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## **Neem (*Azadirachta indica*) Seed Cake/Kernel as Protein Source in Ruminants Feed**

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### **Authors' contributions**

*The review paper was jointly put together by the two authors. Author AA developed the concept of the paper with contribution from author SAM. The two authors made the literature searches. Author AA wrote the first draft with due consultation with Maigandi who read it, made corrections and added his input. They two authors read and agreed on the final draft.*

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### **ABSTRACT**

Ruminant production that is very popular in Nigeria livestock production faces series of problems, chief among them is the shortage of protein supply in adequate amount for optimum performance of the animals. The forages, which constitute the bulk of the source of feed for these animals, fluctuate in supply with poor nutrient content especially during the dry season of the year. The conventional protein concentrates which boost the protein supply faces intense competition from man. It has become imperative for intensive effort to be made at making the unconventional sources of protein available to the farmers. Neem seed cake/ kernel cake fits as one of the unconventional protein supply in view of the high level of the protein content and balancing of the amino acids. It is capable of offering a big relief to these protein shortages. The neem seed is readily available in the northern part of Nigeria that is the home to the largest of number of ruminants in the country. However, they are not readily acceptable to the animals due its pungent smell and bitterness caused by the bioactive principles present. This paper reviewed availability of neem seed in Nigeria, the antinutritional and other bioactive factors inherent in the cake as well as the methods of processing and removing them. The review also highlighted the nutritional quality of the cake, effect on haematological and biochemical characteristics; and the economics of use

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of the cake. The paper concluded that neem seed cake/kernel could readily serve as safe source of protein to the ruminants with appropriate treatment to remove active principles.

*Keywords: Neem kernel cake; Alkali treated neem kernel; haematological; biochemical; Uda lambs and Uda rams.*

## 1. INTRODUCTION

Ruminant production in Nigeria is popular among the rural farmers. They are widely distributed in among rural, urban, and peri-urban areas representing about 63.7% of the total grazing domestic animals in Nigeria [1]. Ruminants account for major supply of national meat supply [2]. However, the level of domestic livestock production falls short of demand [3]. The average Nigerian consumes only 3.245g of animal protein per day, out of the 34g recommended [4]. The most important factor responsible for the gap in the relationship between the demand and supply of ruminants in Nigeria is the supply of feed both in quantity and quality.

The main feed resources for small ruminants are natural pastures consisting of legumes and browse species [5]. These pastures depend on rainfall, which fluctuates especially in the northern part of the country where the largest percentage of the animals are raised. The scarcity of energy and protein feedstuffs during dry the season is a major setback to ruminant livestock production in the tropics [6]. The increase in human population further worsens the situation because of the pressure placed on the available land for grazing by other agricultural and non agricultural activities. During this period, the available forages are dry, protein content is very low and there is marked decrease in voluntary intake and digestibility by the animal [7,8]. The nutritional problems of ruminants have been increased by competition between man and the animals for the scarce grains and the protein concentrates feed making it difficult to meet up with nutritional requirements of the animals at affordable cost. Other factors which have contributed to the increasing cost of feed are under-production of various ingredients used in feed formulation and high inflation rates.

The commonest protein supplement for livestock feed in Nigeria in periods of low yield and availability of poor quality herbage are groundnut cake (GNC) and cotton seed cake (CSC). GNC is the major plant protein supplement used in Nigeria. The unextracted groundnut has about 26 - 30% protein and it mainly consumed by humans while Groundnut cake has a protein content of about 38 - 47% [9]. It is palatable however, deficient in lysine, methionine and threonine but rich in vitamin E, K , B, thianine and niacin [11]. CSC is obtained from cotton after the removal of the lint, followed by oil extraction from the seed. It has a protein content of 38-44% [12] depending on the efficiency of oil extraction but deficient in lysine, methionine, leucine and isoleucine [13].

The prices of GNC and CSC products have been rising thereby increasing the cost of production. Researchers therefore considered the use of alternative sources of feed ingredients in order to reduce the cost of production. One of the promising material is the neem (*Azadirachta indica*) kernel cake. Information available on Neem plant (*Azadirachta indica*) indicated that it is the only species in the genus *Azadirachta*. It is native to India and Burma, growing in tropical and semitropical regions [13]. It has several uses and can be grown under reforestation and social foresting programmes. The neem tree grows well in well drained deep soil, sandy loams with ground water at 3.048 meter dept or more. Neem

tree can perform well in dry soils that are poor in nutrients and have low rainfall per annum requirement (130 mm) [14]. The tree has the advantage of growing on marginal lands, where it will not compete with food crops [15].

Despite its availability and the derivable benefits from the use of the cake, its use is still beleaguered by series of problems. So the main objective of this study is to create awareness on the potentials of the use of neem seed cake in Nigeria. The study dwelt on the nutritional and antinutritional components; and the different methods of removing the bioactive in the cake. This was done with data obtained from reputable peer reviewed journals, published and unpublished reports on the use of neem seed cake (NSC)/neem kernel cake (NKC) as an unconventional sources of protein in ruminants.

## **2. NEEM (*Azadirachta indica*) TREE DISTRIBUTION AND SEED AVAILABILITY**

Over four millions of neem trees have been planted in the northern part of Nigeria especially in Borno, Kano, Katsina and Sokoto states; and rich in protein [16]. About 3,500 hectares of land is under cultivation in Kebbi, Sokoto and Zamfara states, with a density of about 1,200 trees per hectare [17]. In Nigeria, neem form about 90% of forestry established in 12 states within the savanna zone under the afforestation programme [18]. It may grow up to 15m tall under ideal conditions and is reported to live up to 200 years [19]. It takes about five years to produce the first fruit crop but can produce a good yield in the third year [20]. The fruit yield is extremely variable ranging from 10 to 50kg per tree with an average of 20kg [14]. The tree has the ability to withstand frost due to a very suberised back layer and can easily survive desert conditions of temperature above 50°C and takes about five years to produce the first fruit crop but can produce a good yield in the third year [20]. Neem tree flowers between February and May with profuse clusters of small white flowers. The fruits are drupes, turning golden yellow on maturity, which occurs during June to August in India. A full grown tree can produce 30-100 kg fruit depending on rainfall, soil type and ecotype. 50 kg of fruits yield 30 kg of seed giving 6 kg of oil and 24 kg of seed cake [13]. The tree begins bearing fruit after 3 to 5 years and produces about 50 kg fruits annually when mature in India. The seeds are about 2 cm long and 1.5cm diameter, kernel of about 1.5 cm length containing about 30 to 40 percent oil and 5 to 6 years old tree can yield 20 kg kernels [20]. The yield of 20.5 kg fresh fruit for a fully grown neem tree was reported in Nigeria [21] and an average yield of 17.71 kg in Nigeria (Sokoto and its environ) [22]. The large number of the neem trees and its yield in the northern part of Nigeria is an advantage for its use.

## **3. ANTI-NUTRITIONAL FACTORS OF NEEM SEED CAKE AS FEED INGREDIENT**

The possibility of using NSC in livestock ration was explored by [23] using the feeding practice of local farmers in Southern India. However, NSC pungent odour and the bitter taste caused by the active principles isolated from different parts of the plant namely azadirachtin, meliacin, gedunin, salanin, nimbin, valassin and many other derivatives of these principles constitute the hindrances to its use. Despite the high CP content, its incorporation in animal diets was discouraged due to their adverse effect on their performance because of the presence of bitter and toxic triterpenoids mainly nimbin, nimbidin, azadrachtin and salanin [24].

Biologically active principles isolated from different parts of the plant include: azadirachtin, meliacin, gedunin, salanin, nimbin, valassin and many other derivatives of these principles.

Meliacine forms the bitter principles of the neem oil; the seed also contain tignic acid (5-methyl-2-butanic acid) responsible for the distinctive odour of the oil [25,26,27,28]. Neem seed cake is very unpalatable due to the presence of salanolide meliacin which has been found to be one of the active principles of neem seed oil [29]. These compounds are natural products called triterpenoids or more specifically, linonoids and they are concentrated in the seed despite their presence in other parts of neem tree.

Poor palatability was accompanied by either poor weight gain or loss of body weight along with lowered nutrient digestibility in crossbred calves fed concentrate mixture containing NSC that contributed 12.5, 25, or 50% of crude protein (CP) requirement [30]. The author suggested that NSC was unsuitable for animal feeding even for maintenance. There was gradual decline in growth rate of rams with higher levels of NSC in concentrate ration [31]. This then makes the processing of the cake before being fed to animals very important. The processing of the neem seed into palatable seed cake poses a challenge to its use as animal feed.

#### **4. METHODS OF PROCESSING AND REMOVAL OF THE ACTIVE PRINCIPLES OF NEEM SEED CAKE**

Single seeded mature neem fruit contains 23.8% skin, 47.5% pulp, 18.6% shell and 10.1% kernel. The decortications of depulped seed yields about 26% kernel, which gives 45 to 50% oil leaving the rest as neem kernel cake (NKC) [32]. NKC have been prepared differently by authors. It was prepared by soaking the dried neem fruits in water for 3-4 days and depulped using depulper machine. The seeds were dried for 7 days before being decorticated using a winnowing machine and then crushed after further drying for 3 days [33]. NKC was also prepared by spreading the neem fruit in the sun for fifteen days and then soaked in water for three days and then depulped. The depulped seeds were washed and sun dried for a period of ten days. The dry seeds were decorticated, further dried for five days, crushed and the oil removed manually to produce the neem kernel cake [22]. Another method of preparing NKC is by spreading the seeds in the sun to obtain a constant weight. The dried seeds were soaked in water in an open basin for 72 h. The seed were poured into a jute bag to drain the water and later sun-dried to constant weight. Then, the water soaked and untreated seeds were taken to the mill separately for oil extraction. Cake obtained from the oil-extraction was then ground in a hammer mill.[34].

The bitter taste and pungent odour resulting in poor palatability discourage animals from eating it. NSC has been found to be unpalatable in calves [35], cross-breed bulls [36] and sheep [31] and possess antiparasitic properties [37]. These biologically active principles posses insect repellent, antifeedant, growth inhibitors and other insecticidal prop[erties [38]. hence the need to remove them. The active principles are slightly hydrophilic but freely lipophilic and highly soluble in organic solvents like hydrocarbon, alcohols, ketones and esters [26,25,39]. There are various methods of removing the oil from the neem seed cake. For the expeller NSC, the crushed kernel will be steamed and the oil is pressed out using expeller machine. The hydraulic press NSC processing is devoid of heat. The milled kernel was cold-pressed using the hydraulic press machine until the oil content of the residue (cake) is minimal. To reduce the oil content of the cake, it is further defatted using hexane. The removal of these bioactive can be done using simple techniques as follows [39].

#### **4.1 Water Extraction**

The simplest technique is to crush or grind the kernels and extract them with water. They may be steeped overnight in a cloth bag suspended in a barrel of water or water can be poured into the bag and extract can be collected as it emerges. By using water extraction, it has been estimated that 20-30 kg neem seeds can normally treat one hectare of land. Normally, the proportions employed are about 500 g of kernels steeped in as much as 10 litres of water as they have low solubility in water.

#### **4.2 Hexane Extraction**

Kernels are grated and steeped in the solvent hexane to extract only oil. The residue left after the hexane extraction still contains limonoid active ingredients and also subsequent water or alcohol extraction yields clean limonoids uncontaminated by oil.

#### **4.3 Alcohol Extraction**

It is the most direct process for producing neem based pesticidal materials in concentrated form. Limonoids are highly soluble in alcohol solvents: The grated kernels are usually soaked in ethanol, but sometimes in methanol. It extracts the active ingredients which ranges between 0.2-6.2 percent.

Other attempts have been made at removing the bioactive principles of the cake for improved palatability. The solvent extraction method have been adopted in which the oil from the crushed NKC is extracted using organic solvent of high polarity mixed with water and filtered [40,41]. Others include alcohol treatment [42] and alkali treatment (0.8% NaOH, wt/wt) with boiling (1:2.5wt/vol) of cake followed by water washing and draining off after washing [43]. Of the several methods used to detoxify NKC, for example water washing [44], hexane extraction [41] and alkali treatment of NKC [45], water washing was found to be most effective despite the loss of 22% dry matter [46]. However, to avoid this dry matter loss from water washing, alkali treated (20g NaOH/kg cake, wt/wt) NKC without washing was tried and found to be palatable to adult cattle and buffalo [47], proved promising in the feeding of buffalo calves [48] and; Uda lambs and rams [22].

### **5. NUTRIENT DIGESTIBILITY AND PERFORMANCE**

Feeding NKC without treatment has been shown to have negative effect on nutrient digestibility and performance of ruminants. Poor growth was recorded in cattle when fed diets that contained 27% level of inclusion of NSC as a replacement for groundnut cake [49]. There was poor palatability accompanied by either depressed weight gain or loss of body weight along with lowered nutrient digestibility in crossbred calves fed concentrate mixture containing NSC that contributed 12.5, 25.0 and 50.0% of digestible crude protein requirement, suggesting that the NSC as such was unsuitable for animal feeding even for maintenance [35]. Lowered rumen protozoan count along with reduced enzyme activity was reported in calves fed NSC [50].

Over night soaking of NKC in NaOH (0.8%, wt/wt) and water followed by repeated draining off with two or three times water washing was carried out. There was significantly higher N-balance and a mean growth rate of 403 g/day in the control group and 344 g/day in the experimental group which did not differ significantly ( $P > 0.05$ ) [46]. It was observed that

there was no significant variations in milk yield, milk fat content, and sensory evaluation of milk, dry matter intake and digestibility when WWNKC was incorporated at 40% level in the concentrate diet of dairy cow for 300 days [51].

There were reports of comparable crude protein digestibility and efficiency; and live weight changes in Uda lambs and rams when fed alkali treated neem kernel cake soaked overnight in water and dried in the sun as shown in Tables 1 and 2 respectively. Crude protein digestibility and efficiency in the treatment diets in these two tables compared favourably with control diets.

**Table 1. Live changes and crude protein digestibility of Uda Rams fed Alkali Treated Neem Kernel Cake (ATNKC)**

Parameter	Treatments					±SE
	A	B	C	D	E	
<b>ATNKC inclusion</b>	-	5	10	15	20	
Initial body Weight (kg)	18.50	18.45	18.50	18.50	18.50	1.83
Final body weight (kg)	24.63	27.25	26.25	26.75	24.17	2.20
Body weight gain (kg)	6.13 <sup>b</sup>	8.80 <sup>a</sup>	7.75 <sup>ab</sup>	8.25 <sup>ab</sup>	5.67 <sup>b</sup>	0.83
Av. daily gain (g/day)	72.76 <sup>b</sup>	104.76 <sup>a</sup>	92.26 <sup>ab</sup>	98.25 <sup>ab</sup>	67.50 <sup>b</sup>	9.88
Feed intake (g/day)	692.93 <sup>ab</sup>	856.24 <sup>a</sup>	572.86 <sup>b</sup>	645.23 <sup>ab</sup>	691.02 <sup>ab</sup>	66.48
Dry matter intake (g/day)	658.78 <sup>ab</sup>	813.43 <sup>a</sup>	538.49 <sup>b</sup>	609.45 <sup>ab</sup>	654.34 <sup>ab</sup>	62.71
Crude protein intake (g/day)	107.51 <sup>ab</sup>	133.38 <sup>a</sup>	89.12 <sup>b</sup>	100.61 <sup>ab</sup>	108.04 <sup>ab</sup>	10.51
Crude protein digestibility	77.23 <sup>b</sup>	92.27 <sup>a</sup>	86.47 <sup>a</sup>	86.67 <sup>a</sup>	78.44 <sup>b</sup>	2.20
Protein efficiency	0.68 <sup>b</sup>	0.82 <sup>ab</sup>	1.03 <sup>a</sup>	1.02 <sup>a</sup>	0.71 <sup>b</sup>	0.093
Feed gain ratio	9.23 <sup>a</sup>	8.12 <sup>ab</sup>	5.86 <sup>b</sup>	6.41 <sup>b</sup>	9.67 <sup>a</sup>	0.83

Means not followed by the same superscripts are significantly different ( $P < 0.05$ ) along the row.

Source: 52

A (CSC), B (5% ATNKC), C (10% ATNKC), D (15% ATNKC), E (20% ATNKC)

**Table 2. Live weight changes and crude protein by the fattening Uda Rams fed Alkali Neem Kernel Cake (ATNKC)**

Parameter	Treatments				± SE
	A	B	C	D	
<b>ATNKC inclusion</b>	-	8.5	16.5	25	
Initial Weight(kg)	26.38	26.25	26.25	26.38	1.51
Final Weight(kg)	38.25	40.25	37.38	36.38	1.20
Weight Gain(kg)	11.88 <sup>ab</sup>	14.0 <sup>a</sup>	11.13 <sup>b</sup>	10.0 <sup>b</sup>	0.80
Average Daily gain(g)	141.37 <sup>ab</sup>	166.67 <sup>a</sup>	132.44 <sup>b</sup>	119.05 <sup>b</sup>	9.55
Feed Intake(g)	1320.25 <sup>a</sup>	1132.75 <sup>b</sup>	1057.50 <sup>b</sup>	1063.75 <sup>b</sup>	46.30
Dry matter intake(g)	1271.25 <sup>a</sup>	1117.25 <sup>b</sup>	998.25 <sup>b</sup>	1026.50 <sup>b</sup>	41.74
Crude Protein intake(g)	165.51 <sup>a</sup>	145.93 <sup>b</sup>	130.08 <sup>b</sup>	136.28 <sup>b</sup>	5.97
Crude Protein digestibility	83.08 <sup>a</sup>	79.59 <sup>a</sup>	76.11 <sup>a</sup>	66.80 <sup>b</sup>	2.74
Protein efficiency	0.86 <sup>b</sup>	1.14 <sup>a</sup>	1.02 <sup>ab</sup>	0.87 <sup>b</sup>	0.06
Feed gain ratio	9.04 <sup>a</sup>	6.71 <sup>b</sup>	7.77 <sup>ab</sup>	8.77 <sup>a</sup>	0.56

Means not followed by the same superscripts are significantly different ( $P < 0.05$ ) along the row.

Source:22

A (CSC), B (8% ATNKC), C (16% ATNKC), D (25% ATNKC),

## 6. NUTRITIONAL QUALITY OF NEEM SEED CAKE

NSC, a by-product of neem oil industry, is a non-conventional feed ingredient with great potential for livestock feeding [40,53]. It has been noted as a rich protein source with 34% - 38% CP [33] and; 33.20% and 32.90% for alkali treated neem kernel cake (ATNKC) and NKC respectively [22]. Minerals contained in NSC is shown in Table 3. It is balanced in Ca, P but exceptionally high kernel Fe.

**Table 3. Mineral profile of certain neem products (DM)**

Product	%					Ppm						
	Ca	P	Mg	Na	K	Cu	Zn	Fe	Co	Mn	Cr	Pb
Neem leaves	0.72	0.27	0.77	0.56	1.85	30	15	777	8	59	.5	30
Neem fruits	0.29	0.36	0.54	0.36	0.74	10	16	775	3	12	0.2	7.8
Neem seed	0.77	0.31	0.37	0.47	1.94	18	26	970	1.3	34.5	-	14.3
Neem cake	0.96	0.30	0.44	0.40	0.98	19	19	2705	1.5	70	1.0	10.6
FFNSM	0.07	0.01	0.10	0.59	1.52	10	60	300	-	20	-	-

Source: 54

FFNSM: Full fat neem seed meal.

The undecorticated NSC contained 6.5 to 11.6% digestible crude protein[36]. The following are the crude protein percentages of 23.19%, 22.69%, 23.06% and 22.5% for raw neem seed meal, hydraulic press NSC, solvent extracted NSC and expeller NSC respectively [33]. The protein quality of NKC is comparable to that of peanut nut meal (PNM) [55]. Neem cake consists of all essential and non-essential amino acids including sulphur containing ones, but with fewer amounts of histidine, lysine and tyrosine [54].

Chemical composition of NSC/NKC and neem seed meal (NSM) is shown in Table 4 and varied considerably depending on the method of processing. CP varied from 12.35% in NSC to 40.91% in urea treated neem kernel cake (UANKC). The crude fibre was highest in full fat NSM of 40.50% [56] while the lowest value was reported in NKC with 11.40% [45]. The ether extract (EE) is 0.38% in deoiled NSC [57] and 27% in FFNSM [56]. The nitrogen free extract was the lowest in full fat neem seed meal [17] with 14% and highest in NSC [35] with 52.52%. UANKC seemed to be the best because of high crude protein of 40.91% and relatively low crude fibre of 11.43% [58]. ATNKC consisted of 33.76% crude protein [47]. The authors also reported that ATNKC can be a wholesome substitute for PNM in terms of performance.

**Table 4. Chemical composition of various types of neem cake/meal (%DM)**

Neem cake/meal	CP	EE	CF	NFE	Ash	Ca	P	Reference
NSC	12.35	3.3	17.9	52.52	13.93	-	-	[35]
NSC	17.85	3.62	25.90	46.20	5.5	0.72	0.58	[23]
Neem fruit lake	14.97	2.40	26.95	40.92	15.17	1.65	0.31	[59]
NKC	33.50	10.40	11.40	29.70	15.00	-	-	[46]
NSM	35.51	9.14	11.89	28.48	14.98	0.77	0.69	[60]
Hexane Exp. NSM	38.31	1.06	13.46	29.02	18.15	1.05	1.08	[61]
Alcohol Exp. NSM	40.35	0.71	13.92	26.02	19.00	1.12	1.11	[60]
NSC	20.90	14.80	19.20	29.50	15.50	0.14	0.81	[55]
FFNSM	16.80	22.80	34.61	23.10	2.7	-	-	[17]
FFNSM	14.20	27.00	40.50	14.00	14.30	0.07	0.01	[56]
DNCS	18.37	0.381	30.12	34.97	16.16	0.97	0.16	[57]
ATNKC	33.76	5.39	13.77	27.28	19.90	-	-	[47]
UANKC	40.91	4.44	11.43	28.10	15.12	-	-	[58]
ATNKM	36.01	4.80	15.60	27.80	15.80	0.78	0.50	[54]
UANKM	40.06	4.90	15.30	24.12	15.62	0.74	0.45	[54]

NSC: *Neem seed cake*; NKC/NKM: *Neem Kernel Cake/Meal*; WWNKC: *Water wash NKC*; NSM: *Neem seed meal*; FFNSM: *Full fat NSM*; DNCS: *Deoiled NSC*; ATNKC/ATNKM: *Alkali treated NKC/NKM*; UANKC/UANKM: *Urea-Ammoniated NKC/NKM*; Exp: *Expeller*.

## 7. PALATABILITY OF NEEM SEED CAKE/KERNEL CAKE

The palatability of the NSC can be improved with appropriate treatment to remove the active principles. NSC palatability improved when NSC was fed to sheep along with barley, molasses and PNM but consumption of concentrate mixture was reduced from 79 to 39% when NSC levels increased from 59% to 90% respectively [61]. Yearling sheep could completely consume concentrate mixture comprising 75 parts NSC and 25-parts maize but the consumption was reduced to one third when NSC was fed alone [31]. Buffalo calves though continued to relish even after increasing NSC from 5 to 15 parts when fed along with 7 and 20 parts of molasses and PNM respectively, the consumption was reduced to half on withdrawal of molasses [62].

## 8. EFFECT ON HAEMATOLOGICAL AND BIOCHEMICAL CHARACTERISTICS

The use of treated NSC in the feed of ruminants has been proven to be safe for their consumption. Feeding of ATNKC to lambs for up to 20% level has no significant effect on the haematological and biochemical characteristics [52]. Neem bitterness and toxicity can be inactivated by alkali treatment [61]. This was also supported by [54] in his report that ATNKC can convert NKC to a wholesome vegetable protein supplement for growing buffalo calves. Inclusion of water washed NKC in the concentrate mixture of male kids at 15 and 25 parts for 180 days of feeding led to comparable intake and utilization of nutrients, besides normal balance of nitrogen, urinary creatine, blood haemoglobin, cholesterol and activities of glutamate oxalo acetate transaminase (GOT), glutamate pyruvate transaminase (GPT) and alkaline phosphates with significantly lowered blood glucose, urea and total protein [62].

The serum glutamate oxalo acetate transaminase (SGOT) and serum glutamate pyruvate transaminase (SGPT) values in the control and test diets Uda lambs fed ATNKC were comparable [52]. He also showed that the bilirubin total, bilirubin conjugate and bilirubin unconjugate values in the study were normal and conformed to the report of [63] and [64]. These values were within the range of 14-123u/l for SGOT and 15-44u/l for SGPT reported



by [65]. These indicate that inclusion of ATNKC is not toxic to the liver since SGPT and SGOT were excellent markers of liver damage caused by exposure to toxic substances [65]. Incorporation of NSC up to 20% did not alter GOT and GPT activities in the blood [66]. The urea nitrogen level of lambs fed ATNKC and control were not significantly different from each other [52] and were all within the normal range reported for sheep by [64] and [63]. The authors also showed that the sodium and potassium level obtained the blood of Uda lambs fed ATNKC were normal and within the range of 142-160mmol/l for sodium and 4.3-6.3mmol/l for potassium reported by [64] This indicate that ATNKC inclusion up to 20% level did not interfere with the renal functions of the animals.

### 9. ECONOMICS OF USE

NSC has proven to be economical in the feed of ruminants. This is shown in Tables 5 and 6 respectively in which treated NSC inclusion in the feed of Uda lambs and rams compared favorably in cost of feed per kilogram, cost of feed consumed per day and cost of feed per kilogram live weight gain. It was reported that 20% lower cost per weight gain was reported when deoiled peanut was replaced with urea ammoniated NKM in goats [62]. The cost of feed per kg liveweight gain was lower for diets with inclusion of detoxified NSC than with the conventional feed in Nellore sheep [67].

**Table 5. Cost of feed/kg liveweight of Uda lambs**

Parameter	Treatments					±SE
	A	B	C	D	E	
Cost of Feed (\$/kg)	0.28	0.276	0.273	0.276	41.72	-
Cost of feed consumed (\$/day)	0.193 <sup>ab</sup>	0.236 <sup>a</sup>	0.157 <sup>b</sup>	0.178 <sup>b</sup>	0.182 <sup>ab</sup>	2.72
Cost of feed/kg live weight gain (\$/kg)	2.650 <sup>a</sup>	2.254 <sup>ab</sup>	1.700 <sup>b</sup>	1.811 <sup>b</sup>	2.702 <sup>a</sup>	36.24

*Means not followed by the same superscripts are significantly different (P<0.05) along the row.*

Source:22

A:CSC; B: 5% ATNKC ; C :10% ATNKC; D 15% ATNKC; E:25%.

**Table 6. Cost of feed/kg liveweight of Uda ram**

Parameter	Treatments				±SE
	A	B	C	D	
Cost of feed (\$/kg)	0.247	0.227	0.218	31.06	
Cost of feed consumed (\$/day)	0.315	0.254	0.218	0.201	1.38
Cost feed per live-weight gain (\$/kg)	2.225	1.524	1.643	1.694	19.51

*Means not followed by the same superscripts are significantly different (P<0.05) along the row.*

Source:22

A: CSC; B: 8% ATNKC ; C 16% ATNKC; D: 25% ATNKC.

### 10. CONCLUSION

Neem seed is readily available in Nigeria especially in the northern part. It can easily be converted to neem seed cake/kernel cake. The active principles present in the seed have resulted in bitterness and pungent smell which have impacted negatively on the palatability and the consumption. However, the various methods of preparing the cake and removing the active principles have resulted in improved palatability and consumption as shown in the review. It is shown that ruminants utilise feed with treated NKC inclusion comparably with the control diets without any adverse effect on the haematological and biochemical parameters.

Treated neem seed cake/kernel cake can then readily fit in as replacement for the conventional protein sources.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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