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Intake, nutrient digestibility, nitrogen balance, and rumen parameters of Balami, Udah and Yankasa sheep breeds fed *Brachiaria decumbens* or *Digitaria smutsii* hay

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ABSTRACT. The objective of this experiment was to compare three Nigeria sheep breeds fed *Brachiaria decumbens (Stapf)* or *Digitaria smutsii (Stent)* hay for performance, intake, digestibility, and rumen parameters. Each of the three breeds of sheep, which weighed on average 24.7, 25.5, and 25.5 kg (Balami, Uda, and Yankasa, respectively) were assigned to a 2 × 3 completely randomized design. There were significant ($p < 0.05$) differences among breeds, with Balami and Uda presenting the highest intake, rumen parameters, average daily weight gain (ADG) and final body weight (FBW). Sheep fed *D. smutsii* hay presented higher ($p < 0.05$) digestibility, ADG and FBW than those fed *B. decumbens* hay. Balami and Uda breeds fed *D. smutsii* had improved rumen pH, VFA production, and N-NH_3 production, and consequently had improved digestibility and growth performance when compared to the Yankasa breed fed *B. decumbens* hay. It is important to note that the effectiveness of different types of forage and the response of different sheep breeds to those forages can vary based on several factors, including the nutritional content of the forage, the age and health of the animals, and environmental conditions.

Keywords: N-NH_3; performance; production; tropical grasses hay; volatile fatty acids.

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Introduction

Nigeria possesses four breeds of sheep amounting about 53,061,143 (Abubakr, 2022) with more than 90% of this population concentrated in the northern parts of the country. Balami and Uda, which are large and fast-growing breeds, are found in the Northeastern region and Sahelo-Sudan vegetation zone, respectively, while the Yankasa breed which in-between the two large breeds and West African Dwarf (WAD) in terms of size and has the largest population is widespread across the northern part of Nigeria (Adu & Ngere, 1979). The diversity of these breeds of sheep allows for adaptation to different environments and agricultural practices across the country. Differences in the productivity of sheep are primarily attributed to variations in grazing behavior, which can affect the amount and quality of forage intake, which, affecting productivity.

Many grass cultivars available at the National Animal Production Research Institute (NAPRI), in Shika, Zaria, can show considerable variations in productivity and nutritional value, which can interfere with animal performance. However, *Brachiaria decumbens (B. decumbens) and Digitaria smutsii (D. smutsii)* are the most predominantly used due to their adaptation to tropical and subtropical climates and high productivity. Results from several studies comparing digestibility in other breeds of sheep have highlighted the complex interaction of factors that impact sheep productivity, including diet, digestive processes, and rumen physiology. Therefore, understanding these factors is crucial to optimize sheep production and meet their nutritional needs. For example, Chelkapally et al. (2023) and Purbowati et al. (2021) revealed differences in dry matter (DM) and neutral detergent fiber (NDF) digestibility among sheep that received different forage sources. This suggests that the type of forage consumed can impact the digestibility of nutrients in the sheep's diet.

Scanlon et al. (2013) studied the concentration and proportions of volatile fatty acids in Dorper/Damara and Merino sheep, and discovered that Dorper/Damara sheep had higher concentrations than Merino. This means that energy metabolism was higher in Doper/Damara, and it influenced its overall performance above Merino. Similarly, Macêdo et al. (2022) reported that the composition of rumen fluid is influenced by several factors, including the nature of the diet (proportions of rumen degradable and undegradable protein), rumen fluid outflow rates, composition of the microbial population, and rumen pH. These parameters play a crucial role in the digestive processes in the sheep's rumen.

Studies, such as those by Pereira et al. (2021) and Scanlon et al. (2013), have reported variable results when comparing digestibility in different sheep breeds. Factors such as diet, dry matter intake (DMI), diet selection, nutrient digestibility, and rumen parameters have been identified as potential contributors to production differences. In addition, the size of the animal and its digestive tract, as highlighted by Madziga et al. (2022), can affect feed intake and digestibility, which means that larger animals with larger digestive tracts can consume more feed.

The data on Nigerian sheep breeds need to be updated. Therefore, there is a need for comparative research to assess how these breeds perform in terms of feed utilization, growth, and rumen fermentation when they are fed roughage-based diets. The primary objective of the study was to compare Nigerian sheep breeds - specifically Balami, Uda, and Yankasa - when fed roughage-based diets of *B. decumbens* or *D. smutsii* hay. The research aimed to assess differences in digestibility, rumen fermentation, overall performance, and growth among these breeds.

Material and methods

Location and climate conditions

The study was conducted at the Experimental Unit of the Small Ruminant Research Program of the National Animal Production Research Institute, in Shika–Zaria. The Animal Care and Use Committee (Ahmadu, Bello University) approved the study's method and procedures (approval numbers: ABUCAUC/2017/071).

Animals, experimental design, diets

Ten growing rams each of the breeds Balami, Udah, and Yankasa averaged 18 months of age and 24.7, 25.5, and 25.5 kg of body weight (BW), respectively, and were used to evaluate their performance on *B. decumbens* hay or *D. smutsii* hay used as the basal diets. A 2 (grass) × 3 (sheep breeds) factorial design was adopted, totaling six treatment groups with three replications per treatment group. Animals were stratified based on genotype and were randomly allocated to each treatment group within strata, with three Balami, three Uda, and three Yankasa animals per treatment. Two roughages (*B. decumbens* and *D. smutsii* hay) were used.

The concentrate diet was formulated (Table 1) based on corn (38.0 %) and corn bran (18.9 %) as the energy source, cottonseed cake (39.1 %) as the protein source and common salt (1.50 %).

Table 1. Chemical composition (%) of *Brachiaria decumbens* and *Digitaria smutsii* hay, Corn (38%), corn bran (18.9%), cottonseed cake (39.1%), mineral mixture (2.50%), common salt (1.50%), and experimental concentrate.

Nutrients (g kg^{-1} DM)	Ingredients					Concentrate
	B. Decumbens	*D. Smutsii*	Corn	Corn bran	Cotton seedcake	
Dry Matter	916.70	916.30	911.80	911.50	912.30	927.80
Organic Matter	812.60	839.00	867.60	818.70	890.10	812.30
Crude Protein	45.60	57.60	83.10	116.90	285.80	136.30
Ether Extract	38.50	40.50	80.30	110.30	110.50	171.50
Crude Fiber	640.80	628.90	452.10	539.20	502.10	274.00
ADF	453.50	431.20	432.70	349.90	423.50	459.50
NDF	440.90	422.10	480.10	452.10	472.30	562.70
Nitrogen free extract	104.20	150.10	186.10	144.60	63.10	220.00
Ash	87.60	89.20	110.20	100.50	49.80	115.50
ME (MJ kg^{-1} DM)	9.31	9.81	10.69	10.88	10.51	11.40
Cost ($ per kg)	0.07	0.07	0.15	0..06	0.07	0.37

The ME values of the experimental feed ingredients were calculated according to Maff (1975) as follows: ME= (MJ kg^{-1} DM) = 0.012CP + 0.031EE + 0.005CF + 0.014NFE, where ME = metabolizable energy, MJ/KJDM = Mega joule per kilo joules dry matter. Bone meal (2.50 %) was used as the source of mineral to meet the energy (gross energy – 16 MJ kg^{-1} DM) and crude protein (mean CP – 16 %), for an average daily gain of 200 g day^{-1}

according to the National Research Council (NRC, 2007). The animals were allocated into individual pens (1.5 × 1.2 m), and were fed concentrate at a level equivalent to 1% of their BW on a DM basis, while the *B. decumbens* and *D. smutsii* hay were fed *ad libitum*. The daily feeding occurred at 9am after collecting and weighing feed leftovers to determine the daily feed intake. Fresh and clean water was always available.

Intake and growth performance

The amount of feed offered, and the leftovers were weighed for daily adjustment and calculation of intake. Animals were weighed at the beginning of the trial and fortnightly after that during the 90 days of the feeding trial. The fortnightly weights were used to adjust and maintain the pre-determined level of concentrate feeding at 1% body weight. Rams were weighed in the morning after overnight fasting using a suspended weighing scale with sensitivity of 100 grams. The average daily weight gain was calculated as (ADG) = final BW − initial BW/number of experimental days. Feed conversion was also calculated as FC = daily total DM intake / ADG.

Rumen fluid collection

Rumen fluid samples were collected from the sheep at the end of the feeding trial at 0 hr (right before feeding), 2, 4, and 6 hours after feeding, where 20 mL of the fluid was drawn from three sheep of each treatment using a stomach tube. The tube, which is about 90 cm long with a metallic filter attached at one end, was passed through a pipe placed in the mouth of the sheep into the rumen, and a suction pump was attached to the other end of the tube, to draw out the rumen fluid. Philips digital pH meter was used to determine the rumen fluid pH within one minute of collection. The fluid was strained through a muslin cloth, and 20 mL aliquot of the filtrate was taken and mixed with an equal volume of 1N H_2SO_4 saturated with MgSO4 to acidify, deproteinize, and reduce bacterial activity, and then centrifuged at 3000 rpm and allowed to stand for 10 min. Twenty milliliters of the supernatant were decanted into plastic bottles and kept in a deep freezer (−20°C) until analyzed for total volatile fatty acids (VFAs) and rumen ammonia-nitrogen (NH_3-N). Each rumen fluid sample of 5 mL was diluted with 1 mL of deproteinizing solution (25% orthophosphoric acid) to determine the concentration of VFAs. The supernatant was transferred to a new 2 mL vial for GC-MS analysis using a SHIMADZU GC2030-QP2020 NX Gas Chromatography-Mass Spectrometer (San Jose, CA, USA) with an HP-FFAP capillary column. A 1 μL sample was injected at a 5:1 ratio with helium as the carrier gas. Rumen ammonia concentration was determined by steam distillation into boric acid and back titrated with 0.01N hydrochloric acid following the procedure described by Whitehead et al. (1976).

Digestibility and nitrogen (N) balance

Three sheep from each treatment were housed in a metabolism cage. The sheep were allowed 3 days to adjust to the cage environment as the diet remained the same before measurements were taken for seven days. For each ram, total urine output was collected into a 10-L container containing 100 mL of 0.1N H_2SO_4 to prevent ammonia loss from the urine. Ten percent of each day's collection was bulked and stored in a refrigerator until being analyzed for nitrogen. The total fecal output from each ram was also collected and weighed fresh. Ten percent of each day's collection was bulked, dried in the oven for 48h at 55°C, milled and stored in plastic containers for proximate analysis (Osuji et al., 1993). Representative samples of the feeds offered and concentrate feed were taken daily, separately mixed thoroughly, sub-sampled at the end of the collection period, milled in a Christy and Norris mill passing through a 1.0-mm mesh, and stored in air-tight container for proximate analysis. The apparent digestibility was calculated as:

Apparent digestibility (%) = ([Nutrient intake − nutrient in feces] / Nutrient intake) × 100

The nitrogen balance, expressed as daily amounts of nitrogen compounds, was calculated by the equation:

$N\text{-retained } (g\ d^{-1}) = N\text{-intake } (g\ d^{-1}) - N\text{-fecal excretion } (g\ d^{-1}) - N\text{-urinary excretion } (g\ d^{-1})$.

The variables referring to N-retained were presented as a function of N-intake.

Chemical analysis of feed, ingredients, fecal and urinary samples

Chemical analysis of experimental feeds and leftovers was carried out on the representative samples. The samples were mixed and partially oven-dried at 60C° for 72 hours, and the dried samples were ground passing through a 1.0 mm sieve and stored in containers at room temperature until further chemical analysis. The ground samples were analyzed for dry matter (DM), ash, and nitrogen (N) following the procedure of Association of Official Analytical Chemistry (AOAC, 2012). Crude protein (CP) was determined by multiplying N by 6.25. NDF and ADF were analyzed according to Van Soest et al. (1991). The daily fecal output of each animal was bulked, weighed, thoroughly mixed, and sub-sampled. The sample was treated with 20% formaldehyde to stop further bacterial activity and stored in the freezer at −4°C. Total urine production was collected daily into graduated plastic containing 50 mL of 0.1N HCl. A 5% aliquot of total urine output was taken daily and stored in the freezer until required to analyze urinary nitrogen and purine. At the end of the 7-day collection period, urine and fecal output were bulked, thoroughly mixed, and sub-sampled.

Statistical analysis

The experiment was carried out following a completely randomized design in a 3 × 2 factorial scheme (three Nigerian sheep breeds and two tropical forage hays). Variance analyses were carried out for the variables studied, using PROC GLM of SAS® Statistical Analysis System (SAS, 2003), whose model included the effects of dietary hay (*B. decumbens* and *D. smutsii*), Nigerian sheep breed (Balami, Uda and Yankasa); in addition to the covariate slaughter weight as follows: $Y_{ijk} = \mu + H_i + B_j + (HB)_{ij} + \varepsilon_{ijk}$, where: Y_{ijk} = observed value of the response variable; μ = overall average; H_i = effect of the i^{th} hay (i = 1,2); B_j = effect of the j^{th} Nigerian breed (j = 1,2,3); HB_{ij} = effect of the interaction between the i^{th} level of the factor hay (H) and the j^{th} level of the factor breed (B); ε_{ijk} = random error associated with each observation. Rumen fermentation results were analyzed as repeated measures over time (0, 2, 4, and 6 h relative to the morning feeding) using the MIXED procedure of SAS, according to the mathematical model: $Y_{ijk} = \mu + H_i + E_{(i)j} + B_j + (HB)_{ij} + \varepsilon_{ijk}$; where: Y_{ijk} = observed value of the response variable; μ = overall average; H_i = effect of the i^{th} hay (i = 1,2); $E_{(i)j}$ = effect of level i of the factor H in replication k (residue a); B_j = effect of the j_{th} Nigerian breed (j = 1,2,3); HB_{ij} = effect of the interaction between the i^{th} level of the factor hay (H) and the j^{th} level of the factor breed (B); ε_{ijk} = random error associated with each observation. To study the variables included in the mathematical model, the effects of all possible interactions were tested and, as they did not present statistical significance ($p > 0.05$), they were not included in the analyses. Data means were compared by the Ducan test at 5% probability.

Results and discussion

There was a significant ($p < 0.05$) effect of interaction between breed and hay (Table 2) on performance (initial and final BW and ADG) while there was no effect of interaction ($p > 0.05$) on the variables of nutrient intake and digestibility, and therefore, the factors breed, and type of hay were presented separately. In general, all breeds had higher nutrient intake and digestibility when fed *D. smutsii* hay in comparison to *B. decumbens* hay.

Table 2. Effect of interaction between breed and type of hay on nutrient intake, digestibility and nitrogen of Balami, Uda and Yankasa rams fed *B. decumbens* or *D. smutsii* hay.

Variables	Hay type (H) × Nigerian breed (NB)					
	B. decumbens			*D. smutsii*		
	Balami(n=5)	Uda(n=5)	Yankasa(n=5)	Balami(n=5)	Uda(n=5)	Yankasa(n=5)
Performance						
Initial body weight (kg)	25.60±3.66^a	25.40±3.63^a	24.40±3.49^c	25.00±3.57^b	25.00±3.57^b	24.50±3.50^c
Final body weight (kg)	41.40±5.91^b	32.60±4.66^c	31.00±4.43^d	47.80±6.83^a	41.40±5.91^b	37.60±5.37^c
Average daily weight gain (g d^{-1})	0.18±0.03^b	0.08±0.01^d	0.07±0.01^d	0.25±0.04^a	0.18±0.03^b	0.14±0.02^c
Feed conversion (g g^{-1})	5.50±0.06^b	12.00±0.13^d	12.14±0.13^d	4.60±0.05^a	5.50±0.06^b	6.50±0.07^c

$^{a, b, c, d}$Means followed by different superscript letters within the same row differ significantly ($p<0.05$).

The results of the present study contradict the findings of Wildues et al. (2005). The earlier study, conducted with Barbados Blackbelly, Kathadin, and St. Croix lambs, did not report any breed differences regarding nutrient intake when these lambs were fed pasture or hay-based diets. In other words, the previous study did not observe the same variations in nutrient intake among different breeds. Additionally, the present study did not find any breed-forage type interaction, which means that the type of forage (pasture or hay-based) did not significantly impact the differences in nutrient intake and digestibility coefficients among the studied breeds. This contrasts with the findings of Quick and Dehority (1986), who reported no breed-forage type interaction when St. Croix and Targhee cross lambs were fed different types of alfalfa-bromegrass hay (pelleted, chopped, or long).

Regarding breed comparisons (Table 3), nitrogen intake differed among breeds, with the Balami breed presenting the highest intake ($p < 0.05$) and Yankasa the lowest ($p > 0.05$). Balami sheep had higher nitrogen urinary excretion compared to Yankasa and Uda, while Yankasa had similar nitrogen urinary excretion to Uda. There was no significant difference ($p < 0.05$) among breeds for nitrogen fecal excretion. Balami had the highest nitrogen retention, followed by Uda, while Yankasa had the lowest ($p > 0.05$). Nitrogen retention as a percentage of intake was lower ($p > 0.05$) in Yankasa sheep compared to Balami and Uda.

Table 3. Effect of breed on nutrient intake, digestibility and nitrogen balance of Balami, Uda and Yankasa sheep breeds fed *Brachiaria decumbens* or *Digitaria smutsii* hay.

Variables	Breed		
	Balami (n=10)	Uda(n=10)	Yankasa(n=10)
Performance growth			
Initial body weight (kg)	24.70±3.528	25.50±3.571	24.75±3.535
Final body weight (kg)	39.50±5.642^{a}	39.40±5.628^{a}	36.45±5.207^{b}
Average daily weight gain (g d^{-1})	0.16±0.023^{a}	0.15±0.021^{a}	0.13±0.019^{b}
Feed conversion (g g^{-1})	6.62±0.945	6.60±0.943	6.77±0.967
Dry matter intake (kg)			
Concentrate intake	0.40±0.057^{a}	0.36±0.051^{b}	0.34±0.049^{ab}
Hay intake	0.56 ±0.080^{a}	0.53±0.076^{a}	0.44±0.063^{b}
Total feed intake	0.96±0.137^{a}	0.89±0.127^{a}	0.78±0.111^{b}
Other nutrients intake (kg)			
Organic matter	0.87±0.124^{a}	0.80±0.114^{a}	0.70±0.100^{b}
Crude protein	0.12±0.017^{a}	0.10±0.014^{ab}	0.08±0.011^{b}
Ether extract	0.11±0.016^{a}	0.09±0.013^{b}	0.07±0.010^{c}
Neutral detergent fiber	0.49±0.070^{a}	0.48±0.067^{ab}	0.44±0.063^{b}
Acid detergent fiber	0.33±0.047	0.32±0.046	0.29±0.041
Digestibility coefficient (%)			
Dry matter	65.28±9.33^{a}	63.81±9.12^{b}	61.94±8.85^{c}
Organic matter	65.29±9.33^{a}	63.36±9.05^{b}	64.06±9.15^{b}
Crude protein	57.76±8.25^{a}	55.29^{b}±7.89	52.53±7.50^{c}
Neutral detergent fiber	55.56±7.94^{a}	54.07±7.81^{b}	52.66±7.52^{c}
Acid detergent fiber	54 .13±7.73^{a}	53.20±7.60^{b}	52.50±7.50^{c}
Nitrogen (N) balance			
N-intake (g day^{-1})	55.68±7.95^{a}	54.34±7.76^{b}	51.21±7.32^{c}
N-fecal (g day^{-1})	18.71±2.67	18.10±2.59	18.86±2.69
N-urinary (g day^{-1})	10.44±1.49^{b}	10.86±1.55^{ab}	11.28±1.61^{a}
N-retained (g day^{-1})	26.53±3.79^{a}	25.37±3.62^{b}	21.06±3.01^{c}
N-retained (%N-intake)	47.65±6.81^{a}	46.71±6.67^{a}	41.14±5.88^{b}

$^{a, b}$ Means followed by different superscript letters within the same row differ significantly ($p < 0.05$) according to Dunkan's test.

DMI was different among sheep breeds, however there were interactions between factors. Balami rams showed higher intake and better performance compared to Uda and Yankasa rams. The DMI differences were attributed to a combination of body weight and the specific sheep breed. This suggests that the breed plays a role in determining feed intake.

The digestibility of dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), and acid detergent fiber (ADF) reduced in Balami rams when compared to Uda and Yankasa breeds. This reduction in digestibility could be due to the higher dry matter intake in Balami sheep. The findings of this study are consistent with the results of Harun and Sali (2019), who also found that feed intake is influenced by breed differences when hay is used as a basal diet. Larger sheep breeds generally have higher energy requirements to maintain their bodily functions, which leads to higher dry matter intake (Simões et al., 2021). In addition, a breed's basal metabolism also influences how much feed it needs to intake (Carvalho et al., 2020).

Different breeds of ruminant animals can exhibit variations in DM digestibility. In this specific study, the observed effects of breed on DM digestibility were not consistent with the findings of a study conducted by Ramadhan et al. (2022), which focused on desert goats. Similarly, Quick and Dehority's (1986) study did not find significant differences in DM digestibility between hair (St. Croix) and wool breeds. In contrast to the present study's findings, a study conducted by Silva et al. (2004) in Brazil, reported higher DM intake and digestibility coefficients in hair breeds compared to wool cross lambs. This suggests that breed-related differences in DM digestibility may vary across different regions and feeding conditions, possibly due to variations in forage types and quality. This study notes that, in contrast to DM digestibility, there was an increase in crude protein digestibility coefficient and improved nitrogen (N) balance in Balami rams compared to Uda and Yankasa. This result aligns with the findings of Ramadhan et al. (2022), which found higher crude protein digestibility in desert goats, which suggests that breed-related differences in crude protein digestibility may be more consistent.

This study also observed significant differences in the intake of certain nutrients among the different breeds. It suggests that the breeds in the study might have varying nutritional requirements or preferences when consuming pasture or hay-based diets. Hence, the differences in digestibility coefficients indicate how efficiently the lambs were able to digest and absorb nutrients from their diets. These differences suggest that breed-specific factors may affect how effectively the rams utilize the nutrients from their feed.

Sheep fed *D. smutsii* hay had higher ($p < 0.05$) intakes of crude protein and ether extract, as well as higher final body weight and ADG compared to those fed *B. decumbens* hay as shown in Table 4. There was no significant ($p > 0.05$) difference in feed conversion efficiency between the two hay types. Animals fed *D. smutsii* hay had significantly higher ($p < 0.05$) coefficients of digestibility of all nutrients (DM, OM, CP, NDF, and ADF) when compared to those fed *B. decumbens* hay. Nitrogen intake and urinary excretion were higher in animals fed *D. smutsii* hay compared to *B. decumbens* hay. There was no significant ($p > 0.05$) difference in nitrogen fecal excretion between the two hay types.

Table 4. Effect of hay type on intake, nutrient digestibility and nitrogen of Balami, Uda and Yankasa sheep fed *Brachiaria decumbens* or *Digitaria smutsii* hay.

Variables	Hay type	
	B. decumbens (n=15)	*D. smutsii (n=15)*
Performance growth		
Initial body weight (kg)	25.00±3.57	24.97±3.56
Final body weight (kg)	37.57±5.37^b	39.33±5.62^a
Average daily weight gain (g d^{-1})	0.14±0.02^b	0.16±0.02^a
Feed conversion (g g^{-1})	6.64±0.95	6.38±0.91
Dry matter intake (kg)		
Concentrate Intake	0.35±0.05	0.38±0.05
Hay Intake	0.49±0.07	0.53±0.08
Total feed Intake	0.84±0.12	0.91±0.13
Other nutrients intake (kg)		
Organic matter	0.77±0.11	0.83±0.12
Crude protein	0.09±0.01^b	0.11±0.02^a
Ether extract	0.08±0.01^b	0.10±0.01^a
Neutral detergent fiber	0.48±0.07	0.47±0.07
Acid detergent fiber	0.32±0.05	0.32±0.05
Digestibility coefficient (%)		
Dry matter	63.37±9.05^b	63.98±9.14^a
Organic matter	63.95±9.14^b	64.52±9.16^a
Crude protein	54.88±7.84^b	55.50±7.93^a
Neutral detergent fiber	43.82±6.026^b	44.37±6.34^a
Acid detergent fiber	42.95±6.13^b	43.61±6.23^a
Nitrogen balance		
N-intake (g day^{-1})	53.35±7.62^b	54.13±7.73^a
N-fecal (g day^{-1})	18.60±2.66	18.51±2.64
N-urinary (g day^{-1})	10.67±1.52^b	11.05±1.58^a
N-retained (g day^{-1})	24.08±3.44	24.56±3.51
N-retained (%N-intake)	45.05±6.44	45.29±6.47

$^{a, b}$Means followed by different superscript letters within the same row differ significantly ($p < 0.05$).

The rams in the present study had a positive nitrogen balance when fed both types of hay. However, those fed *B. decumbens* hay had a lower nitrogen balance compared to those fed *D. smutsii* hay. This was attributed to the lower nitrogen intake when fed *B. decumbens* hay, which had a lower crude protein (CP) content compared to *D. smutsii* hay. Regardless of the type of hay, there were differences in nitrogen balance among the three breeds of sheep. Balami and Uda retained more nitrogen than Yankasa. The results of the present study showed that Balami and Uda had the highest values of nitrogen intake and nitrogen retention. This finding is consistent with the study of Silva et al. (2004) which reported higher crude protein digestibility and nitrogen retention in Santa Ines (a hair breed) compared to wool crossbreeds.

Final body weight and average daily weight gain (ADG) were higher ($p < 0.05$) in Balami and Uda breeds compared to the Yankasa breed. There was no significant difference between the three breeds in terms of feed conversion efficiency. Nutrient intakes (organic matter, crude protein, ether extract, and neutral detergent fiber) varied significantly among breeds, with Balami generally showing higher intake values ($p < 0.05$). The digestibility coefficients of dry matter, organic matter, crude protein, neutral detergent fiber, and acid detergent fiber were significantly affected by the breed. Balami had the highest ($p < 0.05$) digestibility coefficients of all nutrients, followed by Uda and then Yankasa.

There was no effect of interaction ($p > 0.05$) on rumen parameters, therefore the factors breed (Table 5) and type of hay (Table 6) will be presented separately. The rumen pH levels observed in this study ranged from 6.32 to 6.79 and fell within the typical pH range for sheep, which is between 5.5 and 7.5. This is consistent with the findings of Franzolin and Dehority (1996), who noted that rumen pH can vary and is influenced by the type of diet that the animals are consuming. Furthermore, research by Allen (1997) suggested that rumen pH is not solely determined by the fiber content of the diet but is also influenced by the balance between rumen volatile fatty acids (VFAs) and ammoniacal nitrogen (NH_3-N) levels. In this study, it is suggested that the adequate fiber content in the sheep's diet, combined with fermentable carbohydrates from supplemental concentrate, helped maintain optimal rumen pH levels ranging from 6.41 to 6.82. This indicates that the diet composition likely played a role in stabilizing rumen pH within the appropriate range for the rams.

Table 5. Effect of breed on rumen parameters of Balami, Uda and Yankasa rams fed *B. decumbens or D. smutsii* hay.

Variables	Nigerian breed		
	Balami (n=10)	Uda (n=10)	Yankasa (n=10)
Rumen pH			
0h	6.46±0.08	6.39±0.08	6.33±0.08
2h	6.66±0.08[a]	6.59±0.08[b]	6.49±0.08[c]
4h	6.81±0.08[a]	6.79±0.08[ab]	6.71±0.08[b]
6h	6.67±0.08[a]	6.62±0.08[b]	6.55±0.08[c]
Ammonia Nitrogen (NH_3-N) (mg 100 mL^{-1} rumen fluid)			
0h	3.34±0.04	3.31±0.04	3.31±0.04
2h	5.69±0.07[a]	5.66±0.07[a]	5.38±0.06[b]
4h	9.68±0.12[a]	9.48±0.11[ab]	8.87±0.11[b]
6h	7.38±0.09[a]	7.44±0.09[a]	7.01±0.08[b]
Total volatile fatty acids (TVFA) (mmol 100 mL^{-1} rumen fluid)			
0h	10.71±0.13[a]	10.76±0.13[a]	10.01±0.12[b]
2h	12.33±0.15[a]	12.11±0.14[b]	11.87[c]±0.14
4h	11.75±0.14[a]	11.45±0.14[ab]	11.24±0.13[b]
6h	11.48±0.14[a]	11.29±0.13[b]	11.31±0.13[b]

[a,b,c]Means followed by different superscript letters within the same row differ significantly ($p < 0.05$); Before feeding (0h), and post feeding (2, 4 and 6 hours).

Table 6. Effect of hay type on rumen parameters of Balami, Uda and Yankasa rams fed *B. decumbens or D. smutsii* hay.

Variables	Hay type	
	B. decumbens (n =15)	*D. smutsii (n=15)*
Rumen pH		
0h	6.39±0.07	6.37±0.07
2h	6.55±0.08[b]	6.62±0.08[a]
4h	6.78±0.08	6.76±0.08
6h	6.61±0.08	6.62±0.08
Ammonia Nitrogen (NH_3-N; mg 100 mL^{-1} rumen fluid)		
0h	3.23±0.04	3.28±0.04
2h	5.54±0.07	5.60±0.07
4h	9.20±0.11[b]	9.49±0.11[a]
6h	7.25±0.09	7.29±0.09
Total volatile fatty acids (TVFA) (mmol 100 mL^{-1} rumen fluid)		
0h	10.09±0.12	10.90±0.13
2h	11.91±0.14[b]	12.30±0.15[a]
4h	11.31±0.13[b]	11.65±0.14[a]
6h	11.21±0.13[b]	11.51±0.14[a]

[a,b]Means followed by different superscript letters within the same row differ significantly ($p < 0.05$) according to Dunkan's test; Before feeding (0h), and post feeding (2, 4 and 6 hours).

This study's results shows that there was a difference in rumen pH between animals that were fed *B. decumbens* and *D. smutsii* at 4 hours after feeding. This suggests that the type of hay had an impact on rumen pH. In addition to the type of hay fed, there were differences in rumen pH relative to the time after feeding. Specifically, at 2 and 6 hours after feeding, rumen pH was notably higher in Balami and Uda. Typically, rumen pH is lowest immediately after feeding and ranges from 0.5 to 4 hours post-feeding. This low pH may be attributed to the balance between acid production, the input of buffers from saliva, and the presence or release of buffers or bases from the feeds. It was observed that the pattern was different from the typical trend.

Average rumen NH_3-N concentrations differed between breeds. Balami and Uda had consistently higher NH_3-N values throughout the sampling periods compared to Yankasa. This difference could be due to genetic factors, feeding behaviors, or other breed-specific characteristics. This agrees with the findings of Li et al. (2018) and Hristov et al. (2018) who found that the composition of the diet, particularly the proportions of rumen-degradable and undegradable protein, has a significant impact on rumen NH_3-N concentrations. Ruminant animals require a balanced diet that provides adequate protein sources for microbial growth and fermentation in the rumen. The rate at which rumen fluid leaves the rumen can affect NH_3-N concentrations, since higher outflow rates may reduce the time available for microbial fermentation and, consequently, ammonia production. In addition, the types and quantities of microorganisms present in the rumen play a crucial role in ammonia production, as different microbes have varying abilities to break down dietary proteins and release ammonia as a byproduct. Moreover, rumen pH is critical for the efficient functioning of the rumen as it affects the activity of rumen microbes, and a suboptimal pH can negatively impact ammonia production and overall digestion.

Regardless of the collection time, when Balami rams were fed *D. smutsii* hay, their mean rumen NH_3-N concentration was slightly higher (9.80 mg 100 mL^{-1}) than *B. decumbens* hay diets (9.57 mg 100 mL^{-1}). To Uda rams, the behavior was simulated with 9.80 mg 100 mL^{-1} of *D. smutsii* hay compared to *B. decumbens* hay diets with a mean of 9.17 mg 100 mL^{-1}. Yankasa breed also exhibited a similar trend.

The present study's findings are in line with Bartocci et al. (1997), indicating that differences in rumen fluid can reflect differences in nutrient digestibility and VFA between breeds or hays. However, these findings disagree with Lin et al. (2023), which did not find significant differences in rumen parameters and nutrient digestibility between different breeds of sheep. The differences in findings may be attributed to several factors, including the specific diets, animal species, and environmental conditions studied in each research.

Our study suggests that the type of hay fed to the animals did not seem to have a significant impact on rumen NH_3-N concentrations. This means that the concentrations were similar regardless of the specific type of hay used, except for 4 hours after feeding. Rumen NH_3-N concentrations exceeded certain critical levels at all sampling times, except for the time just before feeding (0 hours pre-feeding) of both types of hay. This implies that the levels of ammonia nitrogen in the rumen were generally sufficient for microbial growth, except right before feeding. This finding concurs with the report of Dewhurst and Newbold (2022) on the effect of ammonia concentration on *in vitro* rumen microbial protein production. It also agrees with the critical rumen NH_3-N concentration of 50 mg NH_3-N/L rumen fluid as necessary to support microbial growth. In other words, to maintain a healthy microbial population in the rumen, it is important to have at least 50 mg of ammonia nitrogen per liter of rumen fluid. The study found that low rumen NH_3-N concentrations can have negative consequences. It can restrict microbial growth and, consequently, microbial protein synthesis. This, in turn, can reduce the rate of digestion of fiber and cellulose in the rumen, which is significant because microbial activity in the rumen is essential for breaking down complex plant materials like fiber and cellulose, making them digestible to the animal as stated by Kand et al. (2021).

The result of the present study suggests that there are differences in the concentrations of volatile fatty acids (VFAs) in the rumen of the three different sheep breeds (Balami, Uda, and Yankasa) at post-feeding time. Specifically, the VFA concentrations are higher in Balami and Uda compared to Yankasa. The reason for this difference in VFA concentrations is hypothesized to be associated with the higher total dry matter intake by Balami and Uda. This suggests that the sheep breeds that show higher dry matter intake produce more VFAs in their rumen, likely due to differences in their digestive processes. It also aligns with a study conducted by Rasi et al. (2022), which looked at the metabolism of different nutrients in the rumen of several species. This implies that the results of the present study are consistent with previous research on rumen metabolism and nutrient digestion. Above all, it suggests a potential link between breed, dry matter intake, and VFA concentrations in the rumen of sheep, and it supports the idea that different sheep breeds may have variations in their digestive processes and nutrient utilization.

Conclusion

Balami and Uda breeds show better feed utilization, as indicated by the improved rumen pH, VFA and N-NH_3 production, and consequently improved digestibility and growth performance compared to the Yankasa breed when fed *B. decumbens* hay. It is important to note that the effectiveness of different types of forage and the response of different sheep breeds to those forages can vary based on several factors, including the nutritional content of the forage, the age and health of the animals, and environmental conditions. Further research and data collection would be needed to confirm these findings and better understand the reasons behind these feed utilization and performance differences.

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