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Effect of processing on the nutritive value of Canavalia Jackbeans (*Canavalia ensiformis* (L))

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Abstract. A comparative study of roasting, cooking with and without calcium hydroxide and extrusion cooking on the protein quality of Canavalia was conducted. The results suggested both extrusion and pressure cooking with lime to be equally effective in improving the protein quality of Canavalia and superior to pressure cooking alone and roasting, the latter effective possibly in destroying the antiphysiological factors in Canavalia but possibly also damaging its protein quality.

The individual effects of roasting, cooking with different levels of calcium hydroxide, and with water under pressure at different times on the protein quality of Canavalia were also studied. These indicated a beneficial effect of calcium hydroxide added at a level of 0.45% by weight of seed, for 30 minutes under pressure. Cooking in water under pressure for 30 minutes with and without lime added was slightly better than cooking for longer periods of time. Roasting was also effective in improving the quality of Canavalia particularly when the T was adjusted at 170°C, and roasting conducted for 15 minutes. A significant improvement in the protein quality of processed Canavalia was obtained by methionine supplementation.

Introduction

Canavalia ensiformis seeds, are not an important food legume for human consumption, although commonly people consume the boiled immature seeds. Often the mature seeds are roasted, ground and consumed as a drink [9]. Because of its very good adaptability to tropical areas, its relatively high yields [4] and attractive chemical composition [5]. Canavalia merits to be studied further, if not for human consumption, at least for animal feeding. Although there are a number of strains, the most common Canavalia has a white seed coat and each seed weighs around 1.8 g [4]. Previous studies described the protein content and nutritive value of 27 selections of *Canavalia ensiformis* and *Canavalia glandiata* [4]. Protein averages 25.6% on a dry weight basis, which is similar to values found in common beans. Likewise, the protein quality as PER of pressure-cooked seeds average 1.3, a value also similar to most selections of common beans [2]. With respect to yield, there was some variability among cultivars, from 109 g/plant to 408 g/plant, indicating the potential of production [4]. Other studies included the isolation of protein [12] and of starch [13]. A species of Canavalia, known as brown beans (*Canavalia rosea, DC*) in Nigeria has been studied raw and pressure-cooked for functional properties [1]. These authors reported both flours to have good water and oil absorption but they had poor gelation properties. Other functional characteristics studied included foaming and emulsion capacity which were affected in processed flour. Canavalia seeds has been shown to contain a relatively high hemagglutinin activity, as well as a high urease activity [7, 11, 14]. These hemagglutinins are known as canavalin and concavalin A and B. Canavanine content has been informed to be present at a level of 26.5 g/kg [11] and it may interfere with arginine bioutilization [7, 14], because of their close structural similarity. Its nutritive value when raw is unpredictable, with samples being highly toxic, while others are much less so. Often pods in the field are found with partially-consumed seeds, suggesting field rats feed on them when there is need. Although pressure cooking was shown to yield a relatively good product in terms of nutritive value [5], systematic studies to learn of the effects of processing have not been conducted.

In this paper, the effect of various processes on nutritive value are reported.

Material and methods

Seeds from *Canavalia ensiformis* were harvested from experimental fields in the tropical area of southern Guatemala, when the pods were completely dried. After separation from the pods, the seeds were kept at 4 °C until used.

In the first study, the white Canavalia seeds were processed by roasting, pressure cooking with and without calcium hydroxide addition, and by extrusion cooking. Roasting was conducted with a gas-heated-rotating coffee roaster. A lot weighing 2,500 g was placed in the coffee roaster set at 175 °C where it remained for 15 minutes. It was then removed and allowed to cool before grinding into a flour with a hammer mill at 40 mesh. Pressure cooking was done on 2,000 g of seeds to which 8,000 ml of water were added. Cooking was conducted at 15 lb pressure (121 °C) for 30 minutes allowing about 60 minutes to permit soaking of the seeds before applying heat. In one case 0.45% of calcium hydroxide of the seed weight was added and in another case, no lime was added. In the first case, the cooked seed was washed free of lime as much as possible before drying in a convection oven at 60 °C. When dried, it was ground to 40 mesh as before. The extruded product was obtained from 15 kg of broken seeds using a Brady Extruder set at 320 °C. The extruded product was allowed to cool and then it was ground as indicated before.

A second study consisted in roasting the seed at three temperatures: 130, 150 and 170 °C each for 5, 10 and 15 minutes. The seeds were allowed to cool and then were ground.

In a third study, 2000 g lots were pressure-cooked as indicated above, but with additives of 0, 0.45, 0.90 and 1.35% of calcium hydroxide of the seed weight. The cooked material was washed, dried and ground.

The effect of cooking time in the autoclave was studied in a fourth experiment. The material was processed as indicated before using 0.45% lime in one series and no lime in the other. Cooking times after soaking for one hour were set at 30, 60 and 90 minutes. After processing the cooked seeds were dried with air at 60 °C and ground.

Using the extrusion cooking method in a further experiment around 20 kg of Canavalia seeds were processed as described before and then ground to a flour used for amino acid supplementation studies. The diets containing Canavalia flour to provide 10% protein were supplemented with 0.3% DL-Methionine, 0.2% L-Arginine, 0.2% L-Lysine HCl, added alone or in combination.

All diets were analyzed for protein content for biological studies. Diets made up of 10% protein were prepared using the appropriate amount of raw and processed flours. The diets were supplemented with 4% mineral mixtures [8], 5% cottonseed oil, 1% cod liver oil, and adjusted to 100% with corn starch. All diets were supplemented with 5 ml/100 g of a complete B-vitamin mixture [10].

The biological studies were conducted with 22–23 day rats of the Wistar strain. A total of eight animals were assigned per diet treatment placing each in individual cages. They were fed *ad libitum* for a PER assay and water was provided at all times. The temperature of the room was 22 °C and 50% relative humidity with 12 hr light cycles. The animals were weighed every seven days and food intake was also measured every seven days for a 28-day experimental period. All diets were analyzed for protein content for purposes of PER calculation.

Results and discussion

Using the information derived from previous studies [4, 5] as well as from other studies not yet reported, a comparative study of processing methods

Table 1. Comparative study on the effect of four processing methods on the protein quality of canavalia seeds

Process	Average wt. gain (g)	Average diet intake (g)	PER
Roasting	24 ± 5^{c}	205 ± 22^{c}	1.12 ± 0.20^{d}
Alkaline cooking	46 ± 9^{bc}	270 ± 43^{bc}	1.61 ± 0.11^{cd}
Cooking	32 ± 4^{b}	228 ± 14^{b}	1.36 ± 0.12^{bc}
Extrusion cooking	45 ± 6^{b}	264 ± 28^{b}	1.66 ± 0.16^{b}
Casein	133 ± 20^{a}	448 ± 42^{b}	2.81 ± 0.23^{a}

Average with different letter are statistically significant.

on protein quality was conducted. The results are summarized in Table 1. Analysis of variance showed significant differences due to processing on average weight gain, food intake and protein efficiency ratio. Of the processing methods, cooking under alkaline conditions with the addition of calcium hydroxide and extrusion cooking gave similar weight gains, feed intake and PER and both above the roasted products as well as the product cooked in water and under pressure. Of the latter two, roasting induced the least animal performance in terms of weight gain, food intake and PER.

The effects of roasting time and temperature are shown in Table 2. Analysis of variance of all data showed significant differences in weight gain and feed intake for temperature, roasting time and the interaction of $T \times t$. Statistical analysis showed further that better animal weight gain and feed intake was observed as Temperature increased from 130 to 170 °C. However, weight gain even at the highest T never reached the range of values

Table 2. Effect of temperature and length of roasting time on the growth of young rats

Treatment		Average weight gain (g)	Average diet intake (g)
T°C	Time (min)		
130	5	-7 ± 5^{b}	123 ± 17^{bc}
	10	-6 ± 5^{d}	120 ± 11^{c}
	15	$-6 \pm {}^{cd}$	122 ± 13^{c}
150	5	-5 ± 6^{cd}	128 ± 15^{bc}
	10	-1 ± 5^{bcd}	124 ± 13^{bc}
	15	2 ± 4^{bc}	135 ± 8^{bc}
170	5	-5 ± 7^{cd}	115 ± 37^{c}
	10	7 ± 6^{ab}	151 ± 15^{b}
	15	16 ± 5^{a}	182 ± 13^{a}
None	—	-4 ± 5^{cd}	125 ± 13^{bc}

Average values with different letter are statistically different ($P < 0.05$).

Table 3. Effect of calcium hydroxide addition and cooking under pressure on the protein quality of Canavalia

Lime level*	Average weight gain (g)	Average diet intake (g)	PER
0	28 ± 8[b]	243 ± [b]	1.13 ± 0.15[b]
0.45	40 ± 7[b]	281 ± 43[b]	1.34 ± 0.12[b]
0.90	40 ± 7[b]	295 ± 41[b]	1.34 ± 0.12[b]
1.35	40 ± 11[b]	303 ± 66[b]	1.30 ± 0.23[b]

* Based on the dry weight of Canavalia.
Average values with different letters are statistically different ($P < 0.05$).

from pressure cooking. Time of exposure to the different temperatures also showed a positive effect as time increased, however, as for $T°$ the weight gained at the higher time exposure did not improve the quality of the Canavalia seeds as wet cooking did. These results suggest that either a higher T and/or a higher time exposure could result in a higher improvement. However, it must be kept in mind that dry cooking may destroy nutritive quality by destroying or inactivating essential amino acids, particularly lysine [3].

The effect of calcium hydroxide levels of addition is shown in Table 3. Although weight gain, feed intake and PER were similar based on Tukey statistical analysis, the addition of 0.45% calcium hydroxide increased all three parameters which were not improved further by higher additions. At present no explanation is available for the effects of lime addition even if they are not statistically significant. One possibility is the degradation of canavanine, a compound which some investigators indicate inhibit the utilization of arginine [7, 14]. Cooking maize with lime has also been shown to improve the quality of the cereal grain, possibly by increasing the bioavailability of key amino acids, such as tryptophan [6] and of vitamins such as niacin.

The results of pressure cooking time of Canavalia seeds in the absence or presence of calcium hydroxide are shown in Table 4. Raw Canavalia did not support weight gain and all thermic treatments in the presence and absence of calcium hydroxide induced similar weight gains which were not statistically different. Similar results were observed with respect to food intake. Using all values analysis of variance was statistically significant for both weight gain and food intake. Further analysis of the data showed that cooking time from 30 to 90 minutes did not affect weight gain in the presence or absence of lime, however, a lower feed intake was observed for the group fed Canavalia cooked without lime for 90 minutes. Animals consuming Canavalia processed in the presence of lime gained on the average 25 ± 7 g

Table 4. Effect of pressure cooking time in the absence and presence of calcium hydroxide on the protein quality of Canavalia

Treatment	Time (min)	Average weight gain (g)	Average diet intake (g)	PER
Without lime	30	24 ± 6[a]	206 ± 14[a]	1.14 ± 0.23[a]
	60	19 ± 9[a]	202 ± 29[a]	0.95 ± 0.37[a]
	90	19 ± 6[a]	186 ± 31[b]	1.03 ± 0.20[a]
With lime	30	24 ± 6[a]	206 ± 31[a]	1.27 ± 0.19[a]
	60	26 ± 6[a]	218 ± 18[a]	1.24 ± 0.19[a]
	90	26 ± 9[a]	233 ± 35[a]	1.12 ± 0.29[a]
Raw	—	−4 ± [b]	125 ± 13[c]	—

Average values with different letters are statistically different ($P < 0.05$).

and gave a PER of 1.21 as compared to those fed with processed seeds without lime which gained 21 ± 7 g with PER of 1.04 suggesting that lime addition helps in destroying the antiphysiological compounds in Canavalia seeds. In studies with common beans increasing cooking time decreased the nutritive value of beans [3] effect not observed in this study. This difference may be due to seed size, which is about 10 times larger for Canavalia as compared to common beans.

Table 5 summarizes the results of the study in which Canavalia seeds were processed by extrusion cooking. Extruded Canavalia showed a PER of 1.23 which was improved significantly from supplementation with 0.3% methionine, confirming previous results [5, 15]. None of the other amino acids added, arginine and lysine, changed the protein quality of Canavalia over the value found with unsupplemented flour. An improvement was obtained when methionine was also added with arginine and lysine indicating again sulfur amino acids to be deficient in Canavalia seed protein as is the case for other food legumes [3]. Canavanine present in Canavalia shows

Table 5. Effect of amino acid supplementation to extruded Canavalia seeds

Addition	Average weight gain (g)	Average diet intake (g)	PER
None	34 ± 11[c]	244 ± 47[cd]	1.23 ± 0.20[c]
+ Methionine (0.3)	75 ± 14[b]	286 ± 46[bcd]	2.32 ± 0.18[ab]
+ Arginine (0.2)	28 ± 6[c]	222 ± 34[d]	1.05 ± 0.10[c]
+ Met + Arg	83 ± 16[b]	320 ± 48[b]	2.15 ± 0.14[b]
+ Lysine (0.2)	31 ± 10[c]	233 ± 47[d]	1.20 ± 0.27[c]
+ Met + Lys	84 ± 11[b]	299 ± 25[bc]	2.40 ± 0.21[ab]
Casein	123 ± 11[a]	438 ± 35[a]	2.64 ± 0.26[a]

Average with different letters are statistically different ($P < 0.05$).

a close similarity to arginine, interfering with the utilization of this amino acid [7, 14]. Since no effect was observed in this study with the addition of arginine to the diet, it may be concluded that it was destroyed during processing; thus, not interfering with arginine utilization by the rat. It may also be possible that the rat is not affected because of its requirements for growth, of these amino acids.

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References

1. Abbey BW, Ibem GO (1987) Functional properties of raw and heat processed brown bean (Canavalia rosea DC) flour. J Food Sci 52: 406–408
2. Bressani R (1973) Legumes in human diets and how they might be improved. In: Milner M (ed.), Nutritional Improvement of Food Legumes by Breeding. New York: John Wiley & Sons, pp. 15–42
3. Bressani R, Elías LG, Valiente AT (1963) Effect of cooking and of amino acid supplementation on the nutritive value of black beans (*Phaseolus vulgaris* L) Brit J Nutrition 17: 69–78
4. Bressani R, Estrada-Ligorria L, García-Soto A (1989) Some agronomic characteristics of Canavalia sp. Turrialba, in press
5. Bressani R, Gómez Brenes RA, García A, Elías LG (1987) Chemical composition, amino acid content and protein quality of *Canavalia sp. seeds*. J Sci Food Agric 40: 17–23
6. Bressani R, Scrimshaw NS (1958) Lime-heat effects on corn nutrients, effect of lime treatment on in vitro availability of essential amino acids and solubility of protein fractions in corn. J Agric Food Chem 6: 774–778
7. Crine P, Lemieux EJ (1982) Incorporation of Canavanine into rat pais intermedia proteins inhibits the maturation of pro-oxionilanocortin, the common precursor to adrenocortisotropin and -lipotropin. J Biol Chem 257: 832–838
8. Hegsted DM, Mills RC, Elvehjem CA, Hart EB (1941) Choline in the nutrition of chicks. J Biol Chem 138: 459–466
9. Kay DE (1979) Food legumes. TPI crop and product digest No. 3. Tropical Products Institute 56/62, Gray's Inn Road, London WO/X 8LV
10. Manna L, Hauge SM (1953) A possible relationship of vitamin B/3 to orotic acid. J Biol Chem 202: 91–96
11. Natelson S (1985) Canavanine to arginine ratio in alfalfa (*Medicago sativa*) clover (*Trifolium*) and the Jack Bean (*Canavalia ensiformis*). J Agr Food Chem 33: 413–419
12. Molina MR, Argueta CE, Bressani R (1974) Extraction of nitrogenous constituents from the Jack Bean (*Canavalia ensiformis*) J Agric Food Chem 22: 309–312
13. Molina MR, Bressani R (1975) Protein-starch extraction and nutritive value of the Jack Bean and Jack Bean protein isolate. In: Jaffé WG (ed.), Nutritional Aspects of Common Beans and Other Legume Seeds as Animal and Human Foods. Caracas, Venezuela: Archivos Latinoamericanos de Nutrición, pp. 93–108
14. Rosenthal GA (1977) The biological effects and mode of action of L-Canavanine, a structural analogue of L-arginine. Quart Rev Biol 52: 155–178

15. De la Vega A, Sotelo A (1982) Valor nutritivo de la semilla de Canavalia ensiformis sola y suplementada con mentionina y cereales. Rev Soc Quim Mex 26: 92–96