2025 SCIENCELINE

Online Journal of Animal and Feed Research

Volume 15, Issue 5: 257-263; September 30, 2025

ISSN 2228-7701

DOI: https://dx.doi.org/10.51227/ojafr.2025.29

DIETARY LEUCAENA LEAVES IMPROVE GROWTH PERFORMANCE AND CARCASS QUALITY OF VIETNAMESE GOATS

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RESEARCH ARTICLE

PII: S2228770125000029-15

Received: June 26, 2025

Revised: September 12, 2025

Accepted: September 14, 2025

ABSTRACT: The experiment was conducted at a research farm for sixteen male goats, with an average body weight of 12.32 ± 0.14 kg. They were randomly allocated into 4 groups corresponding to 4 diets and fed individually. The diets were formulated to consist of 90% of Guinea grass (*Panicum maximum*) and 10% of concentrated feed as basal (in DM). Leucaena leaves were substituted at 0%, 10%, 20% and 30% of Guinea grass in four respective diets. A 2-week adaptation period was provided for the goats to the diets and feeding system before data collection. Feed intake, weight gain, feed conversion ratio, and carcass traits of goats differed significantly among the four diets ($P < 0.05$). The inclusion of leucaena leaves in the diets increased feed intake. As the levels of leucaena leaves in diets increased up to 30%, there were corresponding improvements in weight gain. Daily weight gain increased from 45 to 61 g/day and feed conversion ratio (FCR) decreased from 8.43 to 6.62 kg feed/kg gain. Higher leucaena inclusion improved carcass traits but did not affect loin meat quality. Economic analysis also indicated that including up to 30% leucaena leaves in the goats' diet provides a profitable outcome for farmers. The economic impact increased with the rising levels of leucaena leaves in the goats' diet. It is recommended that leucaena leaves be utilized for goat raising in smallholder farming systems in Vietnam.

Keywords: Carcass, Feed conversion ratio, Goats, Growth, Leucaena.

INTRODUCTION

Goat production is an important contributor to global meat and dairy supply, particularly in developing countries where smallholders dominate (Hegde, 2020). Goats are valued for their low investment requirements, adaptability to harsh climates, and growing consumer demand for meat. However, productivity remains limited by feed shortages, protein deficiencies, and the decline of natural grazing lands (Mazinani and Rude, 2020; Lohani and Bhandari, 2021; Nguyen et al., 2023). In Vietnam, the goat population has more than doubled in the past decade, with over 417,000 households engaged in small-scale farming, yet feed scarcity continues to restrict production efficiency (Nguyen et al., 2023).

Leucaena (*Leucaena leucocephala*) is a perennial legume that offers a promising solution to these constraints. Rich in crude protein (20–30% DM), it produces over 6 tons DM/ha annually, adapts well to tropical environments, and can be harvested year-round with minimal inputs (Casanova-Lugo et al., 2014). Studies have demonstrated that leucaena improves feed intake, growth, and carcass yield in ruminants (Muinga et al., 1995; Wiyabot, 2022; Marhaeniyanto et al., 2023). Although it contains anti-nutritional compounds such as mimosine, these can be managed when inclusion rates are controlled (De Angelis et al., 2021).

This study aims to investigate the effects of different levels of leucaena leaves in grass-based diets on growth performance, meat quality and economic analysis of goat production in small-scale farming in Vietnam. Co goat production is primarily managed by smallholders, who feed their goats mainly by natural grasses, with leguminous forages rarely included in their diets (Nguyen et al., 2023; Olmo et al., 2024). Therefore, the objective of our experiment is to identify the optimal inclusion rates of leucaena in goat feeds that do not adversely affect animal growth.

MATERIALS AND METHODS

Animals

The experiment was conducted on 16 male goats of the local breed Co goat, at the age of 9 months, with an initial average weight of 12.32 ± 0.14 kg per goat. The goats were vaccinated against pasteurella, cholera, and foot-and-mouth disease. They were uniformly dewormed.

Citation: Liem TN, Dung NM, Duc LM, Hai DT, Tam VTM, An LV, Anh LTQ, Chotchutima S, and Boonsaen P (2025). Dietary leucaena leaves improve growth performance and carcass quality of Vietnamese goats. *Online J. Anim. Feed Res.*, 15(5): 257-263. DOI: https://dx.doi.org/10.51227/ojafr.2025.29

Diets and feeding

Guinea grass (*Panicum maximum* cv. Mombasa) and leucaena (*Leucaena leucocephala* cv. Taramba) were grown at the Institute for Development Studies, University of Agriculture and Forestry, Hue University. Guinea grass was harvested at a cutting interval of 45 days, and leucaena leaves were harvested at a cutting interval of 4 months. Only edible parts of guinea grass and leucaena leaves were collected daily, chopped, and thoroughly mixed before being fed to the goats as fresh matter. The concentrated feed was BEEF622 from the feed market. The chemical composition of the ingredients is presented in Table 1. Goats were randomly divided into 4 groups and fed according to 4 experimental diets with the levels of leucaena at 0%, 10%, 20%, and 30% on a dry matter basis (Table 2), including: Diet 1 (KP1) consists of 90% Guinea grass and 10% concentrated feed; Diet 2 (KP2) consists of 80% Guinea grass, 10% concentrated feed and 10% leucaena; Diet 3 (KP3) consists of 70% Guinea grass, 10% concentrated feed and 20% leucaena; Diet 4 (KP4) consists of 60% Guinea grass, 10% concentrated feed and 30% leucaena.

Goats were kept individually in separate pen cages, equipped with a water supply and free access to mineral blocks. They were fed twice daily at 9:00 a.m. and 3:00 p.m. The feeding process began with concentrates, which were given separately, followed by mixed green feed. The amount of feed in DM provided to goats per day was calculated at 4% of their body weight. At the end of each day, any leftover feed was collected, dried, and weighed. Every month, the amount of feed supply was adjusted according to each goat's body weight to ensure that the feed supply met their nutritional requirements. An adaptation period of 2 weeks before the feeding experiment, which followed, lasted for 4 months, from August to December 2024.

Table 1 - Chemical composition of the ingredients

Ingredients	DM (%)	Chemical composition (% in DM basic)			
		CP	NDF	ADF	Ash
Guinea grass	24.3	8.6	73.0	40.6	8.0
Leucaena leaves	33.2	25.4	33.0	19.2	7.0
Concentrated feed	86.4	19.0	37.6	20.2	10.0

DM is the abbreviation of dry matter, CP is the abbreviation for crude protein, NDF is the abbreviation of neutral detergent fibre, and ADF is the abbreviation of acid detergent fibre.

Table 2 - Ingredient and chemical composition of diets

Ingredient composition (kg/100 kg DM) \ Experimental diets	KP1	KP2	KP3	KP4
Concentrated feed	10	10	10	10
Guinea grasses	90	80	70	60
Leucaena leaves	0	10	20	30
Total in ration	100	100	100	100
Chemical composition (g/kg DM)*				
OM	931	930	929	929
CP	96	113	130	146
EE	19	22	26	29
NDF	694	654	614	574
ADF	386	364	342	321
ME (MJ/kg DM)	9.34	9.61	9.88	10.15

*Values calculated based on the composition of ingredients. OM is the abbreviation of organic matter, EE is the abbreviation of ether extract, ME is the abbreviation of metabolisable energy. Diet 1 (KP1) consists of 90% Guinea grass and 10% concentrated feed; Diet 2 (KP2) consists of 80% Guinea grass, 10% concentrated feed and 10% leucaena; Diet 3 (KP3) consists of 70% Guinea grass, 10% concentrated feed and 20% leucaena; Diet 4 (KP4) consists of 60% Guinea grass, 10% concentrated feed and 30% leucaena.

Experiment design

The experiment was conducted at the research farm of the Institute for Development Studies of the University of Agriculture and Forestry, Hue University, Vietnam, from August 2024 to January 2025. Sixteen (16) goats were randomly divided into 4 groups corresponding to 4 diets (Completely Randomized Design), raised and fed individually in 16 pens. Each pen measured 1.0 m in height, 1.5 m in length, and 0.8 m in width, and was located 0.8 m above the ground. The pens were identical in size and environmental conditions. Each pen had a separate feeder and tap water. All pens were set in an animal facility that maintained uniform environmental conditions.

Data collection

Feed intake was recorded daily for each goat. The body live weight of each goat was measured at 8:00 a.m. before feeding on days 0, 30, 60, 90, and 120 of the experiment. The prices of forages were calculated based on the actual price

of 700 VND/kg of Guinea grass and 1,000 VND/kg of leucaena leaves on the fresh material (Conversion rate: 1 USD ≈ 25,000 VND in December 2024). The price of concentrated feed was determined based on the market price. After 4 months, at the end of the experiment, 12 goats were slaughtered to measure the characteristics of the carcass and the chemical composition of the loin. The measurement of carcass traits in goats was conducted following the Vietnam National Standard on Animal Welfare – Slaughter (TCVN 13905-1:2023). Before slaughter, the goats were fasted for 18 hours, provided free access to water, and measures were taken to minimize stress. The pre-slaughter weight was recorded using the Nhon Hoa Scale 30 kg (model CDH-30) with an error margin of ± 50 g to ± 150 g. The goats were electronically stunned before having their jugular vein and carotid artery cut. Blood was drained into a pre-weighed bucket and weighed. Hair was removed and weighed. The internal organs (digestive tract, lungs, trachea, heart, liver, kidneys, kidney fat, spleen and pancreas) were removed and weighed by Nhon Hoa Scale 10 kg (model PDM 036-2017) with an error margin of ± 5 g to ± 15 g. The empty body weight (excluding blood, hair, and internal organs) was measured. After the skin was removed, the head was separated at the atlas vertebra, and the legs were separated at the carpal and tarsal joints, then weighed. The hot carcass weight was measured without blood, hair, internal organs, head, legs and skin. Finally, loin meat samples were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), and total ash content.

Chemical analysis

Chemical analysis of the samples was conducted to measure dry matter (DM), crude protein (CP), ether extract (EE), and total ash according to AOAC (1990). Additionally, neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analyzed using the method described by Van Soest et al. (1991).

Data analysis

Collected data were statistically analyzed using ANOVA with Minitab version 16.2.0 (2010). Comparison of significant differences in mean values was assessed at the probability level of $P<0.05$. The statistical model used is as follows:

$Y_{ij} = \mu + T_i + e_{ij}$

where: μ represents the overall mean value; T_i denotes the effect of the diet; and e_{ij} is the error term.

RESULTS AND DISCUSSION

Feed intake

The daily feed intake of goats in each month and the average of 4 months differed between the diets ($P<0.05$; Table 3). The lowest feed intake was recorded at 385 g/day for the KP1 without leucaena, while the highest was 427 g/day for the KP2 containing 10% of leucaena in the diet (on a DM basis). The trend of feed intake decreased when leucaena leaf increased to 20 and 30%, although it remained higher than the intake for KP1 without leucaena. Previous studies have shown that substituting leucaena in diets based on grass or maize can lead to increased feed intake (Balogun and Otchere, 1995; Haque et al., 1997; Fasae et al., 2011). Wiyabot (2022) found no significant difference in feed intake when goats were fed diets with leucaena levels at 25%, 50%, 75%, and 100%. However, a diet with 40% leucaena leaves resulted in slight hair loss (Balogun and Otchere, 1995). The leucaena contents of toxicity may contribute to reduced feed intake and productivity (Phaikaew et al., 2012). In our experiment, increasing the level of leucaena leaves in the diets led to higher feed intake compared to goats fed only on guinea grass. A grass-leucaena mix increased feed intake, but excessive leucaena may reduce it (Table 3).

Table 3 - Daily feed intake (g DM/head/day) by month of experiment

Daily feed intake by month	Experiment diet (Mean ± Standard Deviation)				SEM	P value
	KP1	KP2	KP3	KP4		
First month	325 ± 22.8^{b}	402 ± 33.1^{a}	366 ± 23.5^{ab}	356 ± 20.9^{ab}	12.8	0.009
Second month	362 ± 17.4	393 ± 30.0	379 ± 5.1	373 ± 11.8	9.25	0.191
Third month	384 ± 24.8	418 ± 22.0	417 ± 3.1	414 ± 10.5	8.73	0.054
Fourth month	433 ± 12.1	453 ± 20.8	460 ± 6.1	458 ± 14.6	7.20	0.080
Average	385 ± 18.4^{b}	427 ± 23.4^{a}	415 ± 7.4^{ab}	410 ± 13.9^{ab}	8.42	0.028
Daily feed intake of ingredients						
Concentrated feed	85.28 ± 3.22	89.47 ± 5.94	91.28 ± 1.58	88.36 ± 5.84	2.27	0.341
Guinea grass	297 ± 18.16^{a}	283 ± 18.58^{a}	239 ± 5.88^{b}	198 ± 8.70^{c}	7.01	0.001
Leucaena leaves	0^{d}	42.8 ± 2.82^{c}	81.4 ± 2.00^{b}	115.8 ± 5.08^{a}	1.54	0.001

$^{a, b, c}$ values within a row with different letters were significantly different ($P<0.05$). Diet 1 (KP1) consists of 90% Guinea grass and 10% concentrated feed; Diet 2 (KP2) consists of 80% Guinea grass, 10% concentrated feed and 10% leucaena; Diet 3 (KP3) consists of 70% Guinea grass, 10% concentrated feed and 20% leucaena; Diet 4 (KP4) consists of 60% Guinea grass, 10% concentrated feed and 30% leucaena.

Effects of dietary levels of leucaena on the growth of goats

Increasing the level of leucaena leaves in diets that include Guinea grass and concentrated feed resulted in improved live weight and daily weight gain, while also decreasing the feed conversion ratio (FCR) (Table 4). In the first two months, there was no significant difference in the live weight of goats across four diets. However, differences in growth performance became noticeable during the third and fourth months ($P<0.05$). Substituting leucaena leaves into the diets led to a positive increase in the body live weight of the goats ($P<0.05$). During the first month of the experiment, there was no difference in daily weight gain among the diets. However, from the second month to the fourth month, differences in daily weight gain of goats emerged between the control group (KP1), which had no leucaena leaves, and the diets that included leucaena leaves (KP2, KP3, and KP4) ($P<0.05$). Increasing the level of leucaena leaves in the diet was associated with higher daily weight gain in the goats, with the highest gain observed at 30% leucaena leaves in KP3. The FCR improved from KP1 to KP4, decreasing from 8.43 to 6.62, respectively.

The inclusion of leucaena leaves in goat rations has been studied in many countries. Our experiment focused on local breeds "*Co* goat", which typically have smaller body weight and daily weight gains compared to breeds such as Back Thao, Boar, or other crossbreeds (Pham and Nguyen, 2015; Pham et al., 2019). We found that incorporating leucaena leaves at levels up to 30% in the diets of these local breeds of goat in Vietnam improved both feed intake and daily weight gain. These findings align with those of Adejumo and Ademosun (1991); Fasae et al. (2011); Marhaeniyanto et al. (2023), who also reported positive effects from including various levels of leucaena in diets. Specifically, Marhaeniyanto et al. (2023) observed that supplementing with 20% *Leucaena leucocephala* leaves in a concentrate containing 15% crude protein resulted in an average daily gain of 99.29 g/head/day. Conversely, Wiyabot (2022) reported no significant difference in daily weight gain among goats when leucaena was used as a roughage substitute at levels exceeding 50%. Additionally, Adejumo and Ademosun (1991) recommended that to promote growth without adverse effects, leucaena should not comprise more than 40% in goat rations. We recommend including 30% of leucaena in the diet to ensure that toxicity thresholds remain manageable for smallholder farming systems and align well with the needs of our goat breed. Additionally, biomass production of leucaena at the smallholder scale in Vietnam is limited. Therefore, our findings suggest that maintaining this 30% leucaena in the diet will optimize and sustain feed supply effectively.

Table 4 - Weight gain, daily weight gain and feed conversion ratio of goats by month of experiment

Live weight (kg/head)	KP1	KP2	KP3	KP4	SEM	P value
Initial body weight	12.15	12.37	12.55	12.20	0.300	0.778
First month	13.05	13.45	13.68	13.42	0.294	0.530
Second month	14.20	14.90	15.22	15.08	0.304	0.138
Third month	15.95^{b}	16.98^{ab}	17.40^{a}	17.40^{a}	0.268	0.007
Fourth month	17.52^{b}	18.73^{a}	19.33^{a}	19.48^{a}	0.258	0.001
Daily weight gain (g/day)						
First month	30	36	38	41	2.98	0.127
Second month	38^{b}	48^{ab}	52^{a}	55^{a}	2.89	0.009
Third month	58^{b}	69^{a}	73^{a}	78^{a}	2.51	0.001
Fourth month	52^{c}	58^{bc}	64^{ab}	69^{a}	2.00	0.001
Average	45^{c}	53^{b}	56^{ab}	61^{a}	1.59	0.001
FCR (kg feed/kg gain)	8.43^{a}	7.88^{ab}	7.20^{bc}	6.62^{c}	0.246	0.001

$^{a, b, c}$ values within a row with different letters were significantly different ($P<0.05$). Diet 1 (KP1) consists of 90% Guinea grass and 10% concentrated feed; Diet 2 (KP2) consists of 80% Guinea grass, 10% concentrated feed and 10% leucaena; Diet 3 (KP3) consists of 70% Guinea grass, 10% concentrated feed and 20% leucaena; Diet 4 (KP4) consists of 60% Guinea grass, 10% concentrated feed and 30% leucaena.

Carcass quality of goats

There were differences in slaughter body weight, hot carcass weight, and percentage of carcass among goats on different diets (Table 5). Increasing the level of leucaena leaves in their diets resulted in varying growth performance in the goats. The hot carcass weight was found to be higher in the rations containing 20% and 30% leucaena leaves, while the lowest hot carcass weight was observed in the rations without leucaena inclusion ($P<0.05$) (Table 5). The carcass weight, body meat, and their ratios in KP3 and KP4 were higher than those in KP1. Increasing the level of leucaena leaves in the diet markedly improved the carcass characteristics of slaughter goats. However, there were no differences in the meat quality of the loin based on DM, CP, EE, and total ash among diet treatments. The study concluded that incorporating leucaena leaves up to 30% in a basal goat diet of guinea grass and concentrated feed improved meat production, but had no effects on the loin meat quality in local goats. Leucaena inclusion improved carcass traits compared to traditional local goat diets in Vietnam (Pham et al., 2019). This finding aligns with the carcass characteristics observed in Afar goats fed with leucaena in Ethiopia (Terefe et al., 2013; Gebrehiwot et al., 2017) and in indigenous Anglo-Nubian hybrid goats in Thailand (Wiyabot, 2022).

Economic analysis

The cost-benefit analysis of investing in this experiment was calculated based on the prices of animals, feed, and veterinary services for goats during their feeding period. Table 6 provides a summary of the economic impact data on sixteen male goats raised on four different rations. The lowest economic impact was found in KP1. As the inclusion of leucaena leaves in the diets increased from 10%, 20%, to 30%, the economic analysis results increased by 28%, 43% and 62%, respectively, compared to the baseline without leucaena leaves. In the condition of market price fluctuations, we conducted a sensitivity analysis to evaluate how the profit changed in response to a 10% increase or 10% decrease in the sale price. Our findings indicate that, in all scenarios, KP2, KP3, and KP4 consistently generate higher profits than KP1 (Table 6). The cost-benefit analysis of goat farming in this experiment indicates that goat farming can be a profitable business for smallholders in Vietnam when incorporating leucaena leaves at up to 30% dry matter (DM) in their forage. Leucaena is primarily fed to goats as fresh material through cut-and-carry feeding systems, which are both flexible and labor-efficient (Palmer et al., 2010). Under tropical conditions, leucaena can provide over 4 tonnes of foliage per hectare per year (Casanova-Lugo et al., 2014; Cowley and Roschinsky, 2019), making it a valuable feed source for small-scale goat production.

Table 5 - Carcass characteristics and loin meat quality of goats (n=3)

Category \ Experimental diets	KP1	KP2	KP3	KP4	SEM	P value
Pre-slaughter weight (kg)	17.53^{b}	18.57^{ab}	19.20^{a}	19.60^{a}	0.324	0.009
Blood (kg)	0.60	0.61	0.61	0.61	0.027	0.992
Hair (kg)	0.03	0.05	0.04	0.04	0.006	0.122
Internal organs (kg)	5.80	5.45	5.54	5.41	0.092	0.059
Empty body weight (kg)	10.54^{c}	11.48^{bc}	12.22^{ab}	12.89^{a}	0.279	0.002
Head (kg)	1.28^{b}	1.43^{ab}	1.48^{a}	1.54^{a}	0.036	0.006
Legs (kg)	0.50	0.51	0.53	0.60	0.026	0.102
Skin (kg)	1.29^{b}	1.38^{ab}	1.54^{ab}	1.62^{a}	0.062	0.021
Hot carcass weight (kg)	7.47^{c}	8.15^{bc}	8.66^{ab}	9.11^{a}	0.205	0.003
Dressing percentage (%)						
Pre-slaughter weight bases (%)	42,59^{c}	43.88^{bc}	45.12^{ab}	46.45^{a}	0.529	0.005
Empty body weight bases (%)	70.85	71.02	70.91	70.76	0.470	0.982
Chemical composition of loin						
DM (%)	22.55	23.19	23.27	23.23	1.74	0.989
CP (%)	84.72	85.31	86.31	85.70	0.587	0.388
EE (%)	3.78	4.35	3.05	4.02	0.434	0.320
Total ash (%)	4.64	4.59	4.73	5.58	0.210	0.951

$^{a, b, c}$ values within a row with different letters were significantly different (P<0.05). Diet 1 (KP1) consists of 90% Guinea grass and 10% concentrated feed; Diet 2 (KP2) consists of 80% Guinea grass, 10% concentrated feed and 10% leucaena; Diet 3 (KP3) consists of 70% Guinea grass, 10% concentrated feed and 20% leucaena; Diet 4 (KP4) consists of 60% Guinea grass, 10% concentrated feed and 30% leucaena.

Table 6 - Economic analysis of goat raising by diets

Item	Unit	Price (VND)*	Experimental diets			
			KP1	KP2	KP3	KP4
Investment costs						
Animal breed	kg	120,000	1,458,000	1,485,000	1,506,000	1,464,000
Concentrated feed	kg	13,000	133,032	139,571	142,392	137,846
Guinea grass	kg	700	113,466	107,872	91,164	75,647
Leucaena leaves	kg	1,000	-	17,123	32,559	46,315
Vaccine	head	50,000	50,000	50,000	50,000	50,000
Total			1,754,498	1,799,566	1,822,115	1,773,808
Sale income						
Fixed sale price	kg	120,000				
Income	VND		2,103,000	2,247,000	2,319,000	2,337,000
Profit	VND		348,502	447,435	496,885	563,192
% compared to KP1			100	128	143	162
Sensitivity analysis						
Sale price increases by 10%	kg	132,000				
Income	VND		2,313,000	2,472,000	2,551,000	2,571,000
Balance/Profit	VND		558,502	672,434	728,885	797,192
% compared to KP1			100	120	131	143
Sale price decreases by 10%	kg	108,000				
Income	VND		1,893,000	2,022,000	2,087,000	2,103,000
Balance/Profit	VND		138,502	222,434	264,885	329,192
% compared to KP1			100	161	191	238

*Conversion rate: 1 USD ≈ 25,000 VND in December 2024. Diet 1 (KP1) consists of 90% Guinea grass and 10% concentrated feed; Diet 2 (KP2) consists of 80% Guinea grass, 10% concentrated feed and 10% leucaena; Diet 3 (KP3) consists of 70% Guinea grass, 10% concentrated feed and 20% leucaena; Diet 4 (KP4) consists of 60% Guinea grass, 10% concentrated feed and 30% leucaena.

CONCLUSIONS

This study demonstrated that feed intake, weight gain, feed conversion ratio, and carcass traits of goats differed significantly among the four dietary treatments. The inclusion of leucaena leaves in the diets increased feed intake and improved growth performance as the proportion of leucaena rose to 30%. Daily weight gain increased from 45 g/day in the control diet to 61 g/day in the KP4 diet, while the feed conversion ratio improved from 8.43 to 6.62 kg feed/kg gain. Higher levels of leucaena also enhanced carcass traits, although loin meat quality remained unaffected. Economic analysis confirmed that supplementing up to 30% leucaena leaves in goat diets yields profitable outcomes for smallholder farmers, with greater economic benefits at higher inclusion levels. Overall, the findings support the recommendation that leucaena leaves be incorporated into goat feeding strategies to improve productivity and profitability in smallholder farming systems in Vietnam.

DECLARATIONS

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

TN.Liem, NM.Dung, and LM.Duc were responsible for implementing the research activities. DT.Hai and VTM.Tam carried out the laboratory work, while LTQ.Anh conducted the economic analysis. S.Chotchutima and P.Boonsaen collaborated as partners in developing the research plan and provided funding through the project "Improving Smallholder Goat Fattening Systems Based on Fodder from Grasses and Legumes in Thailand, Laos, and Vietnam", supported by the Lancang-Mekong Cooperation Special Fund.

Ethical regulations

All experimental procedures involving animals were conducted in accordance with Vietnamese regulations on animal welfare and research ethics and were approved by the Animal Ethics Committee of Hue University (Approval No. HUVN0055, dated 20 February 2025). The authors also complied with the ARRIVE guidelines.

Funding

This study was funded by the "Lancang-Mekong Cooperation Special Fund" and the research fund of Hue University, code DHH2024-02-180.

Acknowledgements

The authors express thankfulness for the cooperation program on "Improving smallholder goat fattening systems based on fodder from grasses and legumes in Thailand, Laos and Vietnam" funded by the "Lancang-Mekong Cooperation Special Fund" and the research fund of Hue University, code DHH2024-02-180.

Competing interests

The authors declare no competing interests in this research and publication.

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