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Some physicochemical properties and anti-nutritional factors of raw, cooked and germinated Jack bean (*Canavalia ensiformis*)

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Physicochemical properties and anti-nutritional factors of raw, cooked and germinated Jack bean (*Canavalia ensiformis*) were studied. Jack bean seeds were relatively large, measuring 1.88 cm in length, 1.32 cm in width and 1.09 cm in thickness. The 1000 seed weight was 1.78 kg. The seed coat formed about 13.3% of the whole seed, resulting in high fibre content of the meal. The Jack bean was high in protein (23.3%) and starch (24.7%). Hydrogen cyanide and phytate levels in the raw beans were 11.2 mg/100 g and 2.78 g/100 g dry sample, respectively. Haemagglutinin and trypsin inhibitor activities were detected in the bean. Cooking and germination had varied effects on bean constituents. Raw bean flour had a fairly good foam capacity which was reduced considerably by cooking and germination. The Brabender amylograph showed that the bean starch had poor cooked paste properties and this may, in part, explain why the bean is difficult to cook.

INTRODUCTION

Jack bean (*Canavalia ensiformis*) is one of the underexploited tropical dry beans. It is, however, fairly widely distributed, being cultivated in Africa, Asia, the West Indies, Latin America and India (Stanton, 1966; Molina & Bressani, 1973).

The Jack bean can be grown in marginal soils and arid to semi-arid regions not suitable for common legumes such as *Phaseolus* and *Vigna* species. It has, therefore, great potential in most tropical and subtropical parts of the world.

Research information on the Jack bean is not readily available. Available data on the chemical composition showed that the mature beans contain: water 10–11.0%; protein 23–30%; fat 2–3%; carbohydrate 45–53%; crude fibre 5–11%; and ash 3–4% (Molina & Bressani, 1973; Molina *et al.*, 1974; Bressani *et al.*, 1987). The essential amino acid content of the beans is fairly balanced, with methionine and cystine being the most limiting (Molina & Bressani, 1973; Bressani *et al.*, 1987). Feeding trials showed that the bean is low in protein nutritional quality, which was improved by heat-processing and by methionine supplementation. The mineral content of the beans is high and compares favourably with that of most food legumes (Bressani *et al.*, 1987).

Despite its nutritional potential, the Jack bean is rarely used as human food, partly because of the alleged presence in the beans of anti-nutritional and toxic factors such as phytic acid, haemagglutinin, trypsin inhibitors and hydrocyanic acid (Molina & Bressani, 1973). Information concerning the presence of these components in the Jack bean is not readily available, nor are results on the effects of processing on the contents of these components in the beans. This study was, therefore, initiated to determine the physicochemical properties and anti-nutritional components of the Jack bean and to evaluate the effects of traditional processing methods such as cooking and germination on them.

MATERIALS AND METHODS

One batch of Jack bean (*Canavalia ensiformis*) used for this study was collected from a farm in Makurdi, Nigeria. The beans were divided into portions for the various processing treatments.

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Preparation of sample

One portion of raw, clean beans was milled into flour of 300 μm particle size and stored for analysis.

Two hundred grams of selected beans were cooked until tender on an electric stove (General Electric, UK). The cooking was carried out in boiling distilled water (100°C) for about 3 h. After cooking, the water was discarded and the bean samples were dried in an air oven (100°C) for 6 h. The dried samples were milled into flour of 300 μm particle size and stored in screw-capped bottles.

Germination of the beans was achieved by placing 200 g of clean bean seeds washed with 5% (w/v) NaCl solution in a Petri dish containing wet filter papers. The dishes containing the beans were kept at room temperature (29°C) and allowed to germinate for 72 h. The beans were watered at regular intervals (three times a day). Germinated beans were removed and dried in an air oven (100°C) for 6 h. The dried samples were milled into flour of 300 μm particle size and stored for analysis.

All the samples were stored in cold room at 4°C throughout the period of the experiment.

Physical measurements

The seed length, width, thickness and hilum length were measured with a vernier calliper, while the seed coat thickness was measured with a micrometer screw gauge. Other measurements made include the per cent seed coat and 1000 seed weight.

Chemical analysis

The crude protein ($N\times6.25$), ether extract, ash and moisture contents of the raw and treated Jack beans were determined by the AOAC (1975) methods. Neutral detergent fibre (NDF) was determined by the method of Southgate (1976) following enzyme hydrolysis of de-fatted sample. To 1 gram of the sample was added 5 ml of alpha-amylase enzyme (*Bacillus subtilis*, Fluka Biochemicals, Switzerland) (10% enzyme solution in buffer pH 6.0). The mixture was incubated at 25°C for 24 h and the NDF was determined as outlined. The carbohydrate content of the samples was estimated by difference. Starch was determined by the direct acid hydrolysis method as outlined in the AOAC (1975) methods. Starch was calculated by multiplying the value of glucose (Dubois *et al.*, 1956) by a factor of 0.90. Water-soluble sugar was determined in the washings of the starch analysis by the phenol–sulphuric acid method as described by Dubois *et al.* (1956). Hydrogen Cyanide (HCN) content was determined by the alkaline titration method (AOAC, 1975). Phytate determination was carried out by the method described by Davis and Reid (1979).

Haemagglutination assay

A 10 gram sample of bean flour was dissolved in 50 ml phosphate-buffered saline (PBS). The mixture was stirred mechanically for 30 min at 4°C and strained through glass-wool. The suspension was centrifuged at 10 000 rpm for 30 min; the supernatant was centrifuged at 10 000 rpm for 30 min and the supernatant was used for the assay. The activity of haemagglutinin in the bean extract was detected by a modification of method of Kornfield *et al.* (1972) using a 10% (v/v) suspension of washed human and rabbit red blood cells (RBC), respectively. Ten microlitres of PBS (6.7 mM KH_2PO_4, 150 mM NaCl pH 7.4) was spotted on a glass plate followed by 10 μl test sample (extract) and 15 μl 10% RBC suspension. The droplet was mixed with the tip of a glass rod to form a spot 1 cm in diameter. The glass plate was rotated for 3 min and then scored as follows:

(a) 0 No haemagglutination
(b) 1+ Barely discernible agglutination
(c) 2+ Grainy
(d) 3+ Clumpy patches
(e) 4+ Red cells clumped strongly

Trypsin inhibitor assay

Two grams of bean flour (70 mesh) were extracted with 20 ml 0.01 M NaOH. After mixing, the homogenate was left to stand for 2 h at room temperature (29°C) and then centrifuged at 5°C for 20 min at 5000 rpm. The supernatant was collected and an equal volume of 3% (w/v) TCA was added. The mixture was spun at 5000 rpm for 20 min at 5°C. The clear supernatant was again collected and 2 M NaOH was added to adjust the pH to 8.3. The resultant solution was again spun at 5000 rpm for 20 min at 5°C and the supernatant (trypsin inhibitor fraction) was used for the assay. The trypsin inhibitor activity was determined by the method of Erlanger *et al.* (1961) using benzoyl-D,L-arginine-*p*-nitroanilide hydrochloride (BAPNA) (Sigma Chemical Co.) as substrate and trypsin enzyme (BDH, Poole, UK). The result was expressed as μg nitroaniline/g dry sample.

Functional properties

Foam capacity and stability were determined by the procedure described by Okezie and Bello (1988). The cooked paste viscosity of an 8% slurry of the sample was determined with a Brabender viscoamylograph (Brabender Instruments, Inc., Duisbury) equipped with a 700 cmg sensitivity cartridge. The sample was taken through heating, holding and cooling cycles. The sample was heated at 1.5°C/min to 95°C, held for 30 min and then cooled uniformly at the same rate to 50°C and held for 30 min.

RESULTS AND DISCUSSION

Table 1 shows data on some physical characteristics of the Jack bean seeds used for this study. The seeds were white in colour and had a length of 1.88 cm, width of 1.32 cm and a thickness of 1.09 cm. The 1000 seed weight of the beans was 1.783 kg. The Jack bean thus is larger than most legumes such as cowpea, soybean and pinto (Sefa-Dedeh & Stanley, 1979) and is expected to yield high dry matter. Other physical characteristics measured include hilum length of 1.12 cm and seed coat thickness of 0.05 cm. The seed coat is 13.3% of the whole seed. The relatively high seed coat thickness may limit water absorption (Sefa-Dedeh & Stanley, 1979), resulting in a longer cooking time, while the high proportion of the seed coat may increase the fibre content of the meal. This may affect its functional properties.

The data on the proximate composition of whole, raw, cooked and germinated Jack bean are shown in Table 2. The results showed that the Jack bean is a good source of protein and starch. The values of 23.3% for protein and 24.7% for starch compare favourably with those reported by Molina and Bressani (1973). The differences may be due to variety, environmental and soil conditions. Cooking and germination tended to decrease the protein and the starch contents of the beans. As expected, the NDF content of the Jack bean was very high. This may be due to the seed coat fraction and other cellulosic constituents of the beans. The higher NDF value of the germinated bean was probably due to the presence of the vegetative parts of the beans in the meal analysed. The ether extract, ash and total water-soluble sugars of the beans were slightly low compared with the values reported by Molina and Bressani (1973). There were noticeable changes in the values of these constituents as a result of cooking and germination. Cooking caused slight decreases in the fat and ash contents of the sample, but an increase in the soluble sugar content. Germination, on the other hand, increased the ash and soluble sugars of the samples, but decreased the fat content.

The agglutination patterns and the trypsin inhibitor activities of the Jack bean are shown in Table 3. The results show that Jack bean haemagglutinin does not cause agglutination of human red blood cells *in vitro*. Strong agglutination was, however, observed with rabbit red blood cells *in vitro*. Cooking was able to eliminate the haemagglutinin of Jack bean as observed by the zero agglutination. Germination was not, however, able to eliminate or reduce the haemegglutinin of the beans. Vigorous reaction was observed *in vitro* in the three rabbit red blood cells tested. This observation is in contrast to the report of Neilsen and Liner (1988). Those workers reported a gradual decrease in haemegglutinin activity of *Phaseolus vulgaris* with increase in days of germination. It is possible that extending the germination period to about 5 days may bring about decrease in the haemagglutinin activity but germination for 3 days, as was carried out in this study, did not reduce the activity. The raw Jack bean inhibited bean trypsin activity by 55%. Cooking and germination reduced Jack bean trypsin inhibitor activity to 38% and 12%, respectively. In contrast to the effect on haemagglutinin activity, germination was more effective than cooking in reducing the activity of the trypsin inhibitor in the beans. A similar reduction in trypsin inhibitor activity of germinating *P. vulgaris* was reported by Sathe *et al.* (1983). Neilsen and Liner (1988), however, reported that the trypsin inhibitor activity of germinated *P. vulgaris* did not decrease until the ninth day of their 10 day germination study. The reasons for these variations may be due to bean variety and type, as well as to the level of the endogenous enzyme in the beans, which may be affected by the environmental conditions.

The phytate content of the raw Jack bean was 2.78 g/100 g (Table 3). Cooking was not effective in reducing the phytate content of the beans but germination resulted in about 27% reduction in the phytate content. Since phytate is known to bind both minerals and protein (Kon *et al.*, 1973), the reduction in the phytate content may increase the mineral and protein contents of the bean with a resultant increased nutritional quality. The raw Jack bean contained low levels of HCN. The level of 11.2 mg/100 g reported in this study is below the 20 mg/100 g recommended safe limit (Montgomery, 1969). Germination was more effective in reducing the HCN content of the bean with a reduction level of 49.1% compared to 16.1% for the cooked sample.

Table 4 shows data on the amylograph characteristics of undehulled raw Jack bean meal, raw Jack bean flour sieved through 70 mesh sieve (212 μm particle size) and germinated Jack bean flour. The results showed that the Jack bean has poor cooked paste properties. The presence of seed coat fractions, as well as germination, had considerable influence on the viscosity of the flour. The sieved flour had a peak viscosity of 59 BU compared to 6 and 10 BU, respectively, for a whole bean flour and germinated bean flour. When the sieved bean flour slurry was held for 30 min at 95°C, the viscosity decreased drastically, showing poor resistance to shearing by the sample. There were slight increases in viscosity of the flours at 50°C and when the slurries were held for 30 min at 50°C. The poor cooked paste property of Jack bean flour may be attributable to the ratio of the amylose:amylopectin fractions, as well as to the type and amount of other constituents such as lipids,

Table 1. Physical characteristics of Jack Bean seed[a]

Seed length (cm)	1.88 ± 0.004
Seed width (cm)	1.32 ± 0.03
Seed thickness (cm)	1.09 ± 0.09
Hilum length (cm)	1.12 ± 0.02
Seed coat thickness (cm)	0.05 ± 0.01
Seed coat (% of whole seed)	13.30 ± 08
1000 seed weight (kg)	1.783 ± 89.45

[a]Mean ± SD of five determinations from one batch.

proteins, and salts in the flours (Sathe *et al.*, 1982; Zobel, 1984).

The raw Jack bean had a fairly good foam capacity of 20%, while germinated Jack bean had a foam capacity of 8%. Cooked Jack bean flour did not form stable foam. The inability of the cooked bean flour to form stable foam may be due partly to heat-denaturation of the bean protein, while hydrolysis of the protein of the germinated bean flour by the endogenous enzymes may have been partly responsible for the reduction in its foam capacity.

Some important characteristics of the Jack bean observed during the course of this study were: the long cooking time, which lasted for more than 3 h on an electric cooker; the cooked beans tended to show slight toughening after cooking with a not-too-pleasant aroma; the flour from the raw, cooked and germinated samples had some pungent odour.

It is possible that some of the following: (1) the long cooking time of the bean which is energy- and time-consuming; (2) the toughening of the cooked beans after cooling; (3) the unpleasant aroma of the cooked beans; (4) the pungent odour of the bean flour; (5) the poor cooked paste viscosity of the bean slurry; (6) the tough seed coat which may affect processing and utilization of the bean; and (7) the high fibre content of the bean meal, may have been responsible for the apparent lack of consumer interest in the Jack bean.

In the light of these observations, the authors wish to recommend that the preparation from the beans of high quality starch and protein concentrates and isolates which could be used in other food systems should be pursued and expanded. Boiled and toasted whole Jack bean meal could be fed to livestock, thereby sparing the more popular legumes, such as cowpea, soybean and groundnut, for human use.

Table 2. Chemical composition of dry meal from raw, cooked and germinated Jack bean (% dry weight basis)[a]

Component	Raw	Cooked	Germinated
Crude protein			
Whole seed flour	23.3 ± 0.05	21.1 ± 0.19	20.0 ± 0.32
Sieved (70 mesh) flour	47.6 ± 0.10	43.6 ± 0.07	42.1 ± 0.15
Ether extract	2.60 ± 0.15	2.56 ± 0.13	2.24 ± 0.08
Ash	2.76 ± 0.17	2.34 ± 0.09	3.15 ± 0.11
Neutral detergent fibre (NDF)	23.38 ± 2.9	15.57 ± 2.1	40.08 ± 3.4
Starch	24.7 ± 2.3	16.8 ± 1.9	18.6 ± 3.3
Total soluble sugars	0.92 ± 3.1	1.16 ± 2.5	1.58 ± 2.6

[a]Mean ± SD three determinations.

Table 3. Haemagglutinin, trypsin inhibitor activities, HCN and phytate contents of raw, cooked and germinated Jack beans

Sample	Haemagglutinin activity[a]		Trypsin inhibitor activity		HCN (mg/100 g dry sample)[b]	Phytate (g/100 g dry sample)[b]
	Agglutination of rabbit RBC	Agglutination of human RBC	μg/g (Dry Sample)[b]	% Inhibition		
Raw	2+[c]	0	21.8 ± 1.3	55.3	11.2 ± 1.5	2.8 ± 0.31
Cooked	0	ND[d]	14.1 ± 2.1	38.0	9.4 ± 0.62	2.7 ± 0.18
Germinated	2+	ND	4.6 ± 1.9	12.1	5.7 ± 0.73	2.0 ± 0.21

[a]Scoring pattern.
[b]Means ± SD.
[c]Scores: 0, no haemagglutinin; 1+, barely discernible agglutination; 2+, grainy; 3+, clumpy patches; 4+, red blood cells (RBC) clumped strongly.
[d]ND, not determined.

Table 4. Brabender viscoamylograph characteristics of whole Jack bean meal, flour fraction (70 mesh) and germinated flour (70 mesh)

Sample	Pasting temp. (°C)	Brabender viscosity units (BU)				
		Peak	95°C	95°-Hold	50°C	50°-Hold
Whole Jack bean meal	84.4	6	6	6	16	15
Jack bean flour (70 mesh)	83.0	59	58	38	68	74
Germinated bean flour (70 mesh)	85.0	10	10	8	18	18

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