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The nutritional value of soaked-boiled-fermented jackfruit (*Artocarpus heterophyllus*) seed meal for poultry

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Abstract

Chemical analysis, apparent metabolizable energy and one feeding trial were conducted to assess the nutritional value of jackfruit seeds that had been subjected to a combination of soaking, boiling, followed by fermentation. In the feeding trial, five broiler starter diets were formulated with the processed jackfruit seed meal constituting 0, 80, 160, 240 and 320 g/kg of the diet. The jackfruit seeds before and after processing contained 151, 140 g crude protein; 740, 747 g total carbohydrates; 11.1, 1.28 g tannins; 10.0, 1.47 g total oxalates per kg respectively. The apparent metabolizable energy value of the processed jackfruit seed meal was 2368±315 Kcal/kg. Inclusion of the processed jackfruit seed meal affected chick growth, nutrient utilization and organ weights relative to body weight. At 80 and 320 g/kg inclusion, weight gain and feed/gain were depressed by 5.2, 42.1%; 6.2, 40.7% respectively. Feed intake was not affected up to 240 g/kg inclusion but reduced by 18.3% at 320 g/kg. Except for gizzard; weights of liver, caecum, heart, intestines and pancreas were affected. At 80 and 320 g/kg inclusion; weights of caecum, intestine, pancreas and gizzard increased by 69.4, 113.9%; 4.5, 43.2%; 7.3, 46.3%; 11.3, 14.6%, while liver and heart were reduced by 7.7, 22.2%; 27.9, 34.2% respectively. Apart from nitrogen retention; nitrogen digestibility, dry matter digestibility and excreta water content were not affected. Nitrogen retention increased by 38.5% at 320 g/kg inclusion. Processing reduced tannins and oxalates from jackfruit seeds by over 85%. The processed jackfruit seed meal can be included in poultry diets at levels up to 80 g/kg without compromising with: feed intake, feed efficiency, daily weight gain and nutrient utilization. Although the cost per kg gain of birds increased with jackfruit seed meal inclusion, the seeds will eventually be readily available at low or no cost. However, for economic efficiency the cost of collection and treatment should be put into consideration.

Key words: Anti-nutrient, Broiler, Feedstuff, Performance, Processing

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Introduction

Feed in intensive livestock production amounts to a significant proportion of production costs (Mpofu, 2004) and constitutes over 60% of the total production costs of broiler meat (Teguia and Beynen, 2005). In Uganda, poultry feed is highly priced because conventional feedstuffs such as maize are costly and largely used as human food. Apart from wheat, there are currently no globally applicable alternatives to maize and soybean meal for poultry feeding (Leeson, 2004). Maize bran that is commonly used in poultry feeds is currently competed for by the local brewing industry. The high feed costs result into low poultry production, high cost of poultry meat, and protein malnutrition in households. Jackfruit seeds (JS) are alternative feedstuff with potential for poultry feeding. The JS are a by-product from the consumption of Jackfruit where the fleshy part of the fruit is eaten while the seeds are discarded as waste. However, during food shortage, some people in rural areas roast JS and prepare a meal that is eaten with maize-meal or potatoes. Although JS are roasted and eaten by some people, the seeds generally face little competition from humans and livestock animals. The JS in Uganda are an unused feed resource and are readily available for livestock feeding (Ndyomugyenyi et al., 2014). In urban and peri-urban markets, the discarded JS are a potential environmental and health hazard because they have a peculiar smell and attract flies. Use of JS as livestock feed will in addition to reducing cost of livestock feed, contribute to improving the environment by reduction of the quantities of waste to be disposed off.

Despite the availability of JS, little work has been conducted to include the seeds in poultry diets. An attempt to include raw or inadequately treated JS in chicken diets caused retarded growth of the birds because of anti-nutrients (Ravindran et al.,1996). Efficient use of JS in chicken diets will depend on processing techniques that eliminate anti-nutrients from the seeds. Although some anti-nutrients in JS have been identified (Akinmutimi, 2006; Ravindran et al., 1996), little research to eliminate them has been conducted. In addition, little research has been conducted to determine the maximum inclusion levels of processedJackfruit seed meal (JSM) in poultry diets.The objective of this study was to evaluate the nutritional value of soaked-boiled-fermented JSM in poultry diets. The anti-nutrients, apparent nutrient utilization and metabolizable energy value of JSM were also determined.

Materials and Methods

Processing and chemical analysis of jackfruit seeds

The JS were obtained from an urban market in Kampala district, Uganda. The seeds were sun-dried and stored in gunny bags on wooden standsuntil used.The sun-dried seeds were soaked in water at room temperature for 12 hours; drained and rinsed once with fresh water; boiled in water at 100^{o}C for 2 hours; cooled under shade for 12 hours; mixed with fresh water (1kg of seeds: 65mls of water); placed in gunny bags; well covered; allowed to ferment for one week and then sun-dried.

Proximate composition and minerals were determined using procedures of AOAC (1990). Tannins were determined using modified Vanillin assay method (Price et al., 1978) and total oxalates (Day and Underwood, 1986).

Energy bioassay

The apparent metabolizable energy (ME_n) was determined using a modified conventional 4-day total collection procedure similar to that of Bourdillon et al. (1990). Six, 32-day old Ross strain cockerels weighing 434 - 522 g were individually housed in cages. The birds were fed JSM for 7 days, with 3 days of adaptation period followed by 4 days of faecal collection. The diet comprised of JSM (980 g); lake shells (10 g); bone ash (2 g); common salt (3 g); vitamin supplement (5 g) per kg. Feed and water were provided *ad libitum*. The excreta were collected daily and stored in a freezer at 10^{o}C to prevent decomposition or fermentation. The frozen excreta were thawed at room temperature, pooled and homogenized in a blender. For each cage, two representative samples of fresh excreta (0.6 g each) were taken for the determination of nitrogen. The remaining excreta were dried on metallic trays in a forced-air oven at 60^{o}C to minimize losses of energy and nitrogen (Shannon and Brown, 1969). Dry matter of the test feed and the dried excreta were determined by standard procedure of AOAC (1990). Nitrogen content of feed and excreta were determined using LECO analysis (AOAC Method 990.03 for nitrogen correction). Gross energy of the test feed and the dried (60^{o}C) excreta were determined, in duplicate, using an adiabatic bomb calorimeter, Gallenkamp Autobomb Automatic Adiabatic Bomb Calorimeter (CAB001ABI.C.). The gross energy values obtained were used to calculate the ME_n. The ME_n values were corrected to zero nitrogen balance using a factor of 8.22 times the nitrogen retained in the body (Hill and Anderson, 1958).

The ME_n was then computed from the data, all expressed on dry matter basis as follows:

Metabolizable energy per gram feed dry matter = EI - EO - 8.22 N where:

EI = Feed intake x Gross energy of feed

EO = Faecal output x Gross energy of faecal

8.22 = Combustible energy value of uric acid per gram of nitrogen

N = Nitrogen per gram feed - Nitrogen per gram faecal

Growth assays

Day-old, Ross strain broiler chicks were randomly distributed into fifteen weld-meshed cages each measuring 1.0 m^2. Five diets were formulated with JSM at dietary levels of 0, 80, 160, 240 and 320 g/kg. Energy supplement was maize while protein supplements were fish meal and full fat roasted soybean meal. The control diet was formulated to meet the nutritional requirements as recommended by NRC (1984). Heat was provided using hot charcoal via clay pots and 24-hour lighting was ensured using kerosene lanterns. The composition of the diets is shown in Table 1.

Table 1. Composition of broiler starter diets used in the feeding trial (air-dry basis)

Diets	1	2	3	4	5
Processed Jackfruit beans	0	80	160	240	320
Maize	550	470	400	330	250
Fishmeal (550 g/kg CP)	100	100	90	80	80
Soybean meal (full fat)	310	310	310	310	310
DL-Methionine	5	5	5	5	5
Lake shells	5	5	5	5	5
Bone ash	20	20	20	20	20
Salt	5	5	5	5	5
Vitamin-trace mineral premix[1]	5	5	5	5	5
Total	**1000**	**1000**	**1000**	**1000**	**1000**
Composition of diets (g/kg unless otherwise stated)					
Dry matter	883	884	884	886	885
Metabolizable energy (Kcal/kg)	3206	3110	3014	2919	2823
Crude protein	216	219	217	215	218
Lysine	13.3	13.1	12.5	11.8	11.6
Methionine	9.48	9.32	9.00	8.67	8.51
Methionine + Cysteine	12.5	12.2	11.7	11.3	11.0
Crude fat	88.0	87.0	84.0	82.0	80.0
Crude fibre	30.0	31.0	33.0	35.0	36.4
Calcium	12.1	12.5	12.6	12.7	13.1
Phosphorus	8.40	8.30	7.90	7.60	7.50

[1]Premix provided per kg diet: Vitamin A 15,000 I. U., Vitamin D_3 3,000 I. U., Vitamin E 15 I.U., B_{12} 0.013 mg, Vitamin K 4 mg, Riboflavin 10 mg, Folic acid 2 mg, Nicotinic acid 44 mg, Pantothenic acid 13 mg, Biotin 0.064 mg, Vitamin B_1 2.2 mg, Vitamin B6 5.5 mg, Choline Chloride 350 mg, Copper 6.25 mg, Iodine 1.5 mg, Zinc 62.5 mg, Manganese 62.5 mg, Selenium 0.1 mg, BHT (Antioxidant) 100 mg, Zinc Bacitracin 10 mg.

Source: UNGA Farm Care (East Africa) Limited with technical assistance from Frank Wright Limited, part of BASSF Group.

Body weights of chicks were taken at the start of experiment and at the end of each week for three weeks. All the feed provided was weighed and feed consumption was determined weekly for each replicate. The weekly body weight gain and feed intake measurements were used to compute feed/gain. Mortality was recorded as it occurred. At the end of the experiment, three chicks from each replicate group were slaughtered to determine organ weights relative to body weight. Cervical dislocation was used to quickly separate the spinal cord from the brain, hence providing a fast and painless death of the birds.

Experimental design and statistical analysis

A Completely Randomized Design was used with three replicates. Each replicate contained ten broiler chicks.Data obtained were analyzed using General Linear Model (GLM) procedures of Statistical Analysis System (SAS, 2001). Means were separated using Least Significant Difference (LSD) at 5% significant level.

Results and Discussion

Composition of jackfruit seed meal

The nutrient composition of JSM is shown in Table 2. Processing decreased the protein content of JSM by 7.28% while total carbohydrates increased by 0.94%.

Table 2. Composition of raw and processed Jackfruit seed meal (g/kg dry matter)

Composition	Raw	Processed
Dry matter	925±5.5	878±6.5
Crude protein	151±2.5	140±3.0
Ether extract	9.83±0.1	14.2±0.4
Crude fibre	42.0±1.0	46.3±0.5
Ash	37.8±0.7	22.5±0.3
Total carbohydrates	740±5.0	747±6.4
Sodium	4.56±0.03	4.83±0.04
Calcium	61.1±1.2	64.0±1.0
Phosphorus	2.22±0.02	1.96±0.03
Potassium	15.3±0.032	1.12±0.02
Condensed tannins[1]	11.1±0.15	1.28±0.01
Total oxalates	10.0±0.12	1.47±0.03

[1]Catechin Equivalent

The protein content of JSM was higher than the 110 g/kg reported by Tulyathan (2001) and 124 g/kg reported by Ravindran et al. (1996). The protein content of JSM was also higher than that of non-conventional feedstuffs such as bakery cracker residues (94.1 g), cassava with hulls (29 g), passion fruit pulp (137 g), sugar cane juice (16.1 g) and sweet potato (43.9 g) per kg (Rostagno et al., 2005). The total carbohydrates of raw JSM was lower than the 820 g/kg reported by Tulyathan (2001) but close to the 740 g/kg reported by Ravindran et al. (1996). The sodium contentof JSM was higher than that of oats (1 g), rice (1 g), barley (0.2 g) and sorghum (1 g) per kg; calcium was higher than that of oats (1.2 g), rice (1.1 g), barley (0.7 g), sorghum (1.9 g) and wheat (0.5 g) per kg; potassium was higher than that of oats (4.1 g), barley (4.2 g), sorghum (4.1 g) and rice (2 g) per kg (Göhl, 1975). Phosphorus content of JSM was lower than that of maize (3.4 g), millet (4.1 g), oats (3.7 g), barley (22 g), wheat (4.8 g) and rice (2.9 g) per kg (Göhl, 1975). Processing reduced tannins and oxalates from raw JSM by 88.5 and 85.3% respectively. The content of oxalates in raw JSM was higher than the 0.66% reported by Akinmutimi (2006).

Energy bioassay

The apparent metabolizable energy (ME_n) value of the processed JSM ranged from 2053to 2683 Kcal/kg. The variation of ME_n within the same treatment in replicate experiments was probably due to relatively different body sizes and plumage covers among the cockerels. Harper (2000) reported that energy requirements in birds depend on body size, activity patterns, plumage cover and physiological state of the birds. The $ME_n$was lower than that of common conventional energy feedstuffs such as cassava meal (3565 Kcal) and wheat (3612 Kcal) per kg (Ewing, 1997); barley (3038 Kcal), rice (2943 Kcal), oats (2871 Kcal) and millet (2823 Kcal) per kg (Göhl, 1975). Although the $ME_n$of JSM was lower than that of non-conventional feedstuffs such as sweet potato (2727 Kcal)and yeast brewery (2608 Kcal) per kg, it was higher than that of coconut meal (1938 Kcal/kg) (Rostagno et al., 2005). Faeces in the present study were observed to be viscous with whitish coating. The viscosity was probably the cause for low $ME_n$of the processed JSM. The viscosity of JSM was probably due to presence of non-starch polysaccharidesin the seeds. The viscous nature of JSM meal meant that the meal spent shorter time in birds' gastro-intestinal tract, hence reduced contact (digestibility) with digestive enzymes. Annison (1993) reported that soluble non-starch polysaccharide cell-wall component of a feedstuff was responsible for its low ME_n.

Values of nitrogen retention were negative for all the birds. The negative nitrogen retention led to an increase of 0.250 Kcal/g in ME_n after correction from metabolizable energy (ME, uncorrected for nitrogen balance). Values of nitrogen retention values were negative probably because of larger undigested residue from JSM. The undigested residue may have caused nitrogen losses from cockerels to be larger, hence lower values for ME_n compared to ME.

Growth assays

Inclusion of processed JSM in diets affected ($P < 0.05$) the growth performance of broiler chicks (Table 3). At 80 and 320 g/kg inclusion, weight gainand feed/gain were depressed by 5.2, 42.1%; 6.2, 40.7% respectively. Feed intake was not affected up to 240 g/kg but reduced at 320 g/kg inclusion by 18.3%. Reduced feed intake at higher levels of JSM inclusion was probably responsible for the growth depression (Figure 1). Growth depression of birds at levels as low as 80 g/kg JSM inclusion was unexpected considering that Ravindran et al. (1996) reported improved growth performance at levels as high as 250 g/kg inclusion when the seeds were only boiled for 10 minutes. The reason for the disparity could not readily be established.Since tannins and oxalates were greatly reduced after processing, there may be other factors that appeared to depress growth performance when JSM was included in chick diets. Low mortality was observed at 320 g/kg JSM inclusion but the highest mortalities were recorded in the control diet and at 240 g/kg. Low mortalities of birds at higher levels of JSM inclusion suggests that lethal effects of JSM as result of anti-nutrients (Akinmutimi, 2006; Ravindran et al., 1996) were greatly reduced by processing.

Table 3. Effect of feeding graded amounts of treated Jackfruit seed meal from 1 to 21 days of age on the performance and

	SBF Jackfruit seed meal inclusion levels (g/kg)						
	0	80	160	240	320	LSD	*P*
Performance							
Average weight gain/bird, g	449^{a}	426^{ab}	403^{b}	348^{c}	260^{d}	40.6	<0.001
Average feed intake/bird, g	727^{a}	732^{a}	720^{a}	705^{a}	594^{b}	80.0	0.016
Average feed/gain, g/g	1.62^{a}	1.72^{ab}	1.79^{b}	2.02^{c}	2.28^{d}	0.103	<0.001
Mortality, %	6.67	3.33	0.00	6.67	3.33	-	-
Cost per kg gain, Ugx[1]	3096	3328	3376	3711	4243	-	-
Organ weights, g/kg							
Liver	36.5^{a}	33.7^{ab}	30.2^{bc}	31.1^{bc}	28.4^{c}	4.65	0.024
Caecum	3.60^{c}	6.10^{b}	7.20^{ab}	7.50^{ab}	7.70^{a}	1.49	0.006
Heart	11.1^{a}	8.00^{bc}	9.80^{abc}	10.2^{ab}	7.30^{c}	2.61	0.046
Intestines	51.6^{b}	53.9^{b}	57.8^{b}	59.5^{b}	73.9^{a}	9.13	0.002
Pancreas	4.10^{b}	4.40^{b}	3.80^{b}	5.00^{ab}	6.00^{a}	1.37	0.039
Gizzard	46.0^{ab}	40.8^{b}	45.4^{ab}	43.9^{b}	52.7^{a}	8.04	0.076
Nutrient utilization, g/kg unless otherwise stated							
Nitrogen retention, g	1.56^{b}	1.51^{b}	1.35^{b}	1.54^{b}	2.16^{a}	0.375	0.006
Nitrogen digestibility	529^{ab}	551^{ab}	497^{b}	561^{ab}	589^{a}	90.0	0.278
DM digestibility	697^{b}	696^{b}	694^{b}	720^{a}	704^{ab}	18.7	0.061
Excreta water content	719^{b}	719^{b}	718^{b}	740^{a}	726^{ab}	17.2	0.079

[abcd] Means withdifferentsuperscripts are significantly different ($P < 0.05$)

[1]JS are available locally and will eventually be obtained at low cost or no cost; Ugx (Uganda shillings)

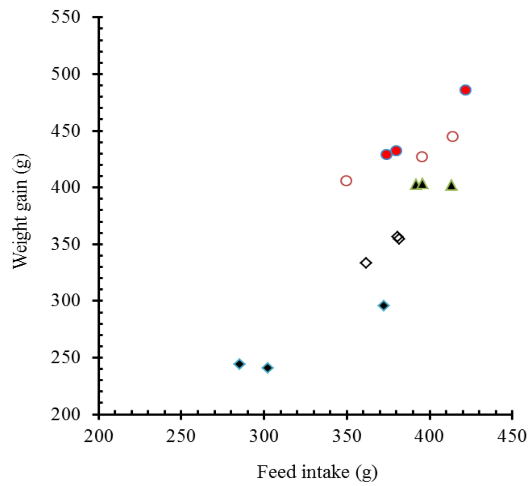

Figure 1. Weight gain versus feed intake of chicks fed on control (●), 80 (○), 160(▲), 240(◇) and 320 g/kg(◆) processed JS diets

The cost per kg gain of birds increased with increasing JSM in the diets. The cost increased by 7.5 and 37.1% at 80 and 320 g/kg inclusion respectively. The cost increased because the seeds were obtained from urban markets at a cost. However, the seeds are readily available in rural areas (Ndyomugyenyi et al., 2014) and will eventually be obtained at low or no cost. Despite the availability of jackfruit seeds, maize remains a better source of energy in poultry diets. This agrees with Leeson (2004) who reported that apart from wheat, there are no substitutes for maize meal in poultry feeding.

Gizzard weight relative to body weight was not affected ($P > 0.05$) by JSM inclusion but other organ weights were affected ($P < 0.05$). At 80 and 320 g/kg JSM inclusion, caecum, intestines, pancreas and gizzard increased in weight by 69.4, 113.9%; 4.5,43.2%; 7.3, 46.3%; 11.3, 14.6%, while liver and heart were reduced by 7.7, 22.2%; 27.9,34.2% respectively. All organs appeared normal at all levels of JSM inclusion. Apart from nitrogen retention ($P < 0.05$), nitrogen digestibility, dry matter digestibility and excreta water content were not affected ($P > 0.05$).

Gizzard weights relative to body weight were not affectedsuggesting a healthy gut for chicks. A well-developed gizzard has been reported to prevent pathogenic bacteria from entering the small intestines thereby reducing the risk of coccidiosis and other enteric diseases (Bjerrum et al., 2005; Engberg et al., 2004). Although gizzard weights were not affected, there was relative increment of 12.7% in gizzard weight at 320 g/kgJSM inclusion. Presence of JSM could have facilitated the increased rate of contraction of the gizzards thereby increasing their weights at higher levels of the JSM. Similar findings were reported when whole grains were used in poultry diets (Engberg et al., 2004; Gabriel et al., 2007; Lu et al., 2011; Roche, 1981). The weights of liver and heart were low at high levels of JSM probably due to the decreased energy content in the diets at these levels (Table 1). Increment in most digestive organ weights with increasing levels of JSM could be explained by several reasons. The small intestine of the newly hatched chick undergoes morphological, biochemical and molecular changes during the early development stages suggesting that higher levels of JSM in chick diets facilitated these processes. Intestinal development after hatching is rapid with respect to enzymatic and absorptive activities (Sklan, 2001; Uni et al., 1999). Increment in caeca size/weight at higher levels of JSM could be due to stress imposed on these organs as they attempted to extract nutrients from nutrient-impoverished diets particularly low energy.The avian caecum is a multi-purpose organ whose functioning can be efficient and vitally important to a bird's physiology, especially during stress periods (Clench and Mathias, 1995). Clench and Mathias (1995) reported that caecal lengths and masses increased when birds were fed on poorer and more fibrous diets and these increases indicated a general size/weight increase.

Nitrogen retention was more positive at high levels of JSM inclusion (Table 3). It was unexpected that growth depression would be associated with high levels of JSM inclusion. The positive nitrogen retention at high levels of JSM inclusion would mean that the chicks were consuming more protein than their bodies needed. The extra protein would most likely contribute to muscle growth, hence promoting growth but this was contrary. Growth depression when nitrogen retention was more positive was probably related to the poor quality of protein in diets constituting JSM. The quality of protein particularly essential amino acids at high levels of JSM inclusion was questionable. According to Tome and Bos (2000), the nutritional value of proteins in feeds may differ considerably in regard to variable factors that include their essential amino acid content.

Conclusions

Jackfruit seeds subjected to soaking, boiling and fermentation reduced their tannin and oxalate contents by over 85%. The processed jackfruit seed meal can be included in poultry diets at levels up to 80 g/kg without compromising with: feed intake (not affected up to 240 g/kg inclusion); feed efficiency (below 2.0 up to 160 g/kg inclusion);weight gain (comparable to the control and at 80 g/kg inclusion i.e. 449.3 v 426.1 g respectively); nutrient utilization (nitrogen and dry matter digestibility);gizzard size and health (reduce disease infections). The cost per kg gain of birds increased when JSM was included in chick diets but the seeds will eventually be readily available at low or no cost. However, for economic efficiency the cost of collection and treatment should be put into consideration.

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