (BDH-Aristar) until a transparent solution is obtained. The instrument was calibrated with known standards and samples analysed at corresponding wavelengths. Selenium was determined as hydride using a hydride generator (VGA-76). The samples digested in HNO_3 were mixed with concentrated HCl and heated to 70–90°C for 10 min and cooled before injection into hydride generator followed by $NaBH_4$.

2.6. Amino acids

Amino acids of *Canavalia* seed flour (whole seed and cotyledon) were analysed by ion exchange chromatography utilising a post-column ninhydrin reaction after acid hydrolysis. An amino acid analyser (LC 5001) from Biotronic Wissenschaftliche Geräte GmbH, Munchen, Germany was used for quantification (Nair, 1977).

Cysteine and methionine were determined as cysteic acid and methionine sulphone after acid hydrolysis and performic acid oxidation. The tryptophan content was determined flourometrically after partial hydrolysis with papain in the presence of 8M urea (Öste et al., 1976). Chemical score was calculated utilising the FAO/WHO amino acid profile for high quality protein (Food and Nutrition Board/National Research Council, 1989) for human consumption as the base.

$$\text{Amino acid} = \frac{\text{grams of essential amino acid in 1g of test protein} \times 100}{\text{score grams of essential amino acid in 1g of FAO/WHO reference protein}}$$

3. Results and discussion

The average seed, cotyledon, and seed coat weights, of *C. gladiata* after air-drying were 3.14, 2.48 and 0.65 g, respectively. The seeds are comparatively large compared to other legume seeds and the percentage seed coat with respect to seed weight was 20.6%. Percentage cotyledon with respect to seed weight was 78.9%. The values reported by Bressani et al. (1987) for the same species are in agreement with these values.

The proximate composition is given in Table 1. The crude protein contents in cotyledon flour and whole seed flour are 29.2 and 26.7%, respectively. The value falls within protein representation in most legumes which is about 17–30% (Reddy et al., 1984). The crude protein content of seeds is high when compared with common cereals like whole wheat flour, parboiled rice and egg where the crude protein content is 8.55, 7.7 and 12.6%, respectively (Statens Livsmedelsverk, 1988) and makes *Canavalia* seeds a good supplement to cereal based diets. The protein content is in agreement with the values reported by Mohan and Janardhanan (1994, 27.8%) and Bressani and co-workers (1987, 25.6%) for the whole seed flour.

The amino acid composition of *C. gladiata* whole seed flour and cotyledon flour are presented in Table 2. The amino acid content in cotyledon flour was higher in most cases than in whole seed, as would be expected. The acidic amino acids, glutamic and aspartic acid together make up one fourth of the total. As with most legumes the lysine content is high with a chemical score of 363. Compared to FAO/WHO/UNU Expert Consultation (1985) reference profile of protein for human consumption the most limiting amino acids are sulphur containing amino acids cysteine and methionine as most other legumes with a chemical score of 76. The characteristic feature of legume seed proteins is that they are markedly deficient in methionine and tryptophan (Morrison & McLaughlan, 1972). This is also true for *C. gladiata* seed. Like most legumes, *Canavalia* would be unsatisfactory as the sole source of dietary nitrogen, due to the limiting amino acids, but would be extremely beneficial as a complement to a cereal diet like rice (Table 2) and can be fitted in to meal patterns in a variety of ways. Different processing methods, fortification of seed flour or supplementation with other foods also could increase its quality.

Carbohydrate content calculated by the difference accounts for 33.4% of the whole seed flour and 53.2% of cotyledon flour on dry basis. The reasons for carbohydrate determination by the difference are the absence of a specific reactive group in all the different carbohydrates, insolubility in any solvent and the vast differences in size. These factors make analysis of carbohydrates by one particular method difficult. Under carbohydrates the major contributions are from starch, fibre and soluble sugar fraction, which were determined in the whole and cotyledon seed flour.

Starch content is 39.6% on dry matter basis and the predominant carbohydrate in the cotyledon flour. Total low molecular carbohydrate represent 3.9% with the highest contribution from sucrose in both the flours (Table 3) contrary to what is reported in literature. Some studies carried out with legumes (Tovar et al., 1990a,b) showed that the enzymatic methods sometimes underestimate the starch content of a sample. Mechanical disruption, protein hydrolysis and strong alkali

Table 1
Chemical composition of *Canavalia gladiata* whole seed flour and cotyledon flour (g/100 g dry matter basis)

Analyses	Composition (%)	
	Whole seed (mean ± SD[a])	Cotyledon (mean ± SD[a])
Moisture (fresh weight)	11.2 ± 0.04	10.5 ± 0.01
Protein	26.8 ± 0.24	29.2 ± 0.55
Fat	2.8 ± 0.01	3.1 ± 0.04
Ash	3.9 ± 0.01	4.3 ± 0.03
Total dietary fibre	33.1	10.2
Soluble	23.9 ± 0.23	6.6 ± 0.51
Insoluble	9.1 ± 0.47	3.6 ± 0.37
Carbohydrates (by difference)	33.4	53.2
Energy (kilojoules kg^{-1} dry matter)	11,082	14,923

[a] SD, standard deviation; $n = 3$.

Table 2
Amino acid composition of *Canavalia gladiata* cotyledon and whole seed flour following acid hydrolysis (mg amino acid/g protein)

Amino acid	FAO/WHO/UNU Expert Consultation (1985; adults)	Cotyledon	Seed whole	Rice[a]
Cysteine	17[b]	7	8	12
Methionine		6	5	26
Aspartic acid		107	102	88
Threonine	9	42	37	32
Serine		49	46	54
Glutamic acid		119	111	152
Proline		37	33	43
Glycine		43	36	45
Alanine		43	41	58
Valine	13	50	45	66
Isoleucine	13	43	49	43
Leucine	19	85	83	82
Tyrosine		29	30	37
Phenylalanine	19[c]	46	41	51
Lysine	16	58	53	37
Histidine	16	26	23	24
Tryptophan	5	10	12	13
Arginine		51	48	77
Chemical score		76		
Limiting amino acid		Methionine + cysteine		

[a] Swedish Food Administration (1988).
[b] Methionine + cysteine.
[c] Phenylalanine + tyrosine.

treatment were suggested as steps to increase starch recovery with enzymatic analysis. The total of soluble and insoluble dietary fibre fractions of the whole seed flour indicates high percentage of fibre in the seed coat.

The value obtained for crude fat content, cotyledon flour 3.1% and whole seed flour 2.8%, from this study is higher than the values reported in literature [1.6% fresh weight (Spoladore and Teixeria, 1987); 99 g kg^{-1} DM (Mohan and Janardhanan, 1994)]. The crude fat content in the seeds is higher than in commonly consumed Indian pulses and fatty acids palmitic, oleic and linoleic are predominant according to Mohan and Janardhanan. Gupta and his co-workers (1983) reported that these seeds should be given some attention as a potential minor oil seed.

Ash content (Table 1) is also in agreement with the values reported by Bressani and co-workers (1987; 3.9%) and Mohan and Janardhanan (1994; 4.15%). The value is indicative of the presence of high mineral content in *C. gladiata* seeds. The mineral analysis (Table 4) indicates high concentration of potassium (1525 mg/100 g) and also magnesium (1722 mg/kg), calcium (1502 mg/kg), phosphorus (4410 mg/kg) and sulphur (2638 mg/kg). Ca:P is 1:3 and is more than the recommended 1:1.5 and is said to have some effect on the level of Ca in the blood of some animals (Food and Nutrition Board/National Research Council, 1989). The content of lead (< 0.8 μg/g) and cadmium (0.05 μg/g) is low but the mercury content is high but still falls within the tolerable intake (0.04 mg/day) according to the Food and Nutrition Board/National Research Council (1989).

The findings from the above study is typical of what one would expect from legume seeds and implicate that the same kind of anti-nutritive factors found in related legumes such as enzyme inhibitors, flatulus causing substances, phytates and also hard to cook phenomenon are to be expected for *C. gladiata* seeds too.

Table 3
Starch and low molecular weight carbohydrates of *Canavalia gladiata* seeds (g$\times10^{-5}$/100 g dry matter basis)

Carbohydrate	Cotyledon (mean ± SD[a])	Whole seed (mean ± SD[a])
Starch (g/100g)	39.6 ± 0.03	30.7 ± 0.01
Glucose	3.8 ± 0.01	3.5 ± 0.01
Fructose	0.1 ± 0.00	0.1 ± 0.00
Sucrose	27.0 ± 0.05	20.6 ± 0.06
Raffinose	3.6 ± 0.01	0.5 ± 0.00
Stachyose	4.6 ± 0.02	3.2 ± 0.01

[a] SD,standard deviation; $n=3$.

Table 4
Content of certain minerals in *Canavalia gladiata* seeds (μg/g)

Mineral	Raw cotyledons (mean ± SD[a])
Calcium	1502 ± 0.77
Magnesium	1722 ± 0.48
Zinc	34.6 ± 0.59
Iron	34.5 ± 0.38
Manganese	9.5 ± 0.84
Potassium (mg/100 g)	1525 ± 0.94
Copper	16.7 ± 0.72
Molybdenum	1.4 ± 2.57
Sodium	2.6 ± 0.06
Nickel	3.9 ± 1.38
Phosphorus	4410 ± 0.64
Sulphur	2638 ± 0.43
Aluminium	8.9 ± 1.52
Cobalt	0.5 ± 0.72
Lead	< 0.8
Selenium (μg/kg)	68 ± 8.1
Mercury (μg/kg)	325 ± 33.9
Cadmium	< 0.05

[a] SD, standard deviation; $n=3$.

Acknowledgements

The authors thank M. Stenberg and T. Olsson for the technical assistance provided. The work was financed by the International Program in the Chemical Sciences, University of Uppsala, Uppsala, Sweden (grant SRI: 07).

References

Asp, N.-G., Johansson, C.-G., Hallmer, H., & Siljeström, M. (1983). Rapid enzymatic assay of insoluble and soluble dietary fibre. *J. Agr. and Food Chem.*, *31*, 476–482.

AOAC (1984). *Official methods of analysis* (14th ed.). Washington, DC: Association of Official Analytical Chemists.

Bressani, R., Gomez, B. R., Garcia, A., & Eliaz, L. G. (1987). Chemical composition, amino acid content and protein quality of Canavalia seeds. *J. Sci Food Agric.*, *40*, 17–23.

FAO/WHO/UNU Expert Consultation (1985). *Energy and protein requirements*. Technical report. Series 724.

Food and Nutrition Board/National Research Council. (1989) *Recommended dietary allowances* (10th ed., pp. 58–68). Washington, DC: National Academy of Sciences.

Gupta, R., Rauf, A., Ahmad, M. A., Ahmad, F., & Osman, S. M. (1983). Chemical screening of seed oils. *J. Oil Technologists Association of India, 15*, 6–7.

Holm, J., Björck, I., Drews, A., & Asp, N.-G. (1986). A rapid method for analysis of starch. *Starch/Stärke, 38* (16), 224–226.

Mohan, V. R., & Janardhanan, K. (1994). The biochemical and nutrient assessment of less known pulses of the genus *Canavalia*. *International J. Food Sci. Nutr.*, *45*, 255–262.

Morrison, A. B., & McLaughlan, J. M. (1972). Availability of amino acids in foods. In E. J. Bigwood (Ed.), *Protein and amino acid functions* (pp. 389–415). Guatemala: Institute of Nutrition of Central America and Panama.

Nair, B. M. (1977). Gas–Liquid chromatographic analysis of amino acids in food samples. *J. Agric. Food Chem.*, *25* (3), 614–620.

Öste, R., Nair, B. M., & Dahlqvist, A. (1976). A simple method for determination of tryptophan in food samples. *J. Agric. and Food Chem., 24-26*, 386.

Purseglove, J. W. (1968) *Canavalia gladiata* (Jacq.) DC. In *Tropical crops: dicotyledons* (Vol. 1, p. 245). London: Longmans, Green and Co.

Reddy, N. R., Pierson, M. D., Sathe, S. K., & Salunkhe, D. K. (1984). Chemical, nutritional and physiological aspects of dry bean carbohydrates—a review. *Food Chemistry, 13*, 25–68.

Smartt, J. (1976). *Canavalia gladiata* (Jacq.) D.C. (Sword bean). In *Tropical Pulses* (p. 58). London: Longman Group.

Spoladore, D. S., & Teixeria, J. P. F. (1987). Chemical composition of seeds of *Canavalia gladiata* D.C. *Bragantia, 46*, 133–139.

Statens Livsmedelsverk. (1988) Energi och Naringsamnen. *Livsmedelstabeller*. Stockholm, Sweden: The Swedish Food Administration.

Tovar, J., Björk, I., & Asp, N.-G. (1990). Analytical and nutritional implications of limited enzyme availability of starch in cooked red kidney beans. *J. Agric. and Food Chem., 38*, 488–493.

Tovar, J., Björk, I., & Asp, N.-G. (1990b). Starch content and Amylosis rate in precooked legume fours. *J. Agric. and Food Chemistry, 38*, 1818–1823.