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A Review on an underutilized legume *Canavalia gladiata*

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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. Under-nourishment in these countries is largely related to the availability of food in the markets, the purchasing power of the households, food distribution among family members as well as the living conditions of the people.

Therefore it is essential to produce or introduce new foods that have high nutritional quality, and also are easy for people with a low income to purchase, this by being less costly to produce and being suitable to the environment by having desirable agronomic features to be cultivated. This could be obtained from the plant materials in abundance, most of which are underutilized. Leguminous seeds which are said to have as much good quality protein as animal proteins should be given priority in this quest. The bean *Canavalia gladiata,* a leguminous plant though eaten not very frequently, but with a potential to become a plant with above desirable features is studied in this paper.

The family Leguminosae is one of the largest families of flowering plants with about 690 genera and 18.000 species of herbs, shrubs, trees and climbers. The sub-family Papilionoideae has about 480 genera and 12,000 species distributed throughout the world (Purseglove, 1968). The genus *Canavalia* to which the plant *Canavalia gladiata*, commonly known as the sword bean and called *awara* in Sinhala belongs, is one of these genera with about 48 species. This genus is tropial and subtropical with two major pulses contributing to agriculture, namely jack bean (*Canavalia ensiformis*) and sword bean *(Canavalia gladiata)* (Smartt, 1976) which are yet to be exploited fully as food sources. The Jack bean *(Canavalia ensiformis)* is very closely related to the sword bean but the seeds can be distinguished by the length of the hilum which is nearly as long as the seed in the sword bean, and less than half its length in the jack bean (Smartt, 1976; Purseglove, 1968). According to Herklots (1972) and Purseglove (1968), the plant *C. gladiata* is considered as an Old World Tropic, whereas *C. ensiformis* is a New World Tropic. Herklots (1972), attributes its widespread distribution in historic times to be due in part to the practice of carrying about the seeds as curios.

C. gladiata is believed to have originated in the Asian continent and spread throughout the tropics. This is now cultivated on a limited scale throughout Asia, the West Indies, Africa and South America and has been introduced into tropical parts of Australia (Purseglove, 1968; Kay, 1979).

Temperature range for cultivation is fairly wide (15-30 ^{0}C) and requires moderately high evenly distributed rainfall, about 900-1500 mm/a. But some cultivars are fairly resistant to drought once established. Reasonably fertile soil is required and many cultivars are susceptible to water logging. The plant is reported to be found at elevations up to 900 m in Asia. Average yield ranges from 720-1500 kgha^{-1} which can be compared with a soya bean yield of 600-1000 kgha^{-1} (Bressani *et al.,* 1987). For use as a vegetable the pods can be harvested in 3 to 5 months when the pod is about 12.5 to 15 cm long before they swell and become hard. Mature seeds are produced in 6 to 10 months time.

The sword bean is relatively resistant to attack from pests and diseases. It is susceptible to a root rot *Colletotrichum lindemuthianum* (Smartt, 1976) and in Asia the crop is reported to suffer from scab, *Elsinoe canavaliae.*

The mature seeds of *Canavalia gladiata* have been originally consumed by people of ancient India, and are now consumed even by urbanized population (Vishnu Mittra, 1981; Rajaram and Janardhanan, 1987). Jack bean and sword bean are advocated to be good sources for extending protein since the protein quality is similar to most edible food legumes, both as a food and a feed (Bressani *et al.*, 1987).

These desirable agronomic and biological features make it a suitable supplement for a tropical country like Sri Lanka. Preparation of a protein isolate and concentrate using the seeds as in soybeans which are the most widely used and also peas, lentils, broad beans and lupin seeds, (Fernandez *et al.*, 1993) could also be beneficial using sword beans but requires further investigation.

Morphology

The plant *Canavalia gladiata* is a vigorous perennial climber often cultivated as an annual (Purseglove, 1968). The height may vary from 4.5 to 10 m. Particularly the degree of twining, the size of the seed pods, the number and the colour of the seed pods show considerable variation. In some areas semi-erect forms are found.

Leaves are trifoliate, with large pubescent leaflets (10 - 18 x 6- 14 cm) which are acuminate with a short point at apex. The petioles are shorter than the leaflets with a groove above and stout with large pulvinus at base and at the base of each leaflet (Purseglove, 1968).

Inflorescence is an axillary long stalked raceme bearing several flowers in succession. The flowers are inverted, the standard being at the bottom (Herklots, 1972). Flowers 3.5 to 4 cm long and are white or pinkish. The seed pods are usually broad and curved with strongly developed ridges. They are about 20-40 cm long and 3. 5-5 cm broad, containing on average 8 to 16 seeds. Seeds are 2.5 -3.5 cm long, white or red in color with a dark brown hilum exteding the entire length of the seed. Germination of the seed is epigeal (Purseglove, 1968). The seed has a tough thick coat which makes it unpopular among the other beans.

According to Burns (1939), Roxburgh described three varieties in India, namely plants with flowers and seeds red, flowers white and seeds red and flowers and seeds white. In Sri Lanka the same three varieties are recognized and have specific common name for each variety (rathu awara, sudu awara and gan awara).

Uses

The young pods are extensively utilized in Asia as a green vegetable (Purseglove, 1968). Rajaram and Janardhanan, (1992) report that tribal people of ancient India have eaten this traditionally but is less popular among the general population. The mature dry beans may be cooked and eaten as food, but requires careful preparation because of the antinutritional factors present (Pursglove, 1968). In Indonesia the seeds are usually boiled twice, washed in clean water, seed coat 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. According to Herklot (1972), not more than a few should be eaten on the first occasion and if there are no harmful effects (headaches or diarrhoea) amount can be increased on subsequent occasions. The roasted and ground beans have been used as a coffee substitute (Bressani *et al.*, 1987) In Sri Lanka the immature pods are made in to curry directly or sometimes after boiling the pods with water, which could be to remove the effects of L-DOPA.

Sometimes this is grown as a cover, green manure, or forage crop. The seeds and green parts are occasionally used for animal feeding (Purseglove, 1968; Bressani *et al.,* 1987).

According to "Bavaprakasha" an ayurvedic text, awara is said to be slightly bitter but a palatable food, but if consumed in large quantities it is said to cause drowsiness and vomiting. It is mentioned, though it is not used as a drug it is good for constipation and some other ailments. The leaves could also be used in treatment of persistent skin rashes. The seeds particularly the pink coloured ones, are sometimes employed in traditional Chinese medicine (Kay, 1979).

Chemical composition of the seed

Moisture and Ash

The moisture content of the fresh seed (approximately) according to Purseglove (1968) is 88.6%. But more important, the moisture content of the dry whole seed is 11.2% and 12.1% as reported by Bressani *et al.*, (1987) and Mohan and Janardhanan (1994) compared to 9.5% of the more common *C. ensiformis* (Souza *et al.*, 1991).

Analysis of the fresh bean for the ash content has yielded 0.6% according to Purseglove (1968) and 1.9% according to Spoladore and Teixeria (1987). The difference could be due to the use of unripe fresh beans by Purseglove (1968) and use of mature seeds by Spoladore and Teixeria (1987). The ash content of the dry weight determined using the AOAC (1975 and 1970) method is 3.9% and 4.2% (Bressani *et al.,* 1987; Mohan and Janardhanan, 1994) which is indicative of a high mineral content. The small differences could be attributed to the variations in the soil conditions. Values reported for jack beans by Souza *et al.* (1991) is 5.4% and the value is higher than in sword beans which is not surprising since the seed coat percentage difference in the two seeds is about 10% dry matter basis.

Carbohydrate

Dry legume carbohydrate percentage can vary from 24-68% in different varieties and includes monosaccharides, oligosaccharides, starch and other polysaccharides. Starch is the most abundant legume carbohydrate with the sugars representing only a small percentage of total carbohydrate of dried seeds (Reddy *et al.*, 1984).

Dietary fiber is also considered to be an important constituent of dried legumes which has been receiving increased attention recently. Its potential contribution to health is said to play an important role in reducing disease risks in; coronary heart disease by lowering the serum cholesterol level by decreasing the absorption (Schneeman, 1986) by interfering micell formation (Vahouny and Cassidy, 1986) and enzyme-substrate interaction (Schneeman, 1987) and thickening the unstirred water layer (Anderson,1985) by the soluble component and reducing transit time and total time available for absorption by the insoluble fraction (Hughes, 1991); improve glucose tolerance (Wolever, 1990) in diabetic subjects by slowing the release of glucose into the blood by increasing the viscosity of the intestinal contents, adsorption to enzymes and substrates (slows enzymatic digestion), and by thickening the unstirred water layer (slows the passage of glucose from intestine to intestinal cells) (Anderson, 1985); reduce the colon cancer risk, by increasing the fecal bulk and thereby decreasing the concentration of carcinogens, co-carcinogens, and / or promoters and minimize the exposure of intestinal cells to these substances by decreasing the transit time (Reddy, 1987).

According to Olson *et al.* (1987) insoluble dietary fiber fraction includes lignin, cellulose and some hemicellulose while pectin, some hemicellulose and other ploysaccharide constitute the soluble dietary fiber fraction.

Seeds of *Canavalia gladiata* contains soluble sugars 7.5% and starch 37.2%, on a fresh weight basis (Spoladore and Teixeria, 1987) comparative to the starch content of *C.ensiformis* (39.44%) (Souza *et al.,* 1991). Starch content of *C. virosa* is higher than that of sword and jack beans (Rodrigues and Torne, 1991).

Spoladore and Teixria (1987) also reported that the fiber content is 6.1% on a fresh weight basis and according to Souza *et al.* (1991) *C. ensiformis* has a fiber content of 7.12%. Crude fiber content of *C. gladiata* according to Bressani *et al.* (1987) is 12.8% (AOAC 1975) and 4.07% of the dry weight from the report of Mohan and Janardhanan (1994) using the AOAC (1970) method.

Studies done using dry mature seeds of kidney beans, sword beans and peanuts have shown that fucose is distributed widely in legume seed hemicellulose as one of the common component of sugars (Teiiti and Takashi, 1966).

According to Tanushi *et al.* (1972) in starchy legumes like sword bean the most abundant oligosaccharide is stachyose and verbascose in the case of *Vicia faba, Pisum sativum* and *Phaseolus vulgaris,* whereas non starchy legumes contain sucrose and alpha-galactosyl sucrose as major oligosaccharides. They have also been able to fractionate the crude fiber into α-, ß-, and γ cellulose.

Rivilleza *et al.* (1990) reported the flatulence potential (oligosaccharide content) of *Canavalia gladiata* is higher than that of jack bean and rice bean but lower than sam-sampling, hyacinth bean, sabawel and lima bean and two minutes of dry roasting resulted in complete removal of oligosaccharides whereas germination resulted in about 30 to 40% decrease after one and two days respectively.

Tada *et al.* (1968) by using electron microscopy studied the structure of starch from sword bean and eight other legumes. But even starch granules fissures usually observed by an ordinary microscope has not been detected in *C. gladiata* seeds. The transversely cut surface of *C. gladiata* mature seeds when studied under the scanning electron microscope showed the starch granules to be covered with a protein matrix, which disintegrated after treatment with pepsin to release elliptical-oval starch granules (Ekanayake, 1999).

Effects of steam cooking on the enzymatic availability of starch were studied in black, red and lima beans. Steam-heating is an effective way to produce resistant starch in legumes where 19-31% DM basis starch were indigestible compared to raw starch (Tovar and Melito, 1996). Also processing methods including fermentation, germination and roasting results in an increase in the content of total dietary fiber by way of resistant starch. This has been observed with bengal gram *(Cicer arictinum),* cowpea *(Vigna unguiculata)* and green gram *(V. radiata)* by Veena *et al.* (1995) and is an effective way of reducing the absorbable starch content, that will be beneficial in some cases.

Proteins and Amino acids

The protein representation in most legumes is about 17-30% (Reddy *et al.*, 1984) and is considered to be of high quality. The protein content in sword bean ranges from 21 to 28% (Bressani *et al.* 1987; Mohan and Janardhanan, 1994) on a dry weight basis. Compared to cereal flours like whole wheat flour, rye flour and also egg where the crude protein content is 8.55%, 2% and 12.6% respectively, the crude protein content of sword bean is high (Statens Livsmedelsverk, 1988) which makes it a good supplement to cereal diets. Of the three *Canavalia* species, *C. gladiata* and *C.ensiformis* are said to have a higher amount of protein than *C. virosa* (Rodrigues and Torne, 1991). Protein content of jack bean is 25.04% (Onuegbu *et al.*, 1993) 27.5% (Souza *et al.*, 1991) and of *C. rosea* DC (brown bean) seed flour is 17.1% (Abbey and Ibeh, 1987) values comparable to that of sword bean.

Solubility of *Canavalia rosea* DC protein according to Abbey and Ibeh, (1987) was at a minimum at pH 4 and increased to a maximum at pH 10. Also the foaming and emulsion capacity of both were dependent on salt concentration and pH.

Many legumes contain substantial amounts of non protein amino acids which contribute to total nitrogen levels. In a study with 14 legumes including *C. ensiformis* the non protein amino acids comprised up to 33.41% of the total N with homoserine being common to legumes (Lucas *et al.*, 1988).

The protein of sword bean contains a high lysine level (6.49%) (Spoladore and Teixeria, 1987 ; Bressani *et al.*, 1987; Rajaram and Janardhanan, 1992) in contrast to cereal proteins which are deficient in this amino acid. Lysine content in jack beans is also high (5.9%) with 84% availability (Souza *et al.*, 1991).

The other major amino acids present are glutamic acid, aspartic acid, isoleucine + leucine and tyrosine + phenylalanine (Rajaram and Janardhanan, 1992).

Valine and other sulphur containing amino acids are present in lower amounts (Bressani *et al.*, 1987; Laurena *et al.*, 1991) whereas the other essential amino acids, isoleucine, leucine, tyrosine, phenylalanine and lysine compare with WHO/FAO (1973) recommended pattern (Mohan and Janardhanan, 1994) (**Table I**)

Table I. Amino acid composition of acid-hydrolysed, purified total seed proteins of *Canavalia gladiata.*

Amino acid	g/kg protein	WHO/FAO (1973) requirement pattern g/kg protein
Glutamic acid	166	
Aspartic acid	153.3	
Serine	36.1	
Threonine	32.8	40
Proline	43.9	
Alanine	39.8	
Glycine	45.6	
Valine	30.9	50
Cystine	Trace	
Methionine	3.8	35
Isoleucine	73.9	40
Leucine	64.0	70
Tyrosine	30.9	
Phenylalanine	31.8	60
Lysine	56.6	55
Histidine	34.6	
Tryptophan	ND	10
Arginine	36.4	

Adapted from Mohan and Janardhanan (1994).

According to Bressani *et al.* (1987) and Mohan and Janardhanan (1994) the protein content in *C. ensiformis* (26.9% and 29.7% respectively) is slightly higher than in *C. gladiata* (25.6% and 27,8%). But the crude protein content in sword bean is higher when compared with other commonly consumed beans (Bressani *et al.*, 1987). Mohan and Janardhanan (1994) also reported that sword bean protein content was high when compared with other commonly consumed Indian pulses (Khan *et al.*, 1979; Kuzayli *et al.*, 1966; Jambunathan and Singh, 1980; Nwokolo, 1987). The protein fractions (Mohan and Janardhanan, 1994), indicate a high globulin fraction (**Table II**)

Table II. Content of total protein and protein fractions of the seeds of *Canavalia gladiata.*

Protein Fraction	g/kg seed flour	g/kg protein
Total protein	210	
Albumins	51	242.9
Globulins	128.7	612.8
Prolamines	9.8	46.7
Glutelins	20.5	97.6

Adapted from Mohan and Janardhanan (1994).

Nutritional quality

Penteado, (1983) showed the biological value of the seed protein tested in rats was 30% of that of casein. Protein efficiency ratio was 1.24 of the pressure cooked sample of *C. gladiata* (45 min, at 1050gcm^{-2}) and the low value (casein 2.89) has been attributed to low sulphur containing amino acids as shown by using *C. ensiformis* supplemented with methionine where the PER has increased to 1.94 from 1.21 of the pressure cooked sample (Bressani *et al.,* 1987).

A study done in the Philippines, among several indigenous legumes together with sword bean showed *in vitro* protein digestibility ranged from 70 to 79%, with raw mature seeds having relatively low relative nutritional values from 11 to 68% which increased to 68-94% and 51-89% after boiling and roasting respectively (Laurena *et al.*, 1991).

In a comparative study of different cooking methods using jack beans, extrusion and pressure cooking with lime were found to be equally effective in improving the protein quality and superior to pressure cooking alone or roasting. Addition of $Ca(0H)_2$ at a level of 0.45% by weight of seed, with cooking for 30 min under pressure was found to be beneficial (Bressani and Sosa, 1990).

It has been shown that rats fed with *C. ensiformis* cake showed improved growth compared with control rats fed with gari (fermented cassava) by Onuegbu *et al.,* (1993). Rats fed with diets based on raw *C. brasiliensis* seed proteins showed weight loss, low NPU values and high nitrogen excretion and macroscopic alterations of key internal organs but heat treatment of seed meal improved the nutritional properties (Oliveira *et al.,* 1994).

Fat

According to Purseglove (1968), the fat present in the fresh bean is 0.2%. Seeds were found to be rich in conventional unsaturated fatty acids like linoleic and linolenic (Gupta *et al.,* 1983; Mohan and Janardhanan, 1994). According to Gupta and his co-workers (1983) the seed of *C. gladiata* should be given some attention as a potential minor oil seed.

Spoladore and Teixeria (1987) reported the fat content in sword bean is 1.6% on fresh weight basis and the fatty acids in the lipid fraction as given in **Table III.**

According to Mohan and Janardhanan (1994) the crude fat content (99 gkg^{-1} on dry weight basis) in sword bean is more than in commonly consumed Indian pulses and fatty acid content (on dry weight basis) in seed lipids of sword bean which has been analysed using gas chromatography (Shimadzu, Model RIA) indicated palmitic, oleic and linoleic to be predominant (**Table III**). The fatty acid composition of *C. ensiformis* is characterized by the presence of palmitic (15%) oleic (54%) linoleic (7%) and linolenic (8%) acids and also is said to be an interesting source of lupeol (Gaydou *et al.*, 1992).

Table III. Fatty acid composition of the seed lipids

Fatty acid	Percentage (fresh weight)[a]	Percentage (dry weight)[b]
Palmitic	19.59	47.16
Stearic	0.82	9.23
Oleic	53.40	23.07
Linoleic	22.27	13.98
Linolenic	2.68	6.56
Eicosadienoic	1.24	ND

[a] Values reported by Spoladore and Teixeria (1987) on fresh weight basis
[b] Values reported by Mohan and Janardhanan (1994) on dry weight basis
ND: Not Determined

Vitamins and Minerals

Analysis of *C. gladiata* by Bressani and his co-workers (1987) (AOAC 1975) has shown (**Table IV**) the presence of high levels of potassium (0.36 g/100 g) as in most legumes (Ezeague and Ologhobo, 1975; Barthakur and Arnold, 1995; Apata and Ologhobo, 1994; Vijayakumari *et al.*, 1993; Mohan and Janardhanan, 1993a; Mohan and Janardhanan, 1993b; Oshodi and Olaofe, 1993). Daloz, (1988) reported that at the green pod and shelled vegetable stages the seed contain more vitamin A, vitamin C, calcium and iron. Radiation of germinating (72-92 hrs) soybean has increased the content of L-ascorbic acid and riboflavin (Sattar *et al.*, 1992) and Danisova *et al.*, (1994) observed an increase in both only after germination with a decrease in thiamine content.

Mohan and Janardhanan, (1994) using an atomic absorption spectrophotometer (Perkin Elmer Model-5000) reported that *C.gladiata* seeds to be a rich source of sodium, potassium and calcium (**Table IV**) when compared with other commonly eaten pulses as *Vigna unguiculata* and *Cicer arietinuml* (Meiners *et al.*, 1976). Mineral composition of *C. ensiformis* by Onuegbu *et al.* (1993) reported, Fe (0.03%), P (0.32%), Mg (0.36%), Ca (0.88%), K (0.52%), and Na (0.08%) by confirming the high Ca and K content. Mineral content of *C. ensiformis, C. gladiata* and *C.virosa* is said to be similar (Rodrigues and Torne,1991).

Table IV. Mineral composition of the seed of *Canavalia gladiata*

Mineral	mg/kg seed flour[a]	g/100[b]
Sodium	59.0	ND
Potassium	19795.2	0.79
Calcium	2912.4	0.20
Magnesium	655.3	0.13
Phosphorus	2730.4	0.40
Iron	36.4	trace
Copper	6.8	1.49
Zinc	13.7	3.17
Manganese	4.6	0.87

[a] Values by Mohan and Janardhanan (1994)
[b] Values by Bressani *et al.* (1987)
ND: Not determined

Though the mineral content of *Canavalia* has been studied the literature on vitamins is very limited compared to other legumes.

Antinutritional Components

Concanavalin A

Kojima *et al.* (1991) purified a lectin from *C. gladiata* on a maltamyl-sepharose column which had an amino acid composition and sugar-binding specificities similar to that of concanavalin A (con A). Proteins immunologically related to con A were found only for the *Canavalia* genus by immunodiffusion studies with anticoncanavalin A IgG antibodies (Carlini *et al.*, 1988).

Concanavalin A is a lectin or a hemagglutinin, generally defined as "Proteins that have a specific affinity for certain sugar molecules." The hemagglutinin activity is possible since most animal cell membranes have carbohydrate moieties which can react with lectins with at least two active sites (Werner, 1980). Many lectins have covalently attached sugar residues and hence are classified as glycoproteins. But concanavalin A is an exception and is devoid of a sugar moiety. Hemagglutinins of higher plants are found mostly in seeds.

Lectins if they are conjugated to ferritin, can be detected in an electron micrograph. The ferritin-con A conjugate specifically binds the outer surface of the red blood cell membrane (Stryer, 1980). Con A at neutral pH is a tetramer, with four identical subunits formed by a single polyeptide chain with 237 amino acids (Cunningham *et al.*, 1975) with high affinity for terminal α-glucosyl and α-mannosyl residues. Con A is a metallo-protein with each subunit having binding sites for a sugar moiety and two metal ions, Mn^{2+} or Mg^{+} and Ca^{2+} (Edelman *et al.*, 1972) which are required for carbohydrate binding activity (Paulova *et al.*, 1971, Sharon and Lis, 1972).

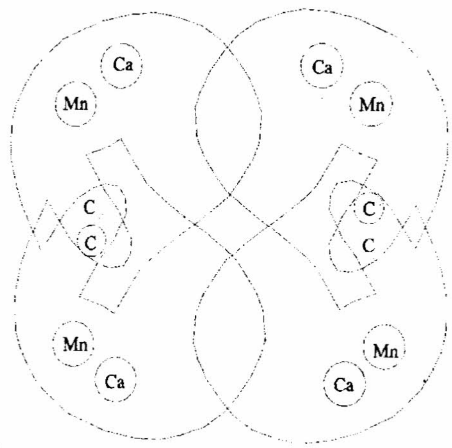

Figure 1. Schematic representation of the tetrameric structure of con A viewed down the Z axis (Adapted from Werner, 1980).

The amino acid composition of the polypeptide chain has been reported after a 24 hr hydrolysis and is said to be similar to that of *C. ensiformis* (Hague, 1975). Purified lectin from *C. obtusifolia* is reported to be mitogenic towards human peripheral blood mononuclear cells (Kamboj *et al.*, 1992).

The synthesis of con A in *C. gladiata* starts 30 days after flowering and has different accumulation patterns during development. The synthesis and accumulation of con A increases gradually until seed maturation is nearly completed which is 80 days after flowering (Yamauchi and Minamikawa, 1986). Mialonier *et al.* (1973) separated the lectin in the cytoplasm of the cotyledon and the embryo and noted its appearance during ripening and disappearance during germination. The low nutritional quality of raw mature seeds (net protein utilization; whole seed -16 and cotyledon -26) could be bue to the high concentration of the lectin. The absence of con A in tender pods may be the reason why this stage is consumed while the mature stage is less popular.

In a separate study on con A from *C. ensiformis*, though the protein appears in the seeds at day 24 after pod formation, there is a lag phase up to day 30 and a logarithmic increase up to day 36 followed by a plateau up to the desiccation stage (Raychaudhuri *et al.,* 1988).

Hague (1975) quantitatively recovered 23-28% of dry seed protein lectins synthesized by three different species of *Canavalia* including *C.gladiata.*

One might question the function of a lectin which is one fourth of the dry weight of the seed protein. Various possibilities have been suggested by different authors. To quote some; protection against fungi (Albersheim and Anderson, 1971), mediation of sugar storage and transport (Ensgraber , 1958; Sumner and Howell, 1936), control of cell division during germination (Sharon and Lis, 1972) and involvement in entry of Rhizobium species into the root cortex (Bohlool and Schmidt, 1974; Hamblin and Kent, 1973).

Kojima *et al.* (1991) found that lectin activity of *Canavalia gladiata* lectin could be detected not only by hemagglutinin assay with trypsinized human erythrocytes, but also by the binding assay with intact horseradish peroxidase. This will account for the fact that the glucose oxidase assay not working on *Canavalia* seed flour extract (Ekanayake, 1999).

Toxic amino acids

Canavanine, a potentially toxic arginine anti-metabolite and canaline, its primary metabolite also a toxic non protein amino acid, are found in seeds of *Canavalia* species. Investigation of these two in *C. ensiformis* has shown that these were synthesized from homoserine and that the degradation of canavanine and canaline was similar to the arginase mediated hydrolysis of canavanine to canaline in the process of canavanine catabolism (Rosenthal and Berge, 1989).

The toxicity of canavanine is due to the structural similarity to arginine. The effect of canavanine is to inhibit (Enneking, 1995) the nitric oxide pathway and thereby affect peristalsis.

Canaline is a structural analogue of citrulline and hence affects the ornithine cycle. Canaline is also toxic due to its ability to react with aldehydes (vitamin B_6) to form oximes and with keto acids (Enneking, 1995).

Schlueter and Bordas (1972) isolated and purified canavanine from *C. gladiata* by hot methanol extraction followed by ion exchange chromatography.

Presence of L-DOPA is also reported by Rajaram and Janardhanan (1992) and by Mohan and Janardhanan (1994) quantitatively (25 g/kg seed flour DM) which is comparable to mucuna sp (Jansz *et al.,* 1977) which are considered to have highest levels of L-DOPA.

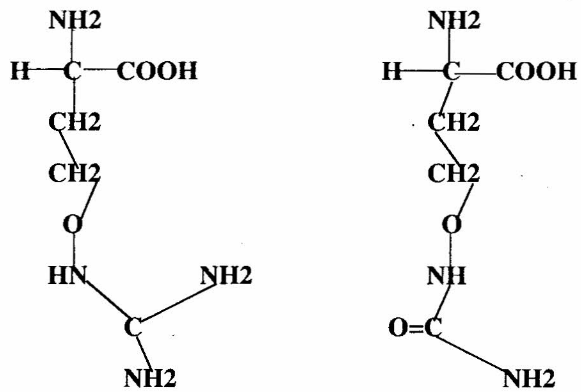

Figure 2. Structures of canavanine and canaline

Polyamines

Sym-homospermidine and canavalamine were found in the seeds of *Canavalia* species but not in those of other leguminous crops (Fujihara *et al.,* 1986). Aminopropyl canavalamine and amino butyl canavalamine which are aliphatic amino acids and also two guanidinoamines, a-guanidinooxypropylamine which is a decarboxylation product of canavanine and N^G-methylagmatine were found by Matsuzaki *et al.* (1990). N^4-methylspermine, spermidine and thermospermine were also found in addition to above mentioned polyamines in the mature seeds of the sword bean (Hamana *et al.,* 1992).

Fujihara *et al.* (1986) found that as the plants reached the reproductive stage homospermine and canavalamine appeared in the immature seed and their concentration increased as seed formation progressed. By contrast, the level of spermidine continuously decreased during development. Also in developing seeds considerable accumulation of canavanine which is the precursor of polyamine biosynthesis was observed.

Protease inhibitors

Substances that have ability to inhibit proteolytic activity of certain enzymes, are found particulary in legumes.

The presence of trypsin inhibitor in the sword bean has been reported by Nagaraja and Pattabiraman, 1991; Rajaram and Janardhanan, 1992; Laurena *et al.,* 1994; Ekanayake, 1999.

Nagaraja and Pattabiraman, (1991) have studied nine varieties of *Canavalia* seeds and have shown they inhibited bovine trypsin and α-chymotrypsin activities. Studies using sephadex G - 100 indicated the inhibitors had molecular weights around 11.0 kDa. Other studies indicated values as high as 90 kDa (Ekanayake, 1999) with the red seeded variety of *C. gladiata.* Action against the proteolytic activity of human pancreatic preparation even at high concentration of the inhibitor protein is reported to be less than 35% (Nagaraja and Pattabiraman, 1991).

Lorenzo *et al.* (1989) reports of three subtilisin inhibitors isolated from jack bean and that the antibodies raised against these inhibitors are specific for different varieties of jack beans and other species of *Canavalia* genus.

Saponins

This group of compounds which has a carbohydrate moiety attached to a triterpenoid or a steroidal aglycone, are commonly found among legumes. Price *et al.* (1987) reported these group of compounds to have deleterious effects (hemolysis and permeabilization of the intestine) whereas Oakenfull *et al.* (1984) reported of cholesterol lowering effect in animals and man.

The presence of toxic saponins which caused nausea and vomiting in *Canavalia* species were reported by Charavanapvan (1943). But he reported that these could be eliminated by soaking in water prior to cooking. The presence of 2,3-dihydro-2,5-dihydroxy-6-methyl-4H-pyran-4-one (DDMP) in the epicotyl of the sword bean seed has also been reported (Okubo, 1993).

Other factors

In a Nigerian study surprising results were reported where cyanide contents of some legumes were compared, *C. gladiatus* is said to have the highest cyanide content when compared with 2 types of *Phaseolus aureue,* 2 types of *Cajanus cajan* and 4 types of *Vigna unguiculata* prior to soaking (1093 mg/kg dry weight in intact seeds; 1223 mg/ kg in testa and 953 mg/kg in cotyledons). After soaking and boiling the cyanide content has reduced markedly in the cotyledons when soaked for 24h and boiled for 3 hours (Okolie and Ugochukwu, 1989). Hydrogen cyanide content of *C. ensiformis* according to Onuegbu *et al.*, (1993) is 243 mg/100g and fungal infections, *Fusarium culmorum* and *Penicillum oxalicum* were associated with the increased CN concentration and also development of the seed rot. Contrary to this report Laurena *et al.* (1994) reported cyanide levels of the order of 50 μg/g comparable to many legumes.

Canatoxin is a neurotoxic protein naturally occurring in *C. ensiformis*. Immunodiffusion studies with anticanatoxin IgG antibodies have shown proteins structurally resembling canatoxin to be present in most of the leguminous seeds except in peanuts and *Ricius communis* (Carlini *et al.*, 1988).

Canatoxin of *C. ensiformis* has been immunologically related to soyatoxin (SYTX) from *Glycine max* which is said to be highly toxic to mice at LD50 7-8 mg/kg body weight when injected intraperitoneally (Vasconcelos *et al.*, 1994)

Sword and jack beans have low levels of condensed tannins (0-2.48 mg catechin/g) and protein precipitable polyphenols (0.16-0.77 mg tannic acid/g). Phytate phosphorous/g level in sword bean is 5 mg/g (Laurena *et al.*, 1994) and 5 mg/g in the whole seed and 8 mg/ g in the cotyedon fraction (Ekanayake, 1999). The low phytate content in sword bean is also a desirable feature since high phytate concentration is one of the reasons for decreased mineral absorption in foods (Wyatt and Triana, 1994); the other being the fiber rich fraction in legumes which has high Ca binding capacity and thereby influence mineral absorption (Elhardallou and Walker, 1995; Pushpanjali and Khokhar, 1995). Danisova *et al.* (1994) showed with soybean, lentils, wheat and barley that phytic acid and phytate content were degraded during germination making more Ca, P and Mg available.

According to Mohan and Janardhanan (1994) the total free phenols and tannins in seed flour on dry matter basis are 7.1 and 0.6 g/kg respectively. The low tannin levels gives *C.gladiata* an advantage since tannins are known to inhibit the activities of digestive enzymes (Jambunathan and Singh, 1981). Percentage of tannins in *C. ensiformis* is 9.43 mg/g (Souza *et al.* 1991)

Two gibberelins (GA22 and GA21)were isolated from immature seeds of sword bean. Their biological activities were tested on dwarf maize mutants d1 and d5, rice, cucumber and dwarf pea. GA21 caused elongation in stem of dwarf maize mutants and dwarf peas but not on rice seedlings and cucumber. Effect of GA22 on dwarf maize mutants, dwarf peas and rice seedlings was more than that of GA 21 with lower concentrations but had no effect on cucumber (Murofushi *et al.*, 1969).

Also an α-amylase inhibitor, polyphenolic in nature, is reported to be present in the seed coat (Ekanayake, 1999).

2 References

Abbey, B. W., and Ibeh, G. O. (1987) Functional properties of raw and heat processed brown bean (*Canavalia rosea* DC) flour. *Journal of Food Science.* **52,** (2) 406-408.

Albersheim, P, and Anderson, A. J. (1971) Proteins from cell walls inhibit polygalacturonases secreted by plant pathogens. *Proc. Nat. Acad. Sci, U. S. A.* **68,** 1815-9

Anderson J. W. (1985) Physiological and metabolic effects of dietary fiber. *Fed. Proc.* **44,** 2902.

Apata, D. F. and Ologhobo, A. D. (1994) Biochemical evaluation of some Nigerian legume seeds. *Food Chemistry.* **49** (4) 333-338.

Association of Official Analytical Chemists (AOAC) (1970) *Official Methods of Analysis,* 11th edn. Washingtin, DC: AOAC.

Association of Offical Analytical Chemists (AOAC) (1975) *Official Methods of Analysis,* 12 th edn . Washington, DC: AOAC.

Barthakur, N. N. Arnold, N. P. and Alli, I. (1995) The Indian laburnum *(Cassia fistuata L.)* fruit: an analysis of its chemical constituents *Plant Foods for Human Nutrition.* **47,** (1) 55-62.

Bohlool, B. B. and Schmidt, E. L. (1974) Lectins: a possible basis for specificity in the *Rhizobium*-legume root nodule symbiosis. *Science,* **185,** 269-71.

Bressani, R., Gimez, B.R., Garcia, A and Eliaz L. G. (1987) Chemical composition, aminoacid content and protein quality of Canavalia seeds. *J. Sci. Food Agrc.* **40,** 17-23.

Bressani, R., and Sosa, J. L. (1990) Effect of processing on the nutritive value of jack beans *(Canavalia ensiformis (L)). Plant Foods for Human Nutrition* **40,** (3) 207-214.

Carlini, C. R. Barcellos, G. B. S., Baeta, Neves, D. V. and Guimarees, J. A. (1988) Immuno-reactivity for canatoxin and concanavalin A among proteins of leguminous seeds. *Phytochemistry.* **27,**(1) 25-30.

Charavanapvan, C (1943) The utilization of jack and sword bean as food *Trop. Agric. Mag. Ceylon Agric. Soc.* **99,** 157-9

Cunningham, B, A., Wang, J. L,. Waxdale, M. J. and Edelman, G. M. (1975) *J. Biol. Chem.* 250, 1503-1512.

Daloz, C. R. (1988) Productivity of vegetable legumes in the special territory of Aceh, Indonesia. *Dessertation Absteacts International B. 317 pp.* Cornell University, Ithaca, New Yirk 14850, USA.

Danisova, C., Holotnakova, E., Hozova, B and Buchtova, V. (1994) Effect of germination on a range on a ramge of nutrients of selected grains and legumes Acta-Alimentaria 23, (3) 287-298.

Edelman, G. M., Cunningham, B. A., Reeke, G. N., Becker, J. W., Waxdal M. J. and Wang, J. L. (1972) The covalent and three-dimensional struture of Concanavalin A. *Proc. Natl. Acad. Sci. USA.* **69,** 2580-2584.

Eknanyake, S. (1999) Food Value and Some Antinutritional Components of *Canavalia gladiata* (Sinh Awara) M. Phil Thesis University of Sri Jayawrdenapura, Nugegoda. Sri Lanka.

Elhardllou, S. B., and Walker, A. F. (1995) Binding capacity of Ca by three starchy legumes in the presence of Ca alone or With Fe, Zn, Mg, and Cu. *Food Chemistry* **52,** (4) 379-384.

Enneking, D. (1995) The toxicity of *Vicia* species and their utilization as grain legumes Centre for legumes in Mediterranean agriclture (CLIMA) Occasional Publication No. 6, University of Westeren Australia, Nedlands W. A. Ph. D. Thesis, University of Aselaide.

Ensgraber, A. (1958) Botan Gesell **71,** 8. Cited in I. E. Liener. 1963. Seed Hemagglutinins. *Economic Botany.* 18, 27-38.

Ezeague, I. E. and Ologhobo, A. D. (1995) Proximate composition of some unfamiliar plant seeds in Nigeria - a short report. *Polish Journal of Food and Nutrition Sciences.* 4/45, (3) 79-83.

Fernandez, Quintela, A., Larralde, J., Macarulla, M. T., Marcos, R and Martinez, J. A. (1993) Legumes and protein concentrates: new outlook and applications. *Alimentaria.* **239,** 59-63.

Fujihara, S., Naksshima, T., Kurogochi, Y. and Yamagauchi, M. (1986) Distribution and metabolism of sym-homospermidine and canavalamine in the seord bean *Canavalia gladiata cv Shironata Plant Physiol* **82,** 795-800.

Gaydou, E. M. Viano, J. and Bourreil P. J. L. (1992) *Canavalia ensiformis* neutral lipids, a rich source of lupeol. *Jounal of the American Oil Chemists Society*. **69**. (5) 495-497.

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

Hamana, K., Niitsu, M., Samejam, K. and Matsuzaki, S., (1992) N4-Mathlthermosperminme in leguminous seeds. *Phytochemistry.* **31**, 1410-12.

Hamblin, J. and Kent, S. P. (1973) Possible role of phytohemagglutinins in *Phaseolus vulgaeis L. Nature Nature New Biol.* **245,** 28-30.

Hague, R. D. (1975) Studies of Storage Proteins of Higher Plants. I. Concanavalin A from three species of the Genus *Canavalia, Plant Physiol.* **55,** 636-42.

Herklots, G. A. C. (1972) Beans and Peas. *Vegetables in south-east Asia* 225-236. London: George Allen and Unwind Ltd, 525pp.

Hughes, S, Joe. (1991) Potential contribution of dry bean dietary fiber to health: Dry beans are a good source of both soluble and insoluble bietary fober, and their consumption is associated with benefits. *Food Technol*. **9,** 122-26.

Jansz, E. R. Pieris, Nirmala, Hettiarachhi, M. and Gunatilake, D. L. (1977) Studies on some local legumes. *Proceedings Institute of Chemistry, Sri Lanka* 6th *Annual Sessions.* pp 41-44.

Jambunathan, R. and Singh, U. (1980) Studies on Desi and Kabuli chickpea *(Cicer arietimum)* cultivars. I Chemical composition, *In proceedings of the Internatioal Workshpo on Chickpea Improvement. ICRISAT, Hyderabad, India, 28 February -2 March 1979, pp. 61-66.*

Kamboj, S. S. Khanna, A., Arora, J. S., Sandhu, R. S. Kaur, K., Sangary, S. and Forrester, J. A. (1992) Purification and characterization of a lectin the seeds of Canavalia obtusifolia DC. Journal of Plant Science Research. **8** (1/4) 83-86.

Kay, E. Daisy, (1979) Food legumes. *TPI crop and Product digest No. 3.* London: Tropical Products Institute. XVI + 435 pp.

Khan, A. M. Jacobsen, I. and Eggum, O. B. (1979) Nutrtive value of some inproved varities of legumes. *J. Sci, Food Agri.* **30,** 395-400.

Kojima, K., Ogawa, H., Seno, N. and Matsumoto, I. (1991) Purification and characterization of *Canavalia gladiata agglutinin. Carbohydrat. Res.* **213,** 275-82.

Kuzayli, M. V., Cowan, J. W. and Sabry, Z. I. (1966) Nutritive value of middle eastern foodstuffs. II. Composition of pulses, seeds, nuts and cereal products of Lebanon. *J. Sci. Food Agr.* **17,** 82-84.

Laurene, A. C. Rivileza, M. J. R. and Mendoza, E. M. T. (1994) Polyohenols, Phytate, Cyanogenic glycosides and tlypsin inhibitor activity several Philippine indigenous food legumes *J. Food Comps. Anal.* **7,** 194-202.

Laurena, A. C. Ridriguez, F. M. Sabino, N. G., Zamora, A. F. and Evelyn M. T. (1991) Amino acid composition, relative nutritive, value and *in vitro* protein digestibility of several Philippine indigenous legumes. *Plane Foods Hum. Nutr, (Dordrecht Neth.)* **41**, 59-68.

Liener I, E. and Kakade M. L. (1980) Protease inbibitors. In *Toxic Constituents of Plant foodstuffs* Ed. by I E Liener 2 nd edn. 7-71.

Lucas, B., Guerrero, A., Sigales, L. and Sotelo, A. (1988) True protein content and non-protein amino acids prestnt in legume seeds, Nutrtition Reports Intrnational . **37** (3) 545-553.

Lorenzo, P., Tovar, Pinelli, E. and Seidl, D. S. (1989) Subtilisin inhibitors in *Canavalia and Vicia faba seeds.* A comparative study. Journal of the Science of Food and Agriculture. **47** (2) 181-190.

Matsuzaki, S., Hanana, K., Okada, M., Niitsu, M. Samejima, K. (1990) Aliphatic pentaamines found in *Canavalia gladiata, Phytochemistry.* **29,** 1311-12.

Meiners, C. R., Derise, N. L. Lau, H. C., Crews, M. G., Ritchey, S. J. and Murphy, E. W. (1976) The content of nine mineral elements in raw and cooked mature dry legumes. *J. Agri. Food Chem,* **24,** 1126-1130.

Mialonier, G., Privat, J. P., Monsigny, M., Kahlem, G. and Durand R. (1973) *Physiol. Veg.* **11,** 519-537.

Mohan, V. R. and Janardhanan, K. (1993a) Chemical composition and nutritional evaluation of two little known species of *Vigna.* Food Chemistry. **48,** (4) 367-371.

Mohan, V. R. and Janardhanan, K, (1993b) Chemical and nutritional evaluation of raw seeds of the tribal *Pulses Parkia roxurghii G, Don and Entada phaseoloides (L.)* Merr. Interational Journal of Food Sciences and Nutrition. 44, (1) 47-53.

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

Murofushi, N., Takahashi, N., Yokta, T., kato, J., Shiotani, Y, and Osaka, S. (1969) Gibberellins in immature seeds of *Canavalia. Agr. Biol. Chem.* **33,** 105-7

Nagaraja, K. N. and Pattabiraaman, T. (1991) Natural Plant enzyne inhibitors: Protease inhibitors in *Canavalia* seeds. *J. Food Sci. Technol.* **28,** 105-7.

Nwokolo, E. (1987) Nutritional evaluation of pigeon pea meal. *Plant Foods Hum. Nutr.* **37,** 283-90.

Okenfull D. G, Topping D L. Illuman R J &Fenwick D E (1984) : Prevention of dietary hypercholesterolaemia in the rat by soya and quillaja saponins. *Nutr, Res. Int* **29** 1039-1041.

Okolie, N. P. & Ugochkwu, E. N. (1989) Cyanide contents of some Nigerian legumes and the effect of simole processing *Food Chemistry.* **32** (3) 209-116.

Okubo, K. (1993) Physiological function of soybean glycosides, especially DDMP saponin *Report of the Soy Protein Research Committee.* **14,** 108-111.

Oliveira, J. T. A. Vasocncelos, I. M., Gondim, M. J. L. Cavada, B, S., Moreira, R. A., Santos, C F. and Moreira, L. I. M. (1994) *Canavalia brasiliensis* seeds Protein quality and nutritional implications of dietary lectin *Journal of the Science of Food and Agriculture.* **64,** (4) 417-424.

Olson, A., Gray, G. M. and Chiu, M-C. (1987) Chemistry and amalysis of soluble dietary fiber *Food Technol.* **41** (2) 71.

Onuegbu, B. A., Zibokere, D. S., Chinah, M. and Ukata, D. (1993) Unconventional food sources: effects of *Canavalia enstformis* seeds on growth and development of domestic rats and effects of fungal infection on nutritional composition to the seeds *Journal of Daiying, Foods and Home Sciences* **12** (2) 62-66.

Oshodi, A. A. Olaofe, O. and Hall G. M. (1993) Amino acid, fatty acid and mineral composition of pigeon pea *(Cajanus cajan) International Journal of Food Sciences and Nutrition.* **43** (4) 187-191.

Paulova, M., Entlicher, M. Ticha. Kostir, J. V. and Kocourek, J. (1971). Studies on phytohemagglutinins VII. Effect on Mn and Ca on hemagglutination and polysaccharide precipitation by pytohemagglutinin of *Pisum sativum L. Biochim. Biophys Acta.* 237. 513-18.

Penteado, M. de V. C. and Lajolo, F. M. (1983) Nutritional and toxicological properties of *Canavalia gladiata cultivated* in Brazil. *Rev. Farm. Bioquim. Uni. Sao. Paulo.* **19,** 126-36.

Price, K. R. Johnson, I. T. & Fenwick, G. R. (1987) The Chemistry and Biological Signficance of Saponins in Food and Feedingstuffs. CRC Crtitcal Reviews in Food Science and Nutrition 26 (1), 27-135.

Purseglove, J. W. (1968) Canavalia gladiata (Jacq.) DC. *Tropical Crops: Dicotyledons* **1,** 245. London : Longmans, Green and Co Ltd, 332p.

Pushpanjali and Khokhar S. (1995) The composition of Indian foods - mineral composition and intakes of Indian vegetarian populations. *Journal of the Sceince of Food and Agriculture.* **67,** (2) 267-276.

Rajaram. N. and Janardhanan, K, (1992) Nutrtitional and chemical evaluation of *Canavalia gladiata (Jacq) DC.* and *Canavalia ensiformis DC:* The underutilized food and fodder crpos in India *Plant Foods Hum, Nutr. (Dorderchi Neth.)* **42,** 329-36.

Raychaudhuri. M., Niyogi, K. and Singh, M.(1988) Temporal regulation in the synthesis of concanavalin A and alpha - mannosidase in the seeds of *Canavalia ensiformids phytohemistey*. 26 (12) 3201-05.

Reddy, B. S. (1987) Dietary fiber and colon cencer: Animal model studies *Prev. Med.* **16,** 559.

Reddy, N. R., Pierson, M. D., Sathe, S. K. and Salunkhe, D. K. (1984) Chemical, Nutritional and Physiological aspects of Dry Bean Carbohydrates-A Review Food Chemistry **13,** 25-68.

Rivilleza, M. J. R., Mendoza, E. M. T. and Raymundo, L. C. (1990) Oligosaccharides in sevral Philippines indigenous food legumes: determination, localization and removal. *Plant Foods Hum. Nutr. (Dordrecht Neth.)* **40,** 83-93.

Rodrigues, B. F. and Torne, S. G. (1991) A chemical study of seeds in three *Canavalia* species. Tropical Sciences. **31,** (1) 101-103.

Rosenthal, G. A. and Brege, M. A. (1989) Catabolism of L-canavnine and L-canaline in the jack bean, *Canacalia ensiformis* (L.) DC. (Leguminosae). *Journal of Agricultural and Food Chemistry.* 37, (3) 591-595.

Sattar, A., Neelofar and Akhtar, M. A. (1992) Radiation effect on ascorbic acid and riboflavin biosynthesis in germinating soybean. *Plant Foods for Human Nutrition.* **42** (4) 304-312.

Schlueter M. and Bordas E (1972) Canavanine in *Canavalia paraguayensis*, *Canavalia gladiata* and *Dioclea paraguayensis* Phytochemistry 11: 3533-3534.

Schneeman, B. O. (1986) Dietary fiber: Physical and chemical properties, methods of analysis, and physiological effects *Food Technol.* **40,** (2) 104.

Schneeman, B. O. (1987) Soluble vs insoluble fiber-Different physiologic effects. *Food Technol.* **41** (2), 81.

Smartt, J. (1976) *Canavalia gladiata* (Jecq.) D. C. (Sword bean). *Tropicl Pulses.* P. 58. London: Longman Group Ltd, 348 pp.

Sharon, N. and Lis, H. (1972) Lectins: cell agglutinating and sugar specific proteins *Science.* **177,** 949-59.

Souza, P. A. de, Souza, H. B. A. be, Durigan, J. F. and Santos J. E. dos (1991) Physicochemical and nutritional evaluation of jack beans *(Canavalia ensiformis) Alimentos Nutricao.* **3** (2) 63-73.

Spoladore, D. S. and Texieria, J. P. F. (1987) Chemical compôsition of seeds of *Canavalia fladiata D. C. Bragantia.* **46,** 133-9.

Sri Lanka Country Report, International Conference on Nutrition (1996) Nutrition and Janasaviya Unit, Ministry of Policy Planning and Implementation, Sethsiripaya, Battaramulla, Sri Lanka.

Stryer, L (1980) Introduction to Biological Membranes. Biochemistry. W. H. Freeman and Company. San Francisco. USA.

Statens Livamedelsverk. (1988) Energi och Naringsamnen *Livsmedelstabeller.* Stockholm, Sweden.

Sumner, J. B. and Howell, S. F. (1936) The identification of the hemagglutinin of the Jack bean with Concanavalin A. *J. Bact*, **32,** 227-37.

Tada, M., Koreeda, A and Nikuni, Z. (1968) Studies on legume starches. X. Surface structure of legume starch granule observed by an electron microscope. *Journal of the Technological Society of Starch.* **16,** 47-50.

Tanushi, S., Kosai, T. and Kawamura, S. (1972) Detrmination of oligosacchrides on some edible legume seeds. **Eiyo To Shokuryo. 25,** 25-7.

Tiiti, N. and Takashi, W. (1966) Determination of fucose in the polysaccharide of some Japanese legumes. *Kagawa Daigaku Nogakubu gakujiutsu Hokoku.* **18,** 115-19.

Tovar, J. and Melito, C. (1996) Steam-cooking and dry heating produce resistant starch in legumes *Journal of Agricultural and Food Chemistry* **44**(9). 2642-2645.

Vahouny, G. V. and Cassidy, M. M. (1986) Effect of dietary on intestinal absorption of lipids. In "CRC *Handbook of Dietary fiber in Human Nutrition,* " ed. G. A. Spoller, P. 212. CRC Press, Raton, Fla.

Vasconcelos, I. M., Trentim, A., Guimaraes, J. A. and Carlini, C. R. (1994) Purification and physiochemical characterization of soyatoxin, a novel toxic protein isolated from soybeans *(Glycine max) Archives of Biochemistry and Biophysics.* **312** (2) 357-366.

Veena, A., Asna, Urooj and Shashikala Puttaraj. (1995) Effect of processing on the composition of dietary flber and starch in some legumes. *Nuhrung.* **39** (2) 132-138.

Vishnu Mittra, (1981) Wild plants in Indian Folk Lore-a historical perspective *In Glimpses of Indian Ithnobotany.* Ed. S. K. Jain, pp37-58. New Delhi: Oxford and IBH Publishing Co.

Vijayakumari, K., Siddhuraju, P. and Janardhanan, K. (1993) Chemical composition and nutritional potential of the tribal pulse *(Bhuhinia malabarica Roxb)* Plant *Foods for Human Nutrition.* **44,** (3) 291-298.

•

Wolver. T. M. S. (1990) Relationship between dietary fiber content and composition in foods and the glycemic index. *Am. J. Clir.* 51,72.

Wyatt, C. J. and Trana, Tejas A. (1994) Soluble and insoluble Fe, Zn, Ca, and phytates in foods commonly consumed in northern Mexico. *Journal of Agricultural and Food Chemistry.* **42,** (10) 2204-2209.

Yamauchi, D. and Minaamikawa T. (1986) *In vivo* studies on protein synthesis in developing seeds of *Canavalia gladiata D. C. Plant cell Physiol.* **27**. 1033-41.