



COMPARISON OF PROTEIN UTILIZATION AND BODY COMPOSITION IN THIN-TAILED LAMBS AND TEXEL CROSSBRED LAMBS FED ON DIFFERENT FEEDING LEVELS

Ari Prima ¹ , Adi R. Satrio ¹ , Ikha V. Rahmawati ¹ , Nuruliarizki S. Pandupuspitasari ¹ , Vita Restitrisnani ¹ , Endang Purbowati ¹ , Mukh Arifin ¹ , Retno Adiwanti ¹ , Agung Purnomoadi ¹ 
Department of Animal Science, Faculty of Animal and Agricultural Sciences, Univesitas Diponegoro, Indonesia 1

ABSTRACT

Article information

Article history:

Received: 12 /1 /2026

Accepted: 25 /6 /2026

Available: 30/6/2026

Keywords:

Body composition, protein utilization, texel cross, thin-tailed sheep.

DOI:

<https://doi.org/10.3389/9/magrj.v54i2.60551>

Correspondence Email:

ari.prima56@gmail.com

College of Agriculture and Forestry, University of Mosul.

This is an open access article under the CC BY 4.0 license (<https://magrj.uomosul.edu.iq>).

This study evaluated the responses of Thin-tailed lambs (TTL) and Texel crossbred lambs (TCL) to different feeding levels in terms of protein metabolism, rumen fermentation, growth performance, and body composition. A total of 20 male growing lambs aged four months were used, consisting of TTL (9.56 ± 0.97 kg) and TCL (15.30 ± 2.84 kg). Lambs were individually housed and fed a complete pelleted diet containing 14.42% crude protein and 70.03% total digestible nutrients (TDN). The experiment used a nested completely randomized design with feeding levels of 4% and 5.5% body weight within each breed group. Texel crossbred lambs had higher dry matter intake, nutrient digestibility, protein retention, and microbial protein synthesis than thin-tailed lambs ($P < 0.05$). Increasing the feeding level increased nutrient intake ($P < 0.05$), but did not improve protein utilization efficiency ($P > 0.05$). Higher feeding levels also reduced rumen pH and increased blood urea concentration after feeding ($P < 0.05$). Body composition analysis showed greater total body water and body protein content in TCL than in TTL ($P < 0.05$), whereas the relative proportions of body components were similar among treatments ($P > 0.05$). Overall, breed exerted a greater influence than feeding level on protein utilization, growth performance, and body composition in lambs.

INTRODUCTION

The global demand for lamb meat continues to increase along with population growth and the rising need for animal protein sources. Sheep are considered an important livestock commodity in many tropical countries because they are adaptable to various environmental conditions, reproduce relatively quickly, and have short production cycles with excellent potential for meat production (Gowane *et al.*, 2017). In addition to contributing to food production, sheep play an important economic role for smallholder farmers as a source of household income, savings, and financial security. In developing countries such as Indonesia, sheep are commonly raised under smallholder production systems because they are relatively easy to manage, require lower production costs than larger ruminants, and are able to utilize locally available feed resources efficiently (Sujarwanta *et al.*, 2024). Although local sheep possess excellent adaptability to tropical environments, their production performance is still considered relatively limited, especially regarding growth rate and carcass yield (Idayanti *et al.*, 2024). For this reason, crossbreeding between local and exotic sheep breeds has increasingly been applied as an approach to improve productivity while

maintaining adaptation to tropical production conditions (Athifa *et al.*, 2024). Such strategies are also relevant to climate-smart livestock systems that aim to improve production efficiency under changing environmental conditions (Wilkes *et al.*, 2017).

Thin-tailed lambs (TTL) are recognized for their ability to survive and perform under tropical feeding conditions, particularly when feed quality is relatively low (Mahgoub *et al.*, 2025). In contrast, Texel sheep generally exhibit faster growth and better carcass characteristics because of their larger body size, although they often require more intensive nutritional and environmental management in tropical areas (Wang *et al.*, 2020). Nevertheless, the success of crossbreeding programs is not determined solely by genetic improvement. Efficient nutrient utilization, especially protein metabolism, also plays an important role in supporting tissue accretion and carcass development. Protein utilization efficiency therefore becomes an important consideration in developing feeding strategies for improving sheep productivity under tropical production systems.

Crossbreeding thin-tailed sheep with Texel sheep produces Texel crossbred lambs (TCL), which are expected to combine the adaptability of local tropical sheep with the superior growth and carcass potential of exotic breeds. However, the success of a crossbreeding program is influenced not only by genetic improvement but also by the animals' ability to efficiently utilize nutrients, particularly protein. Protein plays a major role in tissue growth and carcass development, making protein utilization efficiency an important factor in sheep production systems.

Previous studies have shown that increasing feeding levels and dietary protein concentration can improve nutrient intake and animal performance in sheep. Li *et al.* (2025) reported that increasing dietary protein concentration from approximately 11% to 17.25% increased average daily gain in Suffolk × Hu F1 crossbred sheep from 186.8 g/day to 227.9 g/day, accompanied by improvements in metabolic efficiency and nitrogen retention. Nevertheless, responses to increased feeding levels may differ among breeds because each genotype has different nutrient utilization patterns, metabolic characteristics, and tissue deposition capacities. Yateem *et al.* (2021) reported that local tropical sheep have different body composition characteristics and net protein requirements compared with large-framed sheep, indicating variation in nutrient utilization strategies among genotypes. Mirzaei-Alamouti *et al.* (2021) also emphasized that metabolic responses to feeding level are strongly associated with genotype, particularly regarding protein utilization efficiency and tissue growth patterns.

Although many studies have evaluated the effects of feeding level and dietary protein on sheep productivity, most of them mainly focused on growth performance and general production responses. Information regarding the relationship between increased feeding levels, protein metabolism efficiency, body composition, and carcass production in tropical local sheep and their crossbreeds is still limited. Genetic background is likely to influence protein requirements, nutrient utilization efficiency, and metabolic responses to feeding level, especially when comparing tropical-adapted sheep with larger-framed crossbred sheep (Chelkapally *et al.*, 2023).

Therefore, this study was conducted to evaluate the effects of breed differences between thin-tailed lambs and Texel crossbred lambs, as well as different feeding levels, on protein metabolism efficiency, body composition, and carcass production.

The results of this study are expected to contribute useful information for developing feeding strategies that are more efficient and suitable for improving the productivity of local and crossbred sheep under tropical conditions.

MATERIALS AND METHODS

Ethical approve

The study was carried out at the Research Farm, Faculty of Animal and Agricultural Sciences, Universitas Diponegoro, Semarang, Indonesia. All procedures involving animals followed the ethical standards approved by the Animal Ethics Committee of the same faculty.

Animals, experimental design and treatments

The experimental animals consisted of 20 four-month-old male lambs, comprising 10 Thin-tailed lambs (TTL) and 10 Texel crossbred lambs (TCL). The average initial body weight of Thin-tailed lambs was 9.56 ± 0.97 kg, whereas Texel crossbred lambs weighed 15.30 ± 2.84 kg. The animals were housed individually and served as experimental units throughout the study period. The study used a nested completely randomized design, in which breed (TTL and TCL) was the main factor and feeding level was nested within breed. Feeding levels were determined based on dry matter requirements, with 4% of body weight (BW) as the low level and 5.5% BW as the high level. Accordingly, four treatment combinations were established, each with five replicates. The study consisted of several consecutive phases, including 7 days of preparation, 14 days of dietary adaptation, 7 days of preliminary observation, and 63 days of treatment administration.

Animal feeding and management

The lambs received a pelleted complete feed formulated with 17% peanut hulls, 28% pollard, 10% cassava residue, 8.5% palm kernel meal, 8% corn gluten feed (CGF), 5.5% soybean meal, 2% molasses, 18% rice bran, and a mineral mix. The diet contained 14.42% crude protein and 70.03% total digestible nutrients (TDN). Detailed nutrient contents of the diet used in this study are shown in Table 1. Feed was offered twice daily according to the assigned feeding level, while drinking water was provided ad libitum. Body weight measurements were taken weekly to determine average daily gain (ADG), while feed intake was calculated from the difference between feed offered and feed refused.

Table (1): nutritional content of experimental feed

Nutrients	Content
Dry Matter (DM) (%)	91,30
Crude Protein (%)	14,42
Crude Fiber (%)	20
Crude Fat (%)	5,36
Ash (%)	5,18
Energy (Kcal)	3727
Total Digestible Nutrient	70,03

Dry matter intake was calculated as fresh feed intake multiplied by the dry matter content of the diet. Dry matter and crude protein digestibility were determined

using the total collection method by comparing nutrient intake with nutrient excretion in feces.

Digestion trial, chemical analysis and protein measurement

Feces and urine were collected for 7 consecutive days using the total collection method to evaluate crude protein digestibility and protein utilization. Samples of feed and feces were subsequently analyzed for nutrient composition. Proximate analysis was performed to determine dry matter (DM), crude protein (CP), crude fat, and ash contents according to AOAC (2016) procedures. Crude protein concentration was determined from total nitrogen content analyzed using the Kjeldahl procedure with a conversion factor of 6.25. The nitrogen content of feed, feces, and urine samples was evaluated using the same analytical method.

Rumen fluid samples were collected with the aid of a stomach tube before feeding (0 h) and again at 2 and 4 h after feeding. The collected rumen fluid was immediately filtered through cheesecloth to remove large feed particles. Rumen pH was then measured directly using a digital pH meter that had been calibrated with standard buffer solutions at pH 4.0 and 7.0. Ammonia concentration in the rumen fluid was analyzed using the phenol-hypochlorite colorimetric method, and the absorbance was measured at 630 nm using a spectrophotometer. The ammonia concentration was expressed as mg NH₃/100 mL rumen fluid. Blood samples were collected from the jugular vein at 0, 3, and 6 h after feeding, followed by centrifugation to obtain blood serum. Blood urea concentration was determined using an enzymatic colorimetric method and expressed in mg/dL.

Microbial protein production was estimated from urinary purine derivative excretion. Daily urine samples were analyzed for purine derivatives, mainly allantoin, following the method of Young and Conway (1942). Absorbance was measured at a wavelength of 522 nm using a spectrophotometer. The amount of absorbed microbial purines and microbial nitrogen supply to the intestine were estimated according to the approach described by Chen and Gomes (1992) for sheep, considering metabolic body weight. The calculation assumed microbial purine digestibility of 0.83, a purine nitrogen to total nitrogen ratio of 0.116, and purine nitrogen content of 70 mg N/mmol purine.

Determining body composition (Urea space method)

Body composition was evaluated during the 3rd, 6th, and 9th weeks of the treatment period using the urea space technique. This approach was applied to estimate body water, protein, and fat contents based on urea distribution in body fluids after intravenous urea administration. Estimation of body composition followed the method described by Preston and Kock (1973). The obtained values were expressed both as absolute amounts (kg) and relative proportions (%).

Statistical analysis

Data analysis was performed using analysis of variance (ANOVA) for a nested completely randomized design, where breed served as the main factor and feeding level was nested within breed. Statistical differences among treatments were evaluated at the 5% and 1% significance levels using IBM SPSS Statistics version 25.

RESULTS AND DISCUSSION

Nutrient intake and digestibility

The results showed that dry matter intake, digestible dry matter intake, and dry matter digestibility were higher in Texel crossbred lambs (TCL) than in Thin-tailed lambs (TTL) ($P < 0.05$). Increasing the feeding level from 4% to 5.5% of body weight increased dry matter intake and digestible dry matter intake ($P < 0.05$), but did not affect dry matter digestibility or feed conversion ($P > 0.05$). Detailed results are presented in Table 2.

Table (2): dry matter intake and digestible dry matter intake

Parameters	TCL		TTL		<i>p</i> -value	
	4%	5.5%	4%	5.5%	Breed	Feed
Dry Matter Intake (g/day)	927.71	1,147.98	581	791.29	0.001	0.015
Digestible Dry Matter Intake (g/day)	584.99	717.23	342.43	431.13	0.001	0.115
Dry Matter Digestibility (%)	63.16	61.96	58.35	54.35	0.008	0.286

Protein utilization

The results for crude protein intake, digestible crude protein intake, retained crude protein, and protein excretion via feces and urine showed that all protein utilization parameters were higher in Texel crossbred lambs (TCL) than in Thin-tailed lambs (TTL). Increasing the feeding level from 4% to 5.5% of body weight increased crude protein intake, fecal protein excretion, digestible crude protein intake, and retained crude protein ($P < 0.05$), but did not affect crude protein digestibility or the percentage of retained protein ($P > 0.05$). Detailed results are presented in Table 3.

Table (3): crude protein intake, digestibility, retention, and crude protein excretion

Parameters	TCL		TTL		<i>p</i> -value	
	4%	5.5%	4%	5.5%	Breed	Feed
Crude Protein Intake (g/day)	133.78	165.54	119.83	114.10	0.001	0.015
Digestible Crude Protein Intake (g/day)	101.25	126.87	62.24	81.41	0.001	0.047
Crude Protein Digestibility (%)	75.75	76.17	74.16	71.17	0.038	0.380
Retained Crude Protein (g)	96.56	122.66	58.97	78.09	0.001	0.036
Crude Protein Retention (%)	72.73	73.62	70.14	68.25	0.022	0.583
Crude Protein Excretion						
Feces (g/day)	32.52	38.67	21.54	32.69	0.001	0.003
Urine (g/day)	4.69	4.21	3.27	3.32	0.092	0.863

Evaluation of microbial protein production (MPP), purine derivative excretion, and nutrient conversion efficiency showed that Texel crossbred lambs (TCL) produced more microbial protein than Thin-tailed lambs (TTL) ($P < 0.05$).

Texel crossbred lambs also exhibited higher purine derivative excretion and greater efficiency of protein and organic matter conversion into microbial protein compared with TTL ($P < 0.01$). Feeding level had no significant effect on microbial protein production or purine derivative excretion ($P > 0.05$). However, increasing feeding level significantly improved the efficiency of nutrient conversion into microbial protein ($P < 0.01$). The complete data are shown in Table 4.

Table (4): microbial protein production and purine derivatives.

Parameters	TCL		TTL		<i>p</i> -value	
	4%	5.5%	4%	5.5%	Breed	Feed
Microbial Protein Production (g/day)	3.39	3.41	2.70	3.03	0.036	0.637
Purine Derivatives (mmol/L)	1.22	1.29	1.42	1.46	0.001	0.355
Conversion of protein consumed to microbial protein production (g/g)	39.53	48.77	30.89	37.78	0.001	0.001
Conversion of Organic Matter Consumed to Microbial Protein Production (g/day)	257.52	342.62	202.49	278.22	0.001	0.001
Conversion of Organic Matter Digestible to Microbial Protein Production (g/day)	174.56	237.46	130.89	180.25	0.001	0.001

Conversion rates of digestible crude protein and metabolizable crude protein were generally comparable between Texel crossbred lambs (TCL) and Thin-tailed lambs (TTL) at both feeding levels. Statistical analysis showed no significant effects of breed or feeding level on the conversion of digestible crude protein and metabolizable crude protein ($P > 0.05$). Detailed values for protein conversion are presented in Table 5.

Table (5): conversion of consumed, digestible, and metabolizable crude protein.

Parameters	TCL		TTL		<i>p</i> -value	
	4%	5.5%	4%	5.5%	Breed	Feed
Conversion of Crude Protein Consumed	0.93	0.88	0.84	0.80	0.251	0.803
Conversion of Crude Protein Digestible	0.70	0.67	0.62	0.57	0.084	0.670
Conversion of Metabolizable Crude Protein	0.67	0.65	0.59	0.54	0.065	0.738

Rumen pH, ammonia and urea of blood

Rumen pH values and rumen ammonia concentrations at different observation times showed distinct responses to breed and feeding level. Rumen pH at 2 and 4 hours after feeding was significantly lower at the 5.5% body weight feeding level than at the 4% body weight level ($P < 0.01$). Breed had no significant effect on rumen pH at any observation time ($P > 0.05$). For rumen ammonia concentration, breed had

no significant effect at 2 and 4 hours after feeding ($P > 0.05$), but had a significant effect at 0 hour ($P < 0.05$). Feeding level significantly affected rumen ammonia concentration at 0 hour ($P < 0.05$), but had no significant effect at 2 and 4 hours ($P > 0.05$). The change in rumen ammonia concentration from 2 to 4 hour was influenced by breed ($P < 0.05$), whereas feeding level had no significant effect ($P > 0.05$). The data on rumen pH and ammonia concentrations are presented in Table 6.

Table (6): rumen pH and ammonia concentration at 0, 2 and 4 hours after feeding.

Parameters	TCL		TTL		<i>p</i> -value	
	4%	5.5%	4%	5.5%	Breed	Feed
Rumen pH						
Hour 0	6.66	6.65	6.74	6.62	0.727	0.394
Hour 2	6.23	5.88	6.34	5.86	0.527	0.001
Hour 4	6.48	6.17	6.46	6.26	0.630	0.007
Ammonia Concentration (mg/100 mL)						
Hour 0	82.23	99.11	84.16	84.15	0.827	0.011
Hour 2	99.11	112.07	100.51	101.98	0.621	0.556
Hour 4	118.82	130.90	133.24	134.44	0.356	0.652
Change in Ammonia (mg/100 mL)						
0-2 Hours	27.38	12.96	16.36	17.83	0.752	0.557
2-4 Hours	19.71	18.83	32.72	32.46	0.030	0.993

Blood urea concentrations at 0, 3, and 6 hours after feeding did not differ between Texel crossbred lambs (TCL) and Thin-tailed lambs (TTL) at any observation time ($P > 0.05$). Increasing the feeding level from 4% to 5.5% of body weight resulted in higher blood urea concentrations from 0 to 3 hour after feeding ($P < 0.05$), but no difference was observed at 6 hours after feeding ($P > 0.05$). Mean blood urea values are presented in Table 7.

Table (7): blood urea concentration at 0, 3, and 6 hours after feeding.

Parameters	TCL		TTL		<i>p</i> -value	
	4%	5.5%	4%	5.5%	Breed	Feed
Blood Urea (mg/dL)						
0 Hour	38.70	44.90	42.15	41.52	0.991	0.356
3 Hour	41.72	52.88	45.98	51.62	0.688	0.078
6 Hour	36.78	47.42	41.08	44.40	0.842	0.064
Change in Blood Urea (mg/dL)						
0-3 Hours	3.02	7.98	3.83	10.10	0.426	0.022
3-6 Hours	4.94	5.46	4.90	7.22	0.655	0.692

Productivity and body composition

Average daily weight gain (ADWG) was affected by breed and feeding level and was higher in Texel crossbred lambs (TCL) than in Thin-tailed lambs (TTL), with a significant difference between breeds ($P < 0.05$). Increasing the feeding level from 4% to 5.5% of body weight tended to increase ADWG, but the difference was not statistically significant ($P > 0.05$). Feed conversion values were similar between TCL

and TTL as well as between feeding levels, with no significant differences observed between breeds or feeding levels ($P > 0.05$). A summary of growth performance and feed conversion is presented in Table 8.

Table (8): average daily weight gain, feed conversion ratio.

Parameters	TCL		TTL		<i>p</i> -value	
	4%	5.5%	4%	5.5%	Breed	Feed
Average Daily Weight Gain (g/day)	149.84	190.10	102.94	145.90	0.012	0.060
Feed Conversion Ratio	4.39	3.56	6.90	5.23	0.068	0.096

Body water composition at weeks 3, 6, and 9 showed that body water content was higher in Texel crossbred lambs (TCL) than in Thin-tailed lambs (TTL) at all observation times ($P < 0.05$). Differences in feeding level did not affect body water content in either breed ($P > 0.05$). Detailed data on body water composition are presented in Table 9.

Table (9): body water composition.

Parameters	TCL		TTL		<i>p</i> -value	
	4%	5.5%	4%	5.5%	Breed	Feed
Body Water, kg (%)						
Week 3	5.28	5.05	3.68	4.04	0.001	0.239
	(58.36)	(58.41)	(58.66)	(58.59)	0.368	0.417
Week 6	5.95	5.79	4.31	4.62	0.003	0.300
	(58.22)	(58.26)	(58.55)	(58.49)	0.371	0.417
Week 9	6.30	6.38	4.57	4.96	0.002	0.280
	(58.15)	(58.14)	(58.50)	(58.42)	0.374	0.418
Body Water Gain, kg (%)						
Week 3-6	0.66	0.74	0.63	0.59	0.199	0.795
	(-0.14)	(-0.15)	(-0.05)	(-0.06)	0.080	0.819
Week 6-9	0.36	0.59	0.26	0.34	0.141	0.355
	(-0.07)	(-0.12)	(-0.05)	(-0.06)	0.114	0.336
Week 3-9	1.02	1.33	0.90	0.93	0.028	0.216
	(-0.21)	(-0.27)	(-0.16)	(-0.17)	0.008	0.206

Body protein composition showed that body protein content was higher in Texel crossbred lambs (TCL) than in Thin-tailed lambs (TTL) throughout the observation period ($P < 0.05$). Differences in feeding level did not affect body protein content or percentage in either breed ($P > 0.05$). Detailed data on body protein composition are presented in Table 10.

Table (10): body protein composition.

Parameters	TCL		TTL		<i>p</i> -value	
	4%	5.5%	4%	5.5%	Breed	Feed
Body Protein, kg (%)						
Week 3	0.93 (10.21)	0.87 (9.98)	0.50 (8.00)	0.60 (8.66)	0.000 0.010	0.232 0.218
Week 6	1.11 (10.74)	1.06 (10.68)	0.67 (9.09)	0.75 (9.52)	0.000 0.031	0.314 0.289
Week 9	1.20 (11.02)	1.22 (11.06)	0.74 (9.44)	0.84 (9.92)	0.000 0.036	0.290 0.278
Body Protein Gain, kg (%)						
Week 3-6	0.18 (0.53)	0.20 (0.70)	0.17 (1.09)	0.16 (0.86)	0.199 0.114	0.795 0.745
Week 6-9	0.09 (0.28)	0.16 (0.38)	0.07 (0.35)	0.09 (0.40)	0.141 0.952	0.355 0.529
Week 3-9	0.27 (0.81)	0.35 (1.08)	0.24 (1.44)	0.25 (1.26)	0.028 0.175	0.216 0.541

Body fat composition indicated that the body fat content of Texel Cross (TCL) was higher than that of Thin-tailed lambs (TTL) during the observation period ($P < 0.05$). Differences in feed levels did not result in any differences in body fat accumulation between the two breeds ($P > 0.05$). The complete data on body fat composition are presented in Table 11.

Table (11): body fat composition.

Parameters	TCL		TTL		<i>p</i> -value	
	4%	5.5%	4%	5.5%	Breed	Feed
Body Fat, kg (%)						
Week 3	1.90 (20.97)	1.81 (20.90)	1.29 (20.57)	1.42 (20.66)	0.001 0.281	0.243 0.400
Week 6	2.16 (21.14)	2.10 (21.10)	1.53 (20.72)	1.64 (20.80)	0.002 0.258	0.307 0.378
Week 9	2.30 (21.24)	2.34 (21.26)	1.63 (20.79)	1.77 (20.88)	0.002 0.264	0.289 0.398
Body Fat Gain, kg (%)						
Week 3-6	0.26 (0.18)	0.29 (0.19)	0.24 (0.15)	0.22 (0.14)	0.135 0.080	0.814 0.819
Week 6-9	0.14 (0.09)	0.24 (0.16)	0.10 (0.07)	0.13 (0.08)	0.120 0.114	0.345 0.336
Week 3-9	0.40 (0.27)	0.53 (0.36)	0.34 (0.21)	0.35 (0.23)	0.016 0.008	0.217 0.206

The results of this study showed that breed differences had a greater effect on protein utilization and body composition than feeding level. Texel crossbred lambs (TCL) consistently consumed more dry matter and crude protein than Thin-tailed lambs (TTL), which contributed to higher digestible nutrient intake and greater protein retention. These findings suggest that genetic background plays an important role in determining feed intake capacity and nutrient utilization. Khanaki *et al.* (2021) reported that genetic variation among breeds can influence net protein requirements and patterns of tissue deposition. Sheep with greater growth potential are generally characterized by higher nutrient intake and a greater capacity for body tissue accretion.

In the present study, increasing feeding level increased dry matter and protein intake; however, greater nutrient consumption was not followed by higher protein utilization efficiency. This condition indicates that additional nutrient supply may not always be converted efficiently once the animals' physiological requirements have been sufficiently met. A similar response was described by Khattab and Abdel-Wahed, (2018), who observed that increasing dietary protein levels stimulated growth and nitrogen metabolism without consistently improving nitrogen utilization efficiency. Khattab and Anele, (2022) further explained that excess dietary protein in ruminants is more likely to increase nitrogen excretion than tissue deposition.

Feeding level also affected rumen fermentation characteristics. The lower rumen pH observed at higher feeding levels suggests that increased feed intake altered rumen fermentation activity and fermentation end-product accumulation. Although rumen pH decreased after feeding, it remained within the physiological range and therefore was unlikely to inhibit rumen microbial activity. This observation is consistent with current ruminant nutrition concepts emphasizing that an appropriate balance between fermentable energy supply and protein degradation is essential for maintaining optimal rumen pH and microbial fermentation efficiency (Guo *et al.*, 2024).

Rumen ammonia concentrations showed limited and time-dependent differences between breeds, suggesting variation in protein degradation and nitrogen utilization processes in the rumen. Increased protein degradation was not always followed by efficient nitrogen capture for microbial protein synthesis. Belanche *et al.* (2021) reported that nitrogen utilization efficiency in ruminants is strongly influenced by the synchrony between fermentable energy availability and ruminal protein degradation. Consequently, differences in metabolic characteristics between breeds may affect rumen ammonia concentration and subsequent nitrogen utilization pathways.

Nitrogen metabolism responses were also reflected in blood urea concentrations. Higher blood urea levels observed after feeding, particularly at higher feeding levels, indicate that a portion of absorbed nitrogen was not optimally utilized for microbial protein synthesis or tissue deposition, but was instead converted to urea in the liver and excreted. Blood urea concentration is commonly associated with the relationship between nitrogen intake and the animal's ability to utilize nitrogen efficiently at the metabolic level. The present findings are in agreement with Hristov *et al.* (2019), who suggested that excessive dietary protein may increase nitrogen circulation and excretion without proportional improvement in animal performance.

The greater microbial protein production observed in TCL indicates a more efficient rumen fermentation process compared with TTL. In ruminants, microbial protein represents an important source of absorbable amino acids; therefore, increased microbial protein synthesis may support protein retention and tissue development. Similar observations were reported by Khejornsart *et al.* (2022), who demonstrated that improved microbial protein synthesis efficiency was associated with better growth performance and carcass characteristics in sheep.

Despite differences in protein intake, crude protein conversion efficiency remained largely unchanged among breeds and feeding levels. This finding indicates that increased protein consumption was not fully converted into productive tissue deposition, and part of the excess nitrogen was likely excreted instead. Similar observations have been described in modern ruminant nutrition studies, which emphasize that efficient nitrogen utilization depends on the balance between fermentable energy and degradable protein supply in the rumen (Zhang *et al.*, 2022). Furthermore, increasing the feeding level to 5.5% of body weight may have accelerated the passage rate of digesta through the rumen, thereby reducing retention time for microbial fermentation. As a result, rumen microorganisms may have had less opportunity to utilize available nitrogen efficiently for microbial protein synthesis. Consequently, despite the greater protein intake, the efficiency of protein conversion was not significantly improved because the additional nutrients were not fully utilized before passing from the rumen.

The combined effects of differences in feed intake, nutrient utilization, and rumen fermentation were ultimately reflected in the body composition characteristics of the animals. Differences between TCL and TTL were primarily evident in the absolute amounts (kg) of body water, body protein, and body fat, whereas the proportional composition of body tissues remained relatively stable. This suggests that differences in body composition were mainly driven by variations in body size and growth rate rather than changes in tissue distribution. Feng *et al.* (2025) reported that sheep with higher growth potential have greater net protein and energy requirements, which are reflected in higher absolute tissue accumulation. The findings of the present study are in agreement with Satrio *et al.* (2025), who reported in Thin-tailed lambs that nutritional treatments mainly affected the total amount of tissue deposition rather than the proportional distribution of body components.

In the present study, feeding level did not significantly influence either body composition content or the relative distribution of body tissues, suggesting that the nutritional treatments applied were insufficient to alter tissue deposition patterns. Under these conditions, improvements in sheep productivity may depend more on genetic potential supported by proper nutritional management than on increasing feed allowance alone. This observation is particularly relevant for sustainable sheep production systems, where feed efficiency and adaptability to environmental challenges are increasingly important. Mohamed-Brahmi *et al.* (2024) likewise emphasized that genetic adaptability and efficient utilization of available resources are essential factors contributing to the resilience of sheep production systems, especially in semi-arid and resource-limited environments.

CONCLUSIONS

The present results indicate that breed had a stronger influence than feeding level on nutrient intake, protein retention, and body composition in lambs. Texel crossbred lambs generally exhibited more efficient protein metabolism and better growth performance than Thin-tailed lambs. Increasing feeding level increased nutrient consumption, although improvements in protein utilization efficiency were not observed.

ACKNOWLEDGMENT

The authors stated there is no conflict of interest related to financial, personal, or scientific.

CONFLICT OF INTEREST

The authors would like to express their sincere gratitude to the research team and the funding institutions for their financial support and valuable contribution to this study.

REFERENCES

- AOAC. (2016). Official Methods of Analysis. 20th ed. International, Gaithersburg, MD, USA. <https://doi.org/10.5740/jaoacint.SMPR2016.002>
- Athifa, I. R., Sari, N. L., Zahra, A. P., Maharani, D. N. Y. G., Hidayat, R., & Bintara, S. (2024). The post-weaning growth of lambs from crossbreeding between Garut ewes with Dorper rams. *Pertanika Journal of Tropical Agricultural Science*, 47(3). <https://doi.org/10.47836/pjtas.47.3.07>
- Belanche, A., Martín-García, I., Jiménez, E., Jonsson, N. N., & Yáñez-Ruiz, D. R. (2021). A novel ammoniation treatment of barley as a strategy to optimize rumen pH, feed degradability and microbial protein synthesis in sheep. *Journal of the Science of Food and Agriculture*, 101(13), 5541–5549. <https://doi.org/10.1002/jsfa.11205>
- Chelkapally, S. C., Terrill, T. H., Estrada-Reyes, Z. M., Ogunade, I. M., & Pech-Cervantes, A. A. (2023). Effects of dietary inclusion of dry distillers grains with solubles on performance, carcass characteristics, and nitrogen metabolism in meat sheep: A meta-analysis. *Frontiers in Veterinary Science*, 10, 1141068. <https://doi.org/10.3389/fvets.2023.1141068>
- Chen, X. B. and M. J. Gomes. (1992). *Estimation of Microbial Protein Supply to Sheep and Cattle Based on Urinary Excretion of Purine Derivatives*. Aberdeen, UK: International Feed Resources Unit, Rowett Research Institute. [Estimation of Microbial Protein.pdf](#)
- Feng, W., Zheng, J., Jiao, N., Ma, C., Li, H., Zhang, P., & Guo, J. (2025). Effects of energy intake on nutrient digestibility, nitrogen metabolism, energy utilization, serum biochemical indices, and rumen microbiota in Lanzhou fat-tailed sheep. *Agriculture*, 15(7), 698. <https://doi.org/10.3390/agriculture15070698>

- Gowane, G. R., Gadekar, Y. P., Prakash, V., Kadam, V., Chopra, A., & Prince, L. L. (2017). Climate change impact on sheep production: Growth, milk, wool, and meat. In *Sheep production adapting to climate change* (pp. 31–69). Springer Singapore. <https://doi.org/10.1007/978-981-10-4714-52>
- Guo, W., Na, M., Liu, S., Li, K., Du, H., Zhang, J., & Na, R. (2024). Rumen-degradable starch improves rumen fermentation, function, and growth performance by altering bacteria and its metabolome in sheep fed alfalfa hay or silage. *Animals*, 15(1), 34. <https://doi.org/10.3390/ani15010034>
- Hristov, A. N., Bannink, A., Crompton, L. A., Huhtanen, P., Kreuzer, M., McGee, M., & Yu, Z. (2019). Invited review: Nitrogen in ruminant nutrition: A review of measurement techniques. *Journal of Dairy Science*, 102(7), 5811–5852. <https://doi.org/10.3168/jds.2018-15829>
- Idayanti, R. W., Istianah, I., Putri, S. N. H., Fauziah, A. N., Murniyadi, Z., Esnadewi, L. G., & Purnomoadi, A. (2024). Productivity, carcass traits, and meat quality of local lambs fed with *Carica pubescens* seeds meal. *Tropical Animal Science Journal*, 47(1), 87–96. <https://doi.org/10.5398/tasj.2024.47.1.87>
- Khanaki, H., Dewhurst, R. J., Leury, B. J., Cantalapiedra-Hijar, G., Edwards, G. R., Logan, C., & Cheng, L. (2021). The effect of sheep genetic merit and feed allowance on nitrogen partitioning and isotopic discrimination. *Animal*, 15(12), 100400. <https://doi.org/10.1016/j.animal.2021.100400>
- Khatab, I. M., & Abdel-Wahed, A. M. (2018). Effect of oscillating crude protein content on nitrogen utilization, milk production and performance of sheep. *Egyptian Journal of Nutrition and Feeds*, 21(2), 373–380. <https://doi.org/10.21608/ejnf.2018.75538>
- Khatab, I. M., & Anele, U. Y. (2022). Dry matter intake, digestibility, nitrogen utilization and fermentation characteristics of sheep fed Atriplex hay-based diet supplemented with discarded dates as a replacement for barley grain. *Journal of Animal Physiology and Animal Nutrition*, 106(2), 229–238. <https://doi.org/10.1111/jpn.13577>
- hejornsart, P., Meenongyai, W., & Juntanam, T. (2022). Cassava pulp added to fermented total mixed rations increased tropical sheep's nutrient utilization, rumen ecology, and microbial protein synthesis. *Journal of Advanced Veterinary and Animal Research*, 9(4), 754–760. <https://pmc.ncbi.nlm.nih.gov/articles/PMC9868789/>
- Li, B., Hou, P., Liu, L., Zhao, L., Zhang, X., Yang, C., & Zhang, E. (2025). Effects of the dietary protein level on growth performance, nitrogen metabolism, serum biochemical index, and meat quality of Suffolk × Hu F1 lambs. *Journal of Agriculture and Food Research*, 21, 101808. <https://doi.org/10.1016/j.jafr.2025.101808>
- Mahgoub, O., Osman, N. E. H. I. E., & Lu, C. D. (2025). Nutrient utilization and requirements in sheep and goats raised under different systems and fed low nutritional novel feeds for meat production. *Animals*, 15(18), 2658. <https://doi.org/10.3390/ani15182658>

- Mirzaei-Alamouti, H., Beiranvand, A., Abdollahi, A., Amanlou, H., Patra, A. K., & Aschenbach, J. R. (2021). Growth performance, eating behavior, digestibility, blood metabolites, and carcass traits in growing-finishing fat-tailed lambs fed different levels of dietary neutral detergent fiber with high rumen undegradable protein. *Agriculture*, 11(11), 1101. <https://doi.org/10.3390/agriculture11111101>
- Mohamed-Brahmi, A., Ameer, M., Mekki, I., Tenza-Peral, A., Nasraoui, M., Yagoubi, S., & Mahouachi, M. (2024). Analysis of management practices and breeders' perceptions of climate change's impact to enhance the resilience of sheep production systems. *Animals*, 14(6), 885. <https://doi.org/10.3390/ani14060885>
- Preston, R. L. and S. W. Kock. (1973). *In vivo estimation of body composition in cattle using tritiated water*. *Journal of Animal Science*, 36, pp. 278–285.
- Satrio, A. R., Idayanti, R. W., Adiwinarti, R., Purbowati, E., & Purnomoadi, A. (2025). Body composition of thin-tailed sheep fed with *Carica* seed supplementation (*Carica pubescens*). *Jurnal Ilmu Peternakan Terapan*, 8(2), 87–94. <https://doi.org/10.25047/jipt.v8i2.5504>
- Sujarwanta, R. O., Afidah, U., Suryanto, E., Rusman, Triyannanto, E., & Hoffman, L. C. (2024). Goat and sheep meat production in Indonesia. *Sustainability*, 16(11), 4448. <https://doi.org/10.3390/su16114448>
- Wang, X., Xu, T., Zhang, X., Geng, Y., Kang, S., & Xu, S. (2020). Effects of dietary protein levels on growth performance, carcass traits, serum metabolites, and meat composition of Tibetan sheep. *Animals*, 10(5), 801. <https://doi.org/10.3390/ani10050801>
- Wilkes, A., Barnes, A. P., Batkhishig, B., Clare, A., Namkhainyam, B., Chuluunbaatar, N., & Namkhainyam, T. (2017). Is cross-breeding with indigenous sheep breeds an option for climate-smart agriculture? *Small Ruminant Research*, 147, 83–88. <https://doi.org/10.1016/j.smallrumres.2016.12.036>
- Yateem, C. A., Mustafa, K. N., & Alkass, J. E. (2021). Effect of different protein levels on growth performance, carcass traits, digestibility, and some blood biochemical parameters in Awassi lambs. *Iraqi Journal of Agricultural Sciences*, 52(5), 1070–1076. <https://doi.org/10.36103/ijas.v52i5.1444>
- Young, E. G., & Conway, C. F. (1942). On the estimation of allantoin by the Rimini–Schryver reaction. *Journal of Biological Chemistry*, 142, 839–853. [https://doi.org/10.1016/S0021-9258\(18\)45082-X](https://doi.org/10.1016/S0021-9258(18)45082-X)
- Zhang, Z., Shahzad, K., Shen, S., Dai, R., Lu, Y., Lu, Z., & Wang, M. (2022). Altering dietary soluble protein levels with decreasing crude protein may be a potential strategy to improve nitrogen efficiency in Hu sheep based on rumen microbiome and metabolomics. *Frontiers in Nutrition*, 8, 815358. <https://doi.org/10.3389/fnut.2021.815358>