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EVALUATION OF DETOXIFIED JACK BEAN (*Canavalia ensiformis* (L.) (DC.) IN BROILER STARTER RATIONS WITH AMINO ACID SUPPLEMENTS

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Target audience : Animal nutritionists, feed toxicologists and poultry farmers.

ABSTRACT

An experiment was conducted with broiler chicks allotted to seven dietary treatments, to examine the effectiveness of extraction procedures, autoclaving and dietary supplements of amino acids on the nutritive value of jack beans. Extraction of jack beans with aqueous $NaHCO_3$ solution (8.4 g/l) at temperatures maintained between 80 - 90 ^{o}C for 48 h, followed by autoclaving for 30 minutes at 121 ^{o}C, reduced nutrient contents and canavanine, a toxic amino acid, to significantly lower levels than in similarly but water extracted jack beans. Inclusion of the extracted and autoclaved beans at levels of up to 300 g/kg in broiler starter diets supplemented with methionine, lysine and methionine + lysine, gave faster growth rate and enhanced feed consumption than the control diet. The efficiency of feed conversion, efficiency of feed utilisation and protein efficiency ratio were statistically similar for all dietary treatments. Lysine supplementation improved the performance characteristics of chicks on the $NaHCO_3$-extracted diets while methionine enhanced the performance of birds on the water-extracted autoclaved jack bean (AJB) diets. Amino acid supplements were however ineffective against nutrient retention and utilisation probably due to complex interactions and antagonism between amino acids and their analogues. The use of other amino acids besides lysine for supplementing extracted AJB diets and a careful study of extraction procedures were recommended before the beneficial effects of detoxification can be realised.

Key words : Detoxified jack bean; canavanine; amino acid supplements; broiler chicks.

DESCRIPTION OF PROBLEM

Legumes continue to be prominent as sources of protein for humans and livestock especially in tropical Africa where the greater percentage of the population cannot afford the more expensive animal protein sources.

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Because of the demand by industry and man, only the non-conventional grain legumes, which are not used to any important extent by the human population, are readily available to animals.

Jack bean, *Canavalia ensiformis* is one of the under-utilised grain legumes which show promise as a good source of nutrients for monogastric animals like poultry. The seed may contain up to 30 % protein and its production may be as high as 4,600 kg/hectare, with an average yield ranging from 800 to 1,000 kg/hectare (1). The plant is bushy with a tendency to climb and is mainly used as a cover crop, although it may also be used as a forage or as an ornamental plant. The seeds are commonly eaten in some parts of Nigeria and other African countries either singly or in combination with staple foods such as yam, rice or plantain.

Jack bean seeds are known to contain the usual anti-physiological substances of grain legumes and two toxic amino acids, canavanine and its degradation product, canaline (2, 3). The heat-labile anti-nutritional factors in the seed are easily deactivated by heat treatment but this process is ineffective against canavanine which is known to be heat stable at temperatures of up to 135 ^{o}C (4). The stability of canavanine has necessitated the development of alternative methods of detoxification. Various extraction and processing methods have been used to reduce canavanine concentrations in autoclaved jack beans (5, 6), but despite the marked improvements in the nutritional value of the beans, manifestations of toxicity still persisted in animals fed diets containing processed jack beans.

The aim of the present work was to further investigate the effectiveness of other extraction procedures in reducing canavanine concentration in jack bean and alleviating its toxicity for poultry. Supplementations with methionine and lysine were also used in view of an earlier observation (7), that supplementations with arginine and lysine were only marginally effective in enhancing the nutritive value of autoclaved jack bean (AJB).

MATERIALS AND METHODS

Sample preparation : The raw seeds used in this study were obtained from local markets in Nigeria. The beans, in 1 kg batches were first rinsed thoroughly in warm water, then in a solution of $NaHCO_3$ (8.6 g/l tap water) and incubated at 80 - 90 ^{o}C for 24 h. Beans were then rinsed with tap water and incubated in $NaHCO_3$ solution as before for a further period of 24 h and rinsed again. This material was autoclaved for 1 h at 120 ^{o}C, dried for 48 h at 60 ^{o}C in a hot oven and ground in a hammer mill. Other batches of jack bean seeds were prepared exactly as above except that extraction was accomplished with tap water and incubation maintained at 80 ^{o}C.

Experimental diets : The experiment comprised seven isonitrogenous (225 g/kg crude protein) and isoenergetic (12.15 MJ/kg) broiler chick starter diets formulated on least cost basis, mainly from maize-groundnut cake (GNC) basal diet. The $NaHCO_3$- or water-extracted AJB was included in the control diet at the expense of GNC at the rate of 300 g/kg. Each diet was supplemented with methionine, lysine or methionine + lysine including the basal control diet (Table 1).

Table 1. Composition of experimental diets (g/kg)

Feed Ingredients	Control	$NaHCO_3$ Extracted Diets I	II	III	Water-Extr. Diets IV	V	VI
Maize	485.8	264.1	264.1	262.3	273.1	273.1	273.1
G/nut cake	226.3	162.1	162.1	162.3	155.6	155.6	155.9
Fish meal	84.9	60.8	60.8	60.9	58.3	58.3	58.4
Jackbean seed	-	300.0	300.0	300.0	300.0	300.0	300.0
Wheat offals	110.0	100.0	100.0	100.0	100.0	100.0	100.0
Palm oil	10.0	30.0	30.0	30.0	30.0	30.0	30.0
Bone meal	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Oyster shell	65.0	65.0	65.0	65.0	65.0	65.0	65.0
Salt	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Premix	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Methionine	3.0	3.0	-	3.0	3.0	-	3.0
Lysine	3.0	-	3.0	1.5	-	3.0	1.5
Analytical data(g/kg DM)							
Crude Protein	215.0	220.1	217.9	209.7	27.5	216.5	214.3
Ether extract	89.0	69.9	64.6	70.4	55.7	53.6	51.2
Crude fibre	131.0	131.4	116.4	130.2	139.0	143.8	143.2
Ash	40.8	141.2	150.2	142.7	149.7	171.3	150.5
Carbohydrate	424.6	442.4	450.2	447.0	448.1	415.0	440.8
Sodium	10.0	10.0	15.0	10.0	10.0	10.0	5.0
Potassium	6.0	40.0	50.	10.0	5.0	5.0	10.0
Gross energy(MJ/Kg)	16.9	19.9	19.8	20.9	18.1	19.1	18.4
Nitrogen corected Metabolisable energy (MJ/Kg)	10.34	13.43	12.47	14.84	11.13	12.85	10.00

Chicks and management : 126 day-old unsexed Isa-Brown broiler chicks were used in this study. Eighteen chickens were randomly selected and allotted, using the randomized complete block design, to each of the seven dietary treatments such that there were two replicates of nine chicks per treatment. Feed and water were supplied ad libitum and uniform light was provided 24 h daily. The chicks were weighed individually at the beginning of the experiment and twice weekly thereafter until they were five weeks old when the experiment was terminated.

At 35 d, metabolic studies were carried out for five extra days, during which faecal droppings were collected from four birds (two per replicate) chosen at random from each group. Samples of test ingredients, diets and faeces were analysed for their proximate composition using the A.O.A.C. (8) procedures while their gross energy values were determined using a ballistic bomb calorimeter.

Data collected were analysed by analysis of variance and the means, when necessary, were separated by Duncan's multiple range test (9).

RESULTS AND DISCUSSION

The chemical compositions of jack bean in the raw and extracted seeds are shown in Table 2. The results emphasise the potential of jack bean as a protein-rich feedstuff for livestock. The extractions of whole beans with water and aqueous $NaHCO_3$ solution at elevated temperatures, elicited substantial decreases in crude protein and carbohydrate contents of AJB while dry matter content and metabolisable energy were marginally reduced compared to the raw seeds. The decline in crude protein contents of the extracted products signified a reduction in the concentrations of nitrogenous substances including canavanine and other antinutritional factors. An earlier study which used water and $KHCO_3$ to extract jack beans at 80 ^{o}C measured amino acid and canavanine concentrations directly and reported that there was a drastic decrease in canavanine concentrations in the extracted products (6, 10). When these products were fed to poultry, the performance of birds in terms of growth, feed intake and efficiency of feed utilisation was satisfactory.

Table 2. Chemical composition of raw and extracted jack beans (g / kg DM)

	Raw Jackbean seed	Autoclaved Jackbean (AJB) After Extraction with NaHCO3 Solution (90^{0}C)	Water (80^{0}C)
Dry matter	920.1	910.6	915.2
Crude protein (Nx6.25)	288.3	215.7	219.6
Ether extract	31..5	26.6	20.1
Crude fibre	65.2	60.8	52.4
Ash	38.7	37.0	20.5
Carbohydrate	560.4	516.2	502.1
Sodium	0.08	0.16	0.09
Potassium	8.8	8.0	5.5
Gross energy (MJ / Kg)	20.5	18.11	17.00

The choice of $NaHCO_3$- and water-extraction procedures in this study was based on the report (11) that jack beans contain specific antigenic proteins which resist heat treatment. This hypothesis gained support from the identification of two heat stable globular antigenic proteins, glycinin and coglycinin, in soyabean which were easily removed by treatment with alkali (12).

The results in Table 3 show significantly ($P < 0.05$) varied growth responses by broiler chickens on the different dietary treatments. Chickens fed $NaHCO_3$-extracted AJB diets exhibited faster growth rates ($P < 0.05$) and consumed more feed than all other groups. The body weight gain and feed

Table 3. Production performance of 5-week broilers fed experimental diets.

	Control	Na HCO_3 extr.AJB			Water-extracted AJB			
		I	II	III	IV	V	VI	SEM
Weight Gain (Kg/ chick)	0.54[ab]	0.58[a]	0.63[a]	0.66[a]	0.51[b]	0.49[b]	0.57[a]	0.26
Feed Consumpt. (kg/chick)	1.26[b]	1.48[ab]	1.54[a]	1.60[a]	1.34[b]	1.30[b]	1.34[b]	0.53
Feed Convers. Effic. (FCE)	2.33	2.55	2.44	2.42	2.58	2.65	2.35	0.12
Protein Efficiency Ratio	2.71	3.25	3.06	3.01	2.96	2.91	3.06	0.19
Mortality (%)	0	3.13	4.69	3.13	0	0	0	0
Efficiency of feed utilisation	0.43	0.39	0.41	0.41	0.39	0.38	0.43	0.08

a,b Means within a row with different superscripts are significantly different ($P<0.05$). SEM, standard error of mean.

intake by chicks on water-treated AJB diets were not significantly different from the control diet, except for diet VI which was supplemented with methionine and lysine, and was statistically similar to the $NaHCO_3$-treated AJB diets. The efficiency of feed conversion, efficiency of feed utilisation and protein efficiency ratio were similar for all dietary treatments, indicating that the extracted AJB diets were comparable in nutritional quality to the control diet. The results of this study agree with earlier studies which reported superior performances in fish (13), rat (14) and young chicks (15) fed water-, alcohol- and alkali-extracted legume diets over those fed heat-treated or control diets.

Amino acid supplementation produced significantly effective trends in improving the performance of chicks fed extracted AJB diets. Methionine supplementation is important in legume-based diets because legumes are generally deficient in sulphur amino acids (16). Lysine supplementation of extracted AJB diets was based on the hypothesis that lysine is more effective than other amino acids, especially arginine, in reversing canavanine inhibition at low concentration. The toxicity of canavanine resides in its structural analogy with arginine (4) and canavanine ingested by animals competes with arginine in many enzymatic reactions which utilise arginine (3).

From the results obtained, it appears that the performance characteristics of birds were better when lysine was used alone or in mixture with methionine to supplement $NaHCO_3$-extracted AJB diets. When the birds were fed water-extracted AJB diets, the performance of birds was better when the diet was supplemented with methionine alone or in combination with lysine than with lysine alone. This observation corresponds with the hypothesis put forward and cited by Volcani and Snell (17) that lysine can reverse canavanine inhibition in various biological systems, and, that a higher potential of lysine occurs at low concentration of canavanine. The extraction of jack bean with $NaHCO_3$ reduced the concentration of canavanine in AJB to a lower level than extraction with water and expectedly, the performance of chicks fed $NaHCO_3$-extracted AJB diets was superior to the water-extracted AJB diets. The correlation coefficients of the performance characteristics of experimental birds presented in Table 4 show highly significant ($P < 0.05$) and positive correlations between feed consumption and weight gain ($r = 0.88$) and between feed consumption and feed conversion efficiency ($P < 0.01$, $r = 0.81$) and a moderate correlation between weight gain and feed conversion efficiency ($r = 0.48$, $P < 0.01$). Chick mortality was poorly

Table 4. Correlation coefficients (r) of the performance characteristics of experimental birds

Component	FC	WG	FCE	PER	M
FC	-	0.88**	0.81**	-0.83**	0.04
WG	-	-	0.48**	0.96**	0.08
FCE	-	-	-	-0.95**	-0.08
PER	-	-	-	-	0.06
M					

** Level of significance (P<0.01)

FC = Feed consumption, WG= weight gain,FCE = feed conversion efficiency, PER = protein efficiency ratio, M = mortality.

correlated with all the performance parameters, indicating that the high mortality of chicks on $NaHCO_3$-extracted AJB diets contrary to the survival of chicks on water-extracted AJB diets was not due to the inability of the extraction procedure to eliminate the toxic factors in jack beans, since $NaHCO_3$ extraction was even a better procedure than the water extraction procedure. D'Mello and Walter (6) reported a similar trend in chick mortality and concluded that although the significant reduction in canavanine concentration enhanced animal performance, there was still a manifestation of toxicity in chicks fed $KHCO_3$-treated jack beans. Finot (18) also observed that alkali treatment of feed proteins favours the synthesis of lysinoalanine and other compounds of a similar nature which reduce biological value in addition to elucidating specific pathological lesions. From these reports, it can be concluded that other as yet unidentified heat-stable antinutritional factors in AJB may have been responsible for the chick mortality in the current study.

The nitrogen and nutrient retention coefficients presented in Tables 5 and 6 show peculiar decreases in both water and $NaHCO_3$-extracted AJB diets compared to the control diet. The supplementation of these diets with

Table 5. Nitrogen retention of chicks on experimental diets

Parameters	Control 0	NaHCO$_3$-extr.AJB I	NaHCO$_3$-extr.AJB II	NaHCO$_3$-extr.AJB III	Water-extr.AJB IV	Water-extr.AJB V	Water-extr.AJB VI	SEM
Average daily N intake (g/chick)	2.63	2.55	2.76	2.64	2.33	2.40	2.46	0.06
Average daily N excretion (g / chick)	0.84	0.85	1.03	0.91	0.85	0.96	1.15	0.05
Nitrogen retained (g / chick)	1.80	1.71	1.74	1.74	1.49	1.44	1.31	0.08
*Effficiency of N utilisation	0.68^{a}	0.61^{b}	0.63^{b}	0.66^{ab}	0.64^{ab}	0.60^{bc}	0.53^{c}	0.11
Efficiency of energy utilisation(%)	66.14	71.63	66.37	74.50	65.35	71.01	57.85	2.06

a, b, c for each variate, means in the same row not sharing a common superscript letter are significantly different (P<0.05).

* Nitrogen retained: nitrogen intake.

N = Nitrogen

1 Efficiency of energy utilisation = $\frac{\text{Metabolisable energy}}{\text{Gross energy}} \times 100$

Table 6. Apparent nutrient retention coefficients of experimental birds (%).

Parameters	Control	NaHCO$_3$-extr. AJB I	NaHCO$_3$-extr. AJB II	NaHCO$_3$-extr. AJB III	Water-extr. AJB IV	Water-extr. AJB V	Water-extr. AJB VI	SEM
Dry matter	60.25^{a}	62.06^{a}	51.57^{c}	57.35^{b}	52.23^{bc}	49.83^{c}	43.81^{c}	2.41
Crude protein	68.50^{a}	60.72^{b}	62.87^{b}	65.70^{ab}	63.87^{b}	60.21^{bc}	52.95^{c}	2.20
Crude fibre	31.20^{bc}	38.80^{a}	13.91^{d}	34.43^{ab}	21.74^{cd}	24.34^{c}	9.29^{c}	4.07
Ether extract	86.29	80.55	79.96	79.55	78.89	80.74	82.65	0.95
Available carbohydrate	72.14	70.45	63.62	66.11	61.64	60.02	60.31	1.83

abcd: Means in the same row with different supperscripts differ significantly (P < 0.05).

lysine and methionine enhanced the performance of the animals but was ineffective in improving nutrient retention. While the explanation to this observation may be found in the reasons highlighted above, it is also possible that the complex interactions and antagonisms between amino acids and analogues which contribute significantly to the adverse properties of certain protein feeds may be responsible (18). These antagonisms are exemplified by the reactions between lysine and alanine and between lysine and arginine which occur naturally when diets composed of some legumes are fed (19) and are most clearly demonstrated in young chicks when the synthetic forms of these amino acids are used (7). Apart from this explanation, it is also possible that the vigorous extraction procedures the jack beans were subjected to in this study caused a substantial loss of nutrients, including the essential amino acids which were leached out along with canavanine.

CONCLUSION

It is concluded that:

1. Canavanine and probably other antinutritional factors were removed by extractions with aqueous $NaHCO_3$ solution and water at elevated temperatures followed by autoclaving of the beans.
2. Supplementation of extracted AJB with methionine and lysine enhanced animal performance significantly but did not result in an efficient utilisation of nutrients. It was appropriate to supplement the extracted jack bean with methionine, being a legume, but the choice of lysine seemed to have had more adverse than beneficial effects on the broiler chickens.
3. It is suggested that further studies should be carried out to examine the effects of extraction procedures on the nutrient profile of the extracted jack beans while dietary supplementation of the products in feeding trials should be with amino acids that will actually enhance their utilisation. The cost-effectiveness of such processing treatment and supplementation should be assessed.

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