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Effect of feeding *Asystasia gangetica* weed on intake, nutrient utilization, and gain in Kacang goat

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A B S T R A C T

A high concentration of nitrate and total nitrogen (N) in Chinese violet (CV) weed (*Asystasia gangetica*) has a potential benefit as a digestible protein source for ruminant production in humid tropical regions. We conducted a study using twelve Kacang goats in a crossover design to investigate the effect of CV weed on intake, nutrient utilization, and growth. Four dietary treatments were tested: Guinea grass (*Panicum maximum*) *ad libitum* (GG), GG *ad libitum* and CV (1% live weight, LW) (GG + CV), CV *ad libitum* (CV), and CV *ad libitum* plus cassava chip (1% LW) (CV + CC) (dry matter, DM basis). No sign of nitrite toxicity was observed when the goat fed CV diet while intake, N retention, and LW gain was higher than goats on the GG and GG + CV diets ($P < 0.001$). Digestibility of DM was similar to the goats on the GG + CV diet but higher than the goats on the GG diet ($P < 0.001$). However, the goats on the CV diet had a higher urinary N loss compared to the goats on GG and GG + CV diets ($P < 0.001$). The cassava supplementation (CV + CC) increased DM digestibility and lowered urinary N loss ($P < 0.001$). Hence, the CV weed could be fed as a sole diet or as a supplement to the Kacang goat fed a low-quality forage for improvement of nutrients intake, digestibility, and gain, while the urinary N loss could be lowered by cassava supplementation.

1. Introduction

A presence of weeds in a crop field has benefits such as lowering soil evaporation and erosion. However, weeds can negatively affect crop growth and yield due to competition for light, nutrients, and water (Zimdahl, 2004). In integrated crop-livestock farming, livestock serves a practical sustainable approach for controlling palatable weed species (MacLaren et al., 2020), which depends on the type of livestock and crops. Similar to the other tropical regions, the forage supply of small-scale farmers in the tropical humid regions is limited by resources of land, labors, and other inputs (Valbuena et al., 2012). Hence, ruminants were often supplied by the palatable weeds as the main resources of feed during a period of crop-growing season.

Asystasia gangetica (L.) T. Anderson is a perennial herb of the Acanthaceae family, which is widely distributed in tropical Africa and Asia (Kiew and Vollesen, 1997). The weed is commonly known as the Chinese violet (CV) and currently threat Northern and Eastern part of Australia (Westaway et al., 2016). The weed is fast-growing species, tolerant to low soil fertility and shade, and widely grown in the ground of tree plantation (Adjorlolo et al., 2014; Kiew and Vollesen, 1997). The weed has been fed to livestock by the small-scale farmers in the humid regions of Asia and Africa (Bindelle et al., 2007; Bussmann et al., 2020).

Few studies have been conducted to evaluate the effects of CV feeding on ruminant performance and nutrient utilization (Adjorlolo et al., 2014; Bindelle et al., 2007; Merkel et al., 1999). Comparing to legumes *Paraserianthes falcataria*, *Gliricidia sepium*, and *Calliandra calothyrsus*, CV had higher dry matter (DM), neutral detergent fiber (NDF), and crude protein (CP) digestibility while a higher N urine of CV was related to NH_3 excess in the rumen due to a higher nitrate (NO_3) concentration in the weed (Merkel et al., 1999). The presence of NO_3 could be a benefit for lowering methane (CH_4) production and increasing N supply for microbial protein synthesis in the rumen. Nitrate is a hydrogen sink and has been reported to reduce CH_4 production in beef cattle fed low-quality forage (Callaghan et al., 2014; Hulshof et al., 2012). However, during the reduction of NO_3 to ammonia (NH_3), nitrite (NO_2) is formed. Because the reduction of NO_3 to NO_2 is generally faster than the reduction of NO_2 to NH_3, NO_2 can be accumulated in the rumen, and an excess of NO_2 results in methemoglobinemia (Callaghan et al., 2014; Ku-Vera et al., 2020).

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The higher digestibility indicates that the CV weed could be supplemented to a low-quality forage (Ali et al., 2019b; Aregheore, 2004). Furthermore, an energy source of the readily fermented carbohydrates from CC might improve the NO_3 and NH_3 utilization in the rumen (Hristov et al., 2005; Ku-Vera et al., 2020; Schwab et al., 2005) and so decrease urinary N loss when supplemented to a basal diet of the CV weed. Thus, an evaluation is needed to assess sustainable feeding strategies of the CV weed on the ruminant production of the smallholder farmers in the crop-livestock system. The objective of the study was to evaluate the effects of supplementing a low-quality forage with the CV weed and the basal CV weed diet with the CC supplementation on intake, nutrient utilization, and gain of Kacang goat.

2. Materials and methods

2.1. Animals and experimental design

The animals were cared for according to the Animal Welfare Guidelines of the Indonesian Institute of Sciences. Approval of the experiment was granted from the Faculty of Agriculture, Universitas Sriwijaya, Indonesia.

Twelve male local Kacang goats with live weight (LW) of 10 ± 1.4 kg and six to seven months old were used. The animals were housed in individual pens (1.5 m × 0.75 m) in an open-sided type of house. The animals were treated orally with Oxfendazole (Verm-O, 25 mg per 5 kg LW, Sanbe, Indonesia). The goats were gradually acclimated to the CV diet over 20 days to prevent nitrite toxicity. Before starting the experiment, the goats were stratified based on their LW and allocated to the four treatments. The experimental design was a crossover design which consisted of four diets tested in four periods (Appendix A). Each experimental period lasted for four weeks with three weeks of adaptation and followed by one week of sample collection where feed intake along with feces and urine excretion were measured.

2.2. Experimental feeds

The experimental diets used in the present study consisted of Guinea grass (*Panicum maximum*) *ad libitum* (GG), GG *ad libitum* and CV (1% live weight, LW) (GG + CV), CV *ad libitum* (CV), and CV *ad libitum* plus cassava chip (1% LW) (CV + CC) (DM basis). The composition of the GG, CV, and CC is shown in Table 1. The GG was obtained from existing pastures near the experimental unit. The grass was harvest at 55 to 60 days intervals (after the blooming stage) about 25 cm from the ground every afternoon. The CV weed was obtained from an abandoned rubber plantation in the Universitas Sriwijaya campus. The weed was harvest in the post-blooming stage, at 45 days intervals about 5 cm from the ground every afternoon. The forages were chopped into 5.0 to 10.0 cm particle size the next morning before offering to the animals. The unpeeled CC were made from cassava tubers by chopping the tubers to 0.5 to 1.0 cm pieces then sun-dried for 4 to 5 days depending on sunlight intensity. Cassava crop is a cash crop in sub-urban areas of Palembang city, the tubers for CC were unmarketable size tubers (2 to 3 cm in diameter) which are usually left on the field.

Table 1
Chemical composition of Guinea grass, Chinese violet weed, and unpeeled Cassava chip (g/kg dry matter) used in the study.

	Guinea grass	Chinese violet	Cassava chip
Dry matter (g/kg FM)	213 ± 15.6	168 ± 20.4	863 ± 3.5
Organic matter	901 ± 3.2	860 ± 8.3	984 ± 0.8
Crude protein	107 ± 3.9	160 ± 2.1	43 ± 1.3
Neutral detergent fiber	755 ± 26.0	510 ± 23.8	276 ± 24.9
Acid detergent fiber	371 ± 29.3	338 ± 14.0	61 ± 8.4
Nitrate	0.3 ± 0.02	11.0 ± 0.98	n.a

FM: fresh matter, n.a: not available.

After removing and weighing the refusals from the previous day, the feeds were offered to the animals in separate buckets according to the experimental treatments, making it possible to give the supplements at the same time as the basal feeds. The forages were offered 3 times at 9:00, 13:00, and 17:00 h, while CC was offered at 9:00 h. The basal diet was offered *ad libitum* (allowing for 20% of refusal, fresh matter basis), while the CV and CC supplementations were offered at 1% of LW and were adjusted after each measurement of animal LW. Drinking water and salt-mineral lick were offered for *ad libitum* intake to all animals throughout the experiment.

2.3. Data collection and laboratory analyses

Throughout the whole experimental trial, a digital platform weighing scale was used to record the LW every Sunday and Thursday before offering the feeds. Duplicate subsamples of feed offered were collected each day during the collection week. The daily refusal feeds during the collection week were weighed, sampled (~200 g fresh matter, FM) and then stored at −20 °C. Then, the daily orts were pooled per animal and then sampled (~100 g FM) in duplicate. The samples offered and refused feed and daily fecal excretion were dried at 45 °C for 4 days and reweighed for determination of dry weight.

During seven consecutive days of the collection week, a urine feces separator was fitted below the floor of each individual pen for daily total urine and feces collection. The separator was equipped with a plastic mesh that directed the dropped feces to a 5-L bucket while urine passed through the mesh. Total daily urine excretion was collected using 250 mL/L sulfuric acid to preserve the N. For N analysis concentration, sample of urine (~200 mL) was taken daily after homogenizing and filtering with surgical gaze then kept at −20 °C.

The daily excretions were quantified in the morning during the collection week. Before sampling (~100 g FM), the individual fecal excretion was homogenized and dried at 45 °C for 4 days, and then reweighed for dry weight determination. After drying, the feed and fecal samples were ground to pass a 1-mm mesh. The samples were pooled per animal at the end of each period proportionally to the daily amount. The dried samples were stored in zipper polythene bags prior to analyses.

The samples of feed and feces were analyzed for concentrations of DM, ash, N (AOAC, 1990), NDF, and ADF (Ankom200 fiber analyzer, Ankom Technology cooperation, Fairport, USA) with alpha-amylase and including residual ash (Van Soest et al., 1991). The concentration of OM was calculated by subtracting the ash concentration by 100 while the content of CP was calculated as N × 6.25. The micro Kjeldahl method (AOAC, 1990) was used to determine the N concentrations of urine. The NO_3 was extracted by the method of Liu et al. (2016) and the NO_3 content was measured using a UV–Vis spectrophotometer (Shimadzu 1800). Supply of metabolizable energy (ME, MJ/kg DM) was estimated as 0.0157 × digestible OM (g/kg DM) (AFRC, 1993).

2.4. Statistical analysis

Analysis of variance was performed using the mixed procedure (*lme* function) after confirming the normality of residual data by the Kolmogorov–Smirnov test (R Core Team, 2018). A mixed model with diets and period as fixed effects and animal as a random effect was used. To compare differences among means the Tukey *post hoc* test was applied. The significance was determined at $P < 0.05$.

3. Results

3.1. Feed intake and apparent digestibility of nutrients

The offered CV weed had lower NDF and ADF concentrations and higher CP and NO_3 content than GG, whereas CC had the lowest NDF, ADF, and CP contents (Table 1). Intake of GG was higher for goats on the basal GG diet than goats who received supplements (GG + CV), whereas supplement intake was higher for goats offered GG + CV than those fed CV + CC ($P < 0.001$). The goats on CV and CV + CC had higher total DM and ME intake than those fed GG and GG + CV ($P < 0.001$). The goats on the CV diet had the highest CP intake ($P < 0.001$) followed by those observed on CV + CC, GG + CV, and GG diets. The highest ADF intake was observed in the CC diet and followed by CC + CV, GG + CC, and GG diets, while NDF intake was not significantly different among the dietary treatments. The DM digestibility in the goats fed CV diet was similar to the goats on GG + CV diet but higher than those fed GG diet, whereas the goats on CV + CC diet had the highest DM digestibility ($P < 0.001$). The goats fed CV + CC diet also had the highest OM digestibility ($P < 0.001$) with no difference among the other treatments. Digestibility of CP was the highest in the goats on the CV + CC diet ($P < 0.001$), which was similar to the value on the CV diet. The goats offered GG had the highest NDF digestibility ($P < 0.001$), while the ADF digestibility was not significantly different among diets. The goats on CV + CC diets had similar NDF digestibility with the goats on GG + CV and CV alone diet.

3.2. Nitrogen balance and growth performance

Nitrogen intake was the highest for the goats fed CV alone ($P < 0.001$) whereas the goats fed GG had the lowest N intake (Table 3). The N intake in the goats on GG + CV diet was similar to the goats on GG diet. Daily fecal N excretion was the highest for the goats on CV diet ($P < 0.001$), with no difference among the other treatments. Absorbed N and urinary N were also the highest for goats fed CV diet. The goats on CV + CC diet had similar absorbed N but lower urinary N than the goats fed CV diet solely. The goats on GG diet had the lowest N intake and total excreted N and the highest ratio of fecal and urinary N ($P < 0.001$). The goats on GG diet had the lowest N retention, which was not significantly different from the goats on GG + CV diet whereas the higher N retention was found in goats receiving CV and CV + CC diets ($P < 0.001$). Live weight gain and feed conversion efficiency were higher for the goats on diets of CV and CV + CC than those fed GG and GG + CV ($P < 0.001$).

Eight goats on the GG and GG + CV diets experienced losses of LW during the adaptation and collection weeks (Fig. 1). Regression analysis showed that LW gain significantly correlated ($P < 0.001$) with DM intake (R^2: 0.63) and ME intake (R^2: 0.54). The regression resulted in a daily ME requirement of 536 $KJ/kg^{0.75}$ LW for maintenance and 49.7 $KJ/kg^{0.75}$ LW for gain.

4. Discussion

4.1. Feed intake and apparent digestibility of nutrients

The NDF concentration of the CV weed in the present study was higher, while CP concentration was within the range of the previous studies (Adjorlolo et al., 2014; Bindelle et al., 2007; Merkel et al., 1999). The differences might depend on the plant age or the ratio of leaf and stem (Kumalasari et al., 2020). The NO_3 concentration in the present study was lower than the range of NO_3 concentrations in the CV weed (22–98 g/kg) in Merkel et al. (1999) and have to offer less than 50% of a ration (DM basis) (Rasby et al., 2014). The high level of NO_3 in the weed would be expected to restrict the intake of the goats. However, a higher intake was found in the CV weed alone and CV + CC diets without the negative effect of the NO_2 toxicity. This could be related to the acclimation of the population of rumen microbes to the higher NO_3 in the weed (Latham et al., 2016; Zhou et al., 2011).

The higher CP and the lower NDF concentration in the CV weed supplemented diet could not improve the nutrients intake and digestibility as the intake of the basal GG had 118 g CP/kg DM. Ali et al. (2019b) reported similar basal and supplement intake for heifers fed mixed Rhodes grass hay and wheat straw (7.1% CP and 73% NDF) with sweet potato vine silage supplementation. Piñeiro-Vázquez et al. (2017) also found the similar evidence for heifers on *Pennisetum purpureum* (7.1% CP and 66% NDF) with *Leucaena leucocephala* supplementation. However, when the basal diet had a lower CP concentration, a higher DM intake and digestibility was reported in goats fed *Ischaemum aristatum* (6.8% CP and 40% NDF) with sweet potato vine supplementation (Aregheore, 2004) as well as in steer fed wheat straw (2% CP and 81% NDF) with *Calliandra calothyrsus* supplementation (Korir et al., 2016).

Though the DM digestibility was the lowest in the basal GG diet, the highest NDF digestibility on the basal GG diet might be attributed to the lowest DM intake of the diet. A lowered DM intake could be attributed to the escalated nutrient digestibility in the rumen as a result of a longer retention time in the rumen. A study of Ali et al. (2019a) on steers fed four levels of intake observed a higher NDF and ADF digestibility at a lower intake level. An increase of NDF digestibility, as well as an increase of ruminating time per DM intake when the level of intake was lowered, was also reported in the study of Schulze et al. (2014) on heifers fed four

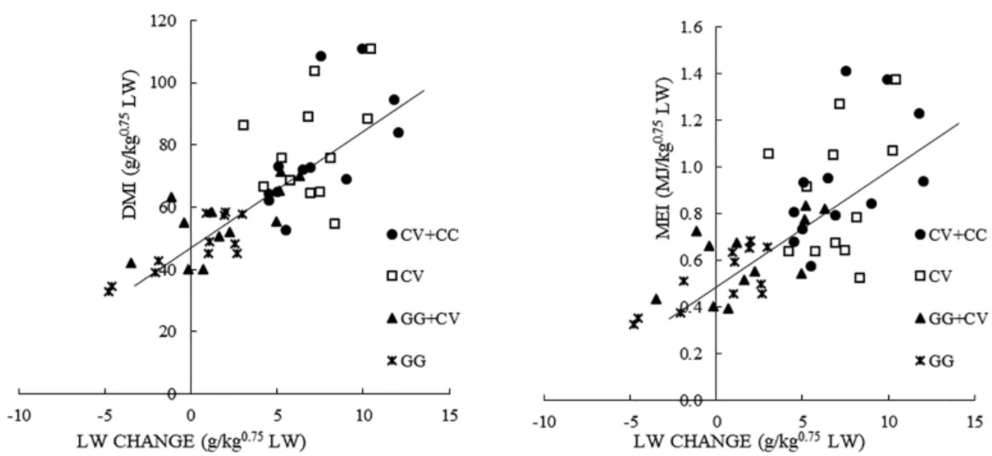

Fig. 1. Relationship between dry matter intake (DMI, left) and metabolizable energy intake (MEI, right) on live weight (LW) change in Kacang goats fed Guinea grass *ad libitum* (GG), GG *ad libitum* and Chinese violet weed (1% live weight, LW) (GG + CV), CV *ad libitum*, and CV *ad libitum* and unpeeled cassava chips (1% LW) (CV + CC). DMI = 3.81 LW change +49.23 (n: 48, R^2: 0.63, $P < 0.001$); MEI = 0.049 LW change +0.536 (n: 48, R^2: 0.54, $P < 0.001$).

levels of grass-clover silage. The lower NDF digestibility when the goat consumed CV weed might be also related to the higher NO_3 concentration in the weed. The higher NO_3 concentration in the feed was reported to reduce the cellulolytic microbial population in the rumen (Latham et al., 2016; Zhou et al., 2011).

The higher DM and OM digestibility in goats fed the CV weed and the cassava supplementation could be explained by the increased supply of both N and the readily available carbohydrates for the rumen fermentation. An improvement of DM and OM digestibility along with a higher N retention and LW gain of goats fed a mix of Gamba grass (*Andropogon gayanus*) and Cassava hay by cassava supplementation was also reported by a previous study (Phengvichith and Ledin, 2007).

4.2. Nitrogen balance and growth performance

Comparing to the basal GG diet, N intake and absorption were higher in the goats fed CV weed (Table 3). Urinary N excretion was also elevated, which might reflect an excess of NH_3 production in the rumen. A higher concentration of NO_3 in the CV weed was also reported (Merkel et al., 1999), which could be degraded to the NH_3 in the rumen. The excess of NH_3 is absorbed in the bloodstream, converted to urea in the liver, and then excreted in the urine (Schwab et al., 2005).

The additional fermentable carbohydrate of CC would have utilized the excess of the rumen-degradable N of the CV weed by microbial uptake in the rumen. This is suggested by the similar value of the absorbed N but the lower N intake in the CV + CC diet (Table 3). Though the present work did not estimate microbial protein supply, the similar absorbed N and lowered urinary N excretion by the CC supplementation could be attributed to an improvement of the microbial protein supply to the host animal (Hristov et al., 2005; Ku-Vera et al., 2020; Schwab et al., 2005). However, in the present study, the improvement did not result in a significantly higher N retention and LW gain of the goats fed the cassava supplementation diet.

The present study demonstrated that feeding the CV weed either as a supplement to the basal diet of low-quality tropical grass or as a sole diet could result in a higher urinary N excretion which potentially increases N_2O emission in the livestock sector. The supplementation of the locally available non-structural carbohydrate, which is affordable for small-scale farmers, improved the nutrients utilization of the CV weed as well as a reduction of N_2O and CH_4 emissions.

Improved growth performance has been well known when ruminants were fed a degradable protein source in the form of forage legumes (Korir et al., 2016; Piñeiro-Vázquez et al., 2017) and leafy crop residue (Aregheore, 2004; Phengvichith and Ledin, 2007). In the present study, feeding of CV weed resulted in an improved gain of Kacang goats. The supplementation with the energy source of CC, however, could not result in a significantly higher LW gain which is related to the similar daily ME intake (Table 2) and digestible CP of the diets (Table 3). Moreover, the goats had the capacity to grow more than 48 g/day when they were fed CV + CC diets.

The averaged LW gain and FCE of the goats on the CV weed and cassava supplementation diets were in the range of gain and FCE (23.5 to 69.4 g/d and 0.04 to 0.11 for LW gain and FCE, respectively) for fifteen growing male Kacang goats fed three diets with three different CP and energy contents (Restitrisnani et al., 2013). The gain was also in the range of Adiwinarti et al. (2019) for growing male Kacang goats with soybean meal supplementations (41.5 to 79.9 g/d). The LW loss of the goats on the basal diet of GG and GG + CV diets reflected an insufficiency of energy intake for their maintenance requirement, which is estimated to be 536 $KJ/kg^{0.75}LW$. The value of ME requirement is lower than an averaged value for goat and sheep (542 $KJ/kg^{0.75}LW$) in the warm climate (Salah et al., 2014) but higher than a value obtained in the study of Luo et al. (2004) for growing indigenous goat (489 $KJ/kg^{0.75}LW$) while the value for gain is higher than values on their studies (24.3 and 19.8 $KJ/kg^{0.75}LW$).

Table 2
Intake and digestibility of nutrients in Kacang goats.

Parameter	GG	GG + CV	CV	CV + CC	SEM	*P*-value
Basal diet intake						
g/d	313.0^b	220.2^a	533.6^c	398.8^b	23.64	<0.001
% LW	2.5^b	1.8^a	4.2^d	3.2^c	0.16	<0.001
Supplement intake						
g/d	n.a	148.6^b	n.a	119.7^a	5.85	<0.001
% LW	n.a	1.2^b	n.a	1.0^a	0.03	<0.001
Nutrients intake (g/d)						
DM	313.0^a	368.8^a	533.6^b	518.6^b	22.89	<0.001
OM	282.0^a	326.7^a	459.6^b	460.0^b	20.04	<0.001
CP	37.4^a	50.4^a	87.6^c	70.7^b	3.97	<0.001
NDF	233.8	240.2	263.7	229.1	12.40	0.4483
ADF	113.2^a	128.0^a	173.9^b	137.6^{ab}	8.23	0.0022
ME (MJ/d)	3.4^a	4.1^a	6.0^b	6.3^b	0.31	<0.001
ME ($MJ/kg^{0.75}$ LW)	0.52^a	0.61^a	0.89^b	0.94^b	0.040	<0.001
Digestibility (g/kg)						
DM	675^a	694^{ab}	717^b	771^c	10.0	<0.001
OM	690^a	697^a	701^a	767^b	9.9	<0.001
CP	556^a	652^b	715^c	726^c	15.4	<0.001
NDF	643^c	615^{bc}	521^a	561^{ab}	19.5	<0.001
ADF	540	532	528	524	26.8	0.953

GG: Guinea grass *ad libitum*, CV: Chinese violet weed *ad libitum*, GG + CV: GG *ad libitum* and CV weed (1% live weight, LW), CV + CC: CV *ad libitum* and unpeeled cassava chips (1% LW).
n.a: not available, DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ME: metabolizable energy was estimated as 0.157 × digestible OM (g/kg DM) (AFRC, 1993).
Values in the same row with different letters represent significant differences ($P < 0.05$).

5. Conclusions

The CV weed could be fed as a supplement to a poor-quality forage or fed solely without any negative effects. Feed intake, nutrient utilization, and gain can be improved when the weed is offered. The supplementation of cassava chips as a source of readily fermented carbohydrates to the weed has the potential to effectively improve nutrients utilization and benefits for lowering urinary N loss. A further study is needed to evaluate the effects of the weed on CH_4 production and rumen fermentation characteristic.

Declaration of competing interest

All the authors have no conflict of interest to declare.

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Table 3
Nitrogen (N) balance, total gain, and feed conversion efficiency (FCE) in Kacang goats.

Parameter	GG	GG + CV	CV	CV + CC	SEM	*P*-value
N balance (g/d)						
N intake	6.0^a	8.1^a	14.0^c	11.3^b	0.64	<0.001
Fecal N	2.5^a	2.7^a	3.9^b	3.0^a	0.14	<0.001
Absorbed N	3.5^a	5.3^b	10.1^c	8.3^c	0.54	<0.001
Urinary N	2.0^a	3.2^b	5.7^c	3.7^b	0.29	<0.001
Fecal N urinary N ratio	1.39^b	0.91^a	0.78^a	0.80^a	0.058	<0.001
N retention	1.5^a	2.1^a	4.4^b	4.6^b	0.35	<0.001
Total gain (g)	51.2^a	355.0^a	1227.5^b	1251.9^b	105.05	<0.001
FCE	−0.01^a	0.03^a	0.09^b	0.09^b	0.009	<0.001

GG: Guinea grass *ad libitum*, CV: Chinese violet weed *ad libitum*, GG + CV: GG *ad libitum* and CV weed (1% live weight, LW), CV + CC: CV *ad libitum* and unpeeled cassava chips (1% LW).
FCE: g LW gain/g dry matter intake.
Values in the same row with different letters represent significant differences ($P < 0.05$).

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Appendix A

Allocation of the twelve Kacang goats (Group A (4, 8, 11), B (5, 10, 12), C (6, 7, 9) and D (1, 2, 3)) to Guinea grass (GG), GG and Chinese violet weed (GG + CV), CV, and CV plus unpeeled cassava chips (CV + CC) dietary treatments during 4 experimental periods.

Period	Animal group			
	A	B	C	D
1	GG	GG + CV	CV	CV + CC
2	CV + CC	GG	GG + CV	CV
3	GG + CV	CV	CV + CC	GG
4	CV	CV + CC	GG	GG + CV

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