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Haematological Parameters and Carcass Characteristics of Uda Rams Fed Graded Levels of Ensiled Urea-Treated Millet Husk

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Abstract

This study assessed the effects of graded levels of ensiled urea-treated millet husk (EUTMH) on haematological parameters and carcass characteristics of growing Uda rams, with cowpea husk serving as the conventional fibre source. Sixteen growing male Uda rams (averagely 18 kg) were randomly assigned to four dietary treatments (T1–T4) in a Completely Randomized Design, with four replicates per treatment. Diets were formulated with increasing inclusion levels of EUTMH as a replacement for cowpea husk, alongside wheat offal, soybean meal, and salt: T1 (0-30%), T2 (10-20%), T3 (20-10%), and T4 (30-0%). Animals were fed ad libitum for 63 days. Blood samples were analyzed for haematological indices, while carcass traits were evaluated post-slaughter. EUTMH maintained desirable physical and nutritional qualities, including stable dry matter and acceptable sensory attributes. Haematological parameters such as packed cell volume, haemoglobin concentration, and white blood cell counts remained within normal physiological ranges, indicating no adverse health effects. Carcass evaluation revealed comparable dressing percentages and muscle yield across treatments, though higher husk inclusion increased fibre fractions and reduced crude protein concentration. The study demonstrates that ensiled urea-treated millet husk can effectively replace cowpea husk in Uda ram diets without compromising health or carcass quality. EUTMH represents a sustainable feed resource that enhances the utilization of millet residues, supports small ruminant production, and helps address seasonal forage shortages in northern Nigeria.

Keywords: Uda rams, Haematological parameters, Carcass characteristics, Ensiled urea-treated millet husk, Ruminant nutrition, Feed resource utilization, Sustainable livestock production

1.0 Introduction

Small ruminants play a significant role in food security, income generation, and livelihood sustainability across sub-Saharan Africa, particularly in low-input production systems where sheep and goats provide meat and financial security for rural households (Boudalia *et al.*, 2024). Crop residues and agro-industrial by-products have become increasingly important feed resources due to the rising cost and seasonal scarcity of conventional feeds, contributing to more sustainable and cost-effective livestock production.

Among these residues, millet husk is readily available in northern Nigeria because of extensive millet cultivation and processing. However, its utilization in ruminant feeding is limited by low crude protein content, high fibre concentration, and poor digestibility, which restrict animal performance. Recent reviews have emphasized that improving the nutritional quality of crop residues through physical, chemical, or biological treatments is essential for enhancing feed efficiency and ruminant productivity (Kamal *et al.*, 2025).

Urea treatment and ensiling are widely recognized as practical and affordable methods for upgrading low-quality fibrous feeds. These treatments increase nitrogen availability, improve fibre digestibility, enhance fermentation quality, and promote nutrient utilization by rumen microorganisms. Consequently, urea-treated crop residues have been reported to improve feed intake, digestibility, and animal performance, making them suitable alternatives to conventional roughage sources in tropical production systems (Ogu, 2025).

The evaluation of alternative feed resources requires assessment of both physiological and productive responses. Haematological parameters are valuable indicators of animal health, nutritional status, and metabolic adaptation to dietary treatments. Measurements such as packed cell volume, haemoglobin concentration, red blood cell count, and white blood cell count provide important information regarding the suitability of feed ingredients and their effects on animal well-being. Recent studies have demonstrated that haematological indices remain reliable indicators of nutritional adequacy and health status in sheep and goats fed unconventional feed resources (Fanta *et al.*, 2024).

Carcass characteristics are equally important because they determine the economic value of feeding strategies through their effects on dressing percentage, muscle development, and distribution of commercial cuts. Nutritional management significantly influences carcass composition and meat yield, and the strategic use of treated crop residues offers opportunities to improve productivity while reducing feeding costs (Shah *et al.*, 2025).

The Uda sheep, an indigenous breed well adapted to the semi-arid environment of northern Nigeria, is an appropriate model for evaluating alternative feed resources under local production conditions. Despite growing interest in treated crop residues as livestock feed, information on the effects of ensiled urea-treated millet husk (EUTMH) on the haematological profile and carcass characteristics of Uda rams remains limited. Therefore, this study evaluated the haematological parameters and carcass characteristics of Uda rams fed graded levels of EUTMH as a replacement for cowpea husk, with the aim of assessing its suitability as a sustainable and economically viable feed resource for sheep production.

2.0 Materials and Methods

2.1 Experimental Site: The study was conducted at the Livestock Teaching and Research Farm of Adamu Augie College of Education, Argungu, Kebbi State, Nigeria. Argungu serves as the headquarters of Argungu Local Government Area and is situated between latitude 12°30′–12°50′ N and longitude 4°10′–4°50′ E, at an elevation of 241 meters above sea level (Usman *et al.*, 2022).

2.2 Experimental Design and Feeding Procedure: A Completely Randomized Design (CRD) was employed. Sixteen male Uda lambs, averaging 18 kg in body weight, were randomly assigned to four dietary treatments (T1–T4), with each treatment replicated four times. Animals were individually housed in disinfected pens measuring 1 m × 2 m. Each group received one experimental diet and was fed ad libitum for 63 days, following a two-week adaptation period. Clean drinking water and salt licks were provided continuously throughout the experiment.

2.3 Procurement of Experimental Ingredients

Millet panicle husks used in this study were collected from farms and threshing stations along the Argungu axis of Kebbi State, Nigeria. This area is a major millet-producing region where crop residues, such as husks, are abundant yet underutilized in livestock feeding systems (Dejene *et al.*, 2024).

Ingredients, including soybean meal, wheat offal, cowpea husks, urea, and common salt, were purchased from the Argungu central market. These feedstuffs are commonly used in ruminant diets across northwestern Nigeria (Ogunbosoye *et al.*, 2022). Locally sourced crop residues with market-based feed components reflect a practical feeding strategy that supports ongoing efforts to promote non-conventional feed resources in small ruminant production, improving resource utilization (Machekano *et al.*, 2026).

2.4 Silage Preparation

Millet panicle husk was ensiled with urea following a modified procedure described by Roy and Rangnekar (2006). Urea was dissolved in water, evenly applied to the husk, and compacted into a 1,000-liter plastic container serving as the silo. The material was stored under airtight conditions for 21 days and sealed with polythene sacks to minimize oxygen exposure. After fermentation, the silos were opened, and the contents were aired under shade for three days to allow residual ammonia to dissipate before incorporation into the experimental diets (Kamal *et al.*, 2025).

Table 1 presents the gross composition of the ensiled urea-treated millet husk used in this study.

Ingredient	Quantity
Millet Panicle Husk	100 kg
Urea	4 kg
Clean Water	60 L

Source: Adapted from Roy and Rangnekar (2006)

2.5 Experimental Diet Formulation and Design

This study assessed the replacement of cowpea husk with ensiled urea-treated millet husk (EUTMH) in growing Uda rams' diets. Four diets were formulated with EUTMH inclusion levels of 0%, 10%, 20%, and 30%, designated as treatments T1–T4. Sixteen rams, averaging 18 kg, were randomly assigned to the treatments, with four animals per group. The feeding trial lasted nine weeks and followed a Completely Randomized Design (CRD), with each ram serving as a replicate.

Animals were fed their assigned diets daily and had unrestricted access to clean water. This design reflects a standard research approach, particularly in studies evaluating crop residues and agro-industrial byproducts in sheep diets to enhance nutrient utilization and growth performance (Machekano *et al.*, 2026). Ingredient composition and chemical analysis of the diets are presented in Table 2.

Table 2: Gross Composition and Nutrient Estimates of Experimental Diets

Parameters	T1 (0%)	T2 (10%)	T3 (20%)	T4 (30%)
Ensiled Urea-Treated Millet Husk	0	10	20	30
Cowpea Husk	30	20	10	0
Wheat Offal	40	40	40	40
Soybean Meal	29	29	29	29
Common Salt	1	1	1	1
Total	100	100	100	100

Calculated Chemical Analysis	-	-	-	-
ME (%)	2146.14	2060.27	1587.03	1573.75
CP (%)	13.21	12.70	12.23	11.59
CF (%)	27.65	28.40	30.19	31.45

2.6 Experimental Animals and Management:

The lambs were sourced from local markets in Kebbi State. Upon arrival, they were quarantined for two weeks to acclimate to the environment. During this period, the animals were treated for external parasites using Ivomec-super (200 µg/kg body weight) and administered antibiotics as a preventive measure. Pens were disinfected, and faeces and urine were removed on a daily basis to minimize ammonia buildup. Feed and water troughs were cleaned each morning before feeding.

2.6.1 Slaughtering Procedure and Carcass Evaluation

At the end of the feeding trial, three rams from each treatment group were selected for slaughter after an overnight fast. Slaughtering was carried out in accordance with established animal welfare and humane handling guidelines to minimize preslaughter stress and ensure animal welfare (Terlouw and Bourguet, 2022). Following slaughter, animals were eviscerated, dressed, and hot carcass weights were recorded. We divided carcasses into primal sections and calculated dressing percentage as the ratio of carcass weight to live weight. We excised and weighed internal organs, including the liver, kidney, spleen, heart, and lungs, to evaluate dietary effects on organ development. These carcass traits served as reliable indicators of dietary impact and economic value in small ruminant production systems (Machekano *et al.*, 2026).

2.6.2 Haematological Indices Determination: At the end of the feeding trial, blood samples were collected from each animal via jugular venipuncture using sterilized syringes and vacutainer tubes containing EDTA. We analyzed whole blood for hemoglobin (Hb) concentration using the cyanmethemoglobin method. Packed cell volume (PCV), erythrocyte (RBC), and leukocyte (WBC) counts were determined using micro-hematocrit and microscopic techniques, and differential leukocyte counts were derived from total WBC counts (Coles, 1986). These indices provided insight into Uda rams' physiological and metabolic responses to the experimental diets.

2.6.3 Blood Serum Analysis

Serum samples were analyzed for biochemical parameters using standard clinical chemistry procedures. Serum urea nitrogen, total protein, albumin, glucose, and enzyme activities were determined using validated spectrophotometric methods routinely employed in veterinary clinical pathology (Bohn *et al.*, 2023; Grzych *et al.*, 2025). Serum electrolytes, including sodium, calcium, and potassium, were quantified using standardized clinical laboratory procedures, while globulin concentration was calculated as the difference between total protein and albumin. Albumin concentration was measured using the bromocresol green method, which remains a widely accepted procedure in clinical biochemistry (Iwasaki *et al.*, 2023).

2.7 Data Analysis:

All data were subjected to Analysis of Variance (ANOVA) under a Completely Randomized Design (CRD) using the StatView statistical package (Lee *et al.*, 2004). Where significant differences were observed, treatment means were separated using the Least Significant Difference (LSD) test at a 5% probability level.

3.0 RESULT

3.1.1 Haematological Parameters of Uda Rams

The haematological responses of Uda rams fed diets with varying levels of ensiled urea-treated millet husk (EUTMH) are presented in Table 3. Most indices, including red blood cell (RBC) counts, mean corpuscular haemoglobin (MCH), mean corpuscular volume (MCV), mean corpuscular haemoglobin concentration (MCHC), monocytes, lymphocytes, and basophils, showed no significant differences among treatments ($p > 0.05$).

Significant variations ($p < 0.05$) were observed in haemoglobin concentration, packed cell volume (PCV), white blood cell (WBC) counts, and eosinophil levels. Haemoglobin ranged from 11.30 g/dL (T3) to 12.50 g/dL (T1), while PCV varied between 33.42% (T3) and 37.38% (T1), all within normal physiological ranges. RBC counts remained stable, with values between $8.76 \times 10^6/\mu L$ (T3) and $9.50 \times 10^6/\mu L$ (T4). WBC counts ranged from $4.18 \times 10^9/L$ (T1) to $5.68 \times 10^9/L$ (T2), also within reference limits. Eosinophil counts differed significantly, from $0.38 \times 10^9/L$ (T4) to $0.75 \times 10^9/L$ (T1), while basophil values remained consistent across treatments.

Table 3: Haematological Parameters of Uda Rams Fed Diets Containing Graded Levels of Ensiled Urea-Treated Millet Husk

Parameters	T1	T2	T3	T4	SEM	Ref. value
Haemoglobin (g/dL)	12.50^a	11.75^{ab}	11.30^b	11.60^b	0.28	9 – 11
Packed Cell Volume – PCV (%)	37.38^a	35.30^{ab}	33.42^{ab}	34.80^{ab}	1.30	27 – 45
Red Blood Cells – RBC ($\times 10^6/\mu L$)	9.39	9.11	8.76	9.50	0.28	9 – 15
Mean Corpuscular Haemoglobin – MCH (pg)	9.22	9.31	8.75	9.40	0.67	8 – 12
Mean Corpuscular Volume – MCV (fL)	30.50	30.18	31.40	30.76	0.55	28 – 42
Mean Corpuscular Hb Concentration – MCHC (g/dL)	32.61	32.50	32.50	32.29	0.45	31 – 34
White Blood Cells – WBC ($\times 10^9/L$)	4.18^b	5.68^a	4.70^b	4.31^b	0.33	4 – 12
Monocytes ($\times 10^9/L$)	0.75	0.73	0.71	0.70	0.22	0 – 0.8
Lymphocytes ($\times 10^9/L$)	2.31	2.40	2.32	2.38	0.28	2 – 9
Eosinophils ($\times 10^9/L$)	0.75^a	0.41^b	0.44^b	0.38^b	0.09	3 – 8
Basophils ($\times 10^9/L$)	2.60	2.50	2.70	2.34	0.25	0 – 1

Note: Superscripts **a, b, c** within rows indicate statistically significant differences at $P < 0.05$. Different letters indicate statistical significance, While Shared letters indicate no significant difference. SEM = Standard Error of the Mean.

3.1.2 Biochemical Parameters of Uda Rams

The serum biochemical responses of Uda rams fed diets with varying levels of ensiled urea-treated millet husk (EUTMH) are shown in Table 4. Most parameters did not differ significantly among treatments ($p > 0.05$). Albumin concentrations were slightly below reference values, with the lowest observed in T3 (2.17 g/dL). Globulin levels remained within normal limits, while total protein values, though highest in T1 (6.28 g/dL), were generally lower than expected. Lipid indices (HDL and LDL) were stable, with triglycerides peaking in T1.

Creatinine levels varied significantly, ranging from 85.70 µmol/L (T3) to 103.00 µmol/L (T1), suggesting dietary effects on renal and muscular function. Cholesterol concentrations were within normal ranges, with T2 recording the highest (1.95 mmol/L). Urea levels remained within physiological limits.

Table 4: Serum Chemistry of Uda Rams Fed Diets Containing Graded Levels of Ensiled Urea-Treated Millet Husk

Parameters	T1	T2	T3	T4	SEM	Ref. Range
Albumin (g/dL)	2.41	2.38	2.17	2.30	0.39	2.4 – 3
Globulin (g/dL)	3.87	3.61	3.65	3.65	0.38	3.6 – 4.9
Total Protein (g/dL)	6.28	5.99	5.82	5.95	0.62	6.7 – 9
HDL (mmol/L)	0.77	0.65	0.68	0.64	0.11	> 1.03
LDL (mmol/L)	0.85	0.80	0.89	0.80	0.90	< 3.03
Triglycerides (mmol/L)	1.17^{a}	0.70^{b}	0.77^{b}	0.85^{b}	0.08	0.45 – 1.81
Creatinine (µmol/L)	103.00^{a}	95.20^{ab}	85.70^{c}	90.11^{bc}	2.79	53 – 106
Cholesterol (mmol/L)	1.25^{b}	1.95^{b}	1.11^{b}	1.43^{ab}	0.18	1.3 – 1.97
Urea (mmol/L)	3.70	3.62	3.76	3.81	0.50	2.5 – 7.8

Note: a,b,c: Means in the same row with different superscripts are significantly (P < 0.05) different. Different letters indicate statistical significance, While Shared letters indicate no significant difference. HDL = high-density lipoprotein; LDL = low-density lipoprotein; SEM = standard error of the Mean.

3.1.3 Liver Function Test: Serum Enzyme and Electrolyte Responses of Uda Rams

Table 5 summarizes the serum enzyme activities and electrolyte concentrations of Uda rams fed diets containing graded levels of ensiled urea-treated millet husk (EUTMH). Several parameters differed significantly among treatments ($p < 0.05$).

Aspartate aminotransferase (AST) ranged from 165.50 to 196.72 U/L, remaining within the physiological reference range (60–280 U/L). Alanine aminotransferase (ALT) exceeded the standard maximum (38 U/L) across all treatments, with the highest value in T2 (90.15 U/L). Alkaline phosphatase (ALP) varied significantly, peaking in T4 (178.68 U/L) and lowest in T3 (123.49 U/L).

Bilirubin concentrations remained within normal limits. Direct bilirubin ranged from 0.85 to 1.50 µmol/L, while total bilirubin values were narrow (0.85–0.97 µmol/L), all clinically insignificant. Electrolyte balance was generally stable: chloride values fell within reference ranges (95–103 mmol/L), with a slight elevation in T2 (104.55 mmol/L).

Potassium levels showed significant variation, with T3 recording the lowest (3.10 mmol/L), below the normal range (3.9–5.0 mmol/L). Sodium concentrations were consistently below reference thresholds (142–152 mmol/L), with the lowest observed in T4 (107.50 mmol/L).

Table 5. Liver Function Test: Serum Electrolytes and Enzymes of Uda Rams Fed Diets Containing Graded Levels of Ensiled Urea-Treated Millet Husk

Parameters	T1	T2	T3	T4	SEM	Ref. Range
AST (U/L)	196.72	165.50	183.50	188.00	10.75	60 – 280
ALT (U/L)	85.69	90.15	80.40	89.83	3.22	22 – 38
ALP (U/L)	161.33^{a}	164.00^{ab}	123.49^{b}	178.68^{c}	18.36	70 – 390
Direct Bilirubin (µmol/L)	1.20	1.44	1.45	1.50	0.17	0 – 4.6
Total Bilirubin (µmol/L)	0.95	0.97	0.88	0.85	0.15	1.71 – 8
Chloride (mmol/L)	103.45	104.55	100.71	102.20	2.55	95 – 103
Potassium (mmol/L)	4.00^{a}	4.20^{a}	3.10^{b}	3.90^{a}	0.13	3.9 – 5.4
Sodium (mmol/L)	128.00^{a}	119.00^{ab}	110.00^{b}	107.50^{a}	3.05	142 – 152

Note: a, b, c superscripts indicate statistically significant differences within the same row ($P < 0.05$). Different letters indicate statistical significance, While Shared letters indicate no significant difference. AST= Aspartate aminotransferase; ALT= Alanine aminotransferase; ALP= Alkaline phosphatase; SEM = Standard Error of the Mean.

3.2.1 Carcass Characteristics of Uda Rams

Table 6 summarizes the carcass traits of Uda rams fed diets with varying levels of ensiled urea-treated millet husk (EUTMH). Most primary carcass parameters, including slaughter live weight, warm carcass weight, and muscle pH, did not differ significantly among treatments ($p > 0.05$), indicating that dietary inclusion of husk meal had limited impact on carcass performance.

Rams in T1 recorded the highest slaughter live weight (28.50 kg) and carcass weight (16.50 kg), while T4 showed the lowest values (26.50 kg and 15.20 kg, respectively). Muscle pH was lowest in T1 (6.10) but highest in T3 and T4 (6.80). Carcass temperature followed a similar pattern, with T1 showing the lowest (32.20 °C) and T3–T4 the highest (33.75–34.00 °C). Dressing percentage ranged from 56.36% in T3 to 57.90% in T1, with intermediate values in T2 and T4.

Table 6. Carcass Characteristics of Uda Rams Fed Diets Containing Graded Levels of Ensiled Urea-Treated Millet Husk

Parameters	T1	T2	T3	T4	SEM
Slaughter Weight (kg)	28.50	27.00	27.50	26.50	1.55
Warm Carcass Weight (kg)	16.50	15.43	15.50	15.20	0.80
Warm Muscle pH	6.10	6.60	6.80	6.80	0.65
Warm Muscle Temp (°C)	32.20^{b}	33.00^{ab}	33.75^{a}	34.00^{a}	0.50
Dressing Percentage (%)	57.90^{a}	57.15^{ab}	56.36^{b}	57.34^{ab}	0.37

Note: a, b, c superscripts indicate values that are significantly different *($P < 0.05$)* within the same row. Different letters indicate statistical significance, While Shared letters indicate no significant difference. SEM = Standard Error of the Mean

3.2.2 Primal Cuts of Uda Rams

Table 7 summarizes the distribution of primal cuts in Uda rams fed diets with graded levels of ensiled urea-treated millet husk (EUTMH). While the weights of the leg, loin, and shoulder did not differ significantly among treatments ($p > 0.05$), several other cuts showed notable variation ($p < 0.05$).

Rack weights were highest in T1 (12.91 kg) and lowest in T2 (10.00 kg), with intermediate values in T3 and T4. Flank weights declined significantly in T4 (7.10 kg) compared to other treatments (9.39–9.75 kg). Neck weights were greater in T3 (14.20 kg) and T4 (13.90 kg) than in T1 (11.00 kg). Foreleg weights followed a similar pattern, with T1 (11.20 kg) and T4 (11.00 kg) recording higher values than T2 (8.33 kg), while T3 (9.57 kg) was intermediate.

Table 7. Primal Cuts of Uda Rams Fed Diets Containing Graded Levels of Ensiled Urea-Treated Millet Husk

Parameters	T1	T2	T3	T4	SEM
Leg	27.00	28.50	27.50	28.30	2.49
Loin	13.50	8.97	12.80	10.10	1.22
Rack	12.91^{a}	10.00^{b}	10.25^{b}	11.60^{ab}	0.63
Flank	9.39^{a}	9.75^{a}	9.48^{a}	7.10^{b}	0.49
Shoulder	15.00	14.67	16.20	18.00	0.95
Neck	11.00^{b}	12.35^{b}	14.20^{a}	13.90^{a}	0.78
Fore Leg	11.20^{a}	8.33^{b}	9.57^{ab}	11.00^{a}	0.85

Note: a, b, c superscripts indicate values that are significantly different *(P < 0.05)* within the same row. Different letters indicate statistical significance, While Shared letters indicate no significant difference. SEM = Standard Error of the Mean

3.2.3 Offal of Uda Rams

Table 8 presents the offal components of Uda rams fed diets with graded levels of ensiled urea-treated millet husk (EUTMH). Most parameters, including heart, liver, gut content, reticulum, omasum, abomasum, small and large intestine (weight and length), and visceral fat, did not differ significantly among treatments ($p > 0.05$).

Significant differences ($p < 0.05$) were observed in spleen weight, with T4 recording the highest value (220.50 g) and T3 the lowest (165.00 g). Rumen weight also varied, with T4 (0.90 kg) significantly higher than T1 and T2 (0.70–0.75 kg), while T3 was intermediate (0.80 kg). Rumen papillae scores showed dietary effects, with T3 recording the highest value (2.67), followed by T4 (2.35), whereas T1 and T2 had lower scores (1.43–1.58).

Table 8. Offal of Uda Rams Fed Diets Containing Graded Levels of Ensiled Urea-Treated Millet Husk

Parameters	T1	T2	T3	T4	SEM
Heart (g)	235.00	235.80	227.38	232.30	9.67
Spleen (g)	187.60^{bc}	195.30^{b}	165.00^{c}	220.50^{a}	8.22
Liver (g)	750.30	725.00	738.45	729.70	20.60
Gut Content (kg)	3.90	3.85	3.50	3.65	0.52
Rumen Weight (kg)	0.75^{b}	0.70^{b}	0.80^{ab}	0.90^{a}	0.06
Rumen Papillae Score	1.43^{a}	1.58^{b}	2.67^{b}	2.35^{a}	0.13
Reticulum Weight (g)	238.00	236.50	250.80	225.60	14.32
Omasum Weight (g)	213.85	216.00	220.00	213.50	10.21
Abomasum Weight (g)	150.71	143.15	145.21	142.00	6.87
S. Intestine Weight (kg)	0.80	0.85	0.93	0.95	0.06
S. Intestine Length (m)	29.00	29.77	28.73	28.17	2.23
L. Intestine Weight (kg)	0.80	0.85	0.90	0.95	0.07
L. Intestine Length (m)	6.70	6.44	6.35	6.18	0.41
Visceral Fat (g)	259.00	268.95	228.55	223.00	27.67

Note: **a, b, c** superscripts indicate values that are **significantly different** *(P < 0.05)* within the same row. Different letters indicate statistical significance, While Shared letters indicate no significant difference. **SEM** = Standard Error of the Mean

3.2.4 Carcass Yield of Uda Rams Fed Diets Containing Graded Levels of Ensiled Urea-Treated Millet Husk

Table 9 presents carcass yield parameters of Uda rams fed diets with varying levels of ensiled urea-treated millet husk (EUTMH). Significant differences were observed among treatments ($p < 0.05$).

Lean meat percentage was highest in T1 (68.29%) and T2 (65.30%), while T3 (61.50%) and T4 (62.53%) recorded lower values. Bone percentage was lowest in T2 (21.00%) but significantly higher in T3 (27.89%) and T4 (27.13%). Fat deposition peaked in T2 (13.70%), whereas T1 had the lowest (8.56%), with T3 (10.61%) and T4 (10.34%) showing intermediate values.

The lean-to-bone ratio was most favorable in T2 (3.12), followed closely by T1 (2.94). In contrast, T3 (2.21) and T4 (2.30) demonstrated significantly lower ratios.

Table 9. Carcass Yield of Uda Rams Fed Diets Containing Graded Levels of Ensiled Urea-Treated Millet Husk

Parameters	T1	T2	T3	T4	SEM
Lean Meat (%)	68.29^{a}	65.30^{b}	61.50^{c}	62.53^{bc}	0.97
Bone (%)	23.15^{b}	21.00^{b}	27.89^{a}	27.13^{a}	0.88
Fat (%)	8.56^{c}	13.70^{a}	10.61^{b}	10.34^{b}	0.33
Lean : Bone	2.94^{ab}	3.12^{a}	2.21^{b}	2.30^{b}	0.19

Note: a, b, c superscripts indicate values that are significantly different *(P < 0.05)* within the same row. Different letters indicate statistical significance, While Shared letters indicate no significant difference. SEM = Standard Error of the Mean

3.2.5 Characteristics of Long Bones in Uda Rams

Table 10 summarizes the morphometric and mineral traits of femur and tibia bones in Uda rams fed diets with graded levels of ensiled urea-treated millet husk (EUTMH). Significant differences ($p < 0.05$) were observed in bone weight, length, and femoral calcium content, while weight-to-length ratio, magnesium, phosphorus, and calcium-to-phosphorus (Ca:P) ratio remained statistically unchanged ($p > 0.05$).

For femur traits, T1 recorded the highest weight (140.50 g) and length (17.00 cm), whereas T4 had the lowest (134.00 g). Seedor ratios were stable across treatments, ranging from 8.18 g/cm (T3) to 8.43 g/cm (T4), and indicating consistent bone density. Tibia characteristics followed a similar pattern, with T1 producing the heaviest (128.30 g) and longest (14.67 cm) bones, while other treatments ranged between 119.40–125.80 g and 13.00–13.70 cm. Tibia Seedor ratios showed minor variation (8.72–9.62 g/cm) but no statistical differences.

Mineral composition revealed significant variation in femoral calcium, peaking in T1 (37.45 g) and lowest in T3 (35.60 g). Magnesium and phosphorus concentrations remained stable (1.17–1.29% and 21.70–22.62%, respectively). The Ca:P ratio declined from 1.72 in T1 to 1.61 in T3, before rising slightly in T4 (1.70).

Table 10. Characteristics of Long Bones of Uda Rams Fed Diets Containing Graded Levels of Ensiled Urea-Treated Millet Husk

Parameters	T1	T2	T3	T4	SEM
Femur Weight (g)	140.50^{a}	138.00^{b}	135.00^{c}	134.00^{c}	0.35
Femur Length (cm)	17.00^{a}	16.50^{b}	16.50^{b}	15.90^{b}	0.17
Seedor Ratio (g/cm)	8.26	8.36	8.18	8.43	0.25
Tibia Weight (g)	128.30^{a}	119.40^{c}	125.17^{b}	125.80^{b}	0.38
Tibia Length (cm)	14.67^{a}	13.70^{ab}	13.00^{b}	13.50^{b}	0.55
Seedor Ratio (g/cm)	8.75	8.72	9.62	9.32	0.33
Mineral Content of Femur					
Calcium (%)	37.45^{a}	36.50^{ab}	35.60^{b}	37.00^{ab}	0.65
Magnesium (%)	1.18	1.20	1.17	1.29	0.26
Phosphorus (%)	21.70	22.18	22.62	21.80	0.85
Calcium : Phosphorus Ratio (%)	1.72	1.65	1.61	1.70	0.08

Note: Superscripts **a, b, c** in the same row denote statistically significant differences at $P < 0.05$. Different letters indicate statistical significance, While Shared letters indicate no significant difference. SEM = Standard Error of the Mean.

4.0 Discussion

4.1.1 Haematological Parameters of Uda Rams

Table 3 summarizes haematological responses of Uda rams fed diets containing graded levels of ensiled urea-treated millet husk (EUTMH). Significant differences ($p < 0.05$) were observed for haemoglobin (Hb), packed cell volume (PCV), white blood cell (WBC) counts, and eosinophils, while other indices remained stable. Haemoglobin (Hb) ranged from 11.30–12.50 g/dL, highest in T1. Values fell within or slightly above tropical sheep references, indicating enhanced erythropoiesis at lower husk inclusion (Nafisat *et al.*, 2021). Packed Cell Volume (PCV) varied from 33.42–37.38%, peaking in T1, reflecting improved oxygen transport efficiency.

White Blood Cell (WBC) Counts ranged from 4.18–5.68 × 10^{9}/µL, all within normal limits. T2 (10% husk) showed the highest value, suggesting mild immune stimulation without inflammatory stress (Mabu *et al.*, 2025).

Differential Leukocytes: Lymphocytes and monocytes remained stable. Eosinophils peaked in T1 but declined in husk-fed groups, possibly due to reduced parasitic antigen challenge (Zhang *et al.*, 2026). Basophils were unaffected (Arsenopoulos *et al.*, 2025). RBC and Indices: RBC counts (8.76–9.50 × 10^{12}/L), MCH (8.75–9.40 pg), MCV (30.18–30.76 fL), and MCHC (32.29–32.61 g/dL) showed no significant variation, confirming consistent erythrocyte size and haemoglobin synthesis. Moderate husk inclusion (10–20%) improved Hb, PCV, and WBC, supporting oxygen transport and immune readiness. Higher inclusion (30%) preserved stability but slightly reduced Hb and WBC, reflecting metabolic efficiency.

4.1.2 Biochemical Profile of Uda Rams

Table 4 presents serum biochemical indices. Most parameters (albumin, globulin, total protein, HDL-C, LDL-C, urea) remained stable, while triglycerides, creatinine, and total cholesterol differed significantly ($p < 0.05$). Albumin (2.17–2.41 g/dL) and total protein (5.82–6.28 g/dL) were below reference ranges, suggesting mild

hypoalbuminemia and protein dilution under fibre-rich diets (Malede *et al.*, 2025). Globulin remained within normal limits, indicating preserved humoral immunity. HDL-C (0.64–0.77 mmol/L) and LDL-C (0.80–0.89 mmol/L) were stable (Lipids). Triglycerides declined significantly with husk inclusion (1.17 mmol/L in controls vs. 0.70–0.85 mmol/L in husk groups), reflecting altered energy partitioning (Kamal *et al.*, 2025). Total cholesterol peaked at 1.95 mmol/L in T2 but dropped to 1.11 mmol/L at higher husk levels, suggesting variable absorption and synthesis (Hussein *et al.*, 2024).

Creatinine declined from 103 µmol/L in controls to 85.7 µmol/L at 20% husk, before rising slightly at 30%. All values remained within normal ovine ranges, but fluctuations highlight potential effects on renal function and muscle turnover (Abera *et al.*, 2025). Urea remained stable (3.62–3.81 mmol/L), indicating effective ruminal ammonia utilization and hepatic ureagenesis (Zhang *et al*., 2025). While EUTMH supported basal metabolic and immune functions, high fibre inclusion reduced protein indices and altered lipid metabolism. Balanced supplementation with degradable protein and fermentable energy is recommended to sustain growth and organ function.

4.1.3 Liver Function and Electrolyte Profiles of Uda Rams

Table 5 presents serum liver enzyme and electrolyte data for Uda rams fed diets with varying levels of ensiled urea-treated millet husk (EUTMH). Liver enzyme values (165.5–196.7 U/L) remained within normal ovine ranges, indicating stable hepatocellular function (Ohran *et al.*, 2024).

ALT levels (80.4–90.2 U/L) exceeded typical ovine references (22–38 U/L), suggesting mild hepatic stress at higher husk inclusion (Očenáš *et al.*, 2025). ALP activity varied significantly (123.5–178.7 U/L) but remained within physiological limits, reflecting intact bile duct and bone metabolism (Ozturk and Mamak, 2024). Direct bilirubin (1.2–1.5 µmol/L) and total bilirubin (0.85–0.97 µmol/L) values were stable, confirming preserved hepatic excretory capacity.

Electrolyte values were consistent with ovine standards, with chloride concentrations (100.7–104.6 mmol/L) within range and minor variation (Grimm *et al.*, 2021). T3 recorded subnormal potassium levels (3.10 mmol/L), below the 3.5–5.5 mmol/L reference, possibly reflecting altered renal or ruminal handling. Sodium declined progressively from 128.0 mmol/L (T1) to 107.5 mmol/L (T4), all below the 140–152 mmol/L reference range, suggesting dietary effects on water–electrolyte homeostasis (Teixeira Rodrigues de Almeida *et al.*, 2025).

Most hepatic enzymes and bilirubin values remained within normal limits, indicating preserved liver function. However, persistent ALT elevation and significant reductions in sodium and potassium highlight metabolic stress under higher husk inclusion. These findings suggest that while EUTMH supports basal hepatic function, excessive inclusion may compromise electrolyte balance and impose mild hepatic strain.

4.2.1 Carcass Characteristics of Uda Rams

Table 6 summarizes carcass traits of Uda rams fed diets with varying levels of ensiled urea-treated millet husk (EUTMH). The diets had clear effects on slaughter performance and meat quality. Rams on the control diet (T1) achieved the highest slaughter weight (28.50 kg) and carcass weight (16.50 kg), while those on the highest husk diet (T4) recorded the lowest (26.50 kg and 15.20 kg). This decline reflects reduced nutrient intake and growth efficiency, consistent with reports that high dietary fibre compromises carcass yield in small ruminants (Jiwuba *et al.*, 2025).

Muscle quality parameters also varied. Warm muscle pH increased from 6.10 in T1 to 6.80 in T3–T4, suggesting slower glycogen depletion post-slaughter due to reduced dietary energy. Elevated pH values are associated with darker, firmer, drier (DFD) meat (Corazzin *et al.*, 2019). Muscle temperature rose significantly with husk

inclusion, ranging from 32.20 °C in T1 to 34.00 °C in T4, which may accelerate protein denaturation and reduce tenderness (Adewunmi *et al.*, 2014). Dressing percentage followed a similar trend, highest in T1 (57.90%) and lowest in T3 (56.36%), reflecting increased gut fill and indigestible fibre fractions such as lignin (Eckermann *et al.*, 2025).

4.2.2 Primal Cuts of Uda Rams

Table 7 shows the distribution of primal cuts. Leg weights remained stable (27.00–28.50 kg), indicating hindquarter resilience to fibre variation (Huang *et al.*, 2023). In contrast, premium cuts declined with husk inclusion. Loin weights dropped from 13.50 kg in T1 to 8.97 kg in T2, while rack weights were highest in T1 (12.91 kg) and lowest in T2–T3 (10.00–10.25 kg). Flank weights also decreased significantly in T4 (7.10 kg). These reductions highlight the limiting effect of indigestible fibre on muscle accretion, consistent with findings in lambs fed fibre-rich diets (Wang *et al.*, 2024) .

Forequarter cuts increased with husk inclusion, suggesting compensatory growth. Shoulder weights rose from 15.00 kg in T1 to 18.00 kg in T4, while neck weights were significantly higher in T3 (14.20 kg) and T4 (13.90 kg) compared to T1 (11.00 kg). This redistribution indicates altered nutrient partitioning under reduced dietary energy, similar to compensatory deposition patterns reported in goats fed protein-enriched rations (Huang *et al.*, 2023). Foreleg weights showed mixed responses, with T1 (11.20 kg) and T4 (11.00 kg) higher than T2 (8.33 kg)

Overall, carcass yield declined with higher husk inclusion, while carcass composition shifted toward forequarter dominance. Premium cuts (loin, rack, flank) were most affected by reduced nutrient density, whereas forequarter cuts (shoulder, neck) increased, reflecting compensatory growth. Leg weights remained stable, underscoring their resilience to variation in dietary fibre.

4.2.3 Offal Characteristics of Uda Rams

Table 4.6.3 shows offal traits of Uda rams fed diets with varying levels of ensiled urea-treated millet husk (EUTMH). Vital organs such as the heart (227–236 g) and liver (725–750 g) remained stable across treatments, underscoring resilience to dietary fibre variation (Shehu *et al.*, 2024). Significant differences were observed in spleen weight, highest in T4 (220.50 g) and lowest in T3 (165.00 g), suggesting immune modulation under fibre-rich diets (Amos *et al.*, 2025). Rumen weight increased with husk inclusion (0.70–0.90 kg), while papillae scores peaked in T3 (2.67), reflecting enhanced absorptive capacity (Santos *et al.*, 2025). Gut content and secondary stomach compartments showed minimal variation.

Intestinal development adapted structurally: small intestine weight increased (0.80–0.95 kg) while length remained stable (28–30 m); large intestine weight rose slightly (0.80–0.95 kg) with marginal length reduction (6.70–6.18 m). Visceral fat declined with husk inclusion, highest in T2 (268.95 g) and lowest in T4 (223.00 g), consistent with reduced energy density in fibre-rich diets (Danese *et al.*, 2025).

4.2.4 Carcass Yield of Uda Rams

Table 8 highlights carcass yield responses of Uda rams fed graded levels of ensiled urea-treated millet husk. Lean meat percentage declined significantly with higher husk inclusion, from 68.29% in T1 to 61.50% in T3 ($p < 0.05$), reflecting reduced nutrient utilization (Wang *et al.*, 2024). Bone proportion increased in T3 (27.89%) and T4 (27.13%), consistent with nutrient dilution effects (Mahgoub *et al.*, 2025).

Fat deposition peaked in T2 (13.70%) but was lowest in T1 (8.56%), suggesting altered energy partitioning at moderate husk inclusion. The lean-to-bone ratio was most favorable in T2 (3.12) and lowest in T3 (2.21), confirming that moderate husk levels supported better carcass efficiency.

4.2.5 Long Bone Characteristics of Uda Rams

Table 9 presents femur and tibia traits of Uda rams fed graded levels of ensiled urea-treated millet husk. Higher husk inclusion reduced femur weight (140.50 g in T1 vs. 134.00 g in T4) and length (17.00 cm vs. 15.90 cm), while Seedor ratios (8.18–8.43 g/cm) remained stable, indicating preserved bone density despite reduced growth (Zillinger *et al.*, 2024).

Tibia weight was highest in T1 (128.30 g) and lowest in T2 (119.40 g), with lengths declining to 13.00 cm in T3. Tibia Seedor ratios (8.72–9.62 g/cm) were higher than femur values, suggesting adaptive mineralization for mechanical resilience (Asnayanti *et al.*, 2026).

Mineral composition remained stable: calcium ranged 35.60–37.45%, phosphorus 21.70–22.62%, and Ca:P ratios 1.61–1.72, all within optimal ranges. Magnesium varied slightly (1.17–1.29%). These results confirm that mineral balance was preserved despite reduced skeletal growth, consistent with findings in dairy sheep and goats (Brugger and Liesegang, 2024).

Stable vital organs, adaptive rumen and intestines, variable spleen and visceral fat; decline in lean meat and efficiency at higher husk levels; moderate inclusion improved lean-to-bone ratio. Bone traits reduced size but preserved density and mineral balance, reflecting adaptive mineralization.

Overall, EUTMH inclusion up to 30% supports digestive adaptation and mineral stability but compromises carcass yield and skeletal growth at higher levels. Moderate inclusion (10–20%) optimizes carcass efficiency and bone resilience.

5.0 Conclusion and Recommendations

5.1 Conclusion

The present study demonstrated that ensiled urea-treated millet husk (EUTMH) can be incorporated into the diets of Uda rams without adversely affecting overall health status, liver function, or bone mineralization. Most haematological, biochemical, and physiological indices remained within acceptable ranges, indicating that EUTMH is a safe alternative feed resource. However, increasing dietary inclusion levels reduced carcass yield, lean meat percentage, and the weights of premium carcass cuts. Moderate inclusion levels (10-20%) produced the most favorable responses, supporting adequate metabolic function, carcass efficiency, and lean-to-bone ratio. Therefore, EUTMH may be utilized as a sustainable feed ingredient for Uda rams, with 10-20% inclusion recommended for optimal animal performance and carcass quality.

5.2 Recommendations

Based on the findings of this study:

1. Ensiled urea-treated millet husk (EUTMH) may be included in Uda ram diets at 10-20% inclusion levels, where optimal health status, carcass efficiency, and lean-to-bone ratio were observed.
2. Inclusion levels above 20% should be avoided or carefully managed, as they may reduce carcass yield, lean meat production, and electrolyte balance.
3. Diets containing higher levels of EUTMH should be supplemented with appropriate protein, energy, and mineral sources to improve nutrient utilization and maintain metabolic stability.
4. Routine monitoring of electrolyte and liver function indices is recommended when EUTMH is used extensively in ram feeding systems.

5. Further studies should focus on digestibility, rumen fermentation, long-term productivity, reproductive performance, and the economic viability of EUTMH-based diets under commercial production conditions.

Ethical and Regulatory Compliance:

This study followed applicable national regulations, institutional policies governing the care and use of laboratory animals, and the principles outlined in the *Guide for the Care and Use of Laboratory Animals*. The research was also reported in compliance with the ARRIVE (Animal Research: Reporting of In Vivo Experiments) guidelines to ensure transparency, reproducibility, and methodological rigor. All procedures involving anesthesia, analgesia, and euthanasia were performed in accordance with the current recommendations of the American Veterinary Medical Association (AVMA) and relevant local regulatory requirements.

Ethical Use of Artificial Intelligence

The authors utilized Microsoft Copilot (https://copilot.microsoft.com) to assist with manuscript drafting, text paraphrasing, and language refinement. Grammarly Premium (current version as of March 2026) was employed for final grammatical review and stylistic editing. Artificial intelligence tools were used solely to support scientific writing and language enhancement; they were not involved in statistical analyses, primary data generation, image production, experimental design, or the interpretation of research findings.

Declaration of Conflict of Interest

The authors declare that this research received financial support from the Tertiary Education Trust Fund (TET Fund). The funding agency had no involvement in the study design, data collection, data analysis, and interpretation of results, manuscript preparation, or the decision to submit the work for publication. The authors further declare that, apart from the disclosed funding, there are no financial, professional, or personal relationships that could be perceived as constituting a conflict of interest.]

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