Research Article

Wedelia trilobata (L.) Hitch: Biomass and Goat-Feeding Potential in Southwest Vietnam

Danh Mo

Kien Giang University, Vietnam. No. 320A Highway 61, Minh Luong Town, Chau Thanh District, Kien Giang Province.

Abstract | A study at Kien Giang University, Vietnam, was conducted to evaluate the biomass and potential utilization of *Wedelia trilobata* (L.) Hitch. as a forage for goats. Using twelve plots from a 48 m^2 land area, the first experiment showed that the biomass of *Wedelia* in fresh and dry matter (DM) rose significantly (P<0.05) when harvesting at times from 3, 5, 7 to 9 weeks following planting and regeneration. With a yield of 22.4 tons/ha/year, the harvest period of 9 weeks had the best yield. *Wedelia* tends to lose nutritive value (P<0.05) when harvesting time increases (crude protein, CP 10.4-18.8% DM and acid detergent fiber, ADF 20.1-33.5% DM). Significantly (P<0.05) lower in CP and higher in ADF, the regenerated *Wedelia* was compared to the planting period. The second experiment was a Latin square on 4 goats over 4 periods across 4 treatments. The treatments were dietary forage (50% *Wedelia* and 50% grass in DM)-to-concentrate (F:C) ratios of 4:0, 3:1, 2:2, and 1:3 (DM basis). The daily consumption of *Wedelia* by the goat varied considerably (P<0.05) between treatments (38.2-139 g DM, equivalent to 15-50% of the total DM intake), but there was no significant difference (P>0.05) in daily total DM intake (2.63-2.85% of their live weight). As the concentrate level increased, there was a significant (P<0.05) increase in digestibility, nitrogen retention efficiency, and methane emissions. For reduced methane emission intensity, it is advised to maintain dietary F:C ratios between 1:3 and 2:2; however, studies on *Wedelia* as the forage at higher levels should continue.

Keywords | Goat, Wedelia, Forage, Concentrate, Utilization, Emission

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***Correspondence** | Danh Mo, Faculty of Natural Resources and Environment, Kien Giang University, Vietnam. No. 320A Highway 61, Minh Luong Town, Chau Thanh District, Kien Giang Province; **Email:** dmo@vnkgu.edu.vn
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INTRODUCTION

Goat farming plays an important role in providing meat and milk, generating income, and improving livelihoods for people in Southwestern Vietnam. Goats have been raised commonly for a long time, and more recently, they have become more popular because they require little forage, low investment, few diseases, reproduce quickly, and their meat is easy to consume. Many experts also said that goats can withstand harsh climate changes, heat, and drought better than other ruminant species (Feleke *et al*., 2016; Pragna *et al*., 2018). Goat farming in Vietnam was growing steadily from 2014 to 2021, it has climbed by 65.9%. Southwest Vietnam has about 16.2% of the national goats, mainly raised on smallholder farms (GSO, 2023). However, the Southwestern region of Vietnam is mostly lowland, low-lying, and filled with alluvium from the Mekong River system, so it is more suitable for growing rice and tropical fruits than grasslands. Pasture is an important challenge in ruminant production, so research into new forage sources is necessary. Goat farming in this area relies on natural pastures or the utilization of by products from corn, potato sweets, bananas, soy, jackfruit, etc. These sources are competed with by others such as buffaloes, cattle, sheep, and rabbits, making them rare and expensive. Meanwhile, the tropical climate in Southwestern Vietnam is favorable for many plant species to thrive due to long sunshine and heavy rainfall (GSO, 2023), but these plants can only be suitable for goats (Papachristou, 1997). Rations are a very important decision in the cost and productivity of goat farming, of which forage accounts for about 20 to 100% (Barbosa *et al*., 2018). Therefore, utilizing non-traditional forage resources will reduce costs, thereby improving profits for smallholder farms. The dietary forage-to-concentrate (F:C) ratios have been shown to influence nutrient utilization, weight gain, and methane emissions of goats (Lima *et al*., 2016; Na *et al*., 2017; Barbosa *et al*., 2018), but research in this region is limited.

Wedelia trilobata (L.) Hitch. (called *Wedelia* for sort) is native to Central America and commonly cultivated or grown naturally for ground cover or as ornamental plants in Southwest Vietnam. It can grow quickly and is well adapted to harsh, dry, and hot climates (Zhang *et al*., 2020). *Wedelia* has an approximately similar crude protein (CP) content to natural grass and lower fiber (Mo, 2017), so it can be a good alternative to natural grass for forage. However, due to the presence of secondary metabolites (Balekar *et al*., 2014), questions about its potential toxicity to animals need to be answered. Goats are, meanwhile, a species with a very wide feed spectrum, they can eat more poisonous plants than other ruminants due to the rapid adaptability of the rumen microbiota (Papachristou, 1997). Moreover, Patra *et al*. (2017) suggested that supplementing or utilizing forages containing secondary metabolites was very promising to mitigate enteric methane. A previous experiment has shown that *Wedelia* had significantly lower *in vitro* methane production than the control but has not been tested *in vivo* (Mo, 2017). The purpose of this study was to evaluate the biomass and potential of *Wedelia* for feeding goats in Southwest Vietnam by substituting it as a part of the forage.

MATERIALS AND METHODS

Location

The experiments were conducted in Minh Luong Town, Chau Thanh District, Kien Giang Province (9054'48.3"N, 105009'22.3"E) located in Southwest Vietnam. Sample analysis was done in the laboratories of Kien Giang University. This region's climate is of the tropical delta, characterized by high temperatures and humidity, long sunshine, and heavy rainfall (GSO, 2023).

Wedelia cultivation

An experiment with 12 plots of land (4 m^2/plot) was carried out to cultivate *Wedelia* to evaluate the biomass and chemical composition of the species. *Wedelia* was cultivated with stems that ranged in length from 20 to 30 cm, chopped into 4-5 pieces for each bush. The bushes were spaced 20 to 30 centimeters apart. Every bush was buried between 10 and 20 centimeters below the surface. *Wedelia* was not fertilized; it receives daily irrigation. After planting and regeneration, it was harvested by cutting near the land surface at 3, 5, 7, and 9 weeks (3 random plots per time) to determine its biomass. There is not yet information about the genetic variation of *Wedelia* in this region. The experiment soil was mainly alluvium and belonged to the Fluvisol or Plinthosol group (Vu *et al*., 2011), both characterized by low organic carbon, poor total and available nitrogen (N), and exchangeable cations (K^+, Na^+, Ca^{2+}, Mg^{2+}) ranging from low to moderate (Dung *et al*., 2019).

Goat feeding

A latin square experiment was carried out on four male crossbred Bachthao goats (local x Bachthao x Boer) over four periods across four dietary treatments to assess the potential of *Wedelia* as a part of the forage in diets. The experimental goats' live weight (LW) was 11.9±2.29 kg/head. Before the experiment, they were adapted to individual cages and vaccinated against foot-and-mouth disease. The time for each period was 21 days (from the 14 to the 19th day was used for sampling). Treatments were diets with F:C ratios of 4:0, 3:1, 2:2, and 1:3. The forage included 50% natural grass (*Barachiaria mutica*) and 50% *Wedelia* (dry matter, DM basis). Before feeding, the grass and *Wedelia* were combined, and the concentrate was stored separately in a different feeder. The concentrate included 35% of oil-extract soybean, 32% of broken rice, 32% of rice bran, and 1% of premix. It was mixed once for the whole time of the experiment. Each kg of premix contained 100,000 IU of vitamin A, 30,000 IU of vitamin D3, 210 mg of vitamin E, 130 mg of vitamin B12, 875 mg of nicotinic acid, 25 mg of folic acid, 4.6% of lysine, 8,000-12,000 mg of copper, 9,000-12,000 mg of iron, 5,000-8,000 mg of zinc, 4,000-6,000 mg of manganese, 15-25 mg of selenium, 10-15 mg of cobalt, 50-80 mg of iodine, and 18-25% of calcium. The diets with the F:C ratios of 3:1, 2:2, and 1:3 had a suitable CP for the growth of indigenous goats with 10 kg of LW and a weight gain of 50 g/day and a F:C of 4:0 to meet the requirement for a weight gain of 25 g/day (NRC, 2007). Goats were fed half of their diet at 8:00 am and half at 2:00 pm every day. The daily feed provision for every goat ensured an excess of 350 g DM/kg LW (Mellado, 2016). Water was free to drink and replenished every day. The chemical composition of the feeds for goats is shown in Table 1.

The cage was 1.2 x 1.0 x 1.2 m in size, made of wood, with a floor 0.3 m above the ground, and under the floor, there was a catchment net to separate feces and urine. Each cage had its own feeding trough and drinking trough. During the experiment, cages, feeding troughs, and drinking troughs were cleaned daily. To measure methane gas, design 4 respiration-metabolism chambers made of 5 mm thick transparent mica that cover the cage from top to bottom. Only during the methane measuring period was this chamber utilized.

Table 1: Chemical composition (%DM, except DM as %) of feeds.

Feeds	DM	OM	CP	EE	NDF	ADF
Natural grass	20.0	82.2	11.2	3.60	69.0	36.9
Wedelia	14.2	80.5	13.4	5.36	40.5	31.5
Concentrate	85.0	74.1	20.4	7.76	24.5	17.5

DM: dry matter, OM: organic matter, CP: crude protein, EE: ether extract, NDF: neutral detergent fiber, ADF: acid detergent fiber.

Measurements and sampling

The weight of the offered feeds was minus the refusal feeds to find the feed intake. To determine the daily weight changes per LW, the goats were weighed in the morning before feeding at the start and finish of each experimental period, which lasted for two days in a row. Nitrogen retention (NR) was calculated by recording the difference between N intake minus N expelled in feces and urine, and apparent digestibility was assessed by recording the difference between the nutrients consumed and excreted (McDonald *et al*., 2010). Methane emissions were directly measured within a respiratory-metabolism chamber system (Li *et al*., 2010). Methane gas was constantly measured for 72 hours at the flow rate of air 40 m^3/h by the methane meter (FG 110, Kimo, France), with data updated every 30 minutes (Wang *et al*., 2017). Feeds and feces samples were quickly brought to the laboratory to be dried (55 °C for about 24-48 hours), ground finely (1 mm), and stored in cold conditions (-20 °C) to wait for analysis. Urine samples were treated with 10% H_2SO_4 before being sampled for the N analysis on the same day.

Sample analysis

The chemical composition consisting of DM, organic matter (OM), CP (N x 6.25), ether extract (EE), and crude fiber (CF) was determined according to AOAC (1990). The method of Goering and van Soest (1970) was used to determine acid detergent fiber (ADF) and neutral detergent fiber (NDF). The chemical composition was used to calculate gross energy (GE), following the recommendation of Giger-Reverdin *et al*. (1994). The difference between the GE consumed and the GE expelled was used to calculate digestible energy (DE) at the suggestion of NRC (2007). Urine N was determined using the method of Hach (2015).

Data analysis

Data were subjected to analysis of variance using Minitab 21 software (Minitab, 2022). The sources of variation in the biomass experiment were the harvest time and random error, following the model of $Y_{ij} = \mu + T_i + e_{ij}$, where Y_{ij} = dependent variable, μ = overall mean, $T_{i.}$ = effect of treatment being harvest time, and e_{ij} = error.

Sources of variation in the feeding experiment were the animal, period, F:C ratio, and random error, similar to the model of $Y_{ijk} = \mu + A_i + P_j + T_k + e_{ijk}$, where Y_{ijk} = dependent variable, μ = overall mean, A_i = effect of animal, P_j = effect of period, T_k = effect of treatment being the F:C ratio, and e_{ijk} = error. When the F test at the source of variation in harvest time, or F:C, was significant (P<0.05), Tukey's test was used to compare pairs of treatments.

RESULTS AND DISCUSSIONS

Biomass of *Wedelia*

Table 2 presents the experimental results of *Wedelia* cultivation, which indicate that there is a significant (P<0.05) difference in the biomass of *Wedelia* in fresh and DM harvested at different intervals after planting and regeneration. The largest output is obtained at a harvesting time of nine weeks. The DM biomass at this time is significantly (P<0.05) different from the 3 and 5th weeks of harvest, but not significantly (P>0.05) different from the 7th week. Harvesting at nine weeks had the best yield (22.4 vs. 10.4 to 20.2 tons of DM/ha) when projecting for the whole year, but the difference was not significant (P>0.05) yet when compared to other dates.

Table 2: Biomass (tons/ha) of *Wedelia* harvested at different times.

Harvested time, weeks	After planting		After generating		Whole-year	
	Fresh	DM	Fresh	DM	Fresh	DM
3	4.36^a	0.474^a	6.63^a	0.727^a	95.5	10.4
5	10.9^{ab}	1.13^a	19.4^{ab}	1.97^{ab}	158	16.2
7	22.4^b	2.37^{ab}	24.9^b	3.06^{bc}	176	20.2
9	31.2^b	3.71^b	34.7^b	4.03^c	191	22.4
P-value	0.015	0.015	0.005	0.004	0.171	0.109

DM: dry matter. $^{a, b}$ means within columns with different letters were significantly different (P<0.05).

The biomass of *Wedelia* is less than that of other pastures in Southwest Vietnam, such as *Paspalum attritum*, which ranges from 4.93 to 5.68 tons of DM/ha/time for harvest at circa 9 weeks (Manh *et al*., 2007). But marginally greater than (0.43-28.0 tons of DM/ha/year) for legumes in Central Vietnam (Tao and Vien, 2012). Harvesting *Wedelia* at nine weeks is still reasonable, even though the average annual yield at that time has not decreased yet. However, it should be watched at a different harvest time, fertilized, and identified for genetic variation, if any, to obtain more accurate results.

Composition of *Wedelia*

Table 3 displays the findings of the *Wedelia* analysis, which indicate that CP content significantly (P<0.05) decreases with longer harvest times. As harvesting time rises, there is a tendency for the content of DM (except after planting, P=0.077), OM, CF, and ADF to increase significantly (P<0.05). The CP of *Wedelia* at the 7 and 9th weeks of harvest is significantly (P<0.05) lower than the 3 and 5th weeks. Compared to the 3 and 5th weeks of harvest, the CF and ADF of *Wedelia* at the 7 and 9th weeks are significantly (P<0.05) higher. This outcome supports the findings of Hon and Quac (2007) about *Vetiveria zizanioides*, which show that the nutritive value drops with longer harvest times. *Wedelia* taken after planting had a significantly higher nutritive value (higher CP, and lower CF and ADF) than after regeneration (P<0.05). *Wedelia* was not fertilized in this experiment, possibly because the nutrients in the soil were better after planting than after regeneration. Therefore, studies involving the fertilization of *Wedelia* should be carried out for further testing on the interactive impact of fertilizers with the harvested time on its biomass and nutrient content, as well as genetic variation, if any.

Table 3: Chemical composition (%DM, except DM as %) of *Wedelia*.

Harvested time	DM	OM	CP	EE	CF	NDF	ADF
After planting, weeks							
3	10.9	80.4^{b}	18.8^{a}	6.61	13.2^{b}	39.6	20.1^{b}
5	10.4	80.2^{b}	14.9^{b}	5.46	16.5^{a}	39.3	24.7^{b}
7	10.7	81.6^{ab}	12.1^{c}	5.80	16.4^{a}	39.6	31.0^{a}
9	11.8	82.5^{a}	12.2^{c}	5.70	17.9^{a}	40.4	33.5^{a}
P-value	0.077	0.011	0.001	0.189	0.001	0.945	0.001
After generations, weeks							
3	11.1^{ab}	79.7^{b}	15.3^{a}	7.00	12.5^{d}	37.3	27.1^{b}
5	10.3^{b}	81.2^{b}	14.3^{a}	7.02	15.3^{c}	39.3	27.9^{b}
7	12.2^{a}	85.0^{a}	11.7^{b}	5.40	17.8^{b}	39.5	33.0^{a}
9	11.6^{a}	84.9^{a}	10.4^{b}	5.57	20.0^{a}	39.6	33.4^{a}
P-value	0.036	0.001	0.001	0.130	0.001	0.198	0.002

DM: dry matter, OM: organic matter, CP: crude protein, EE: ether extract, CF: crude fiber, NDF: neutral detergent fiber, ADF: acid detergent fiber. a, b, c, d means within columns with different letters were significantly different (P<0.05).

When compared to a few other forages, *Wedelia* has a rather good potential nutritive value, with CP and ADF values of 10.4-18.8 and 20.1-33.5% DM, respectively. Some grass in Southwest Vietnam had CP contents only from 7.71 to 14.1% and ADF contents from 29.6 up to 38.9%, according to Dung *et al.* (2007). However, compared to legumes, which had CP contents ranging from 14.9 to 17.0% (Dung *et al.*, 2007), this was less.

Feed intake of goats fed *Wedelia*

Table 4 displays the feed consumption and daily weight changes of goats fed *Wedelia*. The findings show that the goats' daily intake of *Wedelia*, which ranges from 38.2 to 139 g DM and makes up between 15 and 50% of the total DM intake, differs significantly (P<0.05). In contrast, there was no significant change in total DM intake (P>0.05), going from 2.63 to 2.85% of LW. Likewise, there was no significant change in the consumption of OM, CP, and EE (P>0.05) when the diet's F:C ratio changed from 4:0 to 1:3. By contrast, the adjustment in the diet's F:C ratio from F:C 4:0 to 1:3 caused the consumption of NDF and ADF to decrease, but not yet significantly (P>0.05). This goat's DM intake is in line with other authors' observations, which ranged from 2.62 to 3.38% of LW (Hong *et al.*, 2020; Duyen *et al.*, 2020; Truong *et al.*, 2024). Therefore, it may be concluded that although *Wedelia* was said to contain toxic secondary metabolites (Balekar *et al.*, 2014), feeding goats with it did not affect how much they consumed feed. This experiment found no effect of the F:C ratio on DM intake, similar to Lima *et al.* (2016), whereas Barbosa *et al.* (2018) showed a slight effect of the F:C ratio on goat's DM intake (P=0.044) with the forage source of Tifton-85 hay containing more NDF (71.2%). This may be due to the difference in forage (50% grass and 50% *Wedelia*) and the Latin square design of this experiment.

Table 4: Daily nutrient intake and weight changing of goats fed *Wedelia*.

Daily intake	Forage to concentrate ratios				SEM	P
	4:0	3:1	2:2	1:3		
Concentrate, g DM	0^{c}	79^{bc}	168^{ab}	259^{a}	33.2	0.007
Wedelia, g DM	139^{a}	117^{a}	75.6^{b}	38.2^{c}	6.96	0.001
Grass, g DM	154^{a}	113^{b}	74.5^{c}	39.3^{c}	7.64	0.001
DM, % LW	2.63	2.78	2.72	2.85	0.334	0.966
OM, g	238	245	247	255	28.3	0.978
CP, g	43.6	55.2	63.5	73.2	8.36	0.181
EE, g	16.3	21.1	24.4	28.3	3.22	0.154
NDF, g	179	164	141	122	13.7	0.097
ADF, g	117	112	96.8	85.2	9.09	0.156
DE, MJ/kg $LW^{0.75}$	0.467^{b}	0.533^{ab}	0.628^{ab}	0.753^{a}	0.033	0.028
NR, g/kg $LW^{0.75}$	0.558^{c}	0.868^{bc}	1.21^{ab}	1.62^{a}	0.088	0.008
Initial LW, kg	11.7	11.5	11.5	11.5	0.058	0.062
Final LW, kg	12.3	12.1	12.3	12.4	0.067	0.159
LW changing, g/kg	2.28	2.88	3.64	3.67	0.353	0.088

DM: dry matter, OM: organic matter, CP: crude protein; EE: ether extract, NDF: neutral detergent fiber, ADF: acid detergent fiber, DE: digestible energy, NR: nitrogen retention, LW: live weight. a, b, c means within rows with different letters were significantly different (P<0.05).

Table 4 illustrates how the goats' dietary F:C ratio of 4:0 to 1:3 resulted in a significant (P<0.05) increase in the goats' DE intake per kg of $LW^{0.75}$. Similarly, there was a significant (P<0.05) progressive increase in NR per kg of $LW^{0.75}$. There is a significant (P<0.05) difference in the DE intake of the goat-fed diet with the F:C ratio of 4:0 from 1:3. The NR of goats at the dietary F:C ratio of 4:0 vs. the 2:2 and 1:3, and the 1:3 vs. the 3:1 are significantly (P<0.05) different. It is possible that this resulted in an increase in the goats' daily weight change, from 2.28 to 3.67 g/kg of LW, but it is not yet significant (P=0.088). This change is in line with recent feeding experiments in Southwestern Vietnam (Hong *et al*., 2020; Truong *et al*., 2024), goats can vary their weight from 2.72 to 4.90 g/kg of LW for goats weighing between 15 and 25 kg. This study did not yet show an effect of the F:C ratio on LW changing in goats, while Barbosa *et al*. (2018) showed a clear effect on weight gain in goats in a completely randomized design with a period of 57 days. The limitation of this experiment may be that the Latin square design had a short period of experimental unit (21 days), which was able to have a higher error.

Nutrient utilization of goats fed *Wedelia*

The digestibility and nitrogen balance of goats fed *Wedelia* are presented in Table 5. The values of DM, OM, and CP digestibility gradually increased significantly (P<0.05) from the dietary F:C ratio of 4:0 to 1:3. The EE digestibility also increased, but the difference was not significant (P=0.073). In contrast, the NDF and ADF digestibility tends to decrease significantly (P<0.05) from the dietary F:C ratio of 4:0 to 1:3. Nitrogen intake and excretion were not significantly different (P>0.05) between dietary F:C ratios, but nitrogen utilization efficiency (NR/N intake) was significantly increased from 62.2 to 82.3% when increasing the concentrate level in diets, corresponding to F:C from 4:0 to 1:3.

The change in digestibility in Table 4 can be explained, according to NRC (2007) and McDonald *et al*. (2010), because forages contain more fiber, so when changing F:C in the diet, the dietary fiber content increases. Similarly, Lima *et al*. (2016) and Barbosa *et al*. (2018) found that increasing the proportion of concentrate in goat diets increased the OM digestibility and decreased the NDF digestibility. However, Pinho *et al*. (2018) suggested that for goats, eating diets containing a lot of digestible fiber from forages could not affect digestibility. In this experiment, most of the forage affected digestibility, probably due to the higher ADF, which represents more lignocellulose, making it more difficult for ruminal microorganisms to digest. Zhao *et al*. (2011) also stated that diets containing a lot of NDF could reduce the digestibility of goats. The nitrogen utilization efficiency is increased when forage is reduced, possibly due to the higher insoluble nitrogen in forage than concentrate, making it difficult to digest nitrogen (McDonald *et al*., 2010).

Table 5: Nutrient digestibility and nitrogen balance of goats fed *Wedelia*.

Digestibility, %	Forage to concentrate ratios				SEM	P
	4:0	3:1	2:2	1:3		
DM	67.0[c]	69.5[bc]	72.4[b]	77.6[a]	0.803	0.001
OM	69.8[b]	71.4[b]	73.4[ab]	77.9[a]	0.935	0.006
CP	66.1[b]	75.9[a]	78.6[a]	83.1[a]	1.65	0.002
EE	59.3	62.7	73.1	79.3	4.69	0.073
NDF	60.5[a]	57.7[ab]	52.5[b]	51.7[b]	1.60	0.023
ADF	46.2[a]	43.2[ab]	37.4[ab]	36.4[b]	2.08	0.044
Nitrogen balance						
NI, g/d	6.11	8.38	9.76	11.8	0.138	0.119
NF, g/d	1.36	1.34	1.18	1.15	0.125	0.564
NU, g/d	0.936	0.910	0.834	0.633	0.140	0.471
NR/NI, %	62.6[b]	72.6[ab]	77.0[a]	82.3[a]	2.51	0.007

DM: dry matter, OM: organic matter, CP: crude protein; EE: ether extract, NDF: neutral detergent fiber, ADF: acid detergent fiber, NI: nitrogen intake, NF: nitrogen excreted in feces, NU: nitrogen excreted in urine, NR: nitrogen retention. [a, b, c] means within rows with different letters were significantly different (P<0.05).

Methane emission from goats fed *Wedelia*

The results of measuring methane emissions from goats are presented in Table 6. The dietary F:C ratio of 4:0 to 1:3 was followed by a considerable (P<0.05) increase in methane volume each day from 4.09 to 10.4 g. Similarly, methane volume per DM, OM, and GE intake and $LW^{0.75}$ increased significantly (P<0.05). However, the methane emission intensity per kg of LW change was not significantly different (P>0.05) in the treatments. Methane emission intensities per kg of LW change were lower (168-190 g/kg) at the dietary F:C ratios ranging from 1:3 to 2:2.

Table 6: Methane emission of goats fed *Wedelia*.

Methane emission	Forage to concentrate ratios				SEM	P
	4:0	3:1	2:2	1:3		
g/day	4.09[b]	5.65[ab]	8.24[ab]	10.4[a]	1.09	0.026
g/kg DMI	14.1[c]	18.1[bc]	26.4[ab]	30.3[a]	1.88	0.003
g/kg OMI	17.3[c]	22.8[bc]	33.9[ab]	39.7[a]	2.35	0.002
kJ/MJ GEI	35.6[c]	43.8[bc]	62.9[ab]	70.5[a]	4.52	0.005
g/kg $LW^{0.75}$	0.664[c]	0.938[bc]	1.32[ab]	1.60[a]	0.127	0.008
g/kg LW changing	171	168	190	244	47.1	0.659

DMI: dry matter intake, OMI: organic matter intake, GEI: gross energy intake, LW: live weight; [a, b, c] means within rows with different letters were significantly different (P<0.05).

These statistics are consistent with other findings. The methane emissions of Korean native black goats, according to Li *et al*. (2010), range from 0.93 to 1.03 g/kg of $LW^{0.75}$. Methane emissions from Liuyang Black goats in China were measured by Zhang *et al*. (2019) to be around 20.6 g/kg of DM intake, which is equivalent to 32.8 g/kg of OM intake and 64.1 kJ/MJ of GE intake. Similar to this, methane emissions from crossbred (local x Bachthao) goats of about 12 kg of LW were reported by Hong *et al.* (2021) to be from 20.1 to 23.3 g/kg DM intake. Boer goats lost energy through methane emissions from 32.2 to 87.7 kJ/MJ of GE intake, according to Animut *et al*. (2018).

The trend of increasing methane in this study is consistent with the reports of Na *et al*. (2017) and Lima *et al*. (2016), but in contrast to Barbosa *et al*. (2018), methane decreased with the increase of concentrate. This inconsistency may be due to differences in dietary ingredients between studies. In this study, the forage consisted of 50% natural grass (*Barachiaria mutica*) and 50% *Wedelia*; and the concentrate mainly included oil-extract soybean, broken rice, and rice bran. The study by Lima *et al*. (2016) used dehydrated corn plants as the forage, and the concentrate included cracked corn, soybean meal, and soybean oil. Na *et al*. (2017) used tall fescue hay as a forage, and the concentrate consisted of ground corn and soybean meal. The study by Barbosa *et al*. (2018) used the forage of Tifton-85 hay and the concentrate of ground corn and soybean meal. In this study, moreover, the concentrate in the diet was reduced and *Wedelia* increased. *Wedelia* has been shown to contain high levels of secondary metabolites (Balekar *et al*., 2014). These substances have the potential to inhibit enteric methane emissions in goats (Patra *et al*., 2017). It has been also demonstrated that the *in vitro* fermentation of *Wedelia* using goat rumen produces noticeably less methane than that of grass (Mo, 2017). Therefore, to assess more accurately, an experiment should be conducted that just has differences in the F:C ratio for a longer period, and insolates the variation of *Wedelia*.

CONCLUSIONS AND RECOMMENDATIONS

In Southwest Vietnam, the biomass of *Wedelia* could reach about 22.4 tons of dry matter per ha annually, but the impact of fertilizer has not yet been confirmed. *Wedelia* has lower fiber than grass and has the potential to be used as a part of forage to feed goats up to 50% of the diet, but is not yet tested at higher levels. Reducing forage in the diet increased nutrient utilization and methane emissions from goats, but weight gain was not yet detected, probably due to the design of each experimental unit for a short period. Methane data remain inconsistent with another study, perhaps due to differences in dietary ingredients; and have not yet isolated the potential effect of *Wedelia* from the F:C ratio. Once they are clarified, this knowledge will help reduce environmental payments in goat farming. Even so, the study still recommends a dietary F:C ratio between 1:3 and 2:2 for low methane emission intensity.

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NOVELTY STATEMENT

The research confirmed that Wedelia trilobata has high potential as a forage for goats, even though it contains secondary metabolites, and added a data case on how the forage-to-concentrate ratio can be used to obtain low methane emission intensity in goat farming.

AUTHOR'S CONTRIBUTION

The experiment's conception, design, and execution, as well as data analysis, article writing, and final manuscript approval, were all done by an author.

Conflict of interest

The authors have declared no conflict of interest.

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