Original Research Article

Performance, blood profile, rumen characteristics, and anthelminthic effects of *Leucaena leucocephala* leaf meal concentrate diets on West African Dwarf sheep

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Abstract

Sheep production in tropical regions of Africa is often hampered by a high seasonal variability of forage biomass availability with low protein concentration, in meeting their maintenance and production requirements. *Leucaena leucocephala* leaf meal as an excellent drought resistance forage supplement for ruminants was evaluated in a 105-day experiment with sixteen (16) healthy yearling West African Dwarf (WAD) rams with a weight range of 13.94 and 14.98 kg in a completely randomised design, to determine its effects on performance, haematology, serum biochemical indices, faecal egg count and rumen characteristics. Animals were assigned to four treatment groups, each with four replicates, containing 0%, 5%, 10%, and 15% *Leucaena leucocephala* leaf meal (LLLM) in a concentrated diet. A basal diet of *Panicum maximum* and water was provided *ad libitum*. Results showed that growth rates improved with the inclusion level of LLLM in the diets and ranged from 33.90 to 43.33 g/day in WAD sheep fed a 5% and 15% LLLM concentrate diet, respectively. The haematological variables varied ($p < 0.05$) across treatments. Animals fed 10% LLLM had the highest ($p < 0.05$) packed cell volume and red blood cell count (RBC). Haemoglobin concentration, mean corpuscular volume (MCV), and mean corpuscular haemoglobin (MCH) increased ($p < 0.05$) in sheep fed 10 and 15% LLLM. The white blood cell count (WBC) increased ($p < 0.05$) while mean corpuscular haemoglobin concentration (MCHC) decreased ($p < 0.05$) with higher LLLM inclusion levels. Variations were also observed in the serum biochemical indices. Total protein, albumin, globulin and creatinine increased ($p < 0.05$) in LLLM diet-fed sheep. Zero % LLLM-fed sheep had the highest value for aspartate transaminase (AST) and alanine aminotransferase (ALT) ($p < 0.05$). Cholesterol concentration decreased ($p < 0.05$) with elevated LLLM inclusion. The rumen pH increased ($p < 0.05$) while microbial count decreased ($p < 0.05$) with LLLM inclusion in the diets. Ammonia nitrogen was highest ($p < 0.05$) in animals fed 15% LLLM. *Strongyloides papillosus* were observed in the faecal egg count which reduced ($p < 0.05$) with the level of LLLM in the diet. The study concluded that feeding LLLM concentrate diet at 15% inclusion improved sheep feeding and could serve as an anthelminthic as well as a key entry point to sustainable intensification, increasing food security, and decreasing greenhouse emission intensities.

Keywords: blood; faecal egg count; *Leucaena leucocephala*; performance; rumen characteristics; sheep.

INTRODUCTION

Leucaena leucocephala are leguminous trees found as good sources of quality food with various other species being studied for their suitability as a forage plant. They are drought resistant and grow luxuriantly maintaining high-quality yield thereby having the potential to sustain small ruminant production, especially in the dry season (Odeyinka, 2001). They have over the years been developed as alternative feeding strategies with economic benefits for utilising limited feed supply in ruminant production systems (Adejumo and Ademosun, 1991; Moreira et al. 2021). This leguminous tree is abundant in the tropics and valued for its high-quality protein forage and its favourable amino acid profile (Ahmed and Abdelati, 2009), offering significant nutritional benefits as a protein-rich forage to fill dietary gaps for ruminants.

The inclusion of *Leucaena* in animal feed has demonstrated promising results in growth rate, dry matter (DM) digestibility, DM intake, and weight gain (Phenvichith and Ledin, 2007, Fasae et al., 2011a). Its high crude protein content, digestibility, and low fibre content make *Leucaena leucocephala* an excellent supplement for ruminants in the tropics. Studies show its potential to enhance rumen function by providing essential proteins and increasing the availability of compounds like ammonia, amino acids, peptides, and branched short-chain fatty acids. These substances, resulting from protein degradation, promote fibre breakdown by stimulating the growth of rumen bacteria, especially cellulolytic bacteria (El-Deeb et al., 2010). Additionally, the presence of bioactive substances such as tannin has significantly been reported to improve productive performance, serving as a practical and realistic alternative to non-drug gastro-intestinal parasite control strategies as well as supporting the manipulation of rumen fermentation to induce methane mitigation in ruminant production systems (Mahanani et al., 2020; Fasae and Adelusi, 2024). Given these benefits, an increase in the production and utilisation of *Leucaena leucocephala* should be prioritised as its exploitation in its inclusion in diets for sheep production. It is hypothesised that including *Leucaena leucocephala* leaf meal in a concentrated diet significantly impacts the growth performance, blood profile, faecal egg count, and rumen characteristics of Dwarf sheep. This study therefore aimed to use *Leucaena leucocephala* leaf meal to partially replace concentrated protein in feed, by assessing its response on the West African Dwarf breed of sheep.

MATERIALS AND METHODS

Experimental animals and management

The experiment was conducted at the Directorate of University Farm of the Federal University of Agriculture, located in the Odeda Local Government Area of Abeokuta, Ogun State, Nigeria.

The experiment commenced after the approval by the Ethical Committee of the College of Animal Science and Livestock Production, Federal University of Agriculture, Abeokuta, Nigeria with Approval Reference: FUNAAB/COLANIM/AEWC/2022/09/05. Fresh leaves of *Leucaena leucocephala* were harvested from designated plots within the University a month after the second year of flowering and the leaves were then air-dried and ground into a meal. The *Leucaena leucocephala* leaf meal (LLLM) was incorporated into a concentrate diet at inclusion levels of 0%, 5%, 10%, and 15% (Table 1). A total of sixteen (16) healthy yearling West African Dwarf (WAD) rams with a weight range of 13.94 and 14.98 kg were randomly chosen from the flock at the University's Teaching and Research Farm. The animals were fed 300 grams of concentrate daily at 08:00 and *Panicum maximum* at 14:00.

Data collection

Feed intake was measured and recorded daily and weekly for each treatment replicates by subtracting

Table 1. Experimental diet formulation

Ingredients	0% LLLM	5% LLLM	10% LLLM	15% LLLM
Leucaena leucocephala	0	5	10	15
Maize offal	24	24	24	24
Palm kernel cake	30	25	20	15
Wheat offal	28	28	28	28
Rice bran	15	15	15	15
Bone	2.5	2.5	2.5	2.5
*Premix	0.5	0.5	0.5	0.5
Total	100	100	100	100

LLLM – *Leucaena leucocephala* leaf meal
* Vitamin A – 10,000,000 i.u, Vitamin D3 – 2,500,000 i.u, Vitamin E – 20,000 i.u, Vitamin K – 3,000 mg, Vitamin B1 – 1,500 mg, Vitamin B2 – 3,000 mg, Vitamin B3 – 1,500 mg, Vitamin B12 – 15 mcg, Biotin – 15 mcg, Niacin – 15,000 mg, Pantothenic Acid – 5,000 mg, Folic Acid – 1,500 mg, Manganese – 80,000 mg, Zinc – 50,000 mg, Cobalt – 500 mg, Iron – 20,000 mg, Copper – 5,000 mg, Lodina – 1,000 mg, Selenium – 200 mg, Choline – 250,000 mg, Antiodium – 125,000 mg, *Azadiractha indica* – 0.1%, *Allium sativum* – 0.5%, *Zingiber officinale* – 0.2%, *Curcuma longo* – 0.1%.

Table 2. Chemical composition (%) of *Leucaena leucocephala* leaf meal-based concentrate

Parameters	0% LLLM	5% LLLM	10% LLLM	15% LLLM	LLLM	SEM
Dry matter	92.99^{a}	92.91^{a}	92.79^{a}	91.89^{a}	87.66^{b}	6.22
Crude protein	14.73^{c}	15.41^{bc}	16.87^{b}	17.81^{ab}	21.10^{a}	2.01
Ether extract	15.00^{b}	17.05^{a}	15.03^{b}	12.75^{c}	8.02^{d}	1.84
Ash	3.45^{c}	6.67^{a}	4.05^{b}	5.23^{a}	8.70^{a}	1.29
Neutral detergent fibre	34.30	37.10	30.40	32.50	39.00	3.45
Acid detergent fibre	19.60	19.30	20.40	18.20	19.00	2.12
Acid detergent lignin	5.80	6.20	5.40	5.00	5.70	0.83

^{abc} means with the same superscript within the rows are not significantly different ($p > 0.05$)
LLLM – *Leucaena leucocephala* leaf meal

the leftovers from the amount initially offered to each WAD sheep. The body weight gain for each sheep was determined by weighing the sheep and recording the weight every week. The feed conversion ratio was calculated by dividing the total feed intake by the body weight gain of each sheep. Blood samples were collected from each experimental sheep for haematological and biochemical analysis.

In the final week of the experiment, rumen fluid samples were collected from two sheep per treatment at 0 hours before feeding and 6 hours after feeding, and the pH was measured using a portable pH meter (HANNA Instruments HI 98153). Filtered rumen fluid was stored in air-tight bottles and frozen for subsequent analysis of ammonia nitrogen concentrations, as determined by the method of Lanyansunya et al. (2007). For microbial analysis, 10 ml of rumen fluid samples were collected from two sheep per treatment before the morning feeding (Galyean, 1989). Faecal samples were taken at the experiment's beginning, middle, and end to determine the number of eggs or larvae per gram of faeces using the McMaster egg count technique.

Statistical analysis

Data collection was subjected to a one-way Analysis of Variance using the SAS (1999) package and the means were separated using the Duncan multiple range test of the same software at a 5% level of significance.

RESULTS

The result of chemical composition (%) of *Leucaena leucocephala* leaf meal-based concentrate Table 2. The crude protein content increased ($p < 0.05$) by including the LLLM in the diets. LLLM had the least ($p < 0.05$) dry matter (DM) content followed by diets with 15% LLLM which ranked the same ($p > 0.05$) with other dietary treatments. Ash content varied ($p < 0.05$) across treatments with LLLM having the highest and 0% LLLM with the lowest content.

Table 3 shows the performance of West African Dwarf sheep fed varying levels of *Leucaena leucocephala* leaf meal concentrate. The 15% inclusion level of LLLM in sheep's diet brought about the highest final weight, weight gain, weight gain per day, and the best feed conversion ratio, while sheep fed 0% LLLM had the highest metabolic weight.

Table 3. Performance of West African Dwarf sheep fed varying levels of *Leucaena leucocephala* leaf meal concentrate

Parameters	0% LLLM	5% LLLM	10% LLLM	15% LLLM	SEM
Concentrate intake (g/day)	150.30^{d}	155.10^{b}	160.93^{a}	154.06^{c}	0.172
Forage intake (g/day)	427.26^{b}	435.48^{a}	419.09^{c}	390.26^{d}	0.319
Total feed intake (g/day)	577.56^{c}	590.58^{a}	580.02^{b}	544.32^{d}	0.170
Initial weight (kg)	13.94^{b}	14.98^{a}	14.03^{b}	14.07^{b}	0.045
Final weight (kg)	18.01^{b}	18.54^{a}	17.95^{b}	18.62^{a}	0.021
Weight gain (kg)	4.07^{b}	3.56^{c}	3.92^{b}	4.55^{a}	0.038
Weight gain (g/day)	38.76^{b}	33.90^{d}	37.33^{c}	43.33^{a}	0.038
Metabolic weight gain ($W^{0.75kg}$)	18.40^{a}	11.63^{d}	16.48^{c}	17.75^{b}	0.104
Feed conversion ratio	14.90^{c}	17.42^{a}	15.54^{b}	12.56^{d}	0.054

^{abcd} means with the same superscript within the rows are not significantly different ($p > 0.05$)
LLLM – *Leucaena leucocephala* leaf meal

Table 4. Haematological variables of West African Dwarf sheep fed *Leucaena leucocephala* leaf meal-based concentrate diets

Variables	0% LLLM	5% LLLM	10% LLLM	15% LLLM	SEM
Packed cell volume (%)					
Initial	42.38^{a}	38.20^{b}	44.71^{a}	42.08^{a}	0.211
Final	42.00^{b}	36.00^{d}	44.00^{a}	40.00^{c}	0.250
Haemoglobin (g/L)					
Initial	14.01^{a}	13.25^{b}	15.31^{a}	14.13^{a}	0.405
Final	13.20^{ab}	12.00^{b}	14.55^{a}	13.05^{ab}	0.456
Red blood cell (×10^{12}/L)					
Initial	9.67^{a}	8.61^{b}	9.76^{a}	8.84^{b}	0.018
Final	9.70^{b}	8.75^{c}	9.85^{a}	8.90^{c}	0.025
White blood cell (× 10^{9}/L)					
Initial	6.99^{b}	7.01^{ab}	7.61^{a}	7.65^{a}	0.020
Final	7.10^{b}	7.05^{b}	7.70^{a}	7.75^{a}	0.028
Neutrophils (× 10^{9}/L)					
Initial	32.76^{a}	24.95^{c}	26.91^{b}	29.01^{b}	0.020
Final	32.00^{a}	25.50^{c}	27.50^{b}	28.50^{b}	0.025
Lymphocytes (× 10^{9}/L)					
Initial	57.09^{b}	60.98^{a}	59.12^{b}	44.28^{c}	0.487
Final	57.00^{b}	61.50^{a}	59.00^{b}	44.50^{c}	0.490
Eosinophils (× 10^{9}/L)					
Initial	0.00^{b}	0.50^{a}	0.50^{a}	0.50^{a}	0.004
Final	0.00^{b}	0.50^{a}	0.50^{a}	0.00^{b}	0.006
Basophils (x 10^{9}/L)					
Initial	0.50^{c}	1.00^{b}	1.00^{a}	0.50^{c}	0.025
Final	0.50^{c}	1.00^{b}	1.50^{a}	0.50^{c}	0.027
Monocytes (× 10^{9}/L)					
Initial	0.50^{b}	0.00^{c}	1.50^{a}	1.50^{a}	0.004
Final	0.50^{b}	0.00^{c}	1.50^{a}	1.50^{a}	0.005
MCV (fL)					
Initial	42.31^{b}	41.32^{b}	44.68^{a}	44.72^{a}	0.014
Final	42.97^{b}	41.71^{b}	44.82^{a}	45.01^{a}	0.015
MCH (pg)					
Initial	11.41^{b}	11.99^{b}	12.03^{a}	12.47^{a}	0.079
Final	11.62^{b}	11.82^{b}	12.17^{a}	12.60^{a}	0.090
MCHC (g/L)					
Initial	313.20^{c}	336.10^{a}	334.40^{b}	325.10^{c}	0.041
Final	314.40^{d}	334.90^{a}	331.00^{b}	326.70^{c}	0.040

^{abc} means with the same superscript within the rows are not significantly different ($p > 0.05$)
LLLM – *Leucaena leucocephala* leaf meal

The haematological variables of West African Dwarf sheep fed *Leucaena leucocephala* leaf meal-based concentrate diets are presented in Table 4. The animals fed 10% LLLM had the highest ($p < 0.05$) values for packed cell volume and red blood cell count (RBC). The haemoglobin concentration, mean corpuscular volume (MCV) and mean corpuscular haemoglobin (MCH) increased ($p < 0.05$) in sheep fed 10 and 15% LLLM inclusion levels. White blood cell count (WBC) increased ($p < 0.05$) while mean corpuscular haemoglobin concentration (MCHC) decreased ($p < 0.05$) with a higher level of LLLM in the diets. There were variations ($p > 0.05$) within the initial and final values across the variables. Packed cell volume and haemoglobin values were initially higher across the treatments while red blood cells, white blood cells, and mean corpuscular volume were higher for the final values. Mean corpuscular haemoglobin was lower for final values in animals fed 5% LLLM with mean corpuscular haemoglobin concentration having lower final values for 5 and 10% LLLM.

Table 5. Serum biochemical parameters of West African Dwarf sheep fed *Leucaena leucocephala* leaf meal-based concentrate diets

Parameters	0%LLLM	5%LLLM	10%LLLM	15%LLLM	SEM
Total protein (g/L)					
Initial	65.20[c]	78.90[b]	88.70[a]	77.40[b]	0.275
Final	66.00[b]	65.00[b]	84.00[a]	60.50[b]	0.215
Albumin (g/L)					
Initial	45.00[b]	47.70[a]	46.20[a]	46.90[a]	0.135
Final	42.00[b]	43.50[a]	42.50[b]	43.50[a]	0.167
Globulin (g/L)					
Initial	25.10[b]	31.20[b]	42.50[a]	30.50[b]	0.076
Final	24.00[b]	21.50[b]	41.50[a]	17.00[c]	0.082
Creatinine (μmol/L)					
Initial	0.71[b]	1.06[ab]	1.75[a]	1.81[a]	0.013
Final	0.68[d]	1.32[c]	2.06[a]	1.86[b]	0.014
Cholesterol (μmol/L)					
Initial	122.21[a]	111.43[b]	109.72[b]	83.22[c]	0.055
Final	120.70[a]	105.90[c]	112.95[b]	83.40[d]	0.058
Aspartate transaminase (u/L)					
Initial	124.30[a]	74.51[c]	84.01[b]	79.08[b]	0.245
Final	125.00[a]	73.50[d]	82.50[b]	77.00[c]	0.234
Alanine aminotransferase (u/L)					
Initial	57.77[ab]	51.22[b]	52.22[b]	51.09[b]	0.501
Final	63.00[a]	54.50[c]	58.50[b]	58.00[b]	0.478

[abcd] means with the same superscript within the rows are not significantly different ($p > 0.05$)
LLLM – *Leucaena leucocephala* leaf meal

Table 6. The effect of dietary supplement inclusion of *Leucaena leucocephala* leaf meal concentrate diets on rumen pH, ammonia nitrogen and total bacteria count of West African Dwarf sheep

Parameters	0% LLLM	5% LLLM	10% LLLM	15% LLLM	SEM
pH	6.05[d]	6.55[c]	7.05[b]	7.25[a]	0.041
Ammonia nitrogen concentrate (mg/ml)	3.40[b]	3.85[a]	3.05[c]	4.10[a]	0.073
Total bacteria count × (10^5cfu/ml)	1.65[a]	1.20[b]	1.55[a]	0 .35[c]	0.061

LLLM – *Leucaena leucocephala* leaf meal
[abcd] means within the same row with different superscripts differ significantly ($p < 0.05$).

Table 5 shows serum biochemical variables of West African Dwarf sheep fed *Leucaena leucocephala* leaf meal-based concentrate diets. Total protein, Albumin, Globulin and creatinine values increased ($p < 0.05$) in LLLM diets. Zero % LLLM had the highest value of cholesterol, Aspartate transaminase (AST) and Alanine aminotransferase (ALT) ($p < 0.05$). The 15% LLLM concentrate brought about the lowest value of cholesterol indicating that as the level of LLLM increased there was a decrease in cholesterol level.

Table 6 shows the effect of dietary supplement inclusion of *Leucaena leucocephala* leaf meal concentrate diets on rumen pH, ammonia nitrogen, and microbial count of West African Dwarf sheep. The values for the pH increased ($p < 0.05$) with the inclusion levels of LLLM in the diets while ammonia nitrogen was highest ($p < 0.05$) in animals fed 15% LLLM. Microbial count decreased as the inclusion level of LLLM increased.

Figure 1 shows the effect of the *Leucaena leucocephala* concentrate diet on *Strongyloides papillosus* which was influenced by the inclusion of LLLM when fed to WAD sheep.

DISCUSSION

The crude protein content of *Leucaena leucocephala* leaves in this study was slightly higher than the 20.80% reported by Ayssiwede et al. (2011) but was within the range (19.60–26.79) reported for reviewed values for *Leucaena leucocephala* leaves (Fasae and Adelusi, 2024). The supplementation with mixed concentrate resulted in the highest dietary protein availability, hence the highest crude protein levels, similar to earlier observations (Arigbede, 2007). Studies on leguminous

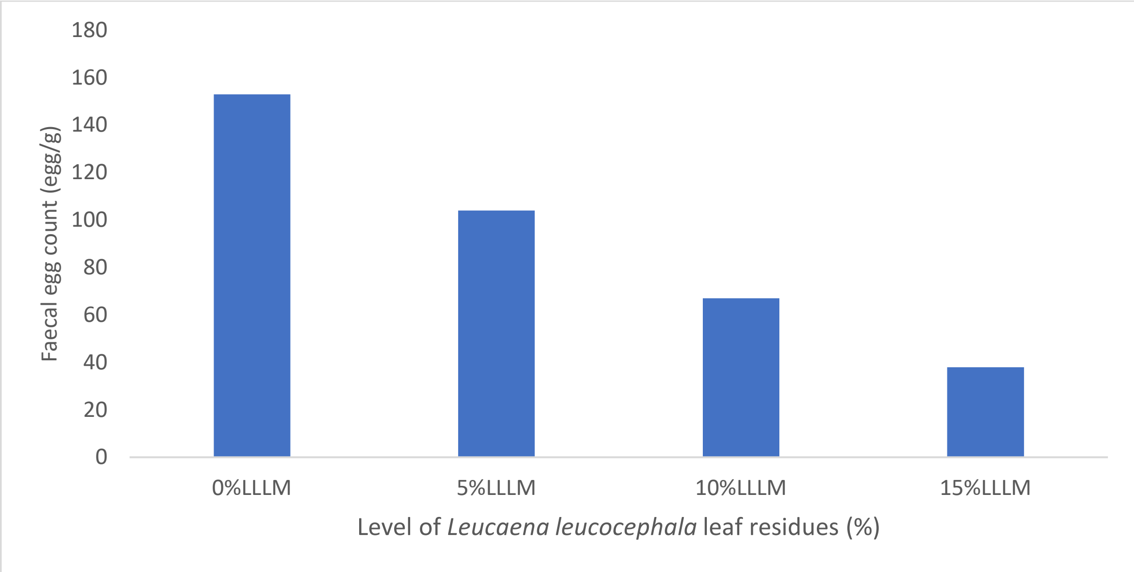

Figure 1. Effect of *Leucaena leucocephala* meal concentrate diet on *Strongyloides papillosus* in West African Dwarf sheep

plants like *Leucaena leucocephala* leaves have shown to be important nutrient-rich feed resources for ruminant production (Pamo et al., 2005). The dietary NDF contents for LLLM species were within the permissible limit guaranteed as optimal intake of tropical feeds by ruminant animals (Van Soest, 1994).

The dry matter content LLLM concentrate diet decreased with each level of inclusion in the diet, aligned with the reports of Edeoga et al. (2006), who observed a dry matter content of 92.80%. This variation could be due to differences in the leaf processing method. The crude protein (CP) content of concentrate diets with varying inclusion of LLLM fed to WAD sheep in this study is higher than the 8% level required for optimal rumen microbial activity (Nagaraja, 2016). These levels also exceed the range of 11.00% to 13.00% known to provide adequate protein for maintenance and moderate growth in ruminants (Sanusi et al., 2013). Ranjahan (2004) reported that insufficient protein provision in a growing animal could likely alter the efficiency of metabolisable energy utilisation.

Leucaena has been identified to contain high amounts of protein, which have been found to enhance feed utilisation thereby improving the rumen ecosystem. Other studies have further shown that Leucaena inclusion in sheep's diet increased voluntary dry matter intake (Fasae et al., 2011a), which corroborates the findings of this study and could have increased digestible organic matter intake by supplying the deficient nutrients in the concentrate diets. Moreover, the low NDF content of the experiment diets in the current study was less than 60%, which showed that low fibre content could be a limitless factor for feed intake since voluntary intake and NDF content are negatively correlated (Ensiminger et al., 1990).

The weight gain (g/day) is within the range values reported for the same breed of sheep (Ndamukong et al., 2010; Fasae et al., 2011b). Lower values (23.33 to 28.57 g/day) were however reported by Odeyinka (1999) for WAD sheep fed Leucaena and Gliricidia leaves, and higher values of 46.00 to 56.00 g/day stated by Adejumo and Ademosun (1991) for WAD sheep on *Panicum maximum*-based diets supplemented with lablab, Leucaena, and Gliricidia foliage. Differences could be attributed to variations in the basal components of the diets, voluntary dry matter intake, feed utilisation efficiency, and the animals' physiological state. Weight gain increased with the level of LLLM in the diets, which could be attributed to more efficient feed utilisation, as indicated by lower feed conversion ratios. The low performance of sheep on 5% LLLM dietary treatment could be attributed to the lower nutrient density extracted from Leucaena which reduced the daily requirement of the animals. Thus, the unbalanced nature of the nutrients that arise from the digestion of LLLM seems to be the major reason for the low weights.

The feed conversion ratio was best in sheep fed 15% LLLM. In comparison, the worst value in sheep fed 5% LLLM which followed the same pattern as weight gain (g/day) could be ascribed to the influence of better nutrient density and quality of nutrients available for utilisation (Tripathi et al., 2006, Odusanya et al., 2017). Orden et al. (2000) suggested that a more efficient synthesis of tissue protein from the ingested feed in the reticule-rumen could contribute to this, and consistent with the findings of Yahaya et al. (2001), who highlighted that improved nitrogen status from Leucaena supplementation enhanced feed intake with favourable growth rates.

The values for packed cell volume, haemoglobin concentration, and red blood cell count were within the physiological ranges reported in various studies for healthy sheep (RAR, 2009; Olayemi et al., 2000; Yusuf et al., 2024). The low post-feeding values observed for packed cell volume and haemoglobin concentration in experimental sheep fed LLLM corroborates the findings of Prasad (1988) in sheep fed Leucaena diet, which was attributed to the influence of anti-nutritional factors in Leucaena. Additionally, the mean corpuscular volume and white blood cell count were within the normal ranges for clinically healthy sheep. Merck (2012) reported a mean corpuscular haemoglobin concentration range of 31–34 g/dL, RAR (2009) reported a mean corpuscular volume range of 4–12 × 10^3/µL, and both RAR (2009) and Merck and Kaplan (2011) reported a white blood cell count range of 23–48 fl. The mean corpuscular haemoglobin values were within the normal range of 8–12 pg (RAR, 2009; Merck, 2012) for healthy sheep but were lower than those reported by Adegun et al. (2011) in sheep fed a Leucaena-based multi-nutrient block. The significantly different values reported in this study decreased with increasing levels of Leucaena inclusion, consistent with Bottini-Luzardo et al. (2016) who reported reduced mean corpuscular haemoglobin values in cattle consuming tannin-rich mature oak (*Quercus incana*) leaves.

The reduction in blood cholesterol (g/L) in sheep-fed LLLM concentrate diets could be attributed to some types of plant antinutrients, such as tannin and saponins, causing a decline in intestinal cholesterol absorption (Nath et al., 2022), which may be the reason behind the cholesterol-lowering effect of LLLM. The AST values fell within the normal reference range of 66–230 IU/L as reported by Merck (2012). This finding aligns with Mahmoud (2013), who observed significantly ($p < 0.05$) reduced AST values with increasing levels of Leucaena stem inclusion in growing lambs. The mean ALT values in WAD sheep fed 5%, 10%, and 15% inclusion levels of Leucaena were lower than the normal reference range of 15–52 IU/L reported by Merck and Kaplan (2011). The significantly lower ALT values observed in this study are supported by Mahmoud (2013), who also reported a significant reduction with increased Leucaena inclusion in growing lambs. Additionally, the values for eosinophils, basophils, and monocytes in this study show their importance as crucial in regulating allergic and inflammatory responses and defending against parasitic infections such as helminthiasis and ectoparasitic infestations (Byanet et al., 2008). The low eosinophil numbers observed in our study indicate that the experimental sheep did not exhibit hypersensitivity reactions to the diets provided.

Strongyloides papillosus as the predominant parasite identified in the faecal egg counts of sheep in this study corroborates earlier reports of its prevalence with significant differences existing for the season, management system, and ecological zone prevalence in sheep across most parts of Nigeria (Anene et al., 1994). The supplemented treatments showed a reduction in egg counts of *Strongyloides papillosus* with increasing levels of LLLM concentrate, while the unsupplemented treatment of 0% inclusion LLLM had the highest egg counts. Worms are a major health problem in ruminant production, significantly ($p < 0.05$) impeding sheep production economically (Buzzulini et al., 2007). The anthelmintic properties of Leucaena, as revealed in this study, indicate that the plant can be used to control helminths. The extracts may disrupt the parasite's lifecycle at the trophozoite stage, preventing further development into adult helminths (Egharevba and Ikhatua, 2008).

This finding aligns with a study by Daniel et al. (2013), who noted that while complete eradication of parasites might be impossible due to their survival strategies, inhibiting their lifecycle can effectively control the disease. Hernández et al. (2014) evaluated an *in vivo* study on *Leucaena leucocephala* extract at a dose of 30 ml per day, determining a reduction of 54% in the elimination of eggs and adult parasites in Katahdin-Pelibuey lambs.

In addition, Daniel et al. (2015) reported that controlling livestock helminths can be achieved through the anthelmintic effects of certain approved commercial regimens, which hinder trophozoites from completing their lifecycle. The motility of trophozoites was gradually inhibited upon introducing the extracts; higher extract concentrations resulted in quicker mortality.

This study suggests that incorporating these plant extracts into sheep feed could help control parasites by interfering with their development. Given the widespread availability of these medicinal plants and the reported resistance of adult helminths to conventional anthelmintic treatments, this alternative method of helminth control could be adopted to break the parasite's lifecycle and halt its progression into adulthood. This method is cost-effective, easy to implement, and could complement existing commercial chemical anthelmintics.

In our study observed rumen pH values were slightly above the reported values (6.00–7.20) optimal for rumen microbial growth and activity (Jallow and Hsia, 2011; Petrovski, 2017). The higher rumen pH in animals on experimental diets may be due to consuming less fermentable feed components. Diets high in protein can induce certain reactions, possibly contributing to the high pH observed in 15% LLLM (Ranjahan, 2001). However, differing results were reported for ruminal pH concerned with the ruminal fluid of ruminants fed values (Mahanta et al., 1998).

Rumen ammonia nitrogen concentration (NH_3-N) with significantly higher values observed in 15% LLLM, reflects adequate crude protein degradability and microbial protein synthesis. Additional protein from Leucaena could increase ammonia availability, stimulating microbial growth and forage breakdown, thereby increasing diet passage rate and voluntary intake (Kakengi et al., 2001). The rumen harbours various facultative anaerobic bacterial communities crucial for fermenting and digesting nutrients, maintaining biological activities, and promoting growth and performance (Morgavi et al., 2010; Vohra et al., 2016).

However, the increase in CP intake from *Leucaena leucocephala* has been reported to induce higher N excretion in the urine, probably leading to higher nitrous oxide emissions with a reduction in enteric methane emissions (Harrison et al., 2015) in ruminants. Methane production by ruminants is a natural process that originates in the rumen during feed digestion at which several microorganism species known as methanogens convert feed such as proteins and starch into amino acids and sugars which are then fermented to become volatile fatty acids, while molecular hydrogen released during the production of acetate and butyrate in the rumen and CO_2 are reduced to methane (Greening et al., 2019).

The amount of methane produced in the rumen depends on the characteristics of the diet. *Leucaena leucocephala* contains secondary metabolite tannins responsible for bounding and precipitating proteins and aids methane mitigation. Albores et al. (2019) observed that using *Leucaena leucocephala* caused a reduction in the daily methane emission of 11–31.56% when the legume was increased from 22% to 44% of the total DM intake. A diversity of other results has been reported in the literature regarding the effect of tropical tree metabolites on ruminal microorganisms and methane emissions (Canul-Solis et al., 2020).

CONCLUSION AND RECOMMENDATIONS

In conclusion, the inclusion of *Leucaena leucocephala* up to 15% improved the growth performance, resulted in no adverse effect on blood indices, gave the best reduction in faecal egg count, and had a positive effect on the ruminal pH of West African Dwarf sheep. *Leucaena leucocephala* meal at 15% inclusion in a concentrate diet could serve as a potential dry season supplementary protein feedstuff source, anthelmintics, and a candidate in mitigating enteric methane production in sheep production systems.

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CONFLICT OF INTEREST

The authors declared no conflicts of interest concerning the research, authorship, and publication of this article.

ETHICAL COMPLIANCE

The authors have followed ethical standards in conducting the research and preparing the manuscript.

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