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The Effect of Replacing Forage with Binahong Leaves on Performance and Methane Gas Production of Local Indonesian Goat

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ABSTRACT

Reducing methane emissions is an important aspect of climate change mitigation, including in goat production. This study evaluated the effect of substituting forage with Binahong leaves on the performance and methane production of Indonesian local goats. This study used 16 Ettawa crossbreds with an average body weight ranging from 18 to 38kg. This study used a randomized group design with 4 treatments and 4 replications, namely P0 : 60% *Brachiaria mutica* + 40% concentrate; P1 : 55% *Brachiaria mutica* + 5% Binahong leaf + 40% concentrate; P2 : 50% *Brachiaria mutica* + 10% Binahong leaf + 40% concentrate; P3 : 45% *Brachiaria mutica* + 15% Binahong leaf + 40% concentrate. The observed variables were nutrient digestibility, feed intake, and methane production. The analysis of variance (ANOVA) showed Binahong leaf had no significant effect (P>0.05) on dry matter (DM) and organic matter (OM) digestibility (DMD, OMD), crude protein digestibility (DCP), neutral and acid detergent fiber digestibility (DNDF, DADF), DM and OM intake (DMI, OMI), average daily gain (ADG) and feed efficiency. However, Binahong leaf treatment had a significant effect (P<0.01) on hemicellulose digestibility and methane gas production. Additionally, there is a tendency for DMI and OMI to decrease, and ADG to increase, followed by an increase in feed efficiency, based on the trend of average values at the 15% level of Binahong leaf use. It can be concluded that methane production can be reduced without adversely affecting performance and nutrient digestibility by using Binahong leaves as a forage replacement in the diet of Ettawa crossbred (PE) which is up to a level of 15%.

Key words: Binahong, Performance, Ettawa crossbred, Nutrient intake, Methane production.

INTRODUCTION

Climate change poses a significant threat to forage production, affecting the quality and spatial distribution of forage resources (Giridhar and Samireddypalle 2015; Martin et al. 2017). In subtropical regions, seasonal variations in forage supply lead to temporal scarcity, with more acute gaps during dry seasons and droughts (Tulu et al. 2023). One of the main challenges is the quality and quantity of available forage, which is often poor and hinders livestock productivity (Fekade 2019). Therefore, there is a need for solutions to overcome the problem of feed availability. One of the potential crops is Binahong (*Anrederacordifolia (Ten) steenis*).

Binahong (*Anredera cordifolia Ten. Steenis*) is a legume that is a viable source of ruminant feed. Binahong leaves contain 71.30% OM, 3534.80kcal/kg energy, 2068.71kcal/kg thermogenic, 1.7% fat, 5.20% crude protein, 14.80% crude fiber, 8.08% ash, Ca 1.28%, and P 0.46% (Kristofer et al. 2021). The potential of Binahong (*Anredera cordifolia*) as a ruminant feed is supported by its diverse phytochemical composition, including flavonoids, saponins, alkaloids, flavonoids, phenols, steroids, polyphenols, triterpenoids, essential oils and saponins (Surbakti et al. 2018; Rohaeni et al. 2024). Additionally, Binahong leave have been demonstrated to possess antibacterial, antioxidant, anti-inflammatory and immunomodulatory properties (Perkasa 2023; Werdiningsih et al. 2023; Rohaeni et al. 2024).

Active compounds found in Binahong leaves can improve the condition of the digestive tract (pH and microflora). Polyphenolic compounds have an antibacterial

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activity against *Staphylococcus aureus* and *Escherichia coli* (Efenberger-Szmechtyk et al. 2021). Saponins are secondary metabolites commonly found in legumes that have the capacity to optimize rumen fermentation and enhance animal productivity (Gunun et al. 2019; Ramdani et al. 2023). Research on the use of Binahong leaves as a ruminant feed has not been widely investigated. Binahong flour up to 30% in concentrate diets increased DMD, OMD, VFA and NH_3 concentrations *in vitro* (Widu et al. 2021). The findings of Liu et al. (2019) indicate that the *in vivo* digestibility of OM, NDF and ADF was increased in ewe lambs fed diets supplemented with saponin-containing tea at a dosage of 2g/ewe/day. More recently, Taiwo et al. (2022) found improved digestibility of DM, CP, NDF and ADF in bulls using saponins extracted from fenugreek seeds. Saponins may alter the site of digestion within the gastrointestinal tract, as proposed by Patra et al. (2009), which may enhance feed digestibility in the rumen. *In vivo* experiments by Hess et al. (2004) showed the effects were confirmed in lambs given 0.6g/kg BW 0.75 of *Sapindus saponaria*. *In vitro* experiments demonstrated that tea saponins at 67 and 133mg/L reduced methane production by 13 and 22%, while higher doses (200 and 267mg/L) showed no additional reduction in methane (Hu et al. 2005).

The production of gas is a significant indicator of the nutritional quality of feedstuff. Microbial fermentation of feed in the rumen generates gases, including methane, carbon dioxide and hydrogen. It is thought that saponins or saponin-containing plants may affect the production of gases due to their impact on digestion. A recent study by Kim et al. (2023) demonstrated that *Albizia saponaria* increased gas production at concentrations of 1 and 2% without affecting the maximum or fractional production. Binahong flour's tannins, saponins and flavonoids may inhibit protozoa growth, allowing better rumen digestion (Miah et al. 2004) and the reduction in the protozoan population may reduce methane production.

However, although the pharmacological benefits of Binahong are well documented, there is no direct evidence from the available literature that specifically addresses its efficacy as a ruminant feed in terms of nutritional value, digestibility and effect on performance. Therefore, the use of Binahong leaves as a forage substitute needs to be further developed and investigated as a goat feed.

MATERIALS AND METHODS

Ethical approval

Study location, period and ethical statement of the study were implemented at the goat farm of the Department of Animal Science Teaching and Research Farm, University of Jambi, Indonesia. The study covered a period of 45 weeks. The experimental procedures used in the study adhered strictly to the regulations of the Ethical Committee on the Use of Animals and Humans for Biomedical Research, University of Jambi, Indonesia.

Diet

The diet consisted of forage, Binahong leaves and concentrates, depending on the treatment. Forage in the form of *Brachiaria mutica* was obtained from the surrounding area. The leaf-shaped Binahong, as well as the stalks and leaf stalks, were obtained from oil palm plantations in the region. The Binahong was dried at 60°C for 24 hours. After 24 hours, the Binahong was ground using a hammer mill. Nutritional values for *Brachiaria mutica* and Binahong are shown in Table 1. The composition of the diets, including the formulation of the concentrate is provided in Table 2.

Table 1: Nutritional contents of Binahong and *Brachiaria mutica*

Parameters (%)	Type of Forage	
	Binahong leaf	*Brachiaria mutica*
Dry matters	90.66	92.58
Organic matters	20.89	11.04
Crude protein	13.15	11.41
Crude fiber	19.65	29.03
Eter extract	8.76	3.19
NDF	52.2	78.71
ADF	16.37	40.42

Source: Laboratory analysis, Faculty of Animal Husbandry, Jambi University

Table 2: Feedstuff and nutrient composition of the experimental diets (DM basis)

Components	Diets (%)			
	0	5	10	15
Brachiaria mutica	60	55	50	45
Binahong	0	5	10	15
Rice brand	14.5	14.5	14.5	14.5
Corn	10	10	10	10
Tofu Dreg	12	12	12	12
Molasess	3	3	3	3
Mineral	0.5	0.5	0.5	0.5
Total	100	100	100	100
Nutrient Composition (%)				
TDN	61.26	61.89	62.52	63.15
Crude Protein	12.73	13.07	13.40	13.7
Ca	0.59	0.62	0.65	0.58
P	0.45	0.48	0.48	0.48

TDN : Total digestible nutrient, Ca : Calsium, P : Phosphorus

The following outlines the experimental design and procedure

A total of 16 male Ettawa crossbred of similar age (8-15 months) and initial body weight (18-38kg) were selected for the study. Goats had unlimited access to feed and water, and were housed in individual pens. A—randomized complete block design (RCBD) with four treatment blocks and replications was used to randomly allocate treatments and animals. The treatments were A: 60% *Brachiaria mutica* + 40% concentrate, B: 55% *Brachiaria mutica* + 5% Binahong + 40% concentrate, C: 50% *Brachiaria mutica* + 10% Binahong + 40% concentrate, D: 45% *Brachiaria mutica* + 15% Binahong + 40% concentrate.

Animals were provided with feed twice a day for 45 days. The adaptation period was 40 days, and the collection period was five days. During the collection period, DM and OM intake was determined by weighing the diets. The total fecal matter was collected daily, and samples underwent drying at 60°C for 24 hours. The diets and feces were also dried in an oven at the same temperature for the same duration. Diets and feces were ground to pass through a 1 mm sieve and combined into a composite sample. DM and OM were analyzed according to AOAC 2019. ADF, NDF and hemicellulose were analyzed according to Van Soest (1982). Feed intake and feed efficiency were calculated according to Suryani et al.

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(2017). Furthermore, methane production was measured using the method for estimating methane emissions (Shibata formula) as follows: Methane production (L day-1) = -0.0849 x DMI2 + 422.793 x DMI - 17.766.

Statistical Analysis

Statistical analysis was performed using SAS and analysis of variance to determine the impact of treatment on the observed variables. Duncan's Multiple Range Test (DMRT) was used to further test for differences between treatments.

RESULTS AND DISCUSSION

The digestibility of nutrients are reported in Table 3. Analysis of variance (ANOVA) results showed that using Binahong leaves as a forage substitute in the diet was not significantly different (P>0.01) on digestibility of DM, OM, crude protein, neutral detergent fiber, acid detergent fiber (DMD, OMD, CPD, DNDF and DADF). However, there was a significant difference (P<0.05) hemicellulose digestibility (D-hemicellulose). This result can be seen that replacing grass with Binahong leaf up to 15% of the diet tended to increase the levels of DMD, OMD, CPD, DNDF, and DADF compared to the control treatment. The findings of a recent study using *Anredera cordifolia (Ten.) Steenis* extract as tannin source did not have a significant effect on DMD, and OMD when tannin supplements of 1, 1.5 and 2% of the DM were added to the diet (Suryani et al. 2024).

Table 3 shows that DMD and OMD increased by 8.15 and 8.66% with Binahong leaf. This trend can be attributed to the presence of bioactive compounds in Binahong, and other secondary metabolites, which are known to have antioxidant and antibacterial properties (Perkasa 2023). It is hypothesized that the bioactive compounds which affects ruminal fermentation. This finding is corroborated by the findings of Lucio-Ruíz et al. (2024), that flavonoid supplementation increased the digestibility of DM, OM, CP, NDF and ADF in small ruminants. Flavonoids reduce ruminal ammonia while increasing volatile fatty acids (VFA) (Lucio-Ruíz et al. 2024). These results align with a prior study (Suryani et al. 2024), indicating that supplementation of Binahong extract in goat diets can increase the VFA *in vitro*. This suggests that flavonoids may regulate rumen microbial activity to improve feed intake. The OMD value was higher in concentrates with 30% Binahong leaf flour compared to those with 0, 10 or 20% (Widu et al. 2021). DMD and OMD is important in determining feed quality. A higher digestibility value indicates a greater proportion of nutrients can be absorbed and utilized by livestock (Widiyanto et al. 2014; Suharti et al. 2019).

Digestibility of crude protein is the proportion of crude protein lost during feed digestion and subsequent metabolism (Ahmad et al. 2020). Up to 15% Binahong leaves in the diet can increase crude protein digestibility by 6.3% (study findings). Furthermore, the coefficient of crude protein digestibility is directly proportional to the increase in ADG of ruminants (Amaliah et al. 2023). In addition, NDF digestibility refers to the amount of NDF nutrients that are fermented by microbes in the rumen (Hambakodu et al. 2020). The presence of high levels of lignin in the diet has been demonstrated to reduce rumen digestibility. The incorporation of Binahong leaves into the diet led to a notable increase in DNDF and DADF (9.57% and 17.30%, respectively) at levels up to 15% (Utama 2021). The ADF composition (cellulose, silica and lignin) is influenced by rumen microbes (Utama 2021).

The results of the ANOVA showed that the Binahong leaf treatment had a highly significant effect (P<0.01) on D-hemicellulose. Further analysis showed that the control treatment significant differences (P<0.01) when compared to treatment at the levels of 5, 10 and 15%. Table 4 shows Binahong leaf supplements have a lower digestibility than the control. This is probably due to the inhibition of rumen microbes by Binahong leaves. The impact of lignin and varying levels of NDF and ADF on digestibility is also a consideration, with previous research indicating lignin and anti-nutritional compounds inhibit rumen microbes (Hambakodu et al. 2020).

Table 4 shows the effect of treatment on animal performance. The ANOVA showed that Binahong had no

Table 3: Effect treatment on nutrient digestibility

Parameters (%)	Treatments (%)				P value
	0	5	10	15	
DMD	68.83±6.83	77.1±1.66	74.96±7.59	71.19±2.87	>0.05
OMD	69.94±6.69	78.89±1.46	76.22±7.22	72.89±2.84	>0.05
CPD	76.87±5.37	84.59±1.24	81.96±5.66	78.72±2.27	>0.05
DNDF	68.51±6.18	78.35±2.14	73.99±7.66	71.89 ±1.81	>0.05
DADF	60.37±8.48	72.82± 2.39	73.15±7.95	66.49±3.22	>0.01
D-Hemicelluloce	6.86±1.67a	5.53±0.31b	1.08±0.14c	5.40±1.78b	<0.01

Values (mean+SD) bearing different letters in a row indicate significant differences (P<0.01).

Table 4: Effect treatment on Goat performance

Parameters	Units	Treatments			
		0	5	10	15
DMI	kg.day^{-1}	1.83±0.39	1.92±0.65	1.57±0.22	1.50±0.43
DM/BW$^{0.75}$ intake	g.kg^{-1} b.wt.$^{0.75}$ d^{-1}	66.42±8.63aa	50.09±5.73b	56.43±0.63ab	54.73±2.27ab
OMI	kg.day^{-1}	1.79±0.38	1.88±0.64	1.54±0.21	1.47±0.42
DM/BW$^{0.75}$ intake	g.kg^{-1} b.wt.$^{0.75}$ d^{-1}	64.94±8.44aa	48.98±5.60bc	55.18±0.62ab	53.52±2.23ab
ADG	kg.day^{-1}	0.29±0.14	0.24±0.16	0.2±0.16	0.33±0.16
Feed efficiency (%)	%	15.14±5.36	11.79±3.87	15.50±11.17	21.52±8.20

Values (mean+SD) bearing different letters in a row indicate significant differences (P<0.05).

statistically significant effect (P>0.05) on feed intake, ADG and feed efficiency. Although the finding does not indicate any significant differences between treatments, it was found that the substitution of Binahong leaves at a level of 5% increased DM intake (DMI) by 4.91% and organic matter intake (OMI) by 5.02%. Conversely, at the 10 and 15% inclusion levels, a decrease in DMI, and OMI was evident as the amount of Binahong leaves in the diet was enhanced, with reductions of 16.1 and 15.92%, respectively. This reduction is probably due o the presence of active compounds in Binahong leaves such as tannins are known for their ability to bind proteins and are also characterized by a bitter taste, which can reduce the palatability of the diet, subsequently decreasing feed intake (DMI) (Zeller 2019). A reduction in DMI is accompanied by a decline in OMI as the level of Binahong leaf inclusion reaches 15%.

The highest level of feed efficiency was achieved through the inclusion of Binahong leaf at a 15% ratio in the diet. This increase in feed efficiency was accompanied by an improvement in the ADG, and a reduction in feed intake at the 15% level in comparison to the control. There was no significant effect (P>0.05) on feed efficiency with the inclusion of Binahong leaf. However, the feed efficiency at the 15% Binahong level was higher than that observed in the control group. Feed efficiency is defined as the ratio of product output to feed intake. Factors influencing efficiency include animal age and weight, and the type and quality of the feed. Several biological mechanisms contribute to feed efficiency in cattle, including digestibility and methane production (Cantalapiedra-Hijar et al. 2018).

The average of daily gain (ADG) tended to increase with the addition of Binahong leaf, reaching a level of significance at 15%. ADG was found to increase by 13.79 with 15% Binahong leaf supplementation in comparison to the control group. It is noteworthy that this increase in ADG was accompanied by a decrease in DMI and OMI. This effect is probably due to the active compounds, which may reduce methane production through the defaunation of protozoa or direct symbiosis with methanogenic bacteria (Aboagye and Karen 2019). A reduction in methane production allows for the allocation of more energy to be available and utilized by the animal, thereby improving performance. The use of saponins and tannins has been demonstrated to reduce the protozoan population in the rumen, thereby reducing methane production during feed fermentation in the rumen (Ningrat et al. 2017; González-Recio et al. 2020).

Fig. 1 illustrates the impact of Binahong supplementation on methane gas production. The analysis of variance demonstrated that the incorporation of varying quantities of Binahong leaves exerted a statistically significant influence (P<0.05) on methane gas production. The orthogonal polynomial test demonstrated a linear relationship between the level of Binahong leaves (X) and the total methane gas production (Y), as represented by the equation Y = -0.9013X + 857.235, with a coefficient of determination (R^2=0.98733).

As illustrated in Fig. 1, the incorporation of Binahong leaf at concentrations up to 15% has been shown to result in a reduction in methane gas production. The existence of active compounds such as tannins and saponins is likely to be responsible for this reduction. Tannins in forages reduce methane by inhibiting the activity of methanogens and protozoa, which are the primary hosts of these microorganisms, as well as other fiber-digesting microbes. Consequently, this results in a reduction in hydrogen (H2) availability (Tuwaidan et al. 2024). This finding is consistent with the results of previous research on high-tannin plants, such as *Lotus pedunculatus*, which have been reported to reduce methane production by up to 30% and can serve as a forage substitute in ruminant diets (Cardoso-Gutierrez et al. 2021). Moreover, Jayanegara et al. (2020) observed that in two different dietary regimens (high forage or high concentrate), the addition of saponins derived from *Sapindus rarak* fruits at concentrations of 0.5, 1, 1.5 and 2 mg/mL medium had no–significant impact on gas production. The addition of condensed tannins at a concentration of 25.9g/kg DM to *Lotus corniculatus* has been shown to decrease cattle methane production (Woodward et al. 2001). Furthermore, it was observed that goats exhibited greater adaptability to tannins in comparison to cattle and sheep, attributed to their enhanced saliva production, which facilitates tannin-binding capacity (Battelli et al. 2023).

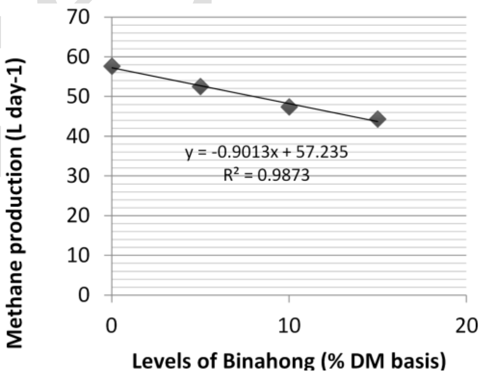

Fig. 1: Relationship between Binahong levels and total methane production.

Conclusion

The utilization of Binahong leaf as a forage substitute in the diet of Ettawa crossbred (PE) goats up to a 15% inclusion level has been demonstrated to reduce methane production without any adverse effects on performance or nutrient digestibility.

Conflict of Interest: No conflict of interest exists with any organisation regarding the matters discussed in this manuscript.

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