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Boer Crossbred Goats Fed Jackfruit Leaves as a Soybean Meal Replacement: Feed Intake, Nutrient Digestibility And Nitrogen Retention

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Abstract | This study aimed to determine the effects of replacing soybean meal with jackfruit leaves on feed consumption, digestibility, and nitrogen retention in Boer crossbred goats. The experiment was carried out at the experimental farm of An Giang University, Vietnam National University Ho Chi Minh City, Vietnam, from January to May 2025. In this experiment, five Boer crossbred goats were included with anaverage initial body weight (BW) of11.4 ± 0.43 kg at age 4 months. It was studied in a Latin square experimental design (5x5) with 21 days/period. Five treatments were jackfruit leaves protein as a soybean meal protein replacement at 0, 25, 50, 75, and 100% crude protein intake (CPI) corresponding to JL0, JL25, JL50, JL75, and JL100 treatments. Tofu waste, soybean meal, *operculina turpethum* vines, elephant grass, and premix were feed basic. The result showed that the JL100 treatment was higher in DMI - dry matter intake ($p<0.05$) than JL0, JL25, and JL50, but not significantly different ($P>0.05$) with JL75 treatments (503, 352, 415, 427, and 470 g/goat/day, respectively). However, in JL0 (2.58%) treatment was less ($P<0.05$) DMI/BW ratio (%) than in JL100 treatments (3.73%), but JL75 treatment (3.34%) was not different ($P>0.05$) with JL25 (3.03%), JL50 (3.09%) and JL100 treatments. The nutrient digestibility was different ($P<0.05$) for dry matter and crude protein in the experiment. The value was highest in the JL0 treatment (65.1% and 73.0%, respectively) and lowest in the JL100 treatment (61.3% and 60.5%, respectively). However, JL50 treatment was not different for crude protein digestibility ($P>0.05$) from JL0 and JL25 treatments. Nitrogen retention was 3.48, 4.49, 4.30, 4.11, and 4.68 g/goat/day corresponding to JL0, JL25, JL50, JL75, and JL100 treatments. To conclude, a total of 50% of the jackfruit leaves offer suitable balance for goats as a soybean meal replacement.

Keywords | Agricultural by-products, Rumen escape protein, Feeds, Small ruminants, digestibility, Replacement

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INTRODUCTION

Goat production is developing in the Mekong Delta, Vietnam. Crossbred goats are better than local goats; the famous goat is the Boer (Nguyen *et al.*, 2023). However, not only the good crossbreed goats, but also the importance of forage quality for farmers with the increased agricultural by-products to improve income and protect the environment from global warming.

A previous study showed that Jackfruit leaves, *Operculina turpethum* vines, and *Wedelia trilobata* L. gave better feed

intake, nutrient digestibility, nitrogen retention, and weight gain than the cabbage waste. The protein solubility of Jackfruit leaves was lower than that of *Operculina turpethum* vines and *Wedelia trilobata* L. and cabbage waste (2.84, 3.59, 5.07, and 6.06%, respectively), as concluded by Truong and Trung (2023). According to Preston and Leng (2021), rumen escape protein is a protein source of low solubility, facilitating the partial escape of the protein from the rumen fermentation. Moreover, Thu *et al.* (2025) suggested that low protein solubility makes a valuable forage option for ruminants, as it can enhance nitrogen utilization efficiency and potentially reduce methane emissions. In another study, soybean meal was determined to be the source of rumen scape protein with a low protein solubility of about 2.22% (Truong and Preston, 2021; Truong and Tuan, 2024). Our previous study suggested that rumen escape protein of forage is essential, and agricultural by-products with low soluble protein content in livestock rations are crucial. The protein solubility of Jackfruit leaves is almost equal to that of soybean meal (2.84 and 2.22%, respectively). Therefore, the experimental hypothesis is that jackfruit leaves protein can replace soybean meal protein on nutrient digestibility and nitrogen retention of Boer crossbred goats.

MATERIALS AND METHODS

Location and time

The experiment was conducted at the experimental farm in An Giang University, An Giang Province, Vietnam. The feeds, refusals, feces and urine were analyzed at laboratory E205 of the Faculty of Animal Sciences, Can Tho University.

Experimental design

Five crossbred Boer goats, with an average initial body weight used in this experiment was 11.4±0.43 kg at about 4 months old. The Latin Square design was used in the experimental goats with five treatments and 5 periods. Five treatments were replacing soybean meal protein with jackfruit leaves at 0% (JL0), 25% (JL25), 50% (JL50), 75% (JL75), and 100% (JL100) (Table 1).

Table 1: Ingredients used in this study

Ingredients (%CP)	JL0	JL25	JL50	JL75	JL100
Tofu waste	17.0	17.0	17.0	17.0	17.0
Soybean meal	39.4	29.5	19.7	9.84	0
Jackfruit leaves	0.00	9.84	19.7	29.5	39.4
Operculina turpethum vines	27.2	27.2	27.2	27.2	27.2
Elephant grass	16.4	16.4	16.4	16.4	16.4
Premix	0	0	0	0	0
Total	100	100	100	100	100

Measurements taken

Feeding procedure

All the feed was supplied separately and weighed before feeding to the experimental goats. In detail, the Jackfruit leaves and soybean meal were fed at a crude protein consumption depending on the treatments. However, the amount of protein was calculated on a dry matter basis and converted to the fresh state of the food. The tofu waste was mixed with the premix before feeding. Elephant grass was fed *ad libitum*, and drinking water was always available. Refused feeds were weighed each morning.

Feeds, nutrient and energy intakes

The nutrient composition of feeds, refuses, feces, and urine was examined in this study. Dry matter (DM) and organic matter (OM) were analyzed using the AOAC (1990) method. The nitrogen (N) in feed, refusals, feces, and urine was specified using the Kjeldahl procedures of AOAC (1990) . However, acid detergent fiber (ADF) and neutral detergent fiber (NDF) were analyzed using the method of Van Soest *et al.* (1991).

Apparent nutrient digestibility

The nutrient digestibility method was practiced in three weeks for each experimental period by McDonald *et al.* (2010), such as the first week for adaptation, the second for diet stabilization, and the third for feces and urine collection.

Metabolizable energy (ME)

The metabolisable energy (ME) in goat diets was calculated according to the suggestion of Bruinenberg *et al.* (2002).

$$ME\ (MJ/head/day) = 14.2 \times DOM + 5.9 \times DCP\ (with\ DOM/DCP < 7)$$
$$ME\ (MJ/head/day) = 15.1 \times DOM\ (with\ DOM/DCP > 7)$$

In this instance, DOM was the digestible organic matter, while DCP was the digestible crude protein.

Nitrogene balance (N)

Daily N retention was calculated using formula:

$$N\ retention = N\ intake - (N\ feces + N\ urine)$$

Daily weight gains (DWG)

At the beginning and end of each experimental period, the goats were weighed on two consecutive days.

$$Daily\ weight\ gain\ (g/goats/day) = (body\ weight\ of\ period\ final - body\ weight\ period\ initial)/21\ day$$

Statistical analysis

ANOVA Linear Model (GLM) of Minitab Reference Manual Release 20 was analyzed using the data (Minitab,

2021). Tukey's pairwise comparisons (P≤0.05) were applied to determine differences between treatments. Data were analyzed using the model $Y_{ijk} = \mu + T_i + G_j + P_k + e_{ijk}$; where Y_{ijk}: = the dependent variable, μ: the overall mean, T_i = the effect of jackfruit leaves as a soybean meal replacement ratio (i = 1 to 5), G_j: the effect of goats (j = 1 to 5), P_k = the effect of period (j = 1 to 5), e_{ijk} = the random error.

RESULTS AND DISCUSSION

Chemical composition of feeds using in this study

The nutrients of feed in Table 2 showed that soybean meal (Figure 1) has the highest CP than tofu waste, jackfruit leaves (Figure 2), *Operculina turpethum* vines (Figure 3), and elephant grass (44.8, 17.5, 14.9, 13.6, and 6.67%, respectively). However, the NDF was lowest in soybean meal compared to tofu waste, *Operculina turpethum* vines, jackfruit leaves, and elephant grass, corresponding to 8.09, 34.7, 36.3, 36.8, and 69.4%. The result analysis of the feed in this experiment was similar to that of another study. The CP of jackfruit leaves was 12.9% as reported by Thanh *et al.* (2021). However, the CP of jackfruit leaves in the study of Keir et at (1997) was 15.0% and Dahlanuddin (2001) was 14.6%. The CP of soybean meal was 46.4%, as Hang *et al.* (2023) reported. A previous Truong and Preston (2021) study concluded that the CP of soybean meal was 41.5%. The nutrients of feed change by time of year, harvest, and soil structure. The nutrient content of elephant grass in this study was similar to the results of Rusdy (2016), who reported that the CP and NDF of elephant grass were about 7.20-18.1% and 57.4-75.4%, respectively.

Table 2: Chemical composition of feeds (% DM basis) used in the experiment.

Feeds	DM, %	In DM, %		
		OM, %	CP, %	NDF, %
Tofu waste	15.7	97.0	17.5	34.7
Soybean meal	87.6	93.5	44.8	8.09
Jackfruit leaves	35.6	87.3	14.9	36.8
Operculina turpethum vines	15.1	88.9	13.6	36.3
Elephant grass	15.6	92.4	6.67	69.4

DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber.

Feed and nutrient intake of experimental goats

The DM intake was significantly different (P<0.05) in this study. It was 352, 415, 427, 470, and 503 g/head/day corresponding to JL0, JL25, JL50, JL75, and JL100 treatments (Table 3). In detail, the proportion of DM per BW (Figure 4) of JL100 treatment (3.73%) was not different (P>0.05) from JL75 treatment (3.34%), but it was higher than JL50, JL25, and JL0 treatments (3.09, 3.03, and 2.58%, respectively). The result in this study was similar to information from Thanh *et al.* (2021), who reported that DM intake as Jackfruit leaves replacing para grass on a DM basis (equivalent to: 0, 36.9, 52.7, and 70% of diet DM) was 2.83-4.45%. Another study of Truong and Trung (2023) for Jackfruit leaves on goat concluded that Jackfruit leaves was good feed for goats by extracting nitrogen in urine lower than feces.

Figure 1: Soybean meal.

Figure 2: Jackfruit leaves.

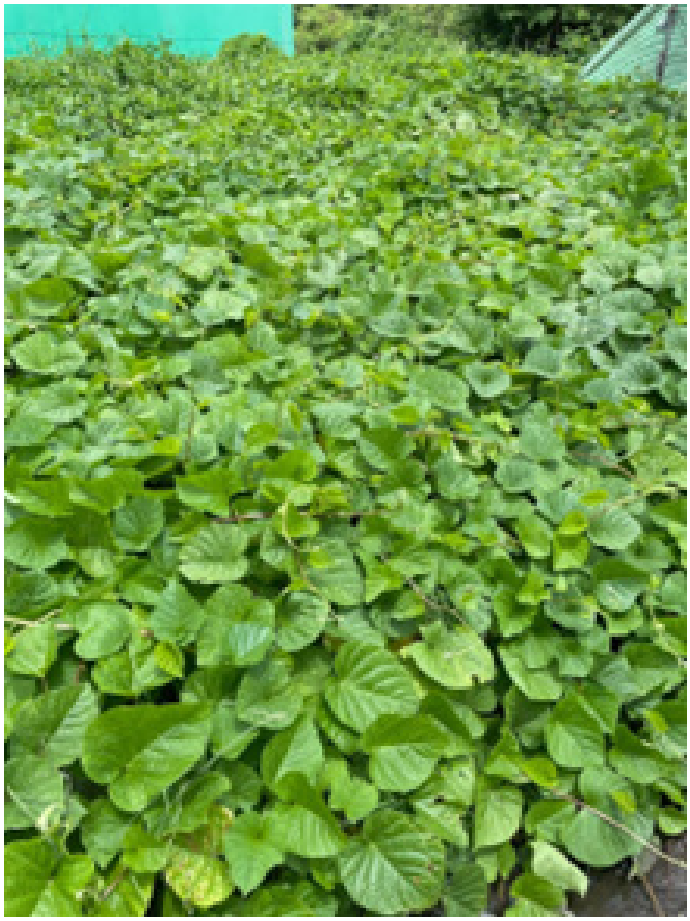

Figure 3: *Operculina turpethum* vines.

Table 3: Feed and nutrient intake of experimental goats

Items	JL0	JL25	JL50	JL75	JL100	SEM	P
Feed intake, g DM/head/day							
Tofu waste	59.1	59.8	65.7	67.3	64.4	6.470	0.860
Soybean meal	53.0^{a}	47.6^{a}	34.3^{b}	17.6^{c}	0.00^{d}	1.570	0.001
Jackfruit leaves	0.00^{e}	47.4^{d}	97.5^{c}	146^{b}	208^{a}	9.550	0.001
Operculina turpethum vines	105	124	140	128	135	11.60	0.308
Elephant grass	133^{a}	135^{a}	87.2^{b}	109^{ab}	92.7^{b}	8.320	0.004
Premix	1.70^{c}	2.04^{b}	2.20^{b}	2.26^{ab}	2.54^{a}	0.062	0.001
Nutrients intake, g DM/head/day							
DM	352^{c}	415^{bc}	427^{bc}	470^{ab}	503^{a}	16.70	0.001
DM/BW, %	2.58^{c}	3.03^{bc}	3.09^{b}	3.34^{ab}	3.73^{a}	0.102	0.001
OM	324^{c}	380^{bc}	387^{abc}	425^{ab}	453^{a}	14.80	0.001
CP	59.7^{b}	67.2^{ab}	70.0^{a}	69.9^{a}	72.1^{a}	2.240	0.017
NDF	148^{c}	173^{abc}	161^{bc}	191^{ab}	199^{a}	7.530	0.003
ME*, MJ/head/day	3.34^{b}	3.94^{ab}	3.73^{ab}	3.83^{ab}	4.36^{a}	0.163	0.013

JL0, JL25, JL50, JL75 and JL100 treatment contained jackfruit leaves protein replacement soybean meal protein at 0, 25, 50, 75 and 100% based on crude protein. DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, BW: body weight. *Bruinenberg *et al* (2002). ^{a,b,c} Means within a row with different letters differ significantly (p<0.05).

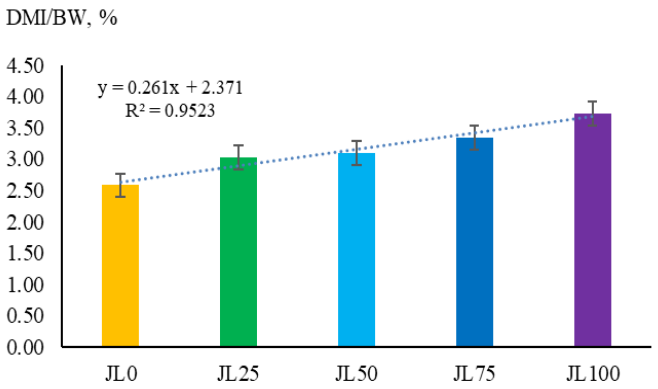

Figure 4: Effect of soybean meal protein replaced by jackfruit leaves protein on DM intake per body weight.

Crude protein consumption

The CP consumption (%) was increased (P<0.05) in the experiment (Table 4). It was 59.7, 67.2, 70.0, 69.9, and 72.1 g/head/day corresponding to JL0, JL25, JL50, JL75, and JL100 treatments. In this study, Boer crossbred goats fed jackfruit leaves as a soybean meal replacement, the total DM of the feed intake was increased (P<0.05). The protein value of jackfruit leaves is lower than that of soybean meal. A result as CP/DM (%) decrease from JL0 treatment to JL25, JL50, JL75, and JL100 treatments (16.9, 16.4, 16.5, 14.8, and 14.3%, respectively). However, the CP/DM of JL50 treatment (16.5%) was not different (P>0.06) from JL25 (16.4%) and JL0 treatments (16.9%), but it was higher than (P<0.05) JL75 (14.8%) and JL100 treatments (14.3%). The CP/DM in this study was higher than that of Chanjula *et al.* (2022) was 11.0-11.6%, and Gunun *et al.* (2023) was 13.7%.

Table 4: Crude protein consumption of experimental goats.

Item	JL0	JL25	JL50	JL75	JL100	SEM	P
CP intake, g/head/day							
Tofu waste	10.3	10.5	11.5	11.8	11.3	1.130	0.860
Soybean meal	23.7^{a}	21.3^{a}	15.3^{b}	7.88^{c}	0.00^{d}	0.705	0.001
Jackfruit leaves	0.00^{e}	7.05^{d}	14.5^{c}	22.0^{b}	31.5^{a}	1.370	0.001
Operculina turpethum vines	14.7	17.4	19.5	18.2	19.8	1.400	0.141
Elephant grass	11.0	11.0	9.13	10.0	9.55	0.596	0.156
Total	59.7^{b}	67.2^{ab}	70.0^{a}	69.9^{a}	72.1^{a}	2.240	0.017
CP/DM, %	16.9^{a}	16.4^{a}	16.5^{a}	14.8^{b}	14.3^{b}	0.240	0.001

JL0, JL25, JL50, JL75 and JL100 treatment contained jackfruit leaves protein replacement soybean meal protein at 0, 25, 50, 75 and 100% based on crude protein. DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, BW: body weight. ^{a,b,c} Means within a row with different letters differ significantly (p<0.05).

Apparent digestibility

Both DM and CP digestibility were significantly different

(P<0.05) in the experiment (Table 5). The DM digestibility was 65.1, 66.4, 61.5, 58.5 and 61.3% corresponding to JL0, JL25, JL50, JL75, and JL100 treatments. The CP digestibility of JL0 did not differ (P>0.05) from JL25 and JL50 treatments (73.0, 72.8, 64.4%, respectively), but it was higher than JL75 and JL100 treatments (57.0 and 60.5%, respectively). The trend of DM and CP digestibility was similar to the result of Thanh *et al.* (2021). The CP digestibility showed a reduced non-linear trend as increased JL in the diets ($y = 0.001x^2 - 0.2592x + 74.9$; $R^2 = 0.8246$; Figure 5). This study's CP digestibility was higher than that of Truong and Trung (2023), who reported that the CP digestibility of fed jackfruit leaves was 54.2%.

Table 5: Nutrient digestibility, and digestible nutrients of experimental goats.

Item	JL0	JL25	JL50	JL75	JL100	SEM	P
Feces, gDM// head/day	122^{c}	141^{bc}	167^{ab}	201^{a}	194^{a}	9,710	0,001
Nutrient digestibility, %							
DM	65.1^{ab}	66.4^{a}	61.5^{ab}	58.5^{b}	61.3^{ab}	1.610	0.030
OM	66.6	68.1	63.8	60.9	63.7	1.600	0.056
CP	73.0^{a}	72.8^{a}	64.4^{ab}	57.0^{b}	60.5^{b}	2.320	0.001
NDF	54.2	53.9	44.4	46.4	49.4	4.270	0.416
Digestible nutrient, g/head/day							
DM	230^{b}	274^{ab}	259^{ab}	269^{ab}	309^{a}	12.20	0.010
OM	217^{b}	257^{ab}	244^{ab}	253^{ab}	289^{a}	11.10	0.010
CP	44.4^{ab}	48.8^{a}	44.8^{ab}	39.4^{b}	44.2^{ab}	1.510	0.014
NDF	82.7	95.4	75.6	87.6	99.4	8.850	0.373

JL0, JL25, JL50, JL75 and JL100 treatment contained jackfruit leaves protein replacement soybean meal protein at 0, 25, 50, 75 and 100% based on crude protein. DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, BW: body weight. ^{a,b} Means within a row with different letters differ significantly (p<0.05).

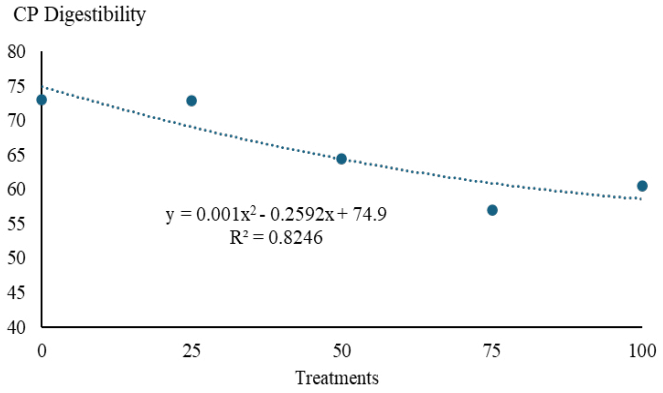

Figure 5: Crude protein digestibility is decreased with a curvilinear trend as the feeding level of JL was increased.

Nitrogen balances

Nitrogen retention (Table 6) showed the greater values (P>0.05) in goats fed jackfruit leaf diets (4.11-4.68 g/head/day) compared with goats fed only soybean meal (3.48 g/head/day). In this study, we could also detect a greater N in feces (P<0.05) of goats fed jackfruit leaves diets, and N in urine decreased (P>0.05) of goats fed jackfruit leaf diets compared with goats fed only soybean meal (Figure 6). The result of jackfruit leaves in this study was similar to that reported by Thanh *et al.* (2021). This characteristic makes it a valuable forage option for ruminants, as it can enhance nitrogen utilization efficiency, as Thu *et al.* (2025) concluded.

Table 6: Nitrogen retention and weight gain of goats in different treatments

Item	JL0	JL25	JL50	JL75	JL100	SEM	P
Urine, g/head/day	964	952	898	849	884	100,0	0,917
Nitrogen balance, g/head/day							
N intake	9.56^{b}	10.8^{ab}	11.2^{a}	11.2^{a}	11.5^{a}	0.358	0.017
N in feces	2.45^{c}	2.94^{bc}	4.02^{ab}	4.88^{a}	4.47^{ab}	0.339	0.001
N in urine	3.63	3.32	2.87	2.19	2.40	0.454	0.198
N retention, g/head/day	3.48	4.49	4.30	4.11	4.68	0.553	0.612
N retention g/$W^{0.75}$/day	0.483	0.638	0.603	0.565	0.654	0.073	0.508
Body weight, kg							
Initial	13.2	13.1	12.8	13.1	12.9	0.365	0.950
Final	13.9	13.8	14.2	14.6	14.2	0.338	0.544
Average daily gain, g/head/day	34.2	36.1	66.2	73.1	61.4	13.70	0.213

JL0, JL25, JL50, JL75 and JL100 treatment contained jackfruit leaves protein replacement soybean meal protein at 0, 25, 50, 75 and 100% based on crude protein. DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, BW: body weight. ^{a,b} Means within a row with different letters differ significantly (p<0.05).

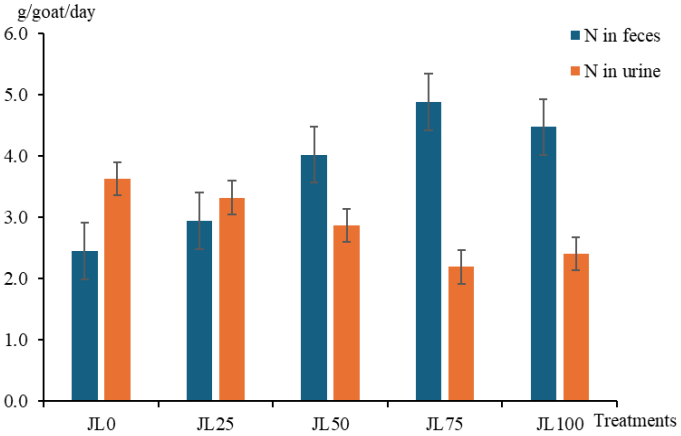

Figure 6: The changes of N in feces and urine from five treatments.

The study's results on the protein substitution of jackfruit leaves for soybean extract showed increased dry matter

intake and protein intake. However, soybean extract's protein value is higher than that of jackfruit leaves, so a large amount of jackfruit leaf dry matter is needed to meet the protein balance between soybean extract and jackfruit leaves. As a result, the CP/DM ratio (%) decreased, and DMD and CPD decreased significantly. However, converting N excretion (decrease in urine and increase in feces) when replacing jackfruit leaves with soybean extract is a positive transformation from inorganic nitrogen to organic nitrogen that helps protect the environment. According to Quang (2023), urinary nitrogen is mainly in urea, which is more rapidly hydrolyzed to ammonia and nitrified to nitrate, whereas fecal nitrogen is primarily in the organic form, which is less volatile. Therefore, decreased nitrogen excretion via urine could reduce ammonia and nitrous oxide emissions into the atmosphere. Because the conversion of ammonia in urine produces N_2O, which is a gas that is toxic to the environment. Therefore, high N content in feces compared to urine is a method to help protect the environment. Increasing protein replacement from soybean meal to jackfruit leaves in the diet of Boer crossbred goats increased DMI, nitrogen retention but decreased digestibility of CP.

CONCLUSION

It was concluded that increasing substitution of jackfruit leaves for soybean meal at 50% in the diet CP of goats effectively reduces urinary N excretion while allowing improvement in DM intake. A level of 50% jackfruit leaves protein as a soybean meal protein replacement in the diet would be recommended to implement performance studies in the goat for better local by-product source utilization for farmers.

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NOVELTY STATEMENT

Effect of Jackfruit leaves on feed consumption, digestibility, and nitrogen retention of Boer crossbred goats studied in present work for new practical findings.

AUTHOR'S CONTRIBUTION

NBTand VNHconceived and designed the field trial. NBT, NTHC, HXN and VNHwrote the paper.

Generative AI and AI-assisted technology statement

This article used Grammarly for Windows software.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

AOAC- Association of Official Analytical Chemists (1990). Official methods of analysis (15th edition). Washington, DC, 1: 69-90.

Bruinenberg MH, Valk H, Korevaar H, Struik PC (2002). Factors affecting digestibility of temperate forages from semi-natural grasslands. Grass Forage Sci., 57(3): 292-301. https://doi.org/10.1046/j.1365-2494.2002.00327.x

Chanjula P, So S, Suntara C, Prachumchai R, Cherdthong A (2022). Efficiency of feed utilization, ruminal traits, and blood parameters of goats given a total mixed diet ration containing extracted oil palm meal. Vet. Sci., 9(11): 612. https://doi.org/10.3390/vetsci9110612

Dahlanuddin (2001). Forages commonly available to goats under farm conditions on Lombok Island, Indonesia. Livest. Res. Rural Dev., 13: 10. http://www.lrrd.org/lrrd13/1/dahl131.htm

Gunun P, Cherdthong A, Khejornsart P, Wanapat M, Polyorach S, Kaewwongsa W, Gunun N (2023). Replacing concentrate with yeast-or EM-Fermented cassava peel (YFCP or EMFCP): Effects on the feed intake, feed digestibility, rumen fermentation, and growth performance of goats. Animals, 13(4): 551. https://doi.org/10.3390/ani13040551

Hang BPT, Cuong NV, Lam V (2023). Effect of replacing soybean meal with ground cassava (*Manihot esculenta* Crantz) foliage in the diet of growing rabbits on feed intake and weight gain. Livest. Res. Rural Dev., 35: 36. http://www.lrrd.org/lrrd35/4/3536bpth.html

Keir B, Lai NV, Preston TR, Orskov ER (1997). Nutritive value of leaves from tropical trees and shrubs: 1. *In vitro* gas production and in sacco rumen degradability. Livest. Res. Rural Dev., 9: 34. http://www.lrrd.org/lrrd9/4/bren941.htm

McDonald P, Edwards RA, Greenhagh JFD, Morgan CA (2010). Animal nutrition (7th edition), Longman Scientific and Technical, N. Y. USA.

Minitab (2021). Minitab reference manual. Release 20.3 for Windows, Minitab Inc, USA.

Nguyen VD, Nguyen CO, Chau TML, Nguyen DQD, Han AT, Le TTH (2023). Goat production, supply chains, challenges, and opportunities for development in Vietnam: A review. Animals, 13(15): 2546. https://doi.org/10.3390/ani13152546

Preston TR, Leng RA (2021). Rumen escape protein. Livest. Res. Rural Dev., 33: 108. http://www.lrrd.org/lrrd33/9/33108prest.htm

Quang NV (2023). Use of natural plant-derived substances to reduce nitrogen excretion and N_2O emissions from ruminants. J. Anim. Sci. Tech., 149: 2-23.

Rusdy M (2016). Elephant grass as forage for ruminant animals. Livest. Res. Rural Dev., 28: 49. http://www.lrrd.org/lrrd28/4/rusd28049.html

Thanh LP, Kha PTT, Tinh PVT, Hang TTT (2021). Effect of

jackfruit leaves on feed utilization and ruminal fermentation of growing goats. Livest. Res. Rural Dev., 33: 104. http://www.lrrd.org/lrrd33/8/33104phuoc.html

Thu NV, Dong NTK, Preston TR (2025). Assessment of crude protein solubility in *Psophocarpus scandens* compared to *Ipomoea aquatica* and *Sesbania grandiflora* as potential protein sources for livestock. Livest. Res. Rural Dev., 37: 27. http://www.lrrd.org/lrrd37/2/3727nvth.html

Truong NB, Preston TR (2021). Soybean meal as source of rumen scape protein for fattening crossbred beef cattle. Livest. Res. Rural Dev., 33: 126. http://www.lrrd.org/lrrd33/10/33126nbtru.html

Truong NB, Trung TT (2023). Effects of forage quality on feed intake, nutrient digestibility and nitrogen retention of post-weaning Saanen crossbred goats. Livest. Res. Rural Dev., 35: 111. http://www.lrrd.org/lrrd35/12/35111nbtr.html, https://doi.org/10.17582/journal.aavs/2024/12.1.148.153

Truong NB, Tuan TT (2024). Effect of sweet potato tuber by-product provision on feed intake, nutrient digestibility and nitrogen retention of Boer crossbred goats. Livest. Res. Rural Dev., 36: 44. http://www.lrrd.org/lrrd36/4/3644nbtr.html

Van Soest PJ, Robertson JB, Lewis BA (1991). Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3598. https://doi.org/10.3168/jds.S0022-0302(91)78551-2