Research Article

Effects of Energy Feed Combinations and Non-Protein Nitrogen on Feed Intake, Nutrient Digestibility and Nitrogen Retention of Saanen Crossbred Goats

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Abstract | The study aimed to determine the effects of feed supplement combinations with or without urea on feed intake, nutrient digestibility, and nitrogen retention of goats. The study was conducted in the experimental farm of An Giang University, which is part of Vietnam National University Ho Chi Minh City, from February to May 2024. Four male Saanen crossbred goats aged five months (15.4±3.32 kg) were studied using a Latin Square design (4 × 4) over 21 days/periods. The four treatments were maise and cassava chips (Ma.C); broken rice and cassava chips (BrR.C); cassava chips, and urea (Ma.C.U); broken rice, cassava chips, and urea (BrR.C.U). The basal diet was premix, tofu waste, *Operculina turpethum* vines, and ad libitum fresh elephant grass. The dry matter consumption per body weight showed a tendency towards a decrease in Ma.C.U (3.11%) and Ma.C treatments (3.11%) than in BrR.C.U (3.31%) and BrR.C (3.25%) treatments. Crude protein digestibility (%) of BrR.C.U was similar to Ma.C.U (P>0.05), but it was higher than (P<0.05) BrR.C and Ma.C (78.0, 78.7, 67.4 and 68.2, respectively). Across treatments, nitrogen retention (g/animal/day) differed (P<0.05). Treatments were 4.18, 7.12, 5.08, and 7.50 g for Ma.C, Ma.C.U, BrR.C, and BrR.C.U. Therefore, the energy feed combination without urea or urea that feed intake, nutrient value and nitrogen retention well from high to low were BrR.C.U, Ma.C.U, BrR.C and Ma.C treatments.

Keywords | Soluble carbohydrates, Combinations, Energy feed, Non-protein nitrogen, Small ruminant, Goat

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INTRODUCTION

The goat population in Vietnam grew from 1.29 to 2.65 million between 2010 and 2020, according to Don *et al*. (2023), representing an impressive average yearly increase of 10.5%. In Vietnam, Olmo *et al*. (2024) reported that goat retail price was A$19.20–25.60/kg in 2023 and the growing goat demand in Vietnamese stands to benefita range of supply-chain participants. This expansion in goat farming has notably contributed to the economic progress of various rural families, resulting in better income levels. Additionally, Ba *et al*. (2021) highlighted a significant shortage of goat meat in the Vietnamese market, presenting an opportunity for Vietnamese and Lao farmers to develop goat farming further and enhance their incomes. However, Tripathi *et al.* (2006) identified that the main challenges to improving ruminant production in tropical environments are the quality and quantity of feed. In response, Preston *et al.* (2021) suggested that to tackle pressing issues like climate change and biodiversity loss, ruminant feeding systems in tropical regions should focus on using trees and shrubs supplemented by carbohydrate-rich residues from agro-industrial crops. Using starch content from agricultural by-products is a promising approach for ruminant feeding (Nhu *et al.*, 2016; Dung, 2014). Nevertheless, the availability of comprehensive data on digestibility and rumen fermentation characteristics is insufficient, which restricts the extent of the findings. Consequently, relying only on these feeds for cattle may not provide enough nitrogen for effective nutrient digestion and feed absorption (Dung, 2014). Furthermore, Truong *et al.* (2024) found that energy feed combinations effectively supporting intake, nutrient value, nitrogen retention, and daily weight gain in Saanen crossbred goats ranked from high to low as follows: broken rice and wheat, broken rice and cassava chips, maise and cassava chips, and maise and wheat. Paengkoum *et al.* (2006) indicated that supplementation of energy enhanced the utilisation of urea and resulted in higher animal performance as a consequence of improved ruminant fermentation, microbial yield and nitrogen balance. To reduce diet-related costs, it could be advantageous to incorporate non-protein nitrogen (NPN) sources like urea into diets high in soluble carbohydrates (Khattab *et al.*, 2013). This research aimed to assess the impact of different energy feed combinations, with or without urea, on the intake of feed, digestibility of nutrients, and retention of nitrogen in Saanen crossbred goats.

Figure 1: Four Saanen crossbred goats in this study.

MATERIALS AND METHODS

Location and Time

The experiment was placed on the experimental farm in An Giang University, which is situated in An Giang Province, Vietnam (10°22'24.1"N 105°25'45.1"E). The laboratory analysis of the meals, refusals, excrement, and urine was conducted at laboratory E205 of the Faculty of Animal Sciences, College of Agriculture, Can Tho University.

Experimental Design and Feeds and Feeding

The research used four male Saanen crossbred goats with an average starting body weight of 15.4±3.32 kg at around five months of age (Figure 1). The four treatments were maise and cassava chips (Ma.C); broken rice and cassava chips (BrR.C); cassava chips, and urea (Ma.C.U); broken rice, cassava chips, and urea (BrR.C.U). The baseline diet included premix, tofu waste, *Operculina turpethum* vines, and fresh Napier grass provided without restriction. The feed ingredients are presented in Table 1.

Table 1: Feed ingredient composition of diet in the experiment.

Ingredients (%DM)	Ma.C	Ma.C.U	BrR.C	BrR.C.U
Maize	15.0	15.0	-	-
Broken rice	-	-	15.0	15.0
Cassava chips	15.0	-	15.0	-
Tofu waste	5.00	5.00	5.00	5.00
Operculina turpethum vines	30.0	30.0	30.0	30.0
Elephant grass	34.3	34.3	34.3	34.3
Urea	-	1.00	-	1.00
Premix	0.70	0.70	0.70	0.70
Total	100	100	100	100

Measurements Taken

Feed, nutrient and energy intakes: Before feeding, all the meals were measured and given individually to the experimental goats. The corn, broken rice, and cassava chips were pulverised into a fine powder. The feed, consisting of maize, broken rice, cassava chips, urea, and premix, was given twice daily at 7:00 am and 1:00 pm, with the specific composition varying according to the therapy. The tofu waste was administered at 1:30 pm. *Operculina turpethum* was administered food at 8:00 am and 2:00 pm. Napier grass (*Pennisetum purpureum*) was freely available. The weight of the feed and any remaining feed was measured in the morning to calculate the daily consumption of feed and nutrients.

The dry matter (DM) and organic matter (OM) contents of the feed, refusals, and faeces were evaluated using the protocols outlined in AOAC (1990). The meals' nitrogen (N) content, refusals, faeces, and urine were analysed using the Kjeldahl procedures outlined in AOAC (1990). Nevertheless, the analysis of neutral detergent fibre (NDF) and acid detergent fibre (ADF) was conducted using the technique developed by Van Soest *et al.* (1991).

Bruinenberg *et al.* (2002) developed a formula to quantify

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metabolisable energy (ME) in animal diets. The formula is ME (MJ/animal/day) = 14.2 x DOM + 5.9 x DCP when the ratio of digestible organic matter (DOM) to digestible crude protein (DCP) is less than 7.0. If the DOM/DCP ratio exceeds 7.0, the formula becomes ME (MJ/animal/day) = 15.1 x DOM. Here, DOM refers to digestible organic matter, and DCP stands for digestible crude protein.

Apparent nutrient digestibility: The apparent digestibility coefficients for dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), and nitrogen retention were determined using the methodology described by McDonald *et al.* (2010). Each experimental session lasted three weeks, comprising a two-week adaptation phase and a one-week collection period for faeces and urine. Daily nitrogen retention was calculated using the method that considers the daily nitrogen intake, nitrogen excreted in faeces, and nitrogen excreted in urine: N retention = N intake - (N faeces + N urine).

Daily weight gains (DWG): The Saanen crossbred goats were weighed in the morning before being fed at the start and conclusion of each trial session, lasting two consecutive days.

Statistical Analysis

The data were analysed using the General Linear Model (GLM) from the Minitab Reference Manual Release 20 (Minitab, 2021). Tukey's pairwise comparisons were used at a significance threshold of $p < 0.05$ to detect differences between treatments. The data were evaluated using the model

$$Y_{ijk} = \mu + T_i + A_j + P_k + e_{ijk}$$

Where;
Y_{ijk}: The dependent variable.
μ: the overall mean.
T_i: the effect of treatment (i = 1 to 4).
A_j: the impact of animal (j = 1 to 4).
P_k: The effect of period (j = 1 to 4).
e_{ijk} = the random error.

RESULTS AND DISCUSSION

Chemical Composition of Feeds

The composition of feed in the present study is shown in Table 2. The results of energy feed presented in Table 2 indicated that the CP content was higher in maise (8.50%) than in broken rice (7.28) and cassava chips (3.50%). However, the NDF of broken rice was lower than cassava chips and maise (10.1, 13.8 and 23.7%, respectively). The NDF and ADF contents of tofu waste were 35.9 and 24.4%. The chemical composition of the feeds used in this investigation closely resembled the composition Dung (2014) reported for maise and cassava. The nutrient composition of soya waste was 32.6% NDF and 24.5% ADF (Dong and Thu, 2023). The elephant grass nutrients in this study were similar to the result of Rusdy (2016), who reported that elephant grass's CP, NDF, and ADF were about 7.20-12.1%, 57.4-75.4% and 30.6-51.7%.

Table 2: Chemical composition (%DM) of feeds used in the field trial.

Feeds	DM, %	In DM, %			
		OM	CP	NDF	ADF
Maize	85.6	96.3	8.50	23.7	4.31
Broken rice	85.2	99.4	7.28	10.1	3.16
Cassava chips	85.8	95.7	3.50	13.8	4.77
Tofu waste	19.1	96.4	17.8	35.9	24.4
Operculina turpethum vines	12.6	86.8	14.2	40.6	30.5
Elephant grass	15.1	90.7	9.04	66.1	45.1
Urea	99.6	-	286	-	-

DM: dry matter; **OM:** organic matter; **CP:** crude protein; **NDF:** neutral detergent fiber; **ADF:** acid detergent fiber.

Table 3: Total nutrient intake of Saanen crossbred by different treatments.

Parameters	Ma.C	Ma.C.U	BrR.C	BrR.C.U	SEM	P
Feed intake, gDM/ animal/day						
Maize	81.7	74.7	0.00	0.00	8.110	0.001
Broken rice	0.00	0.00	75.2	79.7	9.410	0.001
Cassava chips	81.3	74.2	75.6	80.5	5.550	0.754
Tofu waste	27.0	24.6	25.1	26.7	1.820	0.751
Operculina turpethum vines	189	177	181	194	13.50	0.798
Elephant grass	175	172	190	199	16.50	0.655
Urea	0.00	4.82	0.00	5.12	0.544	0.001
Premix	3.83	3.50	3.58	3.79	0.255	0.765
Nutrient intake, gDM/animal/day						
DM	558	531	550	589	33.70	0.690
OM	504	475	500	529	30.60	0.683
CP	57.2[b]	67.9[ab]	56.7[b]	75.1[a]	3.430	0.024
NDF	234	220	227	241	13.90	0.742
ADF	155	141	155	161	10.50	0.592
CP/DM, %	10.4[b]	12.9[a]	10.2[b]	12.7[a]	0.145	0.001
DM/BW, %	3.11	3.11	3.25	3.31	0.100	0.456
ME, MJ/animal/day	5.24	5.20	5.51	5.82	0.283	0.451

a.C: Maize + Cassava chips; **Ma.C.U:** Maize + Cassava chips + Urea; **BrR.C:** Broken rice + Cassava chips; **BrR.C.U:** Broken rice + Cassava chips + Urea; **DM:** dry matter, **OM:** organic matter; **CP:** crude protein; **NDF:** neutral detergent fibre; **ADF:** acid detergent fibre; **BW:** body weight; [a, b, c] values with different superscript letters within one row are significantly different at the level of 5%.

Feed and Nutrient Intakes

Table 3 displays the feed intake and nutrient consumption of goats. The results in Table 3 show no significant difference (P<0.05) in dry matter intake (DMI) between treatments. The treatments Ma. C, Ma.C.U, BrR.C, and BrR.C.U measured 558, 531, 550, and 589 gr/animal/day. The proportion of DMI/BW in this study (Figure 2) tended to be lower in Ma.C.U (3.11%) and Ma.C (3.11%) treatments than in BrR.C.U (3.31%) and BrR.C (3.25%) treatments (P>0.05). The Ma.C.U and BrR.C.U treatments had considerably higher crude protein per dry matter intake (DMI) percentages (P<0.05) than the Ma.C and BrR.C treatments (12.9%, 12.7%, 10.4%, and 10.2%, respectively). Fermentable carbohydrates and rumensolubilized protein and N are essential for ruminal microbial growth, according to Khattab *et al.* (2013). Additionally, nutrition and metabolism depend on converting food protein into body protein, according to Dong and Thu (2020). Fermentable carbohydrates and rumensolubilized protein/N are essential for ruminal microorganism development. The conversion of feed protein into body protein is a crucial nutrition and metabolic process, according to Dong and Thu (2020).

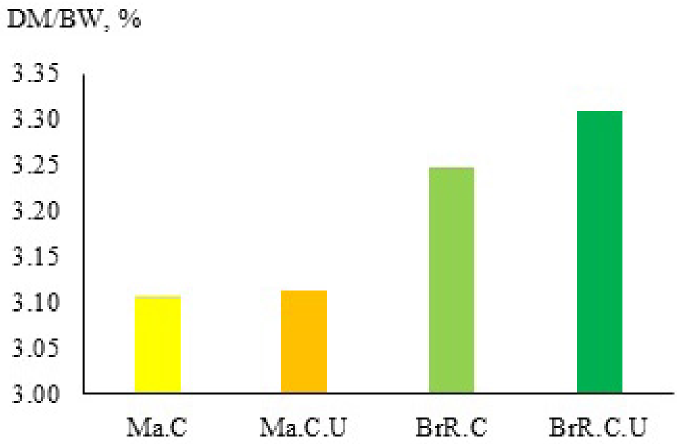

Figure 2: DM intake per body weight.

Digestibility and Digestive Nutrient

The percentage of nutrient digestibility and the amount of digestive nutrients per animal per day are shown in Table 4. The DM digestibility tended to be lower in Ma.C and BrR.C (69.4 and 71.0%) than Ma.C.U and BrR.C.U treatments (71.0 and 72.3%). Similarly, the OM digestibility was like DM digestibility in this study. However, the CP digestibility was affected (P<0.05) by without urea or urea (Figure 3).

The Ma.C and BrR.C treatments showed no significant difference in crude protein (CP) digestibility, with values of 68.2% and 67.4%, respectively (p>0.05). Similarly, no significant difference in CP digestibility was observed between the Ma.C.U and BrR.C.U treatments, with values of 78.7% and 78.0%, respectively (p>0.05). However, the Ma.C.U and BrR.C.U treatments demonstrated significantly higher CP digestibility compared to the Ma.C and BrR.C treatments (P<0.05). In a study conducted by Khattab *et al.* (2013), it was found that the digestion of dry matter (DM), organic matter (OM), crude protein (CP), and non-fibre carbohydrates showed a consistent increase with higher levels of urea in the diet. Urea inclusion at 0 to 1.0% levels resulted in a marginal, non-significant increase in the digestibility of NDF and ADF (P>0.05). Lopes *et al.* (2021) found that adding nitrogen to the diet accelerated bacterial growth that breaks down fibre, improving fibre decomposition and digestibility. Moreover, David *et al.* (2024) showed that protein supplementation may enhance forage intake by optimising the availability of essential components (such as energy and protein) in both metabolic processes and the rumen. This study suggests that the inclusion of urea in the Ma.C.U and BrR.C.U diets positively impacted CP digestibility, likely due to higher levels of rumen ammonia nitrogen and the simultaneous availability of easily digestible carbohydrates from maise, broken rice, and cassava chips.

Table 4: Nutrient digestibility and digestible nutrients of experimental goat.

Parameters	Ma.C	Ma.C.U	BrR.C	BrR.C.U	SEM	P
Feces, gDM/animal/day	179	150	154	168	17.40	0.653
Apparent digestibility, %						
DM	69.4	71.0	71.0	72.3	1.020	0.334
OM	70.5	71.8	72.0	73.2	0.985	0.367
CP	68.2[b]	78.7[a]	67.4[b]	78.0[a]	1.920	0.009
NDF	61.0	61.9	62.6	65.0	1.740	0.472
ADF	55.0	57.2	63.0	61.8	2.280	0.134
Digestible nutrients, gDM/animal/day						
DM	379	381	396	421	19.9	0.647
OM	347	344	365	385	18.8	0.451
CP	38.6[b]	54.8[a]	38.7[b]	58.0[a]	2.82	0.005
NDF	139	141	145	154	7.37	0.525
ADF	83.5	86.9	98.4	98.2	5.82	0.259

Ma.C: Maize + Cassava chips; **Ma.C.U:** Maize + Cassava chips + Urea; **BrR.C:** Broken rice + Cassava chips; **BrR.C.U:** Broken rice + Cassava chips + Urea; **DM:** dry matter; **OM:** organic matter; **CP:** crude protein; **NDF:** neutral detergent fiber; **ADF:** acid detergent fiber; [a, b, c] values with different superscript letters within one row are significantly different at the level of 5%.

Nitrogen Balances and Weight Gain

Table 5 displays the nitrogen balances and weight increase. The measurement of nitrogen retention, as shown in Table 5, is often regarded as the primary indicator of protein nutrition status in ruminant animals. The current investigation revealed that nitrogen retention was enhanced in the Ma.C.U and BrR.C.U diets when the dietary intake of urea (nitrogen) increased, with statistical significance (P<0.05). The recorded values for the Ma.C, Ma.C.U, BrR.C, and BrR.C.U treatments were 4.18, 7.12, 5.08, and 7.50 g/animal/day, respectively. The simultaneous release of easily accessible energy from maise and broken rice, along with the release of ammonia from urea in the Ma.C.U and BrR.C.U diets, seemingly created more favourable conditions for microbial proliferation in the rumen than the low-protein diets. Urea, a nitrogenous compound often found in proteins, is necessary for microbial activity (Pongsub *et al*., 2024). Paengkoum *et al*. (2006) found that using urea or other non-protein nitrogen supplements increased feed intake, rumen digestibility, nitrogen balance, and microbial development.

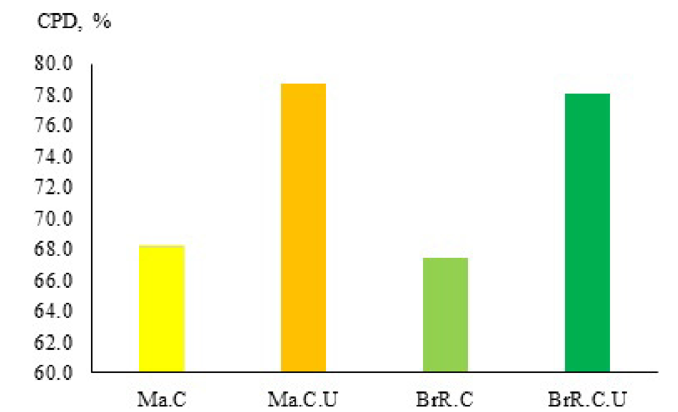

Figure 3: The CP digestibility in this study.

Table 5: Nitrogen retention and daily weight gain of goat in the present study.

Parameters	Ma.C	Ma.C.U	BrR.C	BrR.C.U	SEM	P
Urine, g/animal/day	2,332	1,062	1,179	1,564	399.0	0.206
Nitrogen (N), g/animal/day						
N_{intake}	9.15^{b}	10.9^{ab}	9.07^{b}	12.0^{a}	0.549	0.024
N_{fecal}	2.98	2.10	2.87	2.74	0.427	0.515
N_{urin}	1.99	1.65	1.12	1.77	0.380	0.476
$N_{retention}$	4.18^{b}	7.12^{ab}	5.08^{ab}	7.50^{a}	0.621	0.025
$N_{retention,}$ g/$BW^{0.75}$/day	0.330^{b}	0.551^{a}	0.396^{ab}	0.572^{a}	0.037	0.010
Body weight change, g/animal/day						
$Initial_{body\ weight}$, kg	17.4	16.2	16.3	17.1	0.831	0.663
$Final_{body\ weight}$, kg	17.9	16.8	17.3	18.4	0.647	0.385
DWG, g	22.5	30.7	49.4	65.6	10.20	0.085

Ma.C: Maize + Cassava chips; **Ma.C.U:** Maize + Cassava chips + Urea; **BrR.C:** Broken rice + Cassava chips; **BrR.C.U:** Broken rice + Cassava chips + Urea; **DM:** dry matter; OM: organic matter; **CP:** crude protein; **NDF:** neutral detergent fiber; **ADF:** acid detergent fiber; **DWG:** daily weight gain; ^{a,b,c} values with different superscript letters within one row are significantly different at the level of 5%.

CONCLUSIONS AND RECOMMENDATIONS

Consequently, the administration of BrR.C resulted in increased feed intake, nutritional digestibility, nitrogen retention, and daily weight growth compared to the Ma.C treatment. The treatments with BrR.C and Ma.C with urea, exhibited the highest nutritional value, nitrogen retention and daily weight gain compared to those without urea. The study's findings suggest that the proposed technique for local feed is suitable for goat production.

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NOVELTY STATEMENT

The combination of broken rice and cassava chips was better than maize and cassava chips. Combining urea and energy feed from broken rice and cassava chips was the better choice for Saanen crossbred goat.

AUTHOR'S CONTRIBUTIONS

Nguyen Binh Truong: Conceptualised, devised, and conducted the experiments.
Nguyen Binh Truong: Analysed the data.
Nguyen Binh Truong, Nguyen Thi Hanh Chi, Ho Xuan Nghiep, and Tran Trung Tuan: Authored the work.

All authors evaluated and endorsed the final manuscript.

Conflict of Interest

We certify that there is no conflict of interest.

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