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Effect of Neem Leaf Meal (*Azadirachta indica* A. Juss.) Inclusion Levels on the Growth Performance, Digestibility and Nitrogen Utilization of Yankasa Rams

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ABSTRACT

This study was undertaken to appraise the influence of neem leaf meal (NLM) inclusion on the growth performance, digestibility and nitrogen utilization of Yankasa rams. The study was conducted at Prof. Lawal Abdu Saulawa Livestock Teaching and Research Farm, Federal University Dutsin-Ma. Neem leaf meal (NLM) was air-dried for eight (8) days and incorporated with maize offal, cowpea husk, cotton seed cake, bone meal and salt as diets. Twenty Yankasa rams were randomly assigned to four treatments with A (0%), B (5%), C (10%), and D (15%) NLM inclusion levels in a Completely Randomized Design, each with five replicates. The 84-day growth trial revealed that feed intake decreased with increasing NLM levels, but weight gain was unaffected ($p > 0.05$). The 15% NLM group showed the highest average daily weight gain (112.88 g) and total weight gain (9.19 kg). Feed cost per kilogram and cost per live weight gain improved with higher NLM inclusion. Dry matter digestibility was highest at 10% NLM (91.71%), while ether extract and nitrogen-free extract digestibility were higher in neem-supplemented groups. Nitrogen utilization parameters improved with increasing NLM levels, with higher nitrogen retention and lower faecal nitrogen in NLM fed groups. The results suggest that neem leaves, an underutilized resource, can reduce feed costs while supporting sustainable feeding practices. The recommendation of the research is that neem leaf meal can be included in ram meal as high as 15% for optimal performance.

***Keywords*:** Neem leaf meal, Growth performance, Nutrient digestibility, Nitrogen utilization

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1. INTRODUCTION

Small ruminants like sheep and goat production are viable ventures in Nigeria in view of the obvious benefits and the ease of the production. Aruwayo *et al*. (2015) highlighted that ruminant constitute a noteworthy part of livestock production in Nigeria. They play vital functions in the lives of households in the rural arears, offering distinct advantages over other livestock. It constitutes one of the major protein sources to the urban and rural populace. Aruwayo and Muhammad (2018) reported that small ruminant production performs a crucial function in the provision of protein of animal origin in Nigeria, in addition to possessing an outstanding capacity to mitigate the shortage. Despite their importance, livestock farmers in tropical regions face numerous challenges in production and income generation. These issues are largely due to feed shortages, the poor quality of available feed, slow feed digestibility, and inconsistent weight gain, all of which are exacerbated by seasonal feed imbalances. Small ruminant farmers are particularly affected, especially when the forage is dry, scarce and nutritionally inadequate.

These animals depend solely on natural forages during this dry period. Aruwayo *et al*. (2016) stated that ruminants especially sheep and goats can flourish on roughages with poor nutritive values and agricultural by-products that cannot nourish the non-ruminants. At such period, most available forages become fibrous and have low digestibility, leading to poor ruminant livestock performance. One of the foliage trees that could readily help in alleviating this challenge is Neem (*Azadirachta indica*) tree leaf. The neem tree (*Azadirachta indica*), locally known as "Dogon yaro" in Hausa, is of the Maliaceae family. These trees are widespread across Africa and remains available throughout the year (Ogbuewu *et al*., 2011). Neem tree forage serves as an economical source of nitrogen, energy, and essential micronutrients, offering numerous advantages. These include its widespread availability on farms, easy accessibility for farmers, laxative properties that aid the digestive system, low nitrogen degradability in the rumen, and the ability to introduce variety into the diet. Replacing traditional feed ingredients with tree leaves can significantly lower the cost of supplements compared to commercial concentrates (Ondiek *et al*., 2000). Fujihara *et al*. (2004) stated that seasonal variations in forage quality, showing crude protein deterioration and an increase in neutral detergent fiber with variation in seasons. Therefore, supplementing diets of ruminants that graze natural pastures is necessary to avoid loss of weight during dry periods, which can lead to reproductive losses. Neem leaves present a promising alternative feed resource for smallholder ruminant farmers, retaining their green coloration and nutritional value even during droughts. Despite their bitter taste, neem leaves are readily consumed by livestock, likely due to feed shortages during these challenging times. Neem leaf meal has been documented to be safe for the health of ruminants when supplemented up to 20% level of inclusion as reported by Aruwayo *et al*. (2024). Neem leaf meal was then incorporated into growing Yankasa rams to investigate the effect on the growth performance.

2. MATERIALS AND METHODS

This study was carried out at Prof. Lawal Abdu Saulawa Livestock Teaching and Research Farm, Department of Animal Science, Federal University Dutsin-Ma, Katsina State. The Farm is located within the latitude 12°27’18” N and 7°29’29” E (Garba *et al*., 2024).

2. 1. Preparation of Test Ingredient and Experimental Diet

Fresh neem leaves were obtained from Professor Lawal Abdul Saulawa Livestock Teaching and Research Farm. These leaves were air-dried for 8 days and turned brittle without losing the greenish colouration. They were crushed with use of pestle and mortal. The crushed leaves were embedded in treatment diets at 0, 5%, 10% and 15%. Other feed ingredients that were used are maize offal, cowpea husk, cotton seed cake, bone meal and salt as displayed in Table 1.

Table 1. Ingredient Composition of the experimental diet.

Ingredients (%)	A (Control)	B	C	D
Maize offal	32.50	30.00	33.00	35.00
Cowpea husks	30.00	30.00	30.00	21.50
Cotton seed cake	20.50	18.00	14.00	11.50
Groundnut hay	15.00	15.00	15.00	15.00
Neem leaf meal	0	5.00	10.00	15.00
Bone meal	1.00	1.00	1.00	1.00
Salt	1.00	1.00	1.00	1.00
Total	100	100	100	100

2. 2. Experimental Design

The investigation was conducted in Completely Randomized Design (CRD) and involved the use of twenty (20) Yankasa rams that were randomly assigned to four (4) experimental treatments namely A, B, C, and D after being duly balanced for weight. Each treatment consisted of five (5) experimental animals and each represented a replicate.

2. 3. Experimental Animals and Management

Twenty (20) Yankasa rams of approximately the same age were purchased from Dutsin-Ma local market. These rams were kept in confinement for fourteen days to acclimatize with the environment and to be observed for any incidence of parasites infestation and diseases infection.

Prophylactic treatment were given using oxytetracycline (a broad spectrum antibiotic), Levamisole and Ivemectin was dispensed to them in order to get rid of any possible internal parasite and ecto-parasite respectively during which roughages and concentrates were fed to them.

2. 4. Growth Performance Determination

Initial weight and final weight of the experimental animals were determined at the commencement and completion of the growth trial respectively. Feed intake, weight gain, feed conversion ratio, total weight gain and average daily weight gain were determined as follows:

Feed intake = amount of feed offered- amount of feed left over

Weight gain = final weight – initial weight

Average daily weight gain = Total weight gain divided by no of days of feeding trial

Feed conversion ratio = Total amount of feed consumed divided by total weight gain.

2. 5. Digestibility Trial

Three (3) rams were chosen at random across the four groups and allocated into metabolic cage for collection of the faeces and urine samples. They spent the first seven days in the cage for adjustment and followed by the daily fecal samples collection and weighing. These samples were bulked and representative samples taken for dry matter (DM), crude protein, ether extract, crude fibre, ash and nitrogen free extract determination. The analysis of nitrogen free extract and acid detergent fibre was also carried out. Urine sample was also collected from the animals and put in a sample bottle containing 10% concentrated sulphuric acid to prevent bacterial activities and nitrogen from escaping. It was analyzed for urine nitrogen.

2. 6. Analytical Techniques

The test ingredient, samples of the experimental feeds and faeces were subjected to chemical analysis to determine the proximate composition using AOAC (2000) and crude fibre fractions by Van Soest method (1991). The urine was subjected to nitrogen composition analysis.

2. 7. Statistical Analysis

The data from the research was analyzed using ANOVA in SAS Package (2000), and significant differences between means were further evaluated using Duncan's Multiple Range Test (Duncan, 1955). The following model was used:

$$Y_{ij} = \mu + T_j + e_{ij}$$

where: Y_{ij} = Observation measured,
μ = Overall mean,
T_j = Effect of the jth treatment diet (j = 1… 5),
e_{ij} = Random error.

3. RESULTS AND DISCUSSION

3. 1. The chemical composition of test ingredient and experimental diet.

The proximate composition as depicted in Table 2 shows that the nutrient requirements of the Yankasa rams were satisfied.

Table 2. Chemical Composition of the Test Ingredient and Experimental Diet.

Parameters	**A (Control)**	**B (5%)**	**C (10%)**	**D (15%)**	**Neem leaf meal**
Dry Matter	87.20	87.40	87.20	87.80	88.72
Ether extract	4.97	5.02	4.94	4.93	2.36
Crude Protein	15.27	15.19	15.52	15.48	18.22
Crude Fibre	23.21	22.75	23.11	23.97	16.25
Ash	5.13	7.00	7.28	7.21	6.00
NFE	51.63	50.01	49.15	50.41	45.96
ADF	58.28	59.05	58.17	58.05	54.75
NDF	73.30	74.64	73.44	72.21	71.24

NFE = Nitrogen Free Extract, ADF = Acid Detergent Fibre, NDF = Neutral Detergent Fibre.

Table 1 displays the chemical composition comprising of the proximate and crude fibre analysis of the test ingredient and treatment diets. The proximate composition shows a dry matter content of 87.2 to 87.8%, crude protein (15.27 to 15.52%) and 22.75 to 23.21% of crude fibre. Ether extract value of the diets ranged from 4.93 to 5.02% and that of ash was 5.13 to 7.28%. Acid detergent fibre and nitrogen detergent fibre recorded values that ranged from 58.05 to 59.05% and 72.21 to 73.3% respectively. The proximate composition as depicted in Table 2 showed that the nutrient requirements of the Uda sheep were satisfied. The dry matter content of the experimental diet is adequate for a growing male sheep, although it is lower than the 93.05 to 96.01% reported by Aruwayo *et al*. (2022). The crude protein was within the 15 to 18% recommended for a growing sheep (ARC, 1990) and was therefore adequate for their nutritional requirement.

3. 2. Effect of Neem Leaf Meal on Growth Performance of Yankasa Ram

The results on the influence of neem leaf (*Azadirachta indica)* meal on the growth performance of Yankasa Rams are summarised in Table 3.

Table 3. Growth Performance of Yankasa Ram Fed Neem Leaf Meal Diet.

Parameters	**A (0%)**	**B (5%)**	**C (10%)**	**D (15%)**	**SEM**
Initial weight (g)	16.25	16.25	16.00	16.75	1.68
Final Weight Gain (g)	24.17	24.74	24.94	25.94	4.66
Total weight gain (g)	7.92	8.49	8.94	9.19	0.52

Average daily weight gain (g)	89.28	96.07	102.50	112.88	6.22
Feed intake (g)	937.6[a]	898.5[ab]	855.8[b]	865.5[ab]	13.29
Feed intake (DM)	801.57[a]	792.22[ab]	762.16[b]	755.39 [b]	11.26
Feed Efficiency	0.11[b]	0.12[b]	0.14[a]	0.14[a]	0.05
Cost of feed/ kg (N kg)	259.05	246.43	245.17	219.85	
Cost of feed consumed (N/kg)	20152.12[a]	19100.78[b]	19052.28[a]	15991.42[c]	4.25
COF/LWG (N kg)	2781.45[a]	2490.53[a]	2121.51[ab]	1716.24[b]	146.36

[abc]Mean within the same row with different superscript differ significantly ($p < 0.05$), COF/LWG = cost of feed per live weight gain, SEM = Standard error of mean.

Neem leaf meal has been explored as a feed additive due to its nutritional benefits and potential cost of savings in livestock diets (Garba *et al.*, 2022). The feed intake variation was significant ($p < 0.05$) across the treatments, with consumption decreasing as neem leaf meal inclusion level increased. The highest intake (937.6g) was observed in the control group, while the lowest (855.8g) was noted in the group with the highest inclusion of neem leaf meal. Reduced feed intake might be attributed to the slightly rancorous taste of neem leaf meal, as suggested by Nanang *et al*. (1997) which may affect palatability. However, reduced intake did not negatively impact weight gain, suggesting that neem leaf meal could maintain growth even at lower intake levels and it could have been due to improved nutrient utilization as a result neem meal inclusion. This research reveals non-significant ($p > 0.05$) variation final body weight gain amid the treatments which corresponds to earlier study by Sarkar *et al*. (2016) who also reported non-significant difference ($p > 0.05$) in body weight of indigenous cows fed with neem and pepper leaves.

The average daily weight gain (ADG) was higher in neem-supplemented groups aligning with findings of Amin *et al*. (2008) who observed that neem leaves significantly increased the body weight of cattle. Dida *et al*. (2019) observed that supplementation of 300gm neem leaf had a higher gain of body weight of goats and was economically feasible. Feed efficiency improved with increased neem inclusion, reaching a significant peak ($P<0.05$) of 0.14 in 10% NLM and 15% NLM. This suggests a potential benefit from neem supplementation in improving feed conversion. Efficient utilization of neem may be due to its digestibility and bioactive compounds, which have been found to enhance protein metabolism in livestock (Olafadehan, 2011). The expense of feed intake was statistically lower ($p < 0.05$) in neem-supplemented groups, particularly in the highest inclusion group (N15,991.42). Cost per kilogram of live weight gain (COF/LWG) also decreased, indicating significant ($p < 0.05$) savings in 15% NLM with N1,716.24 compared with 0% NLM (N2,781.45). Neem's bioactive properties may contribute to improved health, reducing additional feed costs (Alagbe *et al.*, 2022). Cost of feed per kg showed non-significant differences ($p > 0.05$) across groups, though a slight reduction was observed in the fourth treatment group.

This supports the economic benefit of neem inclusion, as it maintains growth performance while potentially lowering feed costs.

3. 3. Effect of Neem Leaf Mean on Nutrient Digestibility of Yankasa Ram

Table 4 shows the result of the effect of inclusion levels of neem leaf (*Azadirachta indica)* meal on the nutrient digestibility of Yankasa Rams.

Table 4. Nutrient Digestibility of Yankasa Rams Fed Neem Leaf Meal.

Parameters	A (0%)	B (5%)	C (10%)	D (15%)	SEM
Dry Matter	87.15[b]	90.16[a]	91.71[a]	90.82[a]	1.03
Crude Protein	78.61	84.84	86.16	84.53	3.16
Crude Fibre	92.55	94.86	95.32	94.84	2.58
Ether Extract	82.73[b]	88.16[a]	88.82[a]	86.45[a]	1.08
Nitrogen Free Extract	83.79[b]	86.21[ab]	89.66[a]	88.25[ab]	1.02
Acid Detergent Fibre	93.67	97.05	95.75	95.50	1.41
Neutral Detergent Fibre	92.82	94.85	95.42	94.88	1.52

[abc]Mean within the same row with different superscript differ significantly ($p < 0.05$).

Dry matter digestibility (DM) T1 (97.15%) was statistically higher ($p < 0.05$) than those of T2 (90.16%), T3 (91.71%), and T4 (90.82%). The digestibility of crude protein and crude fibre (CF) ranges from 78.61 to 86.16% and 92.55 to 95.35% respectively and reveals non-significant variation ($p > 0.05$) across the groups. Nitrogen free extract values for the digestibility revealed no significant values in T3 (89.66%) and T4(88.25%) which were significantly higher ($p < 0.05$) than T1 (83.79%) and T2 (86.21%) that were not similar to each other. All treatments had no significant differences ($p > 0.05$) in ADF and NDF digestibility values of 93.67-97.05% and 92.82 to 95.42% respectively across the treatments but are numerically different from each other.

The Table 4 shows that 10% NLM (91.71%) had significantly higher ($p < 0.05$) DM digestibility compared with 0% NLM (87.15%), 5% NLM (90.16%), and 15% NLM (90.82%). High DM digestibility suggests sufficient availability for energy and nutrient for the experimental use. According to Mijinyawa *et al*. (2022), diets containing neem leaf meal improved the digestibility of key nutrients such as DM, CP, and NDF in Yankasa rams. The higher DM digestibility in the control might be due to a lower level of neem or an optimal balance that reduces anti-nutritional effects.

Crude protein digestibility (CP) shows no significant difference among the treatments, suggesting consistent protein availability across diets. This finding aligns with results from Ogbuewu *et al*. (2011), who reported that neem leaf meal did not affect CP digestibility when included at moderate levels. However, high levels of neem in ruminant diets could potentially reduce protein digestibility due to tannins binding to proteins, thereby lowering protein availability (Kumar and Kumar, 2023).

The Crude fibre digestibility (CF) also shows non-significant differences ($p > 0.05$) among the treatments, indicating that fiber digestibility was maintained regardless of neem leaf meal inclusion. Similar results were observed by Singh and Singh (2021), who found that crude fibre digestibility in sheep was largely unaffected by neem leaf meal inclusion at up to 10% of the diet. Neem's fibre content, along with its phytochemicals, may contribute to effective fiber digestion in ruminants, as these compounds can modulate gut microbiota in a way that supports fibre breakdown.

Neem inclusion in the study supports efficient ether extract digestibility as shown with neam leaf base treatments displaying better values of 0% NLM (82.73%) 5% NLM (88.16%) 10% NLM (88.82%)15% NLM (86.45%). This is at variance with the result obtained by Prasad *et al*. (2020) which indicates that neem leaf meal does not significantly impact ether extract digestibility at lower inclusion rates, as ruminants can typically handle the lipid content in neem leaves without adverse effects on fat absorption. This stability in EE digestibility aligns with findings in cattle fed neem leaf-based diets. The outcome of the study shows that 10% NLM (89.66%) had significantly higher ($p < 0.05$) NFE digestibility, which indicates better carbohydrate digestibility in this treatment. NFE reflects the digestibility of non-fibrous carbohydrates, and in this context, studies have shown that neem leaf meal might influence carbohydrate digestibility at varying rates. According to Sharma *et al*. (2022), moderate neem leaf meal inclusion supports carbohydrate digestion, potentially due to improved ruminal fermentation patterns. There was no existence of significant variation ($p > 0.05$) in ADF and NDF digestibility in all the treatments, suggesting consistent fiber digestion across diets. Singh *et al*. (2023) found similar results, noting that neem leaf meal inclusion did not have any significant ($p > 0.05$) impact on ADF and NDF digestibility when used at moderate levels in ruminant diets. The fiber components in neem leaves can complement the diet, supporting fiber breakdown without interfering with the rumen's cellulolytic activity.

3. 4. Effect of Neem Leaf Meal on Nitrogen Utilization of Yankasa Rams

Table 5 revealed the impact of inclusion of neem leaf meal on nutrient utilization of Yankasa Rams.

Table 5. Nitrogen Utilization of Yankasa Rams Fed Neem Leaf Meal.

PARAMETERS	A (0%)	B (5%)	C (10%)	D (15%)	SEM
Nitrogen intake (g)	15.42^{ab}	16.43^{a}	14.71^{b}	16.09^{a}	0.28
Nitrogen in faeces (g)	3.29^{a}	2.40^{b}	2.09^{b}	1.96^{b}	0.18
Nitrogen in urine (g)	1.75	1.91	1.93	1.40	0.11
Nitrogen absorbed (g)	12.13^{b}	13.00^{ab}	12.62^{b}	14.13^{a}	0.28
Nitrogen balance (g)	10.40^{b}	12.12^{a}	10.68^{b}	12.13^{a}	0.31
Nitrogen retained (%)	67.30^{c}	73.76^{ab}	70.71^{b}	77.88^{a}	1.27

^{abc}Mean within the same row with different superscript differ significantly ($p < 0.05$)

Table 5 shows the results of nitrogen utilization by the experimental animals. Nitrogen intake in T2 (16.43g) had the highest intake and was significantly different ($p < 0.05$) from T3 (14.71g) and T4 (14.42g) but not significantly different ($p > 0.05$) from the control (15.42g). In the faecal nitrogen**,** T1 (3.290) showed the highest and is significantly dissimilar from ($p < 0.05$) from T2 (2.40g), T3 (2.09g) and T4 (1.96g). For urinary nitrogen, the values (1.40 to 1.93g) were not statistically similar ($p > 0.05$) from each other. Nitrogen absorbed exhibited significant differences ($p < 0.05$) among treatments, T4 (14.13g) had higher value although similar T2. T2, T3 and T1 were significantly similar ($p > 0.05$). Nitrogen balance ranged from 10.40 to 12.13 and showed statistical variations ($p < 0.05$). T4 and T2 were significantly similar ($p > 0.05$ and different from T1 and T3 which were also similar ($p > 0.05$). Nitrogen retained values were significantly different ($p < 0.05$) among the treatments and the value ranged from 67.30 to 77.88%. However, T4 was higher but significantly similar ($p > 0.05$) to T2. T1 had lower nitrogen retained values than other treatments.

Compared to similar studies, nitrogen intake often correlates with dietary protein content. The differences in faecal nitrogen often indicate variations in dietary nitrogen digestibility. This might imply lower digestibility in the control, as a larger proportion of nitrogen is excreted rather than absorbed. Research by López *et al*. (2005) found that higher-quality protein sources with better digestibility typically reduce nitrogen excretion in faeces, which aligns with the lower faecal nitrogen values in T2. This is in line with findings from studies that emphasize the role of diet formulation on nitrogen digestibility and faecal excretion (Jones and Reed, 2019). Nitrogen excretion in urine is an indicator of protein catabolism and the body's metabolic handling of excess nitrogen.

There was no statistical differences ($P > 0.05$) in urinary nitrogen values which indicates that neem meal did not impact negatively on protein metabolism of the experimental animals. Chunsheng *et al.* (2019) reported that excessive nitrogen in urine reflects inefficient nitrogen utilization, with implications for both metabolic efficiency and environmental nitrogen excretion. Nitrogen absorbed by treatment animals which shows better nitrogen absorption and nitrogen balance indicate their ability to utilize nitrogen in the neem meal based diets. Nitrogen retention is often considered a marker of protein efficiency differed significantly ($p < 0.05$) across treatments that contained neem leaf meal having better nitrogen retention.

This suggests that animals on neem meal were able efficiently utilize protein in the treatment diets. This was corroborated by Adelusi *et al*. (2019) that neem leaf support nitrogen utilization in sheep. This may reflect a balance of intake, absorption, and excretion that supports overall nitrogen utilization without excessive losses (Green, 2017).

4. CONCLUSIONS

- The proximate composition and the crude fibre fraction obtained in the study was assessed to sufficient for the nutritional needs of the experimental animals.
- Based on the growth performance, diets with higher neem leaf inclusion levels (10% and 15%) yielded better growth performance indicators. Rams fed with the 15% NLM diet had the best average daily weight gain (112.88 g/day) and total weight gain (9.47 kg) with a feed efficiency of 0.12 suggesting better efficient feed conversion. Neem leaf was discovered to have enhanced feed utilization efficiency.

- Feed cost per unit of live weight gain (COF/LWG) was lowest for the 15% (N1716.24), indicating that higher neem inclusion levels was more cost-effective.
- Treatments with neem leaf inclusion demonstrated significantly better ($P<0.05$) digestibility as shown in DM, CP, EE and NFE. The data on nitrogen absorbed, nitrogen balance and retention were significantly ($p < 0.05$) better in treatment with 15% NLM implying that neem meal improved digestion and utilization nutrients.

Recommendations

From the study, 10 to 15% inclusion of neem leaf meal, is recommended. However, the most economic level of inclusion is with 15% level which had a cheaper cost per liveweight gain.

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