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Growth, Rumen Ecology Apparent Nutrient Digestibility and Economics of Feed Conversion in Uda Sheep fed Concentrate Diets containing Ensiled Urea-Molasses Treated Soybean Haulms

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ABSTRACT

This study evaluated the effects of incorporating ensiled urea–molasses treated soybean haulms into concentrate diets on growth performance, rumen ecology, nutrient digestibility, and economics of feed conversion in Uda rams. Soybean haulms were treated with a solution of urea and molasses (4:1 w/w), ensiled at 70% moisture, thereafter dried and included in experimental diets at 0, 30, 40 and 50%, (T1, T2, T3 and T4). Twenty yearling Uda rams with average weight of 12.60 ± 0.20 kg used in the experiment were distributed into four groups and assigned to one of the experimental diets in a completely randomized design (CRD). The feeding trail lasted for 84 days. Results showed that all growth indices were not significantly affected ($p>0.05$) by dietary treatments. There was significantly higher total volatile fatty acids, acetate, and propionate concentrations ($p<0.05$), in supplemented groups with rumen pH remaining stable ($p>0.05$). There was significantly higher ($p<0.05$) total and amylolytic bacteria populations in rams fed 30% and 40% inclusion of processed soybean haulms, while protozoa and fungi populations were largely unaffected. Apparent nutrient digestibility coefficients were not significantly ($p>0.05$) influenced, except for nitrogen-free extract digestibility, which declined at the 50% inclusion level. There was a progressive reduction in total feed cost and improved cost efficiency with inclusion of treated soybean haulms, with the lowest feed cost per kilogram weight gain observed at 40% inclusion. It is recommended that processed soybean haulms can be included in concentrate diets of Uda rams up to 40% for optimum production.

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INTRODUCTION

Small ruminants have played crucial role in the livelihoods of rural households especially in Nigeria and other developing countries, thereby contributing significantly to food security, income generation, and socio-cultural activities. Among the indigenous sheep breeds, the Uda sheep is highly valued for its adaptability to harsh environmental conditions, efficient utilization of fibrous feeds, and ability to thrive under extensive production systems. However, productivity of sheep in the tropics is constrained by seasonal fluctuations in the availability and quality of feed resources, particularly during the dry season when natural pastures become scarce and deficient in essential nutrients (Arowolo and He, 2018).

The high cost and competition for conventional feed ingredients such as maize, soybean meal, and groundnut cake have necessitated the exploration of alternative and locally available feed resources for sustainable ruminant production. Crop residues and agro-industrial by-products represent an important feed resource for ruminants because of their abundance and relatively low cost. Among these crop residues, soybean haulms, the vegetative parts remaining after harvesting soybean grains, are readily available in many farming communities and possess moderate nutritive value. Soybean haulms contain appreciable amounts of crude protein and minerals, making them potentially useful as roughage sources in ruminant diets (Ogu *et al.*, 2024). However, their utilization is often limited by high fibre content, low digestibility, and poor palatability, which reduce voluntary feed intake and animal performance.

Various physical, chemical, and biological treatments have been employed to improve the feeding value of crop residues. Urea treatment has been widely recognized as an effective method for improving the nutritive quality of low-quality roughages through ammoniation, which disrupts lignocellulosic linkages, increases nitrogen availability, and enhances fibre digestibility, thereby improving feed utilization by ruminants (Gunun *et al*., 2013; Abdulazeez, 2024; Ogu *et al*., 2024) Molasses, on the other hand, serves as a readily fermentable energy source that improves palatability and provides substrates for microbial growth during ensiling. The combination of urea and molasses has been shown to improve the fermentation characteristics, nutrient composition, and utilization of crop residues by ruminants (Mordenti *et al*., 2021). Ensiling crop residues with urea and molasses can therefore enhance their preservation and feeding value while reducing nutrient losses during storage.

Rumen ecology is a critical determinant of ruminant productivity because microbial populations in the rumen are responsible for the fermentation and degradation of fibrous feed materials. The efficiency of ruminal fermentation influences nutrient digestibility, microbial protein synthesis, and ultimately animal growth performance (Russell and Rychlik, 2001). Dietary modifications that improve the availability of fermentable nitrogen and energy can stimulate microbial activity, enhance rumen fermentation, and increase nutrient utilization. Therefore, in assessing dietary regime, rumen parameters such as ruminal pH, ammonia nitrogen concentration, and volatile fatty acid production will provide insight into the effectiveness of treating soybean haulms with urea and molasses and subsequent ensiling.

Growth performance and nutrient digestibility are important indicators of the suitability of alternative feed resources in ruminant nutrition. Improved nutrient digestibility generally leads to increased nutrient availability for maintenance and growth, resulting in better feed conversion efficiency and weight gain (McDonald *et al*., 2011). Previous studies have reported improvements in intake, digestibility, and growth performance of sheep and goats fed urea-treated crop residues (Khattab *et al*., 2013; Xu *et al*., 2019; Ngele *et al*., 2020; Vorlaphim *et al*., 2021); however, information on the utilization of ensiled urea-molasses treated soybean haulms in diets of Uda sheep remains limited. Therefore, this study was conducted to evaluate the effects of incorporating ensiled urea-molasses treated soybean haulms into concentrate diets at 0, 30, 40, and 50% inclusion levels on growth performance, rumen ecology, and apparent nutrient digestibility of Uda rams.

MATERIALS AND METHODS

Experimental Area

The field experiment was conducted at Animal Science Teaching and Research Farm, Joseph Sarwuan Tarka University Makurdi (JoSTUM), Benue State, Nigeria. Laboratory evaluation of rumen kinetics was carried out in the Animal Nutrition laboratory of the Department of Animal Nutrition, College of Animal Science, Joseph Sarwuan Tarka University, Makurdi. Makurdi is located in the Guinea savannah zone of Nigeria, with geographical coordinates of approximately 8°53′N and 7°73′E as determined using Google Earth (Google, 2023).. The various weather parameters in Makurdi are as reported in Ikyume *et al.* (2025)

Treatment of Soybean Haulms

Molasses, urea and water utilized in processing of soybean haulms represented 1:4:70 part of the total soybean haulms that were processed. The soybean haulms were thoroughly mixed with the solution prepared in the ration mentioned above and ensiled for 21 days. The details of the processing procedures are as described in the work of Ogu *et al*. (2024).

Experimental Design and Diets

The experimental design was a completely randomized design with five (5) replicates in each treatment. There were four experimental diets which contained varying inclusion levels of the processed soybean haulms and served as the different treatments. The four treatment diets were designated as T1, T2, T3 and T4 with soybean haulms inclusion levels of 0, 30, 40 and 50% respectively. The gross composition of the treatment diets is presented in Table 1. Five (5) rams were assigned to each of the different diets with each ram serving as a replicate.

Experimental Animals, Housing, and Management

Twenty (20) yearling Uda rams (10-13 Kg) purchased from the livestock market in the Lafia local government area of Nasarawa State were used in this experiment. Prior to the commencement of the experiment, the rams were quarantined for six weeks, during which they were given prophylaxis treatment to ensure they remained healthy during the experiment. They were administered with antibiotics (oxytetracycline, LA), given multivitamins to boost their appetite and treated for endo and ecto parasite using ivermectin. Other husbandry practices were carried out throughout the experimental period. The animals were housed in individual pens (which were already washed, disinfected with the ideal solution and allowed to fallow for two weeks before the animals' arrival) and managed on a basal diet (*Panicum maximun*) and experimental diets throughout the experimental period at 4% of their body weight each for 84 days. They were also allowed access to clean water *ad libitum.*

Table 1: Gross Composition of Experimental Diets

Ingredients		Treatment Diets		
	T1 (0 %)	**T2 (30 %)**	**T3 (40 %)**	**T4 (50 %)**
Maize	50	20	10	-
Soybean meal	10	10	10	10
Rice offal	10	10	10	10
Palm kernel cake	25	25	25	25
Processed soybean haulms	-	30	40	50
Bone meal	3	3	3	3
Vitamin Premix	1	1	1	1
Table salt	1	1	1	1
Total	**100**	**100**	**100**	**100**

T1= 0% inclusion of urea-molasses treated ensiled soybean haulms,
T2= 30% inclusion of urea-molasses treated ensiled soybean haulms
T3=40% inclusion of urea-molasses treated ensiled soybean haulms
T4= 50% inclusion of urea-molasses treated ensiled soybean haulms

Data Collection

Growth Performance

The initial body weight of the animals was determined before commencement of the experiment with the aid of a weighing scale. Weights of the rams were taken weekly to monitor the progression in the weight changes until the 12th week where final body weight was also measured. The following indices were taken to measure the growth performances of the animals

$$Weight\ gain\ (kg) = Final\ weight - Initial\ weight$$
$$Feed\ Intake\ (kg) = Feed\ offered - feed\ left\ over$$
$$Feed\ conversion\ ratio = \frac{Feed\ intake\ (kg)}{Weight\ gain\ (kg)}$$

Determination of Rumen pH, Metabolites and Microbial Counts

On the day of sampling, rumen fluid were collected 6 hours post-feeding of experimental diets from the animals using the method described by Babayemi and Bankole (2006). The rumen samples were immediately measured for pH using a pH meter (Universal pH test-kit Digital pH meter), thereafter, samples were filtered with a four-layer cheese cloth and the subsamples were divided into two portions. The first portion was used to analyse for total volatile fatty acids (VFA) and the proportions of acetate, propionate and butyrate. The procedure for the determination of the volatile fatty acids is as described in Ikyume *et al*. (2020). The second portion was used for determination microbial count; Protozoa count was done such that samples were properly mixed and a 100 µL of the sample was added on a refreeze-freeride and carefully covered with a cover slip without causing the formation of air bubbles. The slide was set for 10 minutes to allow the settling of protozoa, and slides were examined, using a 10x objective (compound microscope). At least 25 microscopic fields were counted using the eyepiece. For total bacteria count, rumen samples were further processed by dissolving 1 ml of each in 0.85 % normal saline to obtain a diluent. Each of the diluents was further diluted serially in ten folds up to dilution 10^{-6}. To obtain total bacterial counts, an aliquot (0.1 mL) of each sample was inoculated onto nutrient agar (Agar 15.0 %, peptone 5 %, sodium chloride 5 %, yeast extract 2 %, beef extract 1%) medium using a pour plate technique, incubated at 39 ºC for 24 hours. All colonies that grew on the agar were enumerated for total bacterial counts (TBC). For the isolation of lipolytic bacterial, the plate method described in Musa and Adebayo-Tayo (2012) was used; A 0.1 mL were inoculated on modified agar medium containing per litre; 10 g peptone, 5 g NaCl, 0.1 g CaCl, 0.5 g congo red, 1 mL olive oil and 15 g agar. Plates were inoculated at 39 ºC for 24-48 hours, after which the cultures that grew with a clear zone surrounding were enumerated as lipolytic bacteria. Such colonies were further sub-cultured of the same media to measure the zone and activity index calculated as:

$$IL = \frac{clear\ zone\ colony - colony\ diameter}{colony\ diameter}.$$

Bacteria capable of producing amylase were isolated as described by Kanimozhi *et al.* (2014). The media composition per litre included 5 g peptone, 2 g yeast extract, 0.25 g $MgSO_4$, 0.1 g $CaCl_2$, 10 g starch and 13.5 g agar. These were dissolved in distilled water and autoclaved at 121 ºC, 15 PSI for 15 mm. The sterile media was poured into Petri dishes and allowed to set, after which, 100 µL of each sample was inoculated on the surface and incubated for 24-48 hours at 39 ºC for visible colonies, the plates were flooded with 1 % iodine for 20 minutes and drained off, colonies surrounded with clear zones were enumerated as amylolytic bacteria. Such cultures were sub-cultured repeatedly until pure cult ures were obtained and the activity index was calculated as the inverse of clear zone and colony diameter. To isolate proteolytic bacteria, samples were spread on the surface of 10 % skim milk media composed of 15 g agar,5 g pancreatic digest, 2.5 g yeast extract, 1 g glucose and 100 mL skim milk solution. The activity of proteolytic bacteria was tested qualitatively on the skim milk media as an indication of microbes capable of integrating protein (casein). Colonies that gave clear zones were counted and further subcultured for proteolytic index.

Fungi isolation was done by taking an aliquot (0.1 ml) of each sample and was aseptically spread onto potato dextrose agar (PDA) plates using a glass spreader. PDA plates were incubated at 28 ºC for 5-7 days. Different fungal colonies which appeared on the plates were counted. Screening of lipolytic fungi was performed on Tween 80 hydrolysis media (Iftikhar *et al.*, 2011). Samples were spot-inoculated on the media containing 1.5 g peptone, 0.5 g NaCl, 0.1 g $CaCl_2$ and 1.5 g agar, all were dissolved in 100 ml distilled water and autoclaved at 121 ºC, 15 PSI, 15 minutes, after which, 1 ml of Tween 80 was added into the media and distributed into Petri dishes. Inoculated plates were incubated at 28 ºC for 3-5 days. For amylolytic fungi production, 19.5 g of PDA containing 10 % starch (Ogbonna *et al.*, 2014) was sterilized and inoculated with 0.1 ml of serially diluted rumen samples by spread plates, with the aid of a glass spreader. Plates were incubated at 28 ºC for 5 days. After incubation, plates were flooded with 1 % iodine for 20 minutes and drained off. Isolates that showed a clear zone at colony edges were scored for starch hydrolysis. Proteolytic fungi were enumerated on PDA media supplemented with 10 % skim milk.

Determination of Apparent Nutrient Digestibility

By the end of the 84 days feeding trial, the rams were moved into metabolic cages for faecal collection. The metabolic cages were constructed with wire-mesh nets placed under the floor of each cage. The animals were allowed to adjust for four (4) days, thereafter, faecal samples were collected from each of the animals for three (3) in the morning and afternoon. All faecal samples collected from each animal were weighed daily and subsequently bulked together by animal. The faecal samples were subsequently oven-dried at 65°C for 48 hours and ground to 1 mm particle size. Proximate analysis of the ground faecal samples was obtained as described in AOAC (2005). Apparent Digestibility was calculated using the formula below:

$$Apparent\ Nutrient\ Digestibility\ (\%) = \frac{\text{Nutrient Intake} - \text{Feacal Nutrient}}{\text{Nutrient Intake}}\ x\ 100$$

Determination of Economy of Feed Conversion

The prevailing market prices of the ingredients at the time of the study were used to calculate the cost of 1 kg feed consumed and the cost of 1 kg feed consumed per weight gain. The economic performance was determined by computing the feed cost/kg (naira/kg) as follows:

Cost of total feed intake ($₦/Kg$) = *Total feed intake (Kg) X Feed cost per kg (₦)*

Feed cost/kg weight gain = $\frac{Cost\ of\ total\ feed\ intake\ (₦)}{Total\ weight\ gain\ (kg)}$

Statistical Analysis

Data generated on growth performance indices, rumen fermentation kinetics, bacteria count, apparent nutrient digestibility were subjected to one-way analysis of variance using SPSS version 23. Significantly different means were separated using Duncan Multiple Range Test as contained in the Statistical package ($p<0.05$). Data on economy of feed conversion was based on descriptive statistics.

RESULTS AND DISCUSSION

Growth Performance of Uda Rams Fed Varying Levels of Ensiled Urea-molasses Treated Soybean Haulms

The growth performance of Uda rams fed concentrate diets containing varying levels of ensiled urea-molasses treated soybean haulms is presented in Table 2. Final body weight, total and daily weight changes were not significantly ($p>0.05$) affected by the dietary treatments and values ranged from 17.60 to 19.20 kg, 4.80 to 6.60 kg and 0.57 to 0.78 kg/day, respectively. Daily concentrate intake was significantly ($p<0.05$) affected by dietary treatments. Animals fed T1 and T2 recorded similar and significantly higher concentrate intake values of 0.38 and 0.37 kg/day, respectively, compared to those fed T3 (0.33 kg/day) and T4 (0.30 kg/day), which were statistically similar. In contrast, daily forage intake was not affected by treatment and ranged from 1.12 to 1.18 kg/day. Total daily feed intake was not also significantly (p>0.05) influenced by the dietary treatments, ranging from 1.48 to 1.54 kg/day. Likewise feed conversion ratio (FCR) ranged from 20.39 to 27.65 and was statistically similar (p>0.05) across the different treatment groups.

Table 2: Growth Performance of Uda Rams Fed Varying Levels of Ensiled Urea-molasses Treated Soybean Haulms

Parameters	T1	T2	T3	T4	SEM
Initial Weight (kg)	12.80	12.60	12.80	12.80	0.30
Final Weight (kg)	18.80	19.20	19.00	17.60	0.48
Weight Gain (kg)	6.00	6.60	6.20	4.80	0.43
Daily Weight Gain (kg)	0.67	0.78	0.74	0.57	0.01
Daily Concentrate Intake (kg/day)	0.38^{a}	0.37^{a}	0.33^{b}	0.30^{b}	0.01
Daily Forage Intake (kg/day)	1.12	1.17	1.16	1.18	0.01
Total Daily Feed Intake (kg/day)	1.50	1.54	1.49	1.48	0.01
Feed conversion ratio	23.76	20.39	24.40	27.65	1.79

^{a,b}Means with different superscript along the same row are significantly (p<0.05) different
T1= 0% inclusion of urea-molasses treated ensiled soybean haulms,
T2= 30% inclusion of urea-molasses treated ensiled soybean haulms
T3=40% inclusion of urea-molasses treated ensiled soybean haulms
T4= 50% inclusion of urea-molasses treated ensiled soybean haulms

Rumen pH and Volatile Fatty-acids of Uda Rams Fed Varying Levels of Ensiled Urea-molasses Treated Soybean Haulms

The effects of feeding varying levels of ensiled urea-molasses treated soybean haulms on rumen pH and volatile fatty acid (VFA) production in sheep are presented in Table 3. Rumen pH values were not significantly (p>0.05) influenced but numerically increased progressively with increasing levels of ensiled urea-molasses treated soybean haulms, ranging from 5.23 in the control diet (T1) to 6.38 in the diet containing 50% inclusion (T4). Total volatile fatty acid (TVFA) concentration was significantly (P<0.05) affected by dietary treatments. Sheep fed diets containing ensiled urea-molasses treated soybean haulms (T2, T3, and T4) recorded significantly higher TVFA values of 1.99, 1.97, and 1.97 mol/100 mol, respectively, compared with the control treatment (T1), which recorded the lowest value of 1.89 mol/100 mol. However, TVFA was similar (p>0.05) among T2, T3, and T4. In the same vein, acetic and propionic acid concentration were higher (p<0.05) in animals that were supplemented processed soybean haulms, compared to control. Acetic acid concentration values were 0.63 mol/100 mol in T2, while T3 and T4 recorded identical values of 0.62 mol/100 mol. These values were significantly (P<0.05) higher than the value observed in the control treatment (0.56 mol/100 mol). Propionic acid concentration 0.59 mol/100 mol in T2, while T3 and T4 had similar values of 0.58 mol/100 mol, whereas the lowest concentration of 0.54 mol/100 mol was recorded in T1. Butyric acid concentration was on the other hand was not affected (p>0.05) by dietary treatment across all treatment groups, ranging from 0.50 to 0.51 mol/100 mol.

Table 3: Rumen pH and Volatile Fatty-acids of Sheep Fed Varying Levels of Ensiled Urea-molasses Treated Soybean Haulms

Parameters	T1	T2	T3	T4	SEM
Rumen pH	5.23	5.73	6.07	6.38	0.14
TVFAs (mol/100mol)	1.89^{b}	1.99^{a}	1.97^{a}	1.97^{a}	0.02
Acetic acid (mol/100mol)	0.56^{b}	0.63^{a}	0.62^{a}	0.62^{a}	0.01
Propionic acid (mol/100mol)	0.54^{b}	0.59^{a}	0.58^{a}	0.58^{a}	0.01
Butyric acid (mol/100mol)	0.50	0.51	0.51	0.51	0.00

^{ab} **Means with different superscripts along the treatment rows are significant (P<0.05),** TVFAs = Total Volatile Fatty Acids Component.
T1= 0% inclusion of urea-molasses treated ensiled soybean haulms,
T2= 30% inclusion of urea-molasses treated ensiled soybean haulms
T3=40% inclusion of urea-molasses treated ensiled soybean haulms
T4= 50% inclusion of urea-molasses treated ensiled soybean haulms

Rumen Microbial Counts of Uda Rams Fed Varying Levels of Ensiled Urea-molasses Treated Soybean Haulms

The effects of feeding varying levels of ensiled urea-molasses treated soybean haulms on rumen microbial populations of sheep are presented in Table 4. Total protozoa count was not affected (p>0.05) by the dietary treatments and ranged from 18.67 to 82.50 cells/0.1 ml across the treatment groups. Total bacterial count was significantly (P<0.05) influenced by dietary treatment. Sheep fed T2 and T3 recorded the highest bacterial population (108.00 and 150.67 × 10^{6} CFU/ml), and these values were significantly higher than those obtained in T1 (23.33 × 10^{6} CFU/ml) and T4 (30.50 × 10^{6} CFU/ml), which did not differ significantly from each other. Similarly, the population of amylolytic bacteria was significantly (P<0.05) affected by dietary treatment. The higher counts were recorded in T2 and T3 (155.67 and 119.00× 10^{5} CFU/ml), compared only to T4 with amylolytic bacteria count of 42.50 × 10^{5} CFU/ml. Amylolytic bacteria in T1 (108.67 × 10^{5} CFU/ml) was comparable to that of T4. Lipolytic bacterial counts were similar (p>0.05) in all treatment groups and ranged from 52.00 to 67.50 × 10^{5} CFU/ml Likewise, proteolytic bacteria populations ranged from 17.00 to 26.50 × 10^{5} CFU/ml. Total fungi counts varied from 3.50 to 11.67 × 10^{3} CFU, amylolytic fungi counts ranged from 1.67 to 3.33 × 10^{3} CFU, lipolytic fungi counts ranged from 0.33 to 2.00 × 10^{3} CFU, and proteolytic fungi populations ranged from 0.00 to 1.00 × 10^{3} CFU, with all the fungi population indicating no significant (p>0.05) differences across the groups.

Table 4: Microbial Counts of Sheep Fed Varying Levels of Ensiled Urea-molasses Soybean Haulms

Parameters	T1	T2	T3	T4	SEM
Total protozoa count (cells/0.1 ml)	22.67	18.67	22.00	82.50	11.09
Total bacteria count (x10^6 CFU/ml)	23.33^b	108.00^a	150.67^a	30.50^b	19.43
Amylolytic bacteria (x10^5 CFU/ml)	108.67^{ab}	155.67^a	119.00^a	42.50^b	14.70
Lipolytic bacteria (x10^5 CFU/ml)	63.00	52.00	55.33	67.50	7.44
Proteolytic bacteria (x10^5 CFU/ml)	23.33	17.00	20.33	26.50	2.75
Total fungi count (x10^3 CFU)	7.00	6.33	11.67	3.50	1.52
Amylolytic fungi (x10^3 CFU)	3.33	1.67	3.00	2.00	0.39
Llipolytic fungi (x10^3 CFU)	1.00	2.00	0.33	1.50	0.30
Proteolytic fungi (x10^3 CFU)	0.00	1.00	0.00	0.50	0.20

^{ab} **Means with different superscripts along the treatment rows are significant (P<0.05),**
T1= 0% inclusion of urea-molasses treated ensiled soybean haulms,
T2= 30% inclusion of urea-molasses treated ensiled soybean haulms
T3=40% inclusion of urea-molasses treated ensiled soybean haulms
T4= 50% inclusion of urea-molasses treated ensiled soybean haulms

Apparent Nutrient Digestibility by Uda Rams Fed Varying Levels of Ensiled Urea-Molasses Treated Soybean Haulms

The apparent nutrient digestibility of sheep fed varying levels of ensiled urea-molasses treated soybean haulms is presented in Table 5. Dry matter digestibility ranged from 56.82 to 76.69% and was not significantly (p>0.05) affected by the dietary treatment. In the same vein, crude protein digestibility ranged from 57.62 to 64.74%, crude fibre digestibility values ranged from 34.30 to 48.67%, ether extract digestibility was relatively high across all treatments, ranging from 66.30 to 71.64%, while ash digestibility varied from 35.25 to 47.99%. In contrast, nitrogen-free-extract (NFE) digestibility was influenced (p<0.05) the dietary treatments. Sheep fed the control diet (T1) and the diet containing 30% ensiled urea-molasses treated soybean haulms (T2) recorded the higher digestibility values of 59.46 and 49.36%, respectively, compared to those fed T4 (29.16%). However, sheep fed T3 had similar (p>0.05) NFE digestibility (42.26%) with T1, T2 and T4. statistically similar. The digestibility value for T3 (42.26%) was intermediate and did not differ significantly from T1 or T4. The lowest NFE digestibility (29.16%) was observed in sheep fed the 50% inclusion diet (T4), which was significantly lower than the values obtained in T1 and T2.

Table 5. Apparent Nutrient Digestibility (%) by Sheep Fed Varying Levels of Ensiled Urea-Molasses Treated Soybean Haulms

Parameters	T1	T2	T3	T4	SEM
Dry Matter	74.85	76.69	67.31	56.82	3.65
Crude Protein	57.62	61.78	64.74	60.75	2.13
Crude Fibre	34.30	48.67	39.84	37.99	2.65
Ether Extract	70.99	71.64	66.91	66.30	1.24
Ash	41.35	35.25	47.99	41.98	3.21
Nitrogen-free-extract	59.46^a	49.36^a	42.26^{ab}	29.16^b	4.12

^{ab} **Means with different superscripts along the treatment rows are significant (P<0.05),**
T1= 0% inclusion of urea-molasses treated ensiled soybean haulms,
T2= 30% inclusion of urea-molasses treated ensiled soybean haulms
T3=40% inclusion of urea-molasses treated ensiled soybean haulms
T4= 50% inclusion of urea-molasses treated ensiled soybean haulms

Economics of Feed Conversion of Sheep Fed Varying Levels of Ensiled Urea-molasses Treated Soybean Haulms

The economics of feed conversion for sheep fed varying levels of ensiled urea-molasses treated soybean haulms are presented in Table 6. The total cost of forage consumed increased slightly with increasing levels of ensiled soybean haulms, ranging from ₦112.00/kg in T1 to ₦118.00/kg in T4. In contrast, the total cost of concentrate consumed decreased progressively from ₦117.42/kg in the control treatment (T1) to ₦55.20/kg in T4. Consequently, the total cost of feed consumed declined from ₦229.42/kg in T1 to ₦173.20/kg in T4 as the inclusion level of ensiled urea-molasses treated soybean haulms increased. Feed cost per kilogram weight gain ranged from ₦29.83 to ₦38.24/kg. The lowest feed cost per kilogram weight gain was recorded in T3 (₦29.83/kg), closely followed by T2 (₦30.85/kg), indicating superior economic efficiency in these treatments. The highest feed cost per kilogram weight gain (₦38.24/kg) was observed in the control group (T1), while T4 recorded a value of ₦36.08

Table 6: Economics of Feed Conversion for Sheep Fed Varying Levels of Ensiled Urea-Molasses Treated Soybean Haulms

Parameters	T1	T2	T3	T4	SEM
Daily weight gain (Kg)	0.67	0.78	0.74	0.57	0.01
Daily Concentrates intake (Kg)	0.38^a	0.37^a	0.33^b	0.30^b	0.01
Daily Total feed consumed (Kg)	1.50	1.54	1.49	1.48	0.01
Total cost of forage consumed (₦/Kg)	112.00	117.00	116.00	118.00	-
Total cost of concentrates consumed (₦/Kg)	117.42	86.58	68.97	55.20	-

Parameters	T1	T2	T3	T4	SEM
Cost of total feed consumed (₦/Kg)	229.42	203.58	184.97	173.20	-
Feed cost per Kg weight gain (₦/Kg)	38.24	30.85	29.83	36.08	-

[ab] Means with different superscripts along the treatment rows are significant ($P<0.05$).
T1= 0% inclusion of urea-molasses treated ensiled soybean haulms,
T2= 30% inclusion of urea-molasses treated ensiled soybean haulms
T3=40% inclusion of urea-molasses treated ensiled soybean haulms
T4= 50% inclusion of urea-molasses treated ensiled soybean haulms

Discussion

The non-significant differences observed in final body weight, total weight gain, daily weight gain, total feed intake, and feed conversion ratio among treatment groups indicate that ensiled urea-molasses treated soybean haulms can successfully replace conventional feed ingredients up to 50% inclusion without adversely affecting animal performance. The numerical superiority observed in sheep fed 30% inclusion (T2) suggests that moderate incorporation of treated soybean haulms may optimize nutrient utilization and animal growth. The report of Ikyume *et al*. (2023) had recommended the use of soybean haulms in diets of sheep at 30%. In this report, levels up to 50% did not affect growth performance indices. This may be because of the processing of the haulms in this current study which may have enhanced utilization by the animals. Urea treatment increases crude protein content and disrupts lignocellulosic bonds, while molasses supplies readily fermentable carbohydrates that enhance microbial activity and nutrient availability in the rumen. These processes improve the feeding value of crop residues and support animal growth. These observation in growth indices agree with findings of Vorlaphim *et al.* (2021), who reported similar growth performance and nutrient utilization in goats fed urea-treated crop residues compared to untreated residues. On the other hand, improvements in nutrient utilization following urea treatment have been reported by Wahyono *et al*. (2022). The significant reduction in concentrate intake with increasing inclusion levels of treated soybean haulms suggests that the treated forage contributed substantially to meeting the nutrient requirements of the animals, thereby reducing dependence on concentrate feed. This may be true because concentrate intake was not reduced in previous reports where unprocessed soybean haulms were fed to goats (Ikyume *et al*., 2024). The processing of the soybean haulms may have improved the quality of the material thereby leading to the reduction in the concentrate intake. The processing method adopted in this research has been reported to improve the quality of the soybean haulms (Ogu *et al.*, 2024).

The numerical increase in rumen pH from 5.23 in the control diet to 6.38 in the 50% inclusion diet indicates that ensiled urea-molasses treated soybean haulms promoted a more favorable rumen environment and has a tendency to alter the rumen environment at higher levels that those used in this study. Such numerical increase may be associated with ammonia release from urea hydrolysis, which exerts a buffering effect within the rumen. Urea is hydrolyzed by ruminal microbial urease to produce ammonia (NH_3), which can exert a buffering effect within the rumen environment and help maintain conditions favorable for microbial activity and fibre digestion (Hailemariam *et al.*, 2021). The observed pH values fall within the acceptable range for normal ruminal fermentation (5.5–7.0), which supports microbial growth and fibre degradation. In this current study, bacteria populations increased only up to 40% inclusion level, then further declined, while fibre digestion was similar in all treatment, with numerical increase in the processed soybean haulms supplemented groups.

The significant increase in total volatile fatty acids (TVFA), acetate, and propionate concentrations in sheep fed treated soybean haulms indicates enhanced microbial fermentation. Volatile fatty acids are the primary end-products of ruminal fermentation and constitute the major energy source for ruminants (Jiao *et al.*, 2022**)**. Therefore, higher TVFA concentrations suggest improved fermentation efficiency and nutrient utilization. The increase in acetate concentration is particularly important because acetate is the principal end-product of fibre digestion. The higher acetate concentrations observed in T2, T3, and T4 suggest enhanced degradation of structural carbohydrates resulting from improved accessibility of cellulose and hemicellulose following urea treatment. This finding agrees with reports by Anantasook *et al.* (2019), who observed increased VFA production and improved fibre utilization in ruminants fed urea-treated roughages. Similarly, the elevated propionate concentrations indicate improved fermentation of soluble carbohydrates supplied by molasses. Propionate serves as the major precursor of glucose synthesis in ruminants and contributes directly to growth and productive performance. In this study, growth performance index (FCR) was similar across the different treatment groups. The lack of treatment effect on butyrate concentration suggests that the inclusion of treated soybean haulms did not alter fermentation pathways. Dietary treatments may affect acetate and propionate production more strongly than butyrate, while butyrate often remains relatively stable unless major shifts occur in rumen microbial populations or diet composition (Jiao *et al.*, 2022**)**.

The significantly higher total bacterial and amylolytic bacterial populations observed in T2 and T3 indicate that inclusion of ensiled urea-molasses treated soybean haulms stimulated rumen microbial growth. This response is likely attributable to the synchronized supply of nitrogen from urea and fermentable energy from molasses, which supports rapid microbial proliferation (Hailemariam *et al.*, 2021). Amylolytic bacteria are responsible for starch degradation and fermentation of soluble carbohydrates. Their increased population in T2 and T3 suggests that these inclusion levels provided optimal conditions for microbial activity. Enhanced bacterial growth is consistent with the higher concentrations of total volatile fatty acids observed in these treatments. The decline in bacterial populations at the 50% inclusion level may indicate that excessive inclusion of treated soybean haulms altered the rumen environment in a manner that limited microbial efficiency. This may explain the numerical lower weight gain and poorer feed conversion ratio observed in T4. The non-significant differences in protozoa, total fungi, lipolytic bacteria, and proteolytic bacterial populations suggest that the dietary treatments primarily affected carbohydrate-fermenting microorganisms rather than the broader microbial ecosystem. Jiao *et al.* (2022) reported that increases in fermentable substrates and nitrogen availability typically stimulate carbohydrate-utilizing bacterial populations, whereas fungi and protozoa populations may show little or no response unless substantial dietary shifts occur.

The non-significant differences observed in dry matter, crude protein, crude fibre, ether extract, and ash digestibility indicate that ensiled urea-molasses treated soybean haulms did not impair nutrient utilization. Similar findings have been reported for urea-treated crop residues, where improved fibre degradation and nutrient availability maintained or enhanced digestibility coefficients in ruminants (Anantasook *et al*., 2014; Aruwayo *et al*., 2018). Furthermore, Ogu *et al*. (2024) reported that urea-molasses treatment improved the nutritional quality of soybean haulms, while Ikyume *et al*. (2023) observed satisfactory nutrient utilization and performance in sheep fed diets containing soybean haulms. The significant reduction in nitrogen-free extract digestibility at the 50% inclusion level suggests that excessive inclusion of treated soybean haulms may limit utilization of readily available carbohydrates. Reduced carbohydrate digestibility at high inclusion levels may explain the numerically lower growth performance and microbial populations observed in T4. Although urea treatment improved digestibility and rumen fermentation, it has been noted that responses depend on the inclusion level of treated roughage and the balance between fermentable energy and available nitrogen (Anantasook *et al*., 2014).

The progressive reduction in concentrate cost and total feed cost with increasing inclusion levels of treated soybean haulms demonstrates the economic advantage of utilizing locally available crop residues in sheep feeding systems. Begna *et al*. (2023) reported that incorporating treated agro-industrial residues in sheep diets improved feed efficiency and reduced cost per unit weight gain, demonstrating economic advantage of using low-cost roughages in place of conventional concentrates. Although T4 recorded the lowest total feed cost, its lower weight gain resulted in a relatively higher feed cost per kilogram gain compared with T2 and T3. The lowest feed cost per kilogram gain recorded in T3 (₦29.83/kg) indicates superior economic efficiency, suggesting that 40% inclusion represents the most cost-effective feeding strategy. The improved economic performance observed in T2 and T3 reflects the combined benefits of reduced feed costs and satisfactory growth performance. Ogu *et al*. (2024) reported that processing soybean haulms increases nutritional value and supports their use as economical feed ingredients, and this current study also supports the findings by Ikyume *et al*. (2023) that soybean haulms (a crop residue) can be used as a low-cost feed ingredient that reduces dependence on expensive conventional feed materials while maintaining performance.

CONCLUSION

The study demonstrated that ensiled urea-molasses treated soybean haulms can be effectively utilized as a feed resource in diets of Uda sheep without detrimental effects on growth performance, rumen ecology, nutrient digestibility, or feed utilization. Inclusion of the treated soybean haulms improved rumen fermentation as evidenced by increased concentrations of total volatile fatty acids, acetic acid, and propionic acid, while maintaining rumen pH within the optimal range required for microbial activity. The diets containing 30% and 40% ensiled urea-molasses treated soybean haulms supported higher bacterial populations, particularly total and amylolytic bacteria, indicating enhanced rumen microbial activity and improved fermentation efficiency. Apparent nutrient digestibility coefficients like dry matter, crude protein, and crude fibre were generally comparable among treatments, except for nitrogen-free-extract which reduced at 50% inclusion. From an economic standpoint, inclusion of ensiled urea-molasses treated soybean haulms reduced concentrate feed costs and total feed costs. The lowest feed cost per kilogram weight gain was obtained at 40% inclusion, indicating greater economic efficiency and profitability. It was therefore recommended that ensiled urea-molasses treated soybean haulms should be included at 30-40% of the diet for optimum growth performance, rumen function, nutrient utilization and economy of feed conversion.

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