

Effects of Anti-nutritive Constituents of Unprocessed Jack Bean (*Canavalia ensiformis*) (L) (DC) Seed Meal on Poultry Performance

ABSTRACT

Jack bean (*Canavalia ensiformis*) is a good source of plant protein as well as a starch-storing seed and on the basis of the apparent nutrient content, it should be an extremely useful ingredient in animal feeds. The use of untreated *Canavalia ensiformis* seed as a feedstuff for poultry is restricted due to the presence of anti-nutritional factors, as is the case with the other tropical legumes. The anti-nutritional constituents of *Canavalia ensiformis* have been reported to include trypsin inhibitors and concanavalin A which are heat-labile and canavanine and canaline which are hydrosoluble. Other antinutrients are saponins, cyanogenic glycosides, and phenols. *Canavalia ensiformis* seeds can be used as an animal feed ingredient since they are a good source of starch and protein. However, in order to be used as animal feed ingredient, *Canavalia ensiformis* seeds would have to be thermally processed. Heat processing is universally accepted as an effective means of inactivating most, if not all of the heat-labile toxic constituents of legume grains. Research has showed that dietary inclusion of detoxified jack bean seed between 20-30% in feed ration is capable of supporting the growth of poultry birds without adverse effects on performance and physiological parameters of the animals. Several research works had been carried out on how to improve the quality of legumes. These researchers have reported many processing methods. Interestingly, on many occasions, in order to achieve complete inactivation or detoxification of these anti-nutritional factors a combination of two or more processing methods may be needed.

Keywords: *Canavalia ensiformis*, trypsin inhibitors, concanavalin A, canavanine, canaline, saponins, cyanogenic glycosides, poultry.

1. INTRODUCTION

Jack bean (*Canavalia ensiformis*) has a great potential as an economic crop because of its excellent germination and initial growth, which makes its establishment relatively easy [76]. The use of untreated (raw) seeds of jack beans (*Canavalia ensiformis*) in diets of livestock animals is restricted by the presence of various factors which are toxic. However, properly processed jack bean seeds, an unconventional feedstuff have great potential for inclusion in animal diets. Generally, unconventional feed ingredients are very useful for compounding animal feed in geographical locations or in a situation or season when other sources of vegetable protein (soybeans, groundnut cake, and cotton seed meal) are either not available or are too expensive [4, 25, 49].

When considering anti-nutritive substances in the seeds of jack bean which may serve as a potential feedstuff for livestock, it is worth noting that it is particularly the toxic effect connected with the dietary intake of the factor that is significant nutritionally, and not the injection of the antinutrient into the body. This is due to the fact that the ingested substances may be subjected to possible modification by the gastro-intestinal tract [14].

It has been reported by [11] that both wet and dry thermal treatment resulted in a beneficial effect on protein quality with protein efficiency ratio (PER) increasing from raw seed value of 0.10 to 1.21 and 1.18 for wet and dry cooking. These workers also reported the protein quality to be 41.5% as compared with that of casein. The value is similar to that of common food legumes [11].

2. AVAILABILITY AND USES OF JACK BEAN

2.1 Geographical Distribution and Availability of Jack Bean

Jack bean has its origin in the Western part of India and Central America [67]. Jack bean varieties were originally grown in the drought-ridden regions of Arizona and Mexico in ancient times and used as high-protein food and forage crops for several centuries by the natives of Mexico, Southwestern United States, Central American countries, Peru, Ecuador, Bolivia, Brazil, West Indies, Paraguay and Argentina [61]. Jack bean is cultivated and distributed in Africa, Asia, the West Indies, Latin America and India [41].

2.2 Uses of Jack Bean

The mature seeds are cooked and eaten by the Indian tribal sects, Kurumba, Malayali, Erula and other Dravidian groups [44]. In western countries, this legume is used as a cover crop and also the seeds roasted and ground to prepare coffee-like drink [11].

In several homes in Nigeria, jack bean is grown as an ornamental plant, while in some areas in the country it is regarded as snake repellent [69]. In some tropical parts of the world where jack bean is available, its young leaves and green pods are used as vegetables [52, 54].

Native starches in jack bean have been utilized for several years as a raw material in the preparation of various products. Jack bean has been used in foods because of its good thickening and gelling properties. They are also a good texture stabilizer and regulator in food systems [16]. Processed jack bean seeds have also been used as a feed ingredient in livestock feeds [25, 28, 31, 75, 77].

3. THE NUTRITIVE COMPOSITION OF JACK BEAN SEEDS

Jack bean has a good nutritional value [2, 19, 50]. The crude protein content of dry ripe jack bean seed ranges from 26 – 32%. Udedibie [72] [stated that raw jack bean seeds contain reported](#) about 30% [\[d1\]](#) crude protein and 60% nitrogen free extract. The gross energy content of 4.26kcal/g for raw jack bean seeds was reported by [69] for raw jack bean seed. Jack bean contains significant amounts of niacin, thiamine, phosphorus, calcium and iron [11, 19, 36, 70].

The macro-mineral that was most concentrated in raw jack bean seeds was potassium with the value of 9.9g/kg while the lowest was sodium with the content of 0.07g/kg. On the other hand among the micro-mineral iron was the most abundant with the value of 48.7g/kg whereas manganese recorded the lowest value of 15.6g/kg in the raw seed [6].

Jack bean seed is relatively low in sulphur amino acids, but high in lysine. The most limiting amino acid in untreated jack bean seeds was methionine with the value of 0.46g16gN while the lysine content of raw jack bean seeds was found to be 4.42g16gN [2].

[\[d2\]](#)

Generally, processing has been well documented to improve the nutritional quality of jack beans. It is however, of paramount importance that future research should be specifically directed towards evaluating the effect of various processing methods on the nutritive composition of jack beans.

3.1 Proximate Composition of Jack Bean (*Canavalia ensiformis*) Seeds

The proximate composition of jack bean seed as shown in Table 1 reveals its potential value for future use in livestock feeding. Bressani and Sosa [11] reported that jack bean contained about 1-8% ether extract, 8.5% crude fibre, 3.2% ash, 13.5% moisture, 26% [\[d3\]](#) crude protein and 46.1% carbohydrate. D'Mello [19] reported 2.12%, 2.8% and 9.24% for ether extract, ash and crude fibre, respectively. Studies by [69] showed that jack bean contains about 3.16% ether extract, 3.73% ash and 7.8% crude fibre. The ether extract and ash contents of jack bean seeds are quite low while the crude fibre is slightly high. Akande [2] presented the proximate composition of jack bean as containing 28.38% and 28.90% crude protein, 3.10%

and 2.72% crude fat and nitrogen free extract as 53.62% and 51.41% for processed and raw jack bean seeds respectively.

Table 1: Proximate composition of raw and thermally processed jack bean seeds

Content (%)	Processed Jack bean	Raw Jack bean
Dry matter (%)	93.10	94.56
Crude protein (%)	28.38	28.90
Crude fat (%)	3.10	2.72
Crude fibre (%)	5.20	7.80
Ash (%)	2.80	3.73
Nitrogen free extract	53.62	51.41 ^[d4]

Source: [2]

4. ANTI-NUTRITIVE CONSTITUENTS OF JACK BEAN

The use of legumes for livestock nutrition is impeded by the presence anti-nutritional substances in their raw seeds and foliage. Anti-nutritional factors are substances that are found in feedstuff which reduce their nutritional value and also affect the animals adversely in several ways (Table 2). The adverse influence of the dietary raw legumes is associated with the effect of anti-nutritional factors. These adverse effect includes; alteration of gut permeability, growth retardation, reduction in feed intake, impairment of nutrient digestion and nutrient absorption, hyper-activity of the pancreas, interference and disruptions of cellular metabolic processes, impediment of hormonal and enzyme activities etc. [5, 9,15, 34, 37, 46, 47, 53, 56, 60]

The anti-nutritive substances found in jack bean (*Canavalia ensiformis*) seeds are **predominantly**: concanavalin A, trypsin inhibitors, the toxic non-protein amino acids (canavanine and canaline), saponins, cyanogenic glycosides and polyphenols. [3, 21] stated that the occurrence and dietary effect of anti-nutritional factors present in unprocessed plant protein feed ingredients are major constraints to their optimum utilization or as livestock feeds. animals is a significant constraint that decreases their nutritional value and proper utilization.

4.1 Concanavalin A

Concanavalin A, a lectin found in jack bean seeds was first described by [66]. Concanavalin A is a potent haemagglutinin and it is capable of agglutinating the red blood cells of several livestock animals and can also react with the sugar components of the intestinal cells causing a disruption in cell structure which consequently produces abnormalities in nutrient absorption. Jayne-Williams [28] postulated that lectin-induced disruption of the intestinal cell structure permits invasion of lymph, **blood**, and liver by bacteria normally confined within the lumen of the gut. Consequently, the animal succumbs to otherwise innocuous organisms. Concanavalin A adversely affects nutrient absorption and metabolic processes in the gut [28]. Concanavalin A also reduces feed intake in non-ruminants [33].

4.2 Trypsin Inhibitors

Trypsin inhibitors are widely distributed within the plant kingdom, including the seeds of most cultivated legumes. They are protease inhibitors occurring in raw legumes seeds and they are the most commonly encountered group of anti-nutritive constituents of plant origin. These anti-nutritional **substances** inhibits the activity of the proteolytic enzyme (trypsin) in the gut [14, 39, 42, 76]. Trypsin inhibitors have been documented to be partially responsible for the growth-retarding property of raw legumes. The growth retardation has been associated with the inhibition of protein digestion, but there is evidence of pancreatic hyper-activity, resulting in increased production of trypsin with resultant loss of cystine and methionine [42]. Antitrypsin **factors** found in jack bean seeds are heat-labile [10]. Babar et al. [7] confirmed this in their experiment by achieving a total inactivation of antitrypsin activity in jack bean seed

after soaking in water for 24 hours before 20 minutes cooking. Trypsin inhibitors are inactivated by heat especially moist heat, because of uniform heat distribution [12, 40].

Toxic non-protein amino acids jack beans seeds: According to [27] the toxic non-protein amino acids found in jack beans seeds are canavanine and canaline (the product of degradation of canavanine).

4.3 Canavanine

Canavanine is found in most legumes plant *Papilionoideae* [8] and abundantly in jack bean (*Canavalia ensiformis*) (L.) (DC.), constituting up to 63g/kg dry weight of seed [32]. Canavanine toxicity in higher animals is not completely understood [9]. Canavanine is structurally similar to arginine an essential amino acid, for this reason, it antagonizes arginine and impedes nuclear and cellular metabolic activities, consequently producing a toxic effect. Additionally, its toxicity to insects [57] and other organisms [80] is well documented and established and the function and role of this non-protein amino acid in plant defence mechanisms was reported by [8]. The deleterious effects of unprocessed *Canavalia ensiformis* have partly been attributed to the presence of canavanine [19]. Rosenthal [59] posited the interference of the metabolic activity of ribonucleic acid (RNA) by canavanine. This phytochemical may also antagonize arginine.

Researchers [23, 43, 68] have reported the reduction in feed intake of monogastric animals when the feeding of pure canavanine was done. Notwithstanding, this probably might not be the case when canavanine is present in the seed or meal fed to non-ruminant animals, due to the fact that the release of this factor in the gastro-intestinal tract varies when compared to the situation in which canavanine is purely fed to monogastric animals. Canavanine is soluble in water, it is however, heat stable and this presents a great challenge in terms of the inactivation of this anti-nutritive factor.

4.4 Canaline

The hydrolytic cleavage of canavanine by arginase results in the production of canaline and urea. Canaline is a structural analogue of ornithine which is a derivative of arginine. This non-protein amino acid is also found in jack bean seeds. It is heat-stable but solubilises in water. The derivative of canavanine, canaline, inhibits the activity of transaminases [59].

The structural similarity of canaline to ornithine allows canaline to react with the pyridoxal phosphate moiety of BG-containing enzymes to form a covalently bonded stable Schiff base. Therefore, canaline has been shown to be a potent inhibitor of pyridoxal phosphate enzymes [55, 58]. However, canaline toxicity in animals has been suggested to occur in the following ways: by inhibition of enzymes, by competition with ornithine in the arginine urea cycle; or by forming a complex with pyridoxal phosphate cofactor in a manner similar to mimosine [1].

4.5 Saponins

Saponins are considered as one of largest classes of natural plant components, however, their phytochemistry and bio-functionality is not completely understood and known in plants [46]. Saponins are naturally occurring substances that are vastly distributed in all cells of most legumes. They have the ability to form stable, soap like foams in aqueous solutions, make up a complex and chemically diverse set of compounds [46, 63]. Saponins contain a carbohydrate moiety attached to a triterpenoid or steroids. Saponins possess both adverse and beneficial properties [63].

Saponins are known to be temperature sensitive. During processing such as washing, soaking and blanching saponins are dissolved and lost in water [51]. Saponins form complexes that are capable of causing damage to the intestinal mucosa and also affects protein digestion in the gut [34] and the absorption of nutrients across the intestinal wall [15, 30]. It is also known to interfere with the uptake of vitamins and minerals and negatively affects membrane and cell wall permeability [9, 29, 46]. Saponins have been implicated in the retardation of growth rate, decrease in feed intake, prevention of the activity of smooth muscle [15]. Saponins have been reported to be detectable in jack beans [1, 71]. Udedibie et al. [71] found that saponins were not detected after boiling jack beans for the hour. Generally,

saponins and its metabolites can produce several properties that can have either positive or negative effects in different animals [26, 65].

4.6 Cyanogenic Glycosides

Cyanogenic glycosides are anti-nutritive compounds that are widely distributed in the plant kingdom. Cyanogenic glycosides are products of secondary metabolism. Cyanogenic glycosides are majorly vital natural plant components used in the defence mechanism in plant kingdom against herbivores owing to their bitter taste and the release of toxic hydrogen cyanide upon tissue damage or disruption [81]. Hydrogen cyanide production is generally dependent upon the cyanogenic glycoside synthesis and the presence or absence of its degradation enzyme. The main toxic substance producing toxicity is hydrogen cyanide (HCN) [78].

According to the reports of [24] hydrogen cyanide causes disruption in the metabolic processes of the pentose phosphate pathway, this consequently results in decrease in the rate of glycolysis and inhibiting the tricarboxylic acid cycle. Hydrogen cyanide has also been implicated in the inhibition of other vital metabolic activities such as metalloenzymes, many of which contain iron, copper or molybdenum [64].

Jack bean like some other raw legumes contains cyanogenic glycosides from which hydrogen cyanide (HCN) may be released by hydrolysis. Hydrogen cyanide is very toxic to animals even at low concentration. It can cause dysfunction of the central nervous system, respiratory failure and cardiac arrest [21]. It has been stated that there is 108mg/kg hydrogen cyanide present in raw jack bean seeds [62]. According to the research reports of [71] the cyanogenic glycosides in *Canavalia ensiformis* were eliminated within thirty to sixty minutes of boiling.

Others: About 1.3% of polyphenols have been reported in jack bean and, like trypsin inhibitors, they are destroyed by moist heat (30 minutes) rather than dry heat [7].

5. LEVELS OF THE ANTI-NUTRITIONAL FACTORS PRESENT IN RAW JACK BEAN SEEDS

According to [7] about 1.3% of polyphenols is present in jack bean. Raw seeds of jack bean have been reported to contain 13,532 hemagglutinating units (HU) per g of seed, and also 1,682 trypsin inhibitor units (TIU) per g of seed [14]. Canavanine was found to constitute up to 6.3% dry weight of raw jack bean seeds [32]. Concanavalin A constitutes about 20% of the total protein of the seed [17]. Additionally, it has been reported that there is 108mg/kg hydrogen cyanide present in raw jack bean seeds [62].

Table 2. Adverse effects of anti-nutritive constituents of unprocessed jack bean seeds

Anti-nutritive compounds	Dietary effects	References
1. Canavanine	- Antagonizes arginine (an essential amino acid) - Impedes nuclear and cellular anabolic activities - Interferes with the metabolic activity of Ribonucleic acid (RNA)	[57] [59] [59]
2. Canaline	- Inhibits the activity of transaminases - Inhibits of pyridoxal phosphate enzymes - Competes with ornithine in the arginine urea cycle.	[59] [55] [58] [1]
3. Saponins	- Causes intestinal mucosa damage - Affects protein digestion in the gut - Affect the absorption of nutrients across the intestinal wall - Causes reduction in growth and feed efficiency - Interferes with the uptake of vitamins, minerals and adversely affects membrane wall permeability - Prevents the activity of smooth muscle	[34] [34] [30] [15] [29] [15] [29] [9] [46] [15]
4. Cyanogenic Glycoside	- Causes disruption in the metabolic processes of pentose phosphate pathway - Decreases the rate of glycolysis and inhibits the tricarboxylic acid cycle - Inhibits vital metabolic activities of metalloenzymes - It can cause dysfunction of the central nervous system, respiratory failure and cardiac arrest	[24] [24] [64] [21]
5. Concanavalin A	- Causes disruption in the cellular structure of intestinal mucosa and negatively affects nutrient absorption and metabolic processes in the gut - Reduce intake of feed in non-ruminants	[28] [33]
6. Trypsin Inhibitors	- Produces growth retardation, pancreatic hyper-activity and resultant loss of cystine and methionine - Inhibits the activity of the proteolytic enzyme (trypsin) and reduces protein digestibility	[42] [38] [39] [38] [42]

^[d5]6. DIETARY EFFECTS OF JACK BEAN SEEDS ON THE PERFORMANCE OF POULTRY

The proximate content of jack bean seeds has been reported to be suitable for poultry feeding. The amino acid composition of jack bean protein is very similar to that of roasted soybean meal with jack bean containing slightly less lysine than soybean and both having respectively low levels of methionine and cystine [2, 31].

Jayne-Williams [28] reported 100% mortality in fed Japanese quails (*Coturnix coturnix japonica*) with diets containing 500g/kg raw *Canavalia ensiformis* seed, and obtained 100% mortality. However, when *Canavalia ensiformis* seeds were autoclaving^[d6] the seed overcame this effect. ed, no mortality was recorded. Laviada [35] included raw *Canavalia ensiformis* in chick diets at levels of 0, 100, 200 and 300g/kg and oserved that, mortality increased as the inclusion level increased and reached 50% at the 300g/kg level. In a research study conducted by [18], they reported that autoclaved jack bean seeds included at levels of 100 and 150g/kg in chick diet led to growth rate increases of 76% in comparison with that of the raw seeds. Udedibie and Madubuike [69] in their experiment showed that dietary inclusion of unprocessed and processed jack bean (*Canavalia ensiformis*) seeds at 20 percent^[d7] level in the feed, depressed feed intake and percent hen-day egg production with the raw jack bean meal causing greater depression in animal performance.

Kessler [31] in their study examined the effect of two lengths of time ^[d8] of autoclaving the seed of jack bean on the performance of chicks fed with the diets at an inclusion level of 300g/kg diet for the whole of an eight-week growing period and for the finishing (weeks five to eight) period only. These researchers observed faster growth rates in those birds fed autoclaved *Canavalia ensiformis* for five to eight weeks of age, compared with those that received the same treatment from one to eight weeks of age. This suggests that the older birds were less sensitive to the anti-nutritive effect of *Canavalia ensiformis* than the young birds.

Practical experiment on laying hens and broilers showed a significant decrease in feed intake, feed conversion and growth rate for dietary levels as low 10% raw jack bean seeds [13, 45, 79].

Research studies carried out by [48] on the effects of raw jack bean meal on performance of broilers, showed that both feed intake and body weight gain were reduced as the dietary level of raw meal increased, but the reduction became significant only at levels above 10% in the diet. According to the research reports of by [27], laying birds were observed to be more tolerant, although even in these birds, egg production was significantly reduced by the inclusion of 200g/jack bean ^[d9]per kilogram of the diet.

Ensiling with ammonia or urea also seems to be successful in decreasing the toxicity of jack beans for chicks. The combination of autoclaving and ensiling gave better results than simple ensiling [45]. This is probably because of the solubilisation of the toxic factor in the alkaline (urea) solution [47]. Dry urea ensiling before toasting is effective, it has been shown that up to 200g/kg dietary jack beans treated with dry urea and toasted did not have deleterious effect of broiler performance [75].

Udedibie et al. [77] showed that cracking and cooking of jack bean alone is not a good method of processing because dietary inclusion above 20% for broilers resulted in declined performance. Soaking the cracked seeds in urea solution for 24 hours prior to cooking could not appreciably improve its nutritive value when included in broiler diets above 20%. Soaking the cracked jack bean seed in water for 24 hours before cooking for an hour produced the best results, allowing dietary inclusion level of up to 30%. Probably, increasing the period of soaking in water could result in better performance [77]. Fabiyi [25] reported that detoxified jack bean meal can be included at levels up to 20% in broilers rations without adverse effect on performance and physiological parameters of the broilers.

Detoxified jack bean (*Canavalia ensiformis*) has high potentials for poultry feeding [25]. Table 3 presents the recommended dietary inclusion levels of processed jack bean in poultry diets.

Table 3. Recommended dietary inclusion level of processed jack bean in poultry diets

Poultry Type	Recommended Level (%)	Processing Method Used	Source
Japanese (Quails)	50g/kg 5	Autoclaving	[28]
Broilers (Chicken)	300g/kg 30	Autoclaving	[31]
Layers (Chicken)	200g/kg 20	Ensiling in Urea + Boiling	[74]
Broilers (Chicken)	200g/kg 20	Dry Urea Ensiling + Toasting	[75]
Broilers (Chicken)	300g/kg 30	Cracking + Soaking in Water + Cooking	[77]
Layers (Chicken)	100g/kg 10	Boiling	[74]
Broilers (Chicken)	200g/kg 20	Soaking in Wood Ash Solution + Cooking	[69]
Broilers (Chicken)	250g/kg 25		[25]
		Soaking in Urea + Cooking	[73]

7. CONCLUSION

Canavalia ensiformis has a protein quality similar to that of most edible food legumes. Jack bean has a great capability as an unconventional plant protein source for livestock feeding, however, the thermal-labile and non-thermal-labile anti-nutritive substances pose some restrictions in its usage for non-ruminant nutrition. Detoxification of the anti-nutritional factors is necessary for the improvement in the nutritional quality of the legume and to effectively utilize their potential as livestock feed ingredients. An interesting fact is that heat treatment can lead to the improvement of jack bean's nutritive quality. This makes the use of processed seeds in animal nutrition a possibility, especially for monogastric animals. Many research authors have reported several processing methods such as; soaking, cooking, toasting, autoclaving, fermentation, extrusion cooking, sprouting, cracking and chemical treatment to improve the quality of the legume, by of the removal or inactivation of anti-nutritional factors. In many instances, for effective and complete detoxification process, a combination of two or more methods may be required. Further research should be geared towards examining the effect of processing methods on the nutritive quality of jack bean and in addition, effort should be intensified on devising ways of improving the palatability of jack bean for poultry feeding, in order to enhance feed intake.

COMPETING INTERESTS

Author has declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

The sole author prepared the manuscript.

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