OPEN ACCESS
Advances in Animal and Veterinary Sciences

Research Article

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

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Abstract | This experiment aimed to evaluate the influence of age, energy sources and urea on feed intake, nutrient digestibility and nitrogen retention in Saanen crossbred goats. This study employed a 2×(4×4) Latin square design. The first factor was months (5 to 8 and 9 to 12 months), the second factor was an energy source (maize and broken rice), and the third factor was with or without urea. The basic diet consisted of cassava chips, tofu waste, premix, *Operculina turpethum* vines, and fresh elephant grass *ad libitum*. It was found that dry matter (DM) consumption of goats at 5-8 months was higher (P<0.05) than at 9-12 months; DM intake was lower (P>0.05) for maize compared to broken rice while with or without urea was not affected (P>0.05) to DM intake. Crude protein (CP) intake was lower (P<0.05) in goats aged 9-12 months than in those aged 5-8 months. No significant difference (P>0.05) was observed between maize and broken rice, but CP intake was higher with urea supplementation (P>0.05) than without. The organic matter (OM) digestibility (%) of goats at 9-12 months was higher (P<0.05) than at 5-8 months. However, there was no significant difference (P>0.05) between maize and broken rice as energy sources and the OM digestibility tended to be higher (P>0.05) with urea than without. CP digestibility (%) significantly differed between diets with and without urea in this study. However, there were no significant differences (P>0.05) in months and energy sources. Nitrogen retention was lower (P<0.05) without urea and higher with urea. The maize and broken rice were not different (P>0.05) for nitrogen retention. However, nitrogen retention in 5 to 8 months was higher than in 9 to 12 months. No significant interactions were observed between age, energy source, and urea supplementation (P>0.05), but the urine significantly differed from the interaction of energy source and NPN. Therefore, broken rice and urea supplementation were optimal for the goats' diet. The goat from 9 to 12 months had more nutrient digestibility than the 5-8 months. The interaction of the energy source and NPN was statistically different in the urine.

Keywords | Small ruminant, Energy feed, Nutrient digestibility, Weight gain, Interaction, NPN

Received | November 21, 2024; **Accepted** | February 25, 2025; **Published** | April 17, 2025
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Citation | Nghiep HX, Truong NB (2025). Effects of age, energy sources and non-protein nitrogen on feed intake, nutrient digestibility and nitrogen retention in saanen crossbred goats. Adv. Anim. Vet. Sci. 13(5): 1001-1007.
DOI | https://dx.doi.org/10.17582/journal.aavs/2025/13.5.1001.1007
ISSN (Online) | 2307-8316; **ISSN (Print)** | 2309-3331

INTRODUCTION

In Vietnam, Don *et al.* (2023) reported that the goat population grew from 1.29 million to 2.65 million (2010-2020, respectively). The significant shortage of goat meat in the Vietnamese market presents an opportunity for farmers to expand goat farming and increase their incomes (Ba *et al.*, 2021). Likewise, Olmo *et al.* (2024) reported that the growing goat demand in Vietnam stands to benefit a range of supply-chain participants. However, limited data exist on the performance of Saanen crossbred goats supplemented with locally available forage, which could guide farmers in the Mekong Delta on optimal feed utilization. The Saanen crossbreds can utilize feed energy and protein sources more than local goats (Hieu *et al.*, 2020). However, poor energy and protein content forage in goat breeding is common in tropical conditions (Nair *et al.*, 2021; Shinde and Mahanta, 2020). Therefore, the quality and quantity of feed are the main challenges to improving ruminant production in tropical environments (Tripathi *et al.*, 2006). According to Dung (2014), a promising approach for ruminant feeding was starch content from agricultural by-products such as broken rice, maize, cassava. Truong *et al.* (2024) suggested that maize and broken rice are good for the diet of goats in the Mekong Delta. Paengkoum *et al.* (2006) suggested that supplemental energy was enhanced by the utilization of urea, due to higher animal performance as a consequence of improved ruminant fermentation. Suryani *et al.* (2017) reported that urea (non-protein nitrogen, NPN) serves as a macronutrient for the growth of microorganisms. Urea in a diet high in soluble carbohydrates could help lower expenses, as proposed by Khattab *et al.* (2013). Developing and utilizing local feed resources is an effective strategy for feeding ruminants. As a result, it is important to examine the pairing of protein and energy feed sources for goats. Moreover, Goats' nutrient requirements vary with age, presenting a significant challenge. While previous studies have examined the effects of energy sources and urea separately, there is limited research on their combined effects in Saanen crossbred goats of different ages. Therefore, this study aimed to determine the impact of age, energy sources, and urea supplementation on nutrient intake, digestibility, nitrogen balance, and weight gain in goats.

MATERIALS AND METHODS

Location and Time

This research was conducted at the experimental farm of An Giang University from February to May 2024. Laboratory analyses were conducted at the E205 laboratory of the Department of Animal Science at the College of Agriculture, Can Tho University.

Experimental Design and Feeds

In the current study, a Latin square design (2 × 4 × 4) was used with 8 Saanen crossbred goats (Figure 1). In detail, four male Saanen crossbred goats with an average starting body weight of 15.4±3.32 kg at around five months of age. Four male Saanen crossbreed goats (25.2±1.06 kg) at around nine months of age. The present study included three factors:

- The first factor was the month-old of goats from 5 to 8 and 9 to 12 months.
- The second factor was with or without urea.
- The third factor was energy sources from maize and broken rice.

Figure 1: Saanen crossbred goats in this study.

The composition of feed and feed ingredients are presented in Table 1 and Table 2.

Table 1: The nutrient composition of feeds (% DM).

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	19.0	96.7	18.3	35.5	24.2
Operculina turpethum vines	12.6	87.4	13.8	40.6	31.2
Elephant grass	14.9	91.3	9.12	65.5	43.5
Urea	99.6	-	286	-	-

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

Measurements Taken

Feed and nutrient intakes: Before feeding, broken rice, maize, and cassava chips were ground into fine powder. All the diets were measured and given to individual goats in the experiment.

The feed supplement was matched and given twice daily at 7:00 am and 1:00 pm, which included broken rice, maize, cassava chips, urea, and premix from the ingredients of Table 2. The tofu waste was feeding at 1:30 pm. *Operculina turpethum* was supplemented at 8:00 am and 2:00 pm. Elephant grass (*Pennisetum purpureum*) was *ad libitum*. The next morning, any refused feed was weighed to calculate the daily feed and nutrient intake.

Table 2: The feed ingredients of diets (%DM).

Ingredients (%DM)	5-8				9-12			
	NU		U		NU		U	
	Ma	BrR	Ma	BrR	Ma	BrR	Ma	BrR
Maize	15.0	-	15.0	-	15.0	-	15.0	-
Broken rice	-	15.0	-	15.0	-	15.0	-	15.0
Cassava chips	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Tofu waste	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Operculina turpethum vines	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Elephant grass	34.3	34.3	33.3	33.3	34.3	34.3	33.3	33.3
Urea	-	-	1.00	1.00	-	-	1.00	1.00
Premix	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Total	100	100	100	100	100	100	100	100

Mo: months; **Es:** Energy sources; **NPN:** non protein nitrogen; **BW:** body weight; **Ma:** Maize; **BrR:** Broken rice; **NU:** Non Ure; **U:** Urea; 5-8 = from 5 to 8 months, 9-12 = from 9 to 12 months. Ingredients of premix: Vitamin A, Vitamin D3, Vitamin E, ferrous sulfate, zinc oxide, copper sulfate, magnesium sulfate, manganese sulfate, Phytase, Bacillus subtilis, Pediococcus acidilactici, Calcium carbonate.

Chemical analysis: Feeds, refusals, feces, and urine were analyzed for nutrient composition. The method of AOAC (1990) was an analysis of dry matter (DM) and organic matter (OM). The nitrogen (N) in feed, refusals, faeces, and urine was specified using the Kjeldahl procedures of AOAC (1990). However, acid detergent fiber (ADF) and neutral detergent fiber (NDF) were analyzed by the technique of Van Soest *et al.* (1991).

Energy intakes: The metabolisable energy (ME) in goat diets was calculated by the suggestion of Bruinenberg *et al.* (2002).

ME (MJ/head/day = 14.2 × DOM + 5.9 x DCP (with DOM/DCP < 7).

- ME (MJ/head/day)= 15.1 × DOM (with DOM/DCP > 7).

Here,
DOM: The digestible organic matter.
DCP: The digestible crude protein.

Apparent Nutrient Digestibility and Nitrogen Retention

Each experimental period lasted three weeks: the first week for adaptation, the second for diet stabilization, and the third for feces and urine collection (McDonald *et al.* 2010).

The apparent digestibility was dissected by evaluation criteria DM, OM, CP, NDF and ADF. Daily nitrogen retention was calculated from N retention = N intake - (N feces + N urine).

Daily Weight Gains (DWG)

In the morning before being fed at the start and conclusion of each trial. The goats were weighed for two consecutive days.

Data Analysis

The data were subjected to analysis of variance in the General Linear Model of Minitab (2021) software. The statistical model included terms for age, energy sources, NPN level, and interaction between three factors. Tukey's multiple comparison tests contrasted the significantly different treatments (P<0.05).

RESULTS AND DISCUSSIONS

Nutrient Intakes

The DM, OM, CP, and NDF consumption were significantly different (P<0.05) between the months old. However, ADF and ME intake were not different in this study (Table 3). In detail, DM consumption (g/kg BW) of goats from 5 to 8 months was higher than (P<0.05) from 9 to 12 months (31.7 and 27.7 g, respectively). The CP intake (g/kg BW) of goats from 5 to 8 months was higher than (P<0.05) at 9 to 12 months, corresponding to 3.65 and 3.20 g. The ADF intake (g/kg BW) was 8.39 g at 5 to 8 months and was not different at 9 to 12 months (7.21 g). The ME consumption of 5 to 8 months was similar to 9 to 12 months (0.313 and 0.285 MJ, respectively).

The energy sources were not different (P>0.05) in the experiment for nutrient intake. However, feed energy sources tended to be lower in maize than in broken rice. The supplement urea diets were not different (P>0.05) for nutrient consumption, but CP intake was higher with urea (P<0.05). The CP intake (g/kg BW) was lower (P<0.05) for diets without urea (3.03 g) compared to diets with urea (3.82 g). According to Pongsub *et al.* (2024), the supplement urea increased the amount of CP intake due to the quick breakdown of urea into rumen NH_3–N from bacterial enzymes. Accordingly, Paengkoum *et al.* (2006) reported that energy supplementation enhanced urea utilization and resulted in higher animal performance as a consequence of improved ruminant fermentation, microbial yield, and nitrogen balance.

Table 3: Intake of feeds, nutrients and energy of goats.

Iterms	Mo		Es		NPN		P						
	5-8	9-12	Ma	BrR	NU	U	Mo	Es	NPN	Mo*Es	Mo*NPN	Es*NPN	Mo*Es*NPN
Feed intake, gDM/head/day													
Maize	39.1	56.1	95.2	0.0	48.4	46.9	0.014	0.001	0.817	0.014	0.761	0.817	0.761
Broken rice	38.7	59.4	0.0	98.1	49.3	48.8	0.010	0.001	0.940	0.010	0.709	0.940	0.709
Cassava chips	77.9	114.3	93.9	98.4	97.1	95.1	0.001	0.648	0.837	0.669	0.926	0.909	0.621
Tofu waste	25.7	38.4	31.4	32.8	32.5	31.1	0.001	0.655	0.815	0.676	0.914	0.928	0.606
Operculina turpethum vines	185	284	227	242	236	232	0.001	0.541	0.871	0.679	0.850	0.983	0.617
Elephant grass	180	236	203	213	203	213	0.136	0.762	0.764	0.793	0.823	0.794	0.911
Urea	2.48	3.57	2.94	3.12	0.00	6.06	0.036	0.724	0.001	0.963	0.036	0.724	0.963
Premix	3.67	5.44	4.45	4.67	4.61	4.51	0.001	0.639	0.835	0.672	0.928	0.922	0.633
Nutrient intake, gDM/kgBW/day													
DM	31.7	27.7	28.9	30.5	29.5	29.9	0.024	0.357	0.825	0.951	0.989	0.877	0.999
OM	28.8	25.0	26.9	27.7	26.9	26.9	0.021	0.314	0.964	0.941	0.991	0.890	0.994
CP	3.65	3.20	3.34	3.51	3.03	3.82	0.028	0.365	0.001	0.965	0.768	0.838	0.995
NDF	12.9	11.0	11.7	12.1	11.8	12.0	0.041	0.645	0.803	0.686	0.782	0.835	0.899
ADF	8.39	7.21	7.54	8.06	7.82	7.78	0.054	0.377	0.943	0.604	0.683	0.760	0.896
ME, MJ/kg BW	0.313	0.285	0.286	0.312	0.295	0.303	0.150	0.172	0.649	0.957	0.915	0.777	0.867
CP/ME, g/MJ	11.7	11.2	11.7	11.3	10.3	12.7	0.132	0.193	0.001	0.843	0.62	0.608	0.738

DM: dry matter; **OM:** organic matter; **CP:** crude protein; **NDF:** neutral detergent fiber; **ADF:** acid detergent fiber; **Mo:** months; **E:** = Energy sources; **NPN:** non protein nitrogen; **BW:** body weight; **Ma:** Maize; **BrR:** Broken rice; **NU:** Non Ure; **U:** Urea; 5-8 = from 5 to 8 months, 9-12 = from 9 to 12 months.

The CP/ME ratio was higher at 5-8 months (11.7 g/MJ) than at 9-12 months (11.2 g/MJ). Similarly, Maize was 11.7 g/MJ, and broken rice was 11.3 g/MJ. However, They were not different in this study. Otherwise, Without urea was a lower CP/ME ratio than with urea (10.3 and 12.7 g/MJ, respectively). No significant interactions were observed between age, energy source, and urea supplementation (P>0.05).

The data of Table 3 determined that nutrient consumption was higher at 5-8 months than at 9-12 months, higher at broken rice than maize, and higher with urea than without urea.

Digestibility and Digestive Nutrient

The nutrient digestibility of goats tended to be high (P<0.05) in 9 to 12 months and low at 5-8 months old for DM, CP, NDF and ADF (Table 4). However, this study's OM digestibility was significantly different (P<0.05). The DM and CP digestibility of 9 to 12 months (73.4 and 75.4%) were higher than (P>0.05) in 5 to 8 months (70.7 and 71.9%). However, OM digestibility was 75.4% at 9 to 12 months and was better than in 5 to 8 months (71.9%). Both NDF and ADF digestibility was lower (P>0.05) in 5 to 8 months (61.8 and 57.5%) than in 9 to 12 months (64.4 and 61.5%). The nutrient digestibility of goats at 9-12 months old tended to be higher than 5-8 months. This may be due to the lower concentration of ruminant protozoa in younger animals compared to adults (Duarte *et al*., 2018).

The digestibility of energy sources was not significantly different in the experiment. The energy feed from broken rice was higher DM, OM, NDF and ADF digestibility (P>0.05) than maize. The result of the current experiment was similar to that reported by Dung (2014). It was explained that starch from broken rice powder had higher digestibility of DM, OM, NDF, and ADF than maize because the NDF content in broken rice powder (10.1%) was lower than in maize (23.7%) from Table 1. Meanwhile, CP digestibility was higher in maize (74.6%) than in broken rice (73.1%). Another study, Truong *et al.* (2024) reported that starch from different sources such as corn, broken rice, wheat and cassava is not affected in digestibility because its composition has almost the same structure and is formed by amylose and mylopectin. However, the energy feed combination that feed intake, nutrient value well from high to low were broken rice and wheat, broken rice and cassava chip, maize and cassava chip and maize and wheat.

Urea supplementation increased nutrient digestibility (P>0.05) in this study. However, only CP digestibility was significantly higher (P<0.05) in with urea (79.1%) and lower in without urea (68.6%). Consistent with our results, the digestion of DM, OM, CP, and non-fiber carbs rose linearly

Table 4: Digestibility and digestible nutrients of goats.

Iterms	Mo		Es		NPN		P						
	5-8	9-12	Ma	BrR	NU	U	Mo	Es	NPN	Mo*Es	Mo*NPN	Es*NPN	Mo*Es*NPN
Fecal, gDM/head/day	163	211	191	183	194	180	0.055	0.718	0.567	0.833	0.800	0.899	0.459
Fecal, gDM/kgBW/day	9.23	7.34	8.42	8.42	8.57	8.00	0.055	0.663	0.367	0.695	0.779	0.814	0.691
Apparent digestibility, %													
DM	70.7	73.4	71.0	73.1	70.9	73.2	0.106	0.198	0.174	0.731	0.623	0.656	0.601
OM	71.9	75.4	72.7	74.6	72.7	74.6	0.031	0.220	0.224	0.775	0.668	0.629	0.610
CP	72.8	74.9	74.6	73.1	68.6	79.1	0.274	0.458	0.001	0.712	0.921	0.767	0.748
NDF	61.8	64.4	62.2	64.0	61.3	64.5	0.326	0.482	0.182	0.830	0.480	0.240	0.381
ADF	57.5	61.5	57.4	61.6	58.5	60.6	0.203	0.179	0.506	0.424	0.601	0.868	0.478
Digestible nutrients, gDM/kgBW/day													
DM	22.5	20.3	20.5	22.3	20.9	21.9	0.136	0.198	0.506	0.921	0.888	0.772	0.859
OM	20.7	18.9	18.9	20.7	19.5	20.1	0.150	0.172	0.649	0.957	0.915	0.777	0.867
CP	2.69	2.41	2.51	2.59	2.08	3.02	0.118	0.650	0.001	0.960	0.632	0.985	0.882
NDF	8.01	7.12	7.31	7.83	7.28	7.85	0.233	0.480	0.440	0.765	0.685	0.540	0.622
ADF	4.93	4.47	4.37	5.02	4.59	4.81	0.385	0.224	0.674	0.558	0.640	0.824	0.594

DM: dry matter; **OM:** organic matter; **CP:** crude protein; **NDF:** neutral detergent fiber; **ADF:** acid detergent fiber; **Mo:** months; **Es:** Energy sources; **NPN:** non protein nitrogen; **BW:** body weight; **Ma:** Maize; **BrR:** Broken rice; **NU:** Non Ure; **U:** Urea; 5-8 = from 5 to 8 months, 9-12 = from 9 to 12 months.

Table 5: Nitrogen balance and body weight.

Iterms	Mo		Es		NPN		P						
	5-8	9-12	Ma	BrR	NU	U	Mo	Es	NPN	Mo*Es	Mo*NPN	Es*NPN	Mo*Es*NPN
Urin,g/head/day	1,534	2,144	1,982	1,696	1,964	1,714	0.052	0.347	0.412	0.898	0.523	83.00	0.345
Urine, g/kg BW/day	86.2	74.6	86	74.3	86.7	74.0	0.226	0.210	0.189	0.741	0.289	0.017	0.183
Nitrogen (N), g/kg BW/day													
N_{intake}	0.584	0.512	0.534	0.562	0.484	0.611	0.028	0.365	0.001	0.965	0.768	0.838	0.995
N_{fecal}	0.153	0.127	0.132	0.148	0.152	0.128	0.046	0.230	0.071	0.828	0.738	0.593	0.735
N_{urin}	0.090	0.095	0.102	0.084	0.087	0.098	0.759	0.235	0.458	0.985	0.757	0.402	0.581
$N_{retention}$	0.340	0.291	0.300	0.331	0.245	0.385	0.101	0.300	0.001	0.954	0.763	0.656	0.890
Body weight, kg/head													
Initial	16.7	27.9	22.3	22.3	22.4	22.2	0.001	0.992	0.935	0.926	0.937	0.836	0.604
Final	17.6	29.4	23.3	23.7	23.4	23.5	0.001	0.836	0.950	0.915	0.964	0.823	0.634
DWG, g/head/day	42.1	70.9	48.3	64.7	51.3	61.6	0.142	0.395	0.594	0.454	0.920	0.877	0.955

N: nitrogen; **DWG:** daily weight gain; **Mo:** months; **Es:** Energy sources; **NPN:** non protein nitrogen; **BW:** body weight; **Ma:** Maize; **BrR:** Broken rice; **NU:** Non Ure; **U:** Urea; 5-8 = from 5 to 8 months, 9-12 = from 9 to 12 months.

with the diets' increased urea levels reported by Khattab *et al.* (2013). Urea supplementation to animals stimulated nutrient digestibility and improved performance concluded to Wahyono *et al.* (2022). In another study, Ngu *et al.* (2021) reported that the sources of protein and energy affected to rumen microflora of ruminants. One crucial aspect of nutrition and metabolism is the conversion of feed protein into body protein. Given that the addition of urea increased the amount of NH_3–N, the study results of Pongsub *et al.* (2024) demonstrate that the quick breakdown of urea into ruminal NH_3–N by bacterial enzymes is acceptable. Dong and Thu (2018), claim that the body needs protein for both cell repair and synthesis processes.

In the current study, it was not found a different relationship between months old, energy source and urea.

Nitrogen Balances and Weight Gain

The experiment (Table 5) showed a significant difference (P<0.05) in the relationship between energy source and urea in urine.

The N intake was significantly different (P<0.05) with higher in 5-8 months and lower in 9-12 months (0.584 and 0.512 g/kg BW). In 9-12 months, there was a higher N in fecal, but in 5-8 months it was lower (0.153 and 0.127 g/kg BW). The N retention tended to be high in

5-8 months compared to 9-12 months (0.340 and 0.291 g/kg BW/day). The nitrogen balances from energy sources were not different ($P>0.05$) in the experiment. The nitrogen retention of broken rice was greater than that of maize (0.331 and 0.3300 g/kg BW/day, respectively). The urea supplement had a higher N intake ($P<0.05$) than non-urea corresponding to 0.661 and 0.484 g/kg BW/day. The supplement urea had more N retention than without urea (0.385 and 0.245 g/kg BW/day, respectively). Archibeque *et al.* (2007) found that individuals on a high-CP diet retained more nitrogen than those on a low-CP diet. The daily weight gain of goats (g/day) was higher at 9-12 months, broken rice and with urea (70.9, 64.7 and 61.6 g, respectively) than at 5-8 months, maize and without urea (41.1, 48.3 and 51.3 g, respectively). The production gains of ruminants were attributed to the supply of protein sources, which had a significant impact on rumen fermentation and microorganism synthesis in ruminants (Ngu *et al.*, 2019). Moreover, Paengkoum *et al.* (2006) reported that the administration of urea or other non-protein nitrogen supplements stimulated feed intake, rumen digestibility, N balance, and microbial development.

The results of this study showed that goats from 5 to 8 months had a higher nutrient intake (DM, OM, CP, NDF), OM digestibility, N intake, N fecal, and N retention ($P<0.05$) than those from 9-12 months. The feed source from broken rice tended to be better in maize for nutrient intake, nutrient digestibility, nitrogen balance and weight gain. The supplement urea tended to increase nutrient digestibility, N intake, N retention and weight gain. However, it was significant ($P<0.05$) for CP intake, N intake and N retention in the experiment. This study did not find a different relationship between months old, energy source, and urea. However, the relationship between energy feed and NPN was significant in urine (g/kg BW/day).

CONCLUSIONS AND RECOMMENDATIONS

The age of goats affected intake, digestibility, nitrogen balance and weight gain. Broken rice was a better nutrient in the diet than maize on goats. Urea was a factor that influenced nutrient intake, digestibility, nitrogen balance, and weight gain. This was the basis for formulating goat rations from local feed. Diets containing broken rice and urea, adjusted for goat age, are recommended for further studies to optimize feed utilization and growth rates, particularly in developing age-specific feed formulations.

ACKNOWLEDGEMENTS

- This research is funded by Vietnam National University HoChiMinh City (VNU-HCM) under grant number C2024-16-05.
- The Author thanks the experimental farm, An Giang University, Vietnam National University Ho Chi Minh City (VNU-HCM).

NOVELTY STATEMENTS

The age of goats affects nutrient intake per kg body weight and organic digestibility. The urine is affected by the interaction of the energy source and NPN.

AUTHOR'S CONTRIBUTIONS

Nguyen Binh Truong: Conceived, designed and performed the experiments.
Nguyen Binh Truong: Analyzed the data.
Nguyen Binh Truong and Ho Xuan Nghiep: Wrote the paper. All authors reviewed and approved the final manuscript.

Conflict of Interest

We certify that there is no conflict of interest.

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