Research Article

Nutrient Utilization and Growth Performance of Kacang Goats Fed Diets with Different Forage-to-Concentrate Ratios

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Abstract | The balance between forage and concentrate ratios is a key factor in the fattening of Kacang goats, as it influences intake, digestibility, and growth. This study aimed to evaluate the effect of different forage: Concentrate ratios on the performance of Kacang goats under tropical conditions. The study utilized 15 male Kacang goats aged 18–24 months with an initial body weight of 10–14 kg, arranged in a Randomized Block Design with three treatments: T1 (50:50), T2 (40:60), and T3 (30:70). The variables observed included nutrient intake and digestibility, daily weight gain (DWG), feed conversion ratio, and feed efficiency. The results showed that the forage-to-concentrate ratio had a significant effect ($P < 0.05$) on nutrient intake and some aspects of nutrient digestibility. Treatments T1 and T2 resulted in higher dry matter and nutrient intake compared to T3. Digestibility of crude protein, crude fat, and metabolizable energy was also better at moderate ratios (50:50–40:60). However, goat growth did not differ significantly ($P > 0.05$), although biologically, T3 showed a tendency for higher DWG and feed efficiency. These findings indicate that increasing the concentrate ratio to 70% reduces intake and digestibility but has the potential to improve energy utilization efficiency for growth. Conversely, a 50:50 ratio is more optimal for enhancing intake and rumen fermentation stability. Consequently, a forage: Concentrate ratio of 50:50–40:60 is recommended to improve intake and digestibility, while a 30:70 ratio has the potential to enhance growth efficiency.

Keywords | Concentrate, Fattening, Forage, Growth performance, Kacang goats, Nutrient Utilization

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INTRODUCTION

The productivity of Kacang goats in fattening systems is strongly influenced by feed availability and quality, as well as genetic and management factors. However, goat production in tropical regions is often constrained by seasonal fluctuations in feed availability. During the rainy season, abundant forage availability generally supports higher daily weight gain, whereas feed scarcity during the dry season reduces animal productivity and may even increase mortality risk (Tahuk and Dethan, 2010).

Protein and energy are major nutritional components that determine growth performance in goats because adequate nutrient availability is essential for muscle tissue synthesis and body weight gain (Tahuk *et al*., 2008, 2016). Previous studies on Kacang goats have shown that growth performance under intensive feeding systems remains relatively variable and often suboptimal, particularly when nutrient balance and dietary energy utilization are not optimized (Tahuk *et al*., 2021, 2024). These findings indicate that improving the balance between forage and concentrate in the ration may be important to enhance

nutrient utilization efficiency and growth performance in Kacang goats.

The forage-to-concentrate ratio is a key factor influencing nutrient intake, digestibility, and energy utilization in ruminants. Increasing concentrate proportion may improve dietary energy density and growth efficiency; however, excessive concentrate inclusion may also reduce fibre utilization and alter digestive efficiency. Therefore, determining the appropriate forage-to-concentrate ratio is essential to optimize nutrient utilization and production performance in Kacang goats raised under tropical conditions.

Improving feed management, particularly the balance between forage and concentrate, is essential to optimize growth performance in Kacang goat fattening systems. Forage provides fibre necessary for maintaining normal rumen function, whereas concentrate supplies readily available energy and protein required for efficient body tissue growth.

Determining the optimal forage-to-concentrate ratio remains a challenge in goat production systems. Excessive forage levels may limit growth due to low dietary energy density, whereas excessive concentrate inclusion may impair digestive function and increase the risk of ruminal disorders. Previous studies have reported inconsistent responses of goats to different forage-to-concentrate ratios. Akbar *et al.* (2024) found no significant differences in feed intake and nutrient digestibility among several forage-to-concentrate ratios in PE goats, whereas Na *et al.* (2017) reported improved nutrient digestibility with lower forage and higher concentrate proportions.

In general, comprehensive studies evaluating the simultaneous relationship among nutrient intake, digestibility, and energy utilization efficiency in supporting the growth performance of Kacang goats under dry tropical conditions remain limited. Most previous studies have focused primarily on nutrient intake and digestibility separately.

Therefore, this study is novel in that it provides an integrated evaluation of the effects of forage-to-concentrate ratios on feed intake, nutrient digestibility, and their implications for energy utilization efficiency and growth performance in young male Kacang goats under tropical conditions. This approach is expected to improve understanding of the complex relationship among nutrient intake, digestibility, energy utilization efficiency, and growth performance in goats.

Therefore, this study aimed to evaluate the effects of different forage-to-concentrate ratios on nutrient intake, digestibility, growth performance, and feed utilization efficiency in young male Kacang goats. The findings are expected to provide a scientific basis for optimizing ration formulation strategies under tropical production conditions and practical recommendations to improve Kacang goat productivity.

MATERIALS AND METHODS

Time and location of the study

The study was conducted at the Timor University Campus, Kefamenanu City, North Central Timor Regency, over a period of 6 months, encompassing the preparation, implementation, and reporting stages. Analysis of feed, urine, and fecal samples was carried out at the Feed Chemistry Laboratory, Faculty of Animal Science, Marine Sciences and Fisheries, Nusa Cendana University, Kupang.

Research materials

Livestock

A total of 15 young male Kacang goats aged 18–24 months (based on the replacement of permanent incisors), with initial body weights of 10–14 kg, were used as experimental animals. The goats were housed and reared individually in pens measuring 70 cm × 150 cm, equipped with feeders and water troughs.

Feed

The experimental diets consisted of complete silage and concentrate. The complete silage was prepared from king grass (*Pennisetum purpureum* × *Pennisetum glaucum*), *Gliricidia sepium* leaves, bran pollard, and a solution of lontar palm sugar (Table 1). The composition of the complete silage was kept the same in all dietary treatments; therefore, the composition of the complete silage itself was not varied among treatments. The experimental treatments differed only in the proportion of complete silage and concentrate ingredients in the total ration (Table 2 and 3). The ration was formulated based on the nutrient requirements of goats with a body weight of approximately 15 kg (Kearl, 1982), with a target daily weight gain (DWG) of 75 g/goat/day. Fish meal was used as a protein source, whereas ground maize, rice bran, and bran pollard were used as energy sources. A mineral premix was added to meet the animals' mineral requirements (Table 3). The nutrient content of the feed was determined using proximate analysis in accordance with AOAC Standards (2005).

Determination of complete silage quality

The complete silage was evaluated for physical and chemical quality to ensure its suitability as livestock feed. Physical quality was assessed based on colour, aroma, and texture. Good-quality silage was characterized by a brownish-green colour, a fresh acidic aroma without a rotten smell,

and a texture that was neither slimy nor mouldy. Chemical quality was assessed based on dry matter (DM) content, pH, and nutrient composition determined by proximate analysis. Silage with a pH ranging from 3.5 to 4.5 was considered to have good fermentation quality. These evaluations were conducted to ensure that the silage was suitable for consumption and did not impair feed intake or nutrient digestibility.

Equipment and chemicals

The equipment used included a digital livestock scale with an accuracy of 0.1 kg, a feed scale with an accuracy of 10 g, containers for feces and urine, and laboratory equipment for nutrient analysis. The chemicals used included 10% H_2SO_4 solution for urine preservation and 10% formalin solution for fecal preservation.

Design of research

The study employed a Randomized Block Design (RBD) with three dietary treatments and five blocks, with individual goats serving as the experimental units. The goats were blocked according to initial body weight to reduce inter-individual variability. The animals were first weighed, ranked from the lowest to the highest initial body weight, and then divided into five relatively homogeneous blocks. Each block consisted of three goats with relatively similar initial body weights, and each block was randomly assigned to one of the three treatments.

The dietary treatments were as follows:

- T1: Forage:Concentrate = 50:50
- T2: Forage:Concentrate = 40:60
- T3: Forage:Concentrate = 30:70

Treatment T1 consisted of 50% complete silage + 25% ground maize + 10% bran pollard + 5% rice bran + 10% fish meal. Treatment T2 consisted of 40% complete silage + 30% ground maize + 10% bran pollard + 10% rice bran + 10% fish meal. Treatment T3 consisted of 30% complete silage + 35% ground maize + 15% bran pollard + 10% rice bran + 10% fish meal.

Research procedure

Production of complete silage

Complete silage was produced from king grass *(Pennisetum purpureophoides)*, *Gliricidia sepium* leaves, bran pollard, and a solution of lontar palm sugar. The forage was chopped and mixed thoroughly, then gradually placed into a silo (plastic drum) while being compacted to expel air. Fermentation was allowed to proceed for 21 days before the silage was fed to the goats.

Livestock adaptation and maintenance

The goats were adapted to the experimental diets for 14 days before the data collection period. The adaptation period was used to familiarize the animals with the experimental diets and housing conditions, while the silage and concentrate were introduced gradually to minimize abrupt dietary changes. To facilitate measurement of feed intake, complete silage and concentrate were offered separately. The concentrate was offered first, followed by the complete silage. During the adaptation period, both feeds were introduced gradually to allow the animals to adjust to the experimental diets and achieve stable feed consumption.

During the acclimatization period, all animals received a subcutaneous injection of ivermectin at a dose of 0.5 mL per 25 kg body weight as an anthelmintic treatment and an intramuscular injection of B-complex vitamins at a dose of 0.5 mL per 10 kg body weight. These treatments were administered uniformly to all experimental animals as routine health-management procedures and were not

Table 1: Nutritional content of the feed ingredients used in the study[1].

Nutritional content	Feed ingredients				
	Complete silage	Ground maize	Bran pollard	Rice bran	Fish meal
Dry matter (DM) (%)	34.980	89.158	87.229	90.137	89.996
Ash (%)	9.002	1.507	3.713	12.120	18.301
Organic matter (OM) (%)	90.998	98.493	96.287	87.880	81.669
Crude protein (CP) (%)	13.798	11.008	16.196	12.098	53.418
Extract eter (EE) (%)	6.872	6.052	5.706	9.356	9.339
Crude fibre (CF) (%)	22.850	1.173	7.145	17.267	0.419
Carbohydrates (CHO) (%)	70.328	81.433	74.385	66.426	18.943
NFE (%)	47.478	80.261	67.240	49.160	18.524
GE:-(MJ/kg.DM)	17.855	18.821	18.741	17.616	19.410
-(Kkal/kg.DM)	4251.29	4481.10	4462.04	4194.23	4621.42
EM (Kkal/kg.DM	2855.82	3906.17	3579.32	3069.10	3422.36

[1]Results of the Feed Chemistry Laboratory, Faculty of Animal Science, Marine Science and Fisheries, Nusa Cendana University, Kupang (2025); NFE: nitrogen-free extract; GE: Gross energy; EM: Metabolisable energy.

considered experimental treatment factors. Thus, there was no untreated control group for ivermectin or B-complex vitamin administration. All animals were managed and handled in accordance with established animal welfare guidelines.

During the data collection period, the amount of feed offered ranged from 3–5% of body weight on a dry matter basis and was adjusted according to body weight gain. Feed was offered twice daily, in the morning and afternoon, while drinking water was provided ad libitum.

Feces and urine collection

Following the 14-day adaptation period, feces and urine from each goat were collected for 10 consecutive days using the total collection method described by Harris (1970). Feces were collected daily, weighed, and subsampled (100 g). The samples were sprayed with 10% formalin solution and dried to a constant weight. The addition of 10% formalin was intended to prevent changes in nutrient composition during the drying process. At the end of the 10-day collection period, fecal samples from each goat were composited, and a 10% representative subsample was subjected to laboratory analysis.

Urine was collected in containers containing 10% H_2SO_4 solution to preserve nitrogen and prevent nitrogen loss through volatilization. Urine volume was measured daily, and representative samples were collected for laboratory analysis of nitrogen content.

Research variables

Feed intake

The intake of complete silage and concentrate was calculated separately every 24 h based on the difference between the amount of feed offered and the feed refusals collected before the next morning feeding. Complete silage and concentrate were offered twice daily, in the morning and afternoon, while feed refusals were collected and weighed at the same time each day to ensure measurement consistency. Dry matter (DM) intake of complete silage and concentrate was calculated separately based on the amount of feed actually consumed multiplied by the dry matter content of each feed. Nutrient intake, including organic matter (OM), crude protein (CP), ether extract (EE), crude fiber (CF), carbohydrates (CHO), nitrogen-free extract (NFE), gross energy (GE), and metabolizable energy (ME), was calculated separately by multiplying the DM intake of each feed by its respective nutrient content. Total DM and nutrient intake of the goats were obtained by summing the intake derived from complete silage and concentrate.

Nutrient digestibility

Dry matter digestibility was calculated as follows:

DM digestibility (g) = DM intake (g) – DM in feces (g)
DM digestibility (%) = (Digested DM / DM intake) × 100

Where DM intake (g)= % DM in feed × fresh feed intake, and DM in feces (g)= % DM in feces × total feces. The same calculation was used to determine the digestibility of organic matter, crude protein, crude fat, crude fiber, and other nutrients.

Table 2: Nutritional content of the concentrate used in the study[1].

Nutritional content	Treatments		
	T1	T2	T3
Dry matter (DM) (%)	89.04	89.33	89.70
Ash (%)	7.21	6.67	6.42
Organic matter (OM) (%)	92.79	93.33	93.58
Crude protein (CP) (%)	20.11	18.96	17.73
Extract eter (EE) (%)	6.12	5.74	6.35
Crude fibre (CF) (%)	4.91	5.59	6.24
Carbohydrates (CHO) (%)	66.56	68.63	69.50
NFE (%)	61.66	63.03	63.26
GE:-(MJ/kg DM)	18.48	18.43	18.49
-(kcal/kg DM)	4399.11	4387.59	4401.48
EM (kcal/kg DM)	3548.11	3525.89	3541.46

[1]Results of the Feed Chemistry Laboratory, Faculty of Animal Science, Marine Science and Fisheries, Nusa Cendana University, Kupang (2025); NFE: nitrogen-free extract; GE: Gross energy; EM: Metabolisable energy.

Table 3: Nutritional content of the experimental diet[1].

Nutritional content	Treatment		
	T1	T2	T3
Dry matter (DM) (%)	90.55	90.13	90.18
Ash (%)	8.10	8.66	6.06
Organic matter (OM) (%)	91.90	91.34	93.94
Crude protein (CP) (%)	16.60	17.54	14.47
Extract eter (EE) (%)	7.62	7.21	5.87
Crude fibre (CF) (%)	12.45	11.16	9.91
Carbohydrates (CHO) (%)[2]	67.68	66.59	73.60
NFE (%)	55.23	55.44	63.707
GE:-(MJ/kg DM)	18.33	18.23	18.24
-(kcal/kg DM)	4364.39	4340.69	4343.27
EM (kcal/kg DM)	3309.59	3316.45	3398.68

[1]Results of the Feed Chemistry Laboratory, Faculty of Animal Science, Marine Science and Fisheries, Nusa Cendana University, Kupang (2025); NFE: nitrogen-free extract; GE: Gross energy; EM: Metabolisable energy; [2]CHO = CF + NFE

Daily weight gain (DWG)

Body weight measurements were conducted at 14-day intervals to evaluate body weight gain as affected by the

dietary treatments. Before weighing, the animals were fasted for approximately 12 h, while drinking water remained available ad libitum. Body weight measurements were performed in the morning before feed was offered. Average daily weight gain (DWG) was calculated as the difference between final body weight and initial body weight divided by the duration of the observation period, using the following equation:

DWG (kg/day) = (Final body weight – Initial body weight) / Observation period (days)

Feed conversion

Feed conversion was calculated as the ratio of dry matter intake to daily weight gain, using the following equation:

Feed conversion = DM intake (g)/ DWG (g)

Feed utilisation efficiency

Feed utilisation efficiency was calculated as the ratio of daily weight gain to dry matter intake, expressed as a percentage:

Feed efficiency (%) = [Daily weight gain (g)/ Dry matter intake (g)] × 100

Data analysis

Data were analysed using analysis of variance (ANOVA) according to the Randomised Block Design (RBD) procedure with the aid of IBM SPSS Statistics software.

Mathematical model: $Yij = \mu + \tau i + \beta j + \varepsilon ij$

Where: Yij = observed value; μ = overall mean; τi = treatment effect; βj = block effect; εij = experimental error. If the treatment had a significant effect ($P < 0.05$), this was followed by Duncan's test (Sorzano, 2025). In addition to significance tests, supplementary analyses were conducted, including effect size (η^2), statistical power (1–β), and coefficient of variation (CV), to strengthen the statistical and biological interpretation of the results.

RESULTS AND DISCUSSION

Feed intake

The results of the study (Table 4) indicate that the forage-to-concentrate ratios significantly affected ($P<0.05$) dry matter (DM), organic matter (OM), crude protein (CP), crude fat (EE), crude fibre (CF), carbohydrates (CHO), and metabolizable energy (ME) intake, whereas nitrogen-free extract (NFE) intake did not differ significantly ($P>0.05$). Across most variables, T1 (50% forage: 50% concentrate) and T2 (40% forage: 60% concentrate) did not differ significantly, whereas both were higher than T3 (30% forage: 70% concentrate). Thus, increasing the concentrate proportion from 50% to 60% maintained nutrient intake, while increasing it to 70% was associated with a significant reduction in intake.

The lower intake observed in T3 may be related to changes in rumen fermentation associated with the high-concentrate diet. Increasing concentrate to 70% reduces the proportion of physically effective fibre and may reduce chewing activity, saliva secretion, and ruminal buffering capacity. Such changes can influence rumen fermentation and fibre degradation and, consequently, voluntary feed intake. Zhou *et al.* (2022) and Mao *et al.* (2024) reported that high-concentrate diets can modify rumen fermentation and microbial activity, providing a possible explanation for the lower intake observed in T3. Because ruminal pH, volatile fatty acids, and microbial populations were not measured in the present study, these mechanisms should be regarded as possible explanations rather than direct findings.

The highest intake observed in T1 is consistent with the importance of an adequate forage proportion in maintaining physically effective fibre (peNDF) in the diet. Adequate peNDF can support chewing activity, ruminal motility, and rumen function, while the concentrate fraction provides readily fermentable nutrients. Jang *et al.* (2017) emphasised the role of peNDF in regulating feed intake and maintaining rumen health. Therefore, the relatively high intake in T1 may reflect a more balanced forage-to-concentrate supply, although the present study did not directly measure peNDF or rumen fermentation characteristics.

Treatment T2 maintained relatively high intake and was not significantly different from T1. This suggests that increasing the concentrate proportion to 60% did not yet produce a statistically detectable reduction in intake. Nevertheless, the reduction in forage proportion may have reduced effective fibre supply. A decline in effective fibre can reduce chewing activity and salivary buffering, potentially affecting rumen pH and fermentation stability. These considerations are supported by Zhou *et al.* (2022) and Cao *et al.* (2021), who highlighted the importance of effective fibre in maintaining rumen function and feed intake.

In contrast, the significant reduction in intake in T3 indicates that the 30:70 forage-to-concentrate ratio was less favourable for voluntary nutrient consumption under the conditions of this study. High-concentrate diets may increase starch fermentation and favour amylolytic microorganisms while reducing the relative activity of fibrolytic microorganisms. Previous studies have associated high concentrate levels with changes in rumen pH and

microbial balance (Mao *et al*., 2024; Zhang *et al*., 2020; Mgeni *et al*., 2025). These references provide a mechanistic framework for interpreting the present result, but they do not constitute direct evidence that the same rumen changes occurred in the goats used in this experiment.

NFE intake did not differ significantly among treatments, despite the higher NFE concentration of the T3 diet (63.697%) compared with T1 and T2 (approximately 55%). The absence of a significant difference in NFE intake is consistent with the lower overall DM intake observed in T3. Thus, a higher nutrient concentration in the diet did not necessarily result in a higher total nutrient intake when voluntary feed consumption was reduced. The relatively high coefficient of variation for NFE intake also indicates greater individual variation in this response.

Table 4: Feed and nutrient intake of male Kacang goats fed different forage–concentrate ratios (mean ± SEM) with statistical parameters[1].

Parameter		Treatment			P-value	η^2	Statistical power	CV (%)
		T1	T2	T3				
DM intake (g/day)	Forage	219.11±28.12	202.75±28.12	180.95±28.12	0.643	0.09	0.15	31,29
	Concentrate	550.27±92.78	572.10±92.78	517.59±92.78	0.923	0.01	0.06	34.28
	Total	907.68 ± 95.12[a]	773.39 ± 95.12[a]	561.69 ± 95.12[b]	0.009	0.73	0.49	12.30
Ash intake (g/day)	Forage	19.72±2.53	18.25±2.53	16.29±2.53	0.645	0.09	0.15	31.28
	Concentrate	39.68±6.69	38.14±6.69	33.25±6.69	0.923	0.01	0.06	34.28
	Total	67.16 ± 6.84[a]	57.45 ± 6.84[a]	40.72 ± 6.84[b]	0.008	0.74	0.55	11.80
OM intake (g/day)	Forage	199.39±25.29	184.50±25.29	164.66±25.29	0.645	0.09	0.15	31.29
	Concentrate	510.60±86.09	533.96±86.09	484.34±86.09	0.923	0.01	0.06	34.28
	Total	840.53 ± 88.40[a]	715.94 ± 88.40[a]	520.97 ± 88.40[b]	0.009	0.73	0.49	12.10
CP intake (g/day)	Forage	30.23±3.88	27.98±3.88	24.97±3.88	0.645	0.09	0.15	31.29
	Concentrate	110.67±18.69	108.48±18.69	91.76±18.69	0.923	0.01	0.06	34.28
	Total	159.75 ± 18.62[a]	137.45 ± 18.62[a]	96.88 ± 18.62[b]	0.011	0.72	0.47	13.50
EE intake (g/day)	Forage	15.06±1.93	13.93±1.93	12.44±1.93	0.644	0.09	0.15	31.28
	Concentrate	33.66±5.71	32.86±5.71	32.87±5.71	0.923	0.01	0.06	34.28
	Total	48.46± 6.87[a]	48.46 ± 6.87[a]	35.78 ± 6.87[b]	0.014	0.70	0.47	14.20
CF intake (g/day)	Forage	50.07±6.42	46.33±6.42	41.35±6.42	0.645	0.09	0.15	31.29
	Concentrate	27.23±4.38	32.02±4.38	32.30±4.38	0.923	0.01	0.06	34.28
	Total	93.92 ± 8.12[a]	77.77 ± 8.12[a]	57.60 ± 8.12[b]	0.004	0.80	0.79	10.60
CHO intake (g/day)	Forage	154.10±19.77	142.59±19.77	127.26±19.77	0.645	0.09	0.15	31.29
	Concentrate	366.28±65.06	392.63±65.06	359.72±65.06	0.923	0.01	0.06	34.28
	Total	624.21 ± 65.33[a]	530.03 ± 65.33[a]	388.31 ± 65.33[b]	0.010	0.73	0.49	12.00
NFE intake (g/day)	Forage	101.92±12.66	91.60±12.66	85.74±12.66	0.671	0.09	0.14	30.41
	Concentrate	279.83±49.65	296.53±49.65	309.89±49.65	0.923	0.01	0.06	34.28
	Total	338.63 ± 72.15	405.24 ± 72.15	421.65 ± 72.15	0.437	0.23	0.10	18.50
GE Intake (MJ/day)	Forage	101.92±0.48	91.60±0.48	85.74±0.48	0.669	0.09	0.14	30.40
	Concentrate	8.385±1.45	8.670±1.45	9.06±1.45	0.924	0.01	0.06	34.30
	Total	10.65 ± 2.11	12.79 ± 2.11	13.17 ± 2.11	0.451	0.22	0.10	19.20
GE Intake (Kcal/day)	Forage	931.50±119.54	861.93±119.54	769.25±119.54	0.645	0.09	0.15	31.29
	Concentrate	2420.70± 409.00	2510.13± 409.00	2278.18±409.00	0.923	0.01	0.06	34.28
	Total	3952.52 ± 412.85[a]	3370.04 ± 412.85[a]	2449.14 ± 412.85[b]	0.010	0.73	0.49	12.40
ME Intake (Kcal/kg.DM)	Forage	625.74±80.30	579.00±80.30	516.75±80.30	0.645	0.09	0.15	31.29
	Concentrate	1952.42± 328.31	2017.15±328.31	1833.04±328.31	0.923	0.01	0.06	34.28
	Total	3038.50 ± 358.74[a]	2596.87 ± 358.74[a]	1888.73 ± 358.74[b]	0.011	0.72	0.46	13.10

[1]Values are presented as mean ± SEM. T1= 50% forage + 50% concentrate; T2= 40% forage + 60% concentrate; T3= 30% forage + 70% concentrate; SEM was calculated from the error mean square of the randomized complete block design (RCBD). Different superscripts within the same row indicate significant differences according to Duncan's Multiple Range Test ($P<0.05$). η^2 represents effect size, Power indicates post hoc statistical power, and CV is the coefficient of variation. DM= dry matter; OM= organic matter; CP= crude protein; CF= crude fat; CF= crude fibre; CHO= carbohydrates; NEE= nitrogen-free extract; GE= gross energy; ME= metabolizable energy.

Table 5: Feed digestibility in male Kacang goats fed different forage-to-concentrate ratios[1].

Parameter	Treatment			P value	η^2	Statistical power (1–β)	CV (%)
	T1	T2	T3				
Dry matter digestibility (%)	84.72±1.84	84.21±1.84	79.78±1.84	0.107	0.31	0.55	4.97
Ash digestibility (%)	65.86±4.74	64.86±4.74	51.12±4.74	0.128	0.32	0.58	17.42
Organic matter digestibility (%)	86.32±1.62	85.75±1.62	81.06±1.62	0.097	0.32	0.60	4.30
Crude protein digestibility (%)	93.06±0.93[a]	91.51±0.93[a]	88.34±0.93[b]	0.032	0.44	0.80	2.29
Crude fat digestibility (%)	95.73±0.55[a]	94.86±0.55[a]	92.66±0.55[b]	0.006	0.50	0.90	1.32
Crude fibre digestibility (%)	65.71±4.70	65.65±4.70	54.87±4.70	0.212	0.28	0.45	16.96
Carbohydrate digestibility (%)	83.65±1.93	83.49±1.93	78.18±1.93	0.134	0.28	0.52	5.27
NFE digestibility (%)	83.39±2.60	86.42±2.60	81.72±2.60	0.419	0.12	0.30	6.95
Digestible energy (DE) (%)	87.33±1.50	86.64±1.50	82.21±1.50	0.083	0.33	0.62	3.92
Metabolizable energy efficiency (%)	76.53±0.20	76.92±0.20	77.09±0.20	0.186	0.34	0.59	40.58

[1]Data are presented as Mean ± SEM; T1 = male Kacang goats fed 50% forage and 50% concentrate; T2 = 40% forage and 60% concentrate; T3 = 30% forage and 70% concentrate. Different superscripts on the same row indicate a significant difference (P<0.05); ns = non-significant (P>0.05). η^2 = effect size; Statistical power = statistical power; CV = coefficient of variation; NEE = nitrogen-free extract.

Overall, the intake results indicate that the 50:50 forage-to-concentrate ratio (T1) provided the highest and most consistent nutrient intake, while T2 (40:60) maintained intake at a statistically comparable level. Therefore, among the diets tested, a 50:50 ratio is the most defensible option when the primary criterion is maximising voluntary feed and nutrient intake. This recommendation is based on the observed intake responses and should not be interpreted as evidence of superior growth performance.

Feed digestibility

The results of the study (Table 5) show that differences in the forage-to-concentrate ratio had no significant effect (P>0.05) on dry matter (DM), ash, organic matter (OM), crude fibre (CF), carbohydrates (CHO), and nitrogen-free extract (NFE) digestibility, but significantly affected (P<0.05) crude protein (CP), extract ether (EE), and metabolizable energy (ME) digestibility. The overall pattern indicates that the 50:50 and 40:60 diets generally produced more favourable digestibility responses than the 30:70 diet for the variables that were significantly affected.

In general, CP, EE, CHO, and CF digestibility values were numerically lower in T3 than in T1 and T2, although not all differences were statistically significant. The lower digestibility observed for some nutrients at the 30:70 ratio may be associated with the lower forage proportion and the greater contribution of rapidly fermentable concentrate. High-concentrate diets can alter rumen fermentation and microbial composition, potentially affecting fibre degradation (Zhang *et al*., 2020). Because ruminal pH and microbial populations were not measured in this study, this interpretation should be considered a plausible mechanism rather than a direct measurement-based conclusion.

Crude protein digestibility differed significantly among treatments (P<0.05), with T1 showing a higher value than T3. This difference may reflect the different protein sources and the balance between forage and concentrate in the diets. A higher forage proportion may provide protein fractions with degradability characteristics that are more compatible with ruminal microbial activity, whereas a high-concentrate diet may modify rumen fermentation conditions. Pazla *et al*. (2026) also emphasised the importance of the interaction between protein supply and energy availability in determining nutrient utilisation in ruminants. The present result demonstrates a treatment effect on CP digestibility, but it does not by itself establish a specific ruminal mechanism.

Crude fat (EE) digestibility was significantly lower in T3 (approximately 92.66%) than in T1 and T2 (approximately 94.86–95.73%; P<0.05). This indicates that increasing the concentrate proportion to 70% did not improve fat digestibility under the conditions of this experiment. One possible explanation is the greater contribution of maize and its unsaturated fatty acids in T3. Pantoja *et al*. (1994) reported that excessive unsaturated fatty acids can adversely affect fibre-degrading microorganisms, while Yang *et al*. (2022) discussed the effects of unsaturated fatty acids on rumen microbial activity. These studies support a possible explanation for the observed response, although fatty-acid profiles and rumen microbial activity were not measured in the present experiment.

Digestibility of NFE did not differ significantly among treatments, although a numerical decrease was observed in T3. High-concentrate diets can favour starch-fermenting, amylolytic microorganisms and alter the relative contribution of fibrolytic microorganisms (Ramos *et al*., 2021). Rivera-Chacon *et al*. (2024) similarly described the importance of microbial interactions in the

degradation of dietary carbohydrates. In the present study, these mechanisms should be regarded as interpretative possibilities because microbial populations and ruminal fermentation characteristics were not directly evaluated.

The most pronounced treatment effect among the digestibility variables was observed for metabolizable energy (ME) digestibility, with T1 and T2 higher than T3 (P<0.05). The lower ME digestibility in T3 indicates that increasing the concentrate proportion to 70% did not improve the utilisation of dietary energy. A high-starch and relatively low-fibre diet can modify rumen fermentation and the degradation of structural carbohydrates. Pang *et al.* (2022) discussed the influence of dietary carbohydrate composition on rumen microbial fermentation, while Beauchemin *et al.* (2020) and Humer *et al.* (2018) emphasised the importance of maintaining an appropriate balance between forage and concentrate for stable rumen fermentation. These references provide context for the observed ME response, but the present study did not measure ruminal fermentation products or direct energy partitioning.

Taken together, the digestibility results indicate that the 50:50 and 40:60 forage-to-concentrate ratios were more favourable than the 30:70 ratio for the nutrients that responded significantly to treatment. The 30:70 ratio therefore cannot be described as improving overall nutrient utilisation on the basis of the present data. The practical implication is that moderate forage-to-concentrate ratios, particularly 50:50, may be preferable when the objective is to maintain favourable nutrient digestibility in male Kacang goats.

The mechanisms proposed above, particularly those involving ruminal pH, volatile fatty acids, ammonia-N, microbial populations, and fibre degradation, were inferred from the observed digestibility responses and previous literature. These variables were not directly measured in the present study. Therefore, the findings should be interpreted primarily as evidence of treatment differences in nutrient digestibility, while the proposed rumen mechanisms should be considered hypotheses for future research.

Growth performance

Initial and final body weight

Initial body weight and initial metabolic body weight did not differ significantly among treatments (P>0.05; Table 6), indicating that the goats were relatively comparable at the beginning of the experiment. Final body weight also did not differ significantly among treatments (P>0.05). Although T2 and T3 showed numerically higher final body weights than T1, these numerical differences do not provide statistical evidence that the higher concentrate ratios improved final body weight. The relatively high individual variation in growth responses should also be considered when interpreting the numerical differences.

The numerical pattern in final body weight and daily weight gain in T3 is noteworthy because T3 also had lower DM, CP, and energy intake and lower digestibility for some nutrients. However, this apparent contrast should not be interpreted as evidence of superior metabolic energy utilisation or energy partitioning. Measurements such as methane loss, urinary energy, heat production, retained energy, or tissue energy deposition were not conducted in this study. Therefore, any explanation involving greater metabolic efficiency in T3 remains hypothetical and requires direct experimental verification.

Changes in body weight

The forage-to-concentrate ratios did not significantly affect body weight gain or daily weight gain (P > 0.05; Table 6).

Table 6: Changes in body weight, feed conversion ratio, and feed efficiency of male Kacang goats fed different forage-to-concentrate ratios[1].

Parameter	Treatments			P value	η^2	Power (1–β)	CV (%)
	T1	T2	T3				
Initial body weight (kg)^{ns}	10.94 ± 0.42	12.11 ± 0.51	10.58 ± 0.29	0.173	0.26	0.47	16.87
Initial metabolic BW^{ns}	6.01 ± 0.19	6.49 ± 0.23	5.87 ± 0.12	0.169	0.26	0.47	17.02
Final body weight (kg)^{ns}	16.55 ± 1.23	17.87 ± 1.60	17.16 ± 1.42	0.747	0.06	0.11	25.94
Final metabolic BW^{ns}	8.20 ± 0.45	8.69 ± 0.59	8.41 ± 0.52	0.744	0.06	0.11	26.06
Body weight gain (kg)^{ns}	5.61 ± 1.11	6.63 ± 1.29	7.33 ± 1.52	0.620	0.09	0.15	40.71
Average daily gain (g)^{ns}	68.40 ± 13.46	80.88 ± 15.67	89.39 ± 18.53	0.620	0.09	0.15	41.63
Feed conversion ratio^{ns}	13.20 ± 3.14	10.77 ± 2.88	8.05 ± 2.56	0.182	0.24	0.32	35.44
Feed efficiency (%)^{ns}	7.99 ± 2.12	11.36 ± 2.76	16.29 ± 3.42	0.134	0.28	0.48	31.21

[1]Data are presented as mean ± standard error of the mean (SEM). T1= 50% forage + 50% concentrate; T2= 40% forage + 60% concentrate; T3= 30% forage + 70% concentrate; ns= not significant (P > 0.05). η^2= effect size (eta squared). Power (1–β) = statistical power. CV= coefficient of variation. Different superscripts within the same row indicate significant differences (P < 0.05).

Treatment T3 showed numerically higher average daily gain than T1 and T2, but the difference was not statistically significant. Accordingly, the higher numerical ADG in T3 should be reported as an observed numerical difference rather than as evidence of a treatment advantage. The relatively high variability among individual goats may have contributed to the absence of a statistically significant response.

An important observation is that T1 and T2 had significantly higher DM, CP, and energy intake than T3 ($P<0.05$), whereas these higher intakes were not accompanied by significantly higher weight gain. This indicates that, within the range of diets tested, greater nutrient intake did not necessarily translate into greater growth. Nevertheless, the present data do not allow the conclusion that metabolic energy utilisation was more important than intake or digestibility, because energy retention and energy partitioning were not measured.

Crude protein and metabolizable energy digestibility also differed among treatments ($P<0.05$), with higher values generally observed in T1 than T3. However, the absence of significant differences in weight gain indicates that the higher CP and ME digestibility in T1 did not produce a statistically detectable growth advantage. Pazla *et al.* (2026) highlighted the interaction between nutrient supply and utilisation in ruminant production; this provides useful context, but the present experiment cannot identify the metabolic pathways responsible for the numerical growth pattern.

The numerical combination of lower intake and digestibility with higher ADG in T3 may reflect individual biological variation or other unmeasured factors rather than a confirmed improvement in energy partitioning. The production response of ruminants can be affected by maintenance requirements, metabolic activity, rumen fermentation, and nutrient utilisation (Tolkamp, 2010; Rauw, 2025). Propionate production has also been discussed as an important pathway for glucose supply in ruminants (Ungerfeld, 2018; Haque, 2018). However, because rumen fermentation and energy partitioning were not measured in this study, these mechanisms should be considered possible explanations and not direct evidence for the numerical superiority of T3.

Previous studies have shown that dietary energy supply can influence growth performance through changes in rumen fermentation and nutrient availability (Wang *et al.*, 2024), while nutrient utilisation involves complex interactions between intake, digestion, metabolism, and tissue deposition (Mahgoub *et al.*, 2025; Luo *et al.*, 2025; Feng *et al.*, 2025). In the present study, these concepts help explain why intake and digestibility responses were not perfectly aligned with growth responses. Nevertheless, the statistically supported conclusion is that forage-to-concentrate ratio affected nutrient intake and selected digestibility variables, but did not significantly affect growth performance.

Feed conversion and efficiency

Feed conversion ratio (FCR) and feed utilisation efficiency did not differ significantly among treatments ($P>0.05$). T3 showed a numerically lower FCR and higher feed efficiency than T1 and T2, but these differences should be interpreted only as numerical observations and not as evidence that T3 was more efficient. The sample size and individual variation should be considered when interpreting these production ratios.

When considered together with feed intake, T3 had lower DM and nutrient intake but numerically lower FCR and higher feed efficiency. Conversely, T1 had higher intake and digestibility for several nutrients but did not show a statistically superior FCR or feed efficiency. This illustrates that intake and feed conversion are not necessarily linearly related. Lin *et al.* (2023) discussed the multifactorial nature of feed efficiency, including nutrient utilisation and animal-level variation. However, the present study did not measure the metabolic components required to identify the specific causes of the numerical differences among treatments.

The finding that T1 had favourable digestibility but did not have the lowest FCR also indicates that digestibility alone does not determine the final feed conversion response. Rajeev *et al.* (2026) similarly discussed the complexity of relationships among nutrient digestibility, intake, and production efficiency. Thus, the present results support interpretation of FCR and feed efficiency as integrated production outcomes rather than direct measures of metabolic energy efficiency.

The numerical tendency toward lower FCR and higher feed efficiency in T3 may be of interest for future research, but it cannot be attributed conclusively to improved energy conversion because energy retention, methane loss, heat production, and other components of the energy balance were not measured. Ramdani *et al.* (2025) and Feng *et al.* (2025) highlighted the roles of rumen fermentation, microbial activity, and nutrient metabolism in determining feed efficiency. These studies provide a framework for future investigation, whereas the present study establishes only that the numerical differences in FCR and feed efficiency were not statistically significant.

Overall, the production results indicate that the 30:70 forage-to-concentrate ratio produced numerically higher ADG and feed efficiency, but without statistically significant treatment effects. Therefore, T3 should not

be described as superior for growth or feed efficiency. Among the tested diets, the 50:50 ratio provides the most defensible recommendation when nutrient intake and digestibility are prioritised, while the 40:60 ratio may be considered a practical alternative because its intake and several digestibility responses were comparable with T1.

CONCLUSION

The forage-to-concentrate ratio significantly affected nutrient intake and nutrient digestibility in male Kacang goats. Diets containing forage-to-concentrate ratios of 50:50 and 40:60 improved feed intake and nutrient digestibility compared with the 30:70 ratio. Increasing the concentrate proportion to 70% reduced nutrient intake and digestibility; however, goats receiving this diet exhibited numerically higher average daily gain and feed efficiency, although these differences were not statistically significant. These findings suggest that the growth performance of Kacang goats is influenced not only by nutrient intake and digestibility but also by the efficiency of metabolizable energy utilization for body tissue deposition. Overall, forage-to-concentrate ratios of 50:50 to 40:60 can be considered a safer and more stable feeding strategy for improving nutrient utilization and production performance in tropical goat production systems. In contrast, the 30:70 ratio requires more careful feeding management to minimize the risk of reduced nutrient utilization efficiency and potential disturbances in rumen fermentation balance.

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NOVELTY STATEMENT

The novelty of this study lies in demonstrating that increasing the concentrate proportion from 50% to 70% does not necessarily translate into superior growth performance in Kacang goats under tropical conditions. Moderate forage-to-concentrate ratios (50:50–40:60) supported more favourable nutrient intake and digestibility, while the 70% concentrate diet produced only numerical, but statistically non-significant, improvements in growth and feed efficiency.

AUTHORS CONTRIBUTION

PKT: Responsible for conceptualization and research design; coordination of research implementation with the team; periodic monitoring and evaluation of research progress; supervision of all research activities; data analysis; preparation of research reports; writing and revising the scientific manuscript; and dissemination of research findings. WVF: Contributed by assisting the principal investigator in ration formulation, forage processing and preservation, and data collection and analysis; and participated in the preparation of research reports and the writing of the scientific manuscript. SMCN: Contributed by assisting the principal investigator in research preparation, including pen setup and livestock management during the study; conducting data collection; and participating in the preparation of research reports and the writing of the scientific manuscript.

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Statement of conflict of interest

The authors have declared no conflict of interest.

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