PJN
ISSN 1680-5194

# PAKISTAN JOURNAL OF NUTRITION

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OPEN ACCESS Pakistan Journal of Nutrition

ISSN 1680-5194
DOI: 10.3923/pjn.2017.435.443

# Research Article
# Substitution of Concentrate by Ramie (*Boehmeria nivea*) Leaves Hay or Silage on Digestibility of Jawarandu Goat Ration

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## Abstract

**Background:** The lower farmer profit margins that hinder ramie fiber plantation expansion can be overcome by utilizing the 82% of underutilized ramie plantation byproducts as ruminant feedstuffs. Although fresh ramie leaves are highly palatable for livestock, their availability is seasonal; therefore, the forage should be conserved. **Objective:** The aim of this study was to compare the capacity of silage and hay to conserved ramie biomass as a substitute for Jawarandu goat rations. **Methodology:** Three levels of treatments were tested, namely, a control ration (R1), a ration with 10% ramie silage (2) and a ration with 10% ramie hay (R3). Each treatment was repeated three times. Nine female Jawarandu goats with 27±4.68 kg initial body weight were used in this experiment. Feeds and nutrients offered, refused and excreted were measured to calculate feed and nutrient intake and digestibility. **Results:** The results showed that substitution of the concentrate with ramie leaves in the form of silage led to lower intake of feed and nutrients (Crude Protein (CP) and Nitrogen Free Extract (NFE)) and digestibility (dry matter (DMD), organic matter (OMD) and DCP). Substitution with ramie in the form of hay, however, increased digested feed and nutrient intakes. Although the ration contained ramie hay had a lower digestibility in comparison to the control ration, this could be recovered by the increased intake. **Conclusion:** Ramie leaves in the form of hay can be used to substitute 20% of the concentrate in Jawarandu goat rations or be included in 10% of total rations without any problem in availability of digested nutrients for the goat.

Key words: *Boehmeria nivea*, concentrate substitute, ramie hay, ramie silage, Jawarandu goat

Received: April 06, 2017 Accepted: May 03, 2017 Published: May 15, 2017

Citation: Despal, Mubarok, M. Ridla, I.G. Permana and T. Toharmat, 2017. Substitution of concentrate by ramie (*Boehmeria nivea*) leaves hay or silage on digestibility of jawarandu goat ration. Pak. J. Nutr., 16: 435-443.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

The development of the textile industry in Indonesia cannot be supported by the availability of cotton as raw material for the industry. Indonesia produces only 0.3% of its total domestic cotton demand; the rest is imported from temperate countries[1]. This production is projected to decline in the future due to high production costs, agronomic risks (excessive rainfall or extreme drought) and lower profit margins[1]. Substitute fibers should be obtained for sustaining the supply of raw materials to the textile industry in Indonesia. Ramie is the second most important fiber in world trade and it is a tropical plant[2]. Ramie, known as "China grass" is a perennial herbaceous plant of the *Boehmeria* genus[3] under the Urticaceae family, order Urticales and class Magnoliopsida. It is native to China, Japan and the Malay Peninsula, where it has long been used as a textile fiber[2,4,5]. Over 100 species of the *Boehmeria* genus have been identified[2], including *Urtica nivea*, (*Boehmeria nivea*), *Urtica caracasana* (Tahiti), *Urtica crenulata* (India), *Urtica heterophylla* (*Girardinia heterophylla*) (Eastern part of India), *Urtica argentea* (North America, Mexico, Cuba) and *Urtica Japonica* (Sunda Island). However, *Boehmeria nivea* or ramie is the most developed species in China and Southeast Asia[6]. Ramie is a shrub that can be found up to 2 m high, with a habitat of open forest and disturbed vegetation at 600-1200 m altitude[5].

The progression of ramie plantation establishment in Indonesia has been very slow due to low profit margin. Although ramie plants can persist for 13 years and produces 8.70 Mg ha$^{-1}$ year$^{-1}$ of dry stem yield and 2.46 Mg ha$^{-1}$ year$^{-1}$ of dry bast fiber[4], only 18% of the biomass is used in the textile industry[2]. The remaining 82% of the biomass material, composed of 62% stems and 38% leaves and cymes[4], could be used as animal feedstuff to produce income for farmers.

According to Broom[7], ramie (*Boehmeria nivea*) leaves are one of the tropical and sub-tropical shrubs that are eaten by sheep, goats and cattle. The biomass is a good source of nutrition and palatable to all classes of domestic livestock. It is suitable not only for ruminants but also for pig and poultry feeding[2]. Valdivie and de Leon[8] reported that ramie was a high quality forage used to supplement White Semi-Giant and Chinchilla rabbit rations to produce 2.0 and 2.2 kg b.wt., within 91 days. Ramie hay has also been used in sheep rations to supplement natural grass[9] or as a substitute concentrate[10] to improve sheep body weight gain and reduce feed costs.

Ramie leaves are rich in protein, minerals, lysine and carotene contents but low in fiber. Its biomass production can reach up to 300 t of fresh material (or 42 t dry matter) per hectare per year if it is grown for fodder. Ramie biomass left after harvesting fiber for industrial use can reach up to 24 t DM ha$^{-1}$, as reported by Kipriotis *et al*.[2]. According to Conto *et al*.[11], the Crude Protein (CP) content of ramie leaves is 17%, but Kipriotis *et al*.[2] and Miranda *et al*.[12] reported higher CP contents of ramie leaves (22 and 26%, respectively). Its nutritive value has been described as being similar to that of Lucerne[2].

The ramie biomass left after harvesting fiber for industrial use cannot be used in daily rations unless it is conserved. Hay and silage are the most frequent preservation techniques used for forage. These techniques conserve forage by preventing enzyme activities and provide microorganisms with a fertile environment through drying or acidification[13]. The utilization of ramie hay to supplement natural grass-based rations has been successfully reported by Despal[9] to avoid body weight loss in sheep; however, Conto *et al*.[11] reported that ramie is at best medium-quality hay; its nutritional value results are poor (low digestibility and energy value) and animals like it only as fresh feed.

Despal *et al*.[14] and Susanti *et al*.[15] have attempted to ensile ramie leaves to increase ramie palatability. Ensilage is an acidifying technique for forage. Acid is produced by the introduction of spontaneous lactic acid bacteria that convert sugar into lactate[16]. However, most tropical forage is not suitable for silage conservation due to its lower water-soluble carbohydrate content[17]. Despal *et al*.[14] successfully improved the quality of ramie silage by adding 20% w/w fresh cassava meal, pollard, fine grinding corn, rice bran and cassava extract meal as a WSC source and an absorbance agent.

Goats are one of the most adaptable, productive and popular domesticated animals in the tropical islands, especially among local farmers. They provide numerous advantages for improving farmland quality; they thrive on various landscapes, have smaller hoof prints, are agile and excrete manure that can be used as fertilizer. Goats eat efficiently because they have selective feeding habits; they eat plants that challenge other animals, browse overgrown and invasive plants and clean up underutilized species. Goats supply a family with nutritious food such as milk and meat[18]. One of the popular local breeds of goat is the Jawarandu[19]. These goats are dual-purpose animals (milk and meat) that can be kept on a ramie plantation to improve ramie farmer profit margins and improve ramie plantation conditions. These goats can utilize ramie leaves as a substitute for expensive concentrate feeds.

The objective of this study was to compare the ability of ramie leaves, in the form of silage or hay, as a substitute concentrate in Jawarandu goat rations, on feed and nutrient intakes as well as digestibility.

## MATERIALS AND METHODS

**Experimental site:** The experiment was conducted at the Dairy Nutrition Field Laboratory, Department of Animal Nutrition and Feed Technology, Faculty of Animal Science, Bogor Agricultural University. It is located 8.81 km North-west of Bogor city center, Indonesia at 6°33'S latitude, 106°43'32.31"E longitude and 180 m altitude. The site is characterized by hot-humid tropic climate with 26°C average annual air temperature (maximum 30.4 and minimum 21.8°C), 70% relative humidity and 3500-4000 mm annual rainfall.

**Ramie hay and silage production and treatment diets:** Ramie plants were harvested at 60 days[20]. The leaves and tops were chopped to 2 cm pieces using a locally produced chopper machine that was equipped with a 5 HP Honda motor. Ramie hay was made by open sun drying with 21 h of light intensity[21]. The hay was milled using a locally made bur mill that was powered by a 5 HP Honda Motor and sieved to pass a 1 mm screen before it was mixed with other concentrate ingredients. Ramie silage was made in 200 L blue plastic polypropylene drum container silos (made in Shandong-China) with the addition of 20% (w/w fresh) cassava waste as a Water Soluble Carbohydrate (WSC) source and absorbent. Then, the silo was kept anaerobically for 5 weeks. The natural grass used in this experiment was cut daily and offered fresh to the goat. A week of composite samples was made after the seventh day that daily samples were collected. Other ingredients were purchased in the form of dried concentrate from a local poultry shop. The nutrient contents of ingredients used in this experiment are shown in Table 1.

Three type of diets as treatments were formulated to fulfill the requirements of nine female Jawarandu goats with an initial body weight of 27±4.68 kg and 100 g daily gain. The rations were a control ration (R1), a ration containing ramie silage (R2) and a ration containing ramie hay (R3). The composition of each ration and their nutrient contents are shown in Table 2.

The amount of DM feeds offered was 3% b.wt. The nutrients offered were calculated to fulfill the nutrient requirement of the goats[22]. Control feed offered to the goats consisted of 50% forage and 50% concentrate. The ramie leaves were offered to replace 20% of the conventional concentrate or 10% of the total ration.

**Experimental animals:** Nine 1.5 years-old female non-lactating Jawarandu goats with an initial body weight of 27±4.68 kg were grouped into three based on their initial body weight. Within each group, the treatments were assigned randomly (block randomized design). The goats were kept in individual metabolic cages (locally made) equipped with a feeding bucket and drinking water bowl to allow individual feeding and collecting of feces. Before the experiment, the cages were disinfected and the goats were dosed with an anti-parasite albendazole (produced by PT Kimia Farma, Indonesia) 5 mg $kg^{-1}$ b.wt., orally.

Initial body weight was recorded to calculate the amount of feed offered. Each goat received 3% b.wt., DM ration daily, which was distributed into two feeding frequencies. Water was served *ad libitum*. Each goat was fed the treatment diet at 7 am and 2 pm for 14 days during the preliminary phase and 7 days during the collecting period. During the phase, no data were collected. During the collecting period, the amount of feed offered, feed refused and feces excreted were measured and sampled. Measurement was conducted using an analytical balance (OHAUS Pioneer Model PA 214C (210 g capacity, 0.1 mg readability) and PA2201 analytical balances (2200 g capacity, 100 mg readability), China). Two kilograms

Table 1: Feedstuffs used and their nutrient contents

| Ingredients | DM (%) | Ash (% DM) | CP (% DM) | Fat (% DM) | CF (% DM) | NFE (% DM) |
|---|---|---|---|---|---|---|
| Natural grass | 23.9 | 7.93 | 6.64 | 6.98 | 30.94 | 47.51 |
| Cassava waste | 79.8 | 2.40 | 1.87 | 0.32 | 8.90 | 86.51 |
| Corn meal | 86.8 | 2.15 | 10.8 | 4.28 | 2.53 | 80.24 |
| Coconut oil meal | 88.6 | 8.24 | 21.3 | 10.9 | 14.2 | 45.36 |
| Soybean oil meal | 89.5 | 8.16 | 46.9 | 2.66 | 5.90 | 36.38 |
| Ramie leaves | 13 | 19.34 | 21.31 | 3.51 | 43.44 | 12.40 |
| DCP | 100 | 100 | 0 | 0 | 0 | 0 |
| $CaCO_3$ | 100 | 100 | 0 | 0 | 0 | 0 |

DM: Dry matter, CP: Crude protein, CF: Crude fiber, NFE: Nitrogen free extract, DCP: Digestible crude protein, $CaCO_3$: Calcium carbonate, DM: Dry matter

Table 2: Ration composition and nutrient contents

| | Composition (%) | | |
|---|---|---|---|
| Ingredients | R1 | R2 | R3 |
| Natural grass | 50.00 | 50.00 | 50.00 |
| Cassava waste | 15.00 | 6.82 | 15.00 |
| Corn meal | 7.07 | 5.05 | 5.05 |
| Coconut oil meal | 15.73 | 11.23 | 11.23 |
| Soybean oil meal | 10.49 | 7.49 | 7.49 |
| DCP | 1.24 | 0.88 | 0.88 |
| $CaCO_3$ | 0.47 | 0.36 | 0.36 |
| Ramie hay | 0.00 | 0.00 | 10.00 |
| Ramie silage | 0.00 | 18.18 | 0.00 |
| **Nutrient contents** | | | |
| DM | 55.09 | 44.53 | 47.50 |
| Ash | 8.34 | 9.30 | 9.14 |
| CP | 12.63 | 11.95 | 12.18 |
| Fat | 5.83 | 6.38 | 5.53 |
| CF | 19.84 | 21.15 | 23.31 |
| NFE | 53.36 | 51.24 | 49.84 |

DCP: Digestible crude protein, $CaCO_3$: Calcium carbonate, DM: Dry matter, CP: Crude protein, CF: Crude fiber, NFE: Nitrogen free extract

of natural grass samples were collected daily and composited. Other ingredients used were sampled once. Ten percent of feed refusal and feces collected were sampled daily, dried and composited at the end of the collecting period. Feed offered, feed refused and feces samples were dried in an oven at 60°C (Swallow Lte. Scientific Ltd Serial No. K11755, England) for 48 h before grinding to pass a 1 mm screen and stored before being analyzed for their proximate composition.

**Chemical composition analysis:** Proximate compositions were determined according to the Association of Official Analytical Chemists[23] to measure and calculate Dry Matter (DM), Organic Matter (OM), ash, Crude Protein (CP), crude lipid (XL), Crude Fiber (CF) and Nitrogen Free Extract (NFE) of the feed offered, feed refused and feces. Feed and nutrient intake were calculated by subtracting the amount of feed and nutrient refusals from feed and nutrient offered, while digestibility was calculated by subtracting feces from intake.

**Experimental design and statistical analysis:** The experiment used a block-randomized design with 3 types of rations as treatments and 3 replications as a block. The blocks were made according to the initial goat body weight. The mathematical model of the design was:

$$Y_{ij} = m + a_i + b_j + e_{ij}$$

where, $Y_{ij}$ is the observation value at treatment-i and block-j, m is the overall mean, $a_i$ is the effect of ration-i, $b_j$ is the effect of block-j and $e_{ij}$ is the error of treatment-i and block-j. The different response to the treatments with probability ($p<0.05$) were tested using the analysis of variance and further by orthogonal contrast using the statistical package software SPSS version 20 from the IBM corporation[24].

## RESULTS

**Feed offers, refusal and intake:** The amount of feed and nutrients offered, refused and intake are shown in Table 3. The amount of feeds and nutrient offered were varied according to the goat body weight, but there were no statistical differences between treatments. The amount of feed and nutrient refusals also varied between the animals but were not significantly different between the treatments. In all nutrients, the percentage refusal in R2 tended to be higher than R1 and R3 except for the percentage of crude lipid (XL) refused by the sheep, which was higher in R1 compared to R2 and R3.

Feed and nutrient intakes were not significantly influenced by the treatments, although R2 tended to be lower than R1 and R3. The quality of the ration consumed by goats offered with R2 was also lower than R1 and R3, which was expressed by lower CP and NFE but higher ash and XL contents.

**Feces, digested and digestibility of ration and nutrients:** The amounts of feces excreted by the goats are shown in Table 4. The amount of DM and nutrient feces were not significantly different between the treatments except for minerals, which showed that the ration contained ramie hay was higher that other rations. The amount of digested DM, OM and other nutrients were also not significantly different between the treatments. The amount of protein digested was lower for the ration containing ramie silage (R2) and XL, which showed an opposite pattern. Digestible DM, OM, total nutrient, ash, CF and NFE were not significantly different among the treatments. Crude protein digestibility was lower for R2 in comparison to R1 and R3, while XL was lower for R1 in comparison to the ration containing ramie leaves.

## DISCUSSION

The variation of feeds and nutrients offered in this experiment are due to the different body weights of the goats used. Since ramie leaves were harvested from late mature plants, it contained high fiber fractions[25], which led

Table 3: Feed offers, refusal and intake

| | Treatments | | |
|---|---|---|---|
| Parameters | R1 | R2 | R3 |
| **Feed and nutrient offers (g)** | | | |
| DM | 796.98±72.08 | 754.21±41.29 | 867.95±220.82 |
| Ash | 68.03±8.26 | 71.71±3.93 | 79.42±20.21 |
| CP | 99.41±6.93 | 78.97±4.32 | 106.94±27.21 |
| XL | 47.27±5.47 | 56.98±3.12 | 47.91±12.19 |
| CF | 158.49±16.25 | 160.33±8.78 | 174.86±44.49 |
| NFE | 423.79±35.85 | 386.22±21.14 | 458.83±116.74 |
| **Feed and nutrient refusal (g)** | | | |
| DM | 78.25±7.16 | 113.96±73.06 | 83.86±8.36 |
| Ash | 8.42±0.75 | 12.28±7.59 | 9.37±0.88 |
| CP | 6.69±0.41 | 10.48±6.80 | 6.53±2.40 |
| XL | 5.96±1.48 | 3.43±1.78 | 2.57±0.71 |
| CF | 24.05±2.29 | 35.66±23.71 | 23.67±2.57 |
| NFE | 33.19±2.30 | 52.11±33.64 | 40.86±5.42 |
| **Refusal (%)** | | | |
| DM | 9.99±1.53 | 15.47±10.40 | 10.20±3.17 |
| Ash | 12.72±2.06 | 17.53±11.35 | 12.39±3.51 |
| CP | 6.72±0.78 | 13.58±9.25 | 7.33±2.53 |
| XL | 13.25±3.70[b] | 6.13±3.33[a] | 5.76±2.69[a] |
| CF | 15.54±2.72 | 22.79±15.85 | 14.18±4.24 |
| NFE | 7.92±0.98 | 13.82±9.35 | 9.43±3.10 |
| **Consumption/intake** | | | |
| DM (g) | 718.73±77.46 | 640.26±113.17 | 784.09±229.14 |
| OM (g) | 659.13±68.84 | 580.83±101.73 | 714.04±208.30 |
| Ash (g) | 59.61±8.81 | 59.43±11.48 | 70.05±20.85 |
| CP (g) | 92.79±7.14 | 68.50±10.97 | 99.54±28.13 |
| XL (g) | 41.31±6.77 | 53.55±4.83 | 45.34±12.76 |
| CF (g) | 134.44±18.42 | 124.67±32.13 | 151.20±45.61 |
| NFE (g) | 390.59±37.08 | 334.11±54.08 | 417.96±121.88 |
| DM (% b.wt.) | 2.64±0.03 | 2.56±0.32 | 2.65±0.09 |
| Ash (%) | 8.25±0.34[a] | 9.27±0.19[b] | 8.93±0.11[b] |
| CP (%) | 12.95±0.48[b] | 10.72±0.17[a] | 12.72±0.12[b] |
| XL (%) | 5.73±0.35[a] | 8.46±0.85[b] | 5.79±0.08[a] |
| CF (%) | 18.64±0.53 | 19.28±1.65 | 19.25±0.39 |
| NFE (%) | 54.43±0.72[c] | 52.27±0.77[a] | 53.32±0.34[b] |

DM: Dry matter, OM: Organic matter, CP: Crude protein, XL: Crude lipid, CF: Crude fiber, NFE: Nitrogen free extract, [a-c] Values with different superscripts are significantly different ($p<0.05$)

to more CF offered in the ration containing ramie leaves[11]. The low amount of DM and CP offered in R2 was partly due to loss of DM and CP during the ensiling process[16]. According to Madison[13], some alteration might have occurred during the preservation process. Despal *et al.*[14] found losses of DM and CP during the ensiling of ramie leaves with 20% (w/w DM) added cassava extract meal of 6.11 and 16.97%, respectively. A decrease in ramie leaf content during the ensiling process was also found by Susanti *et al.*[15].

In comparison, the ash content was higher in rations containing ramie leaves (R2 and R3), which was caused by the high amount of ash in ramie leaves[2,11,26]. Calcium was the major component of the ash, which reached up to 4% in ramie leaves[2,11]. The high Ca in ramie leaves could be used to fulfill the high Ca requirement of the dual-purpose Jawarandu goat. Despal[9] reported that there was no increase of Ca in the blood of sheep consuming a ration consisting of 25% ramie leaves in comparison to a control, which showed that the Ca was stored in bone, used in target organs or secreted in milk[27].

High variations of feed and nutrient refusals were caused by the different amounts of feed offered. Comparing feed refusal to the feed offered, it was found that the rations containing ramie hay (R3) were as good as the control ration (R1). This finding was supported by Kipriotis *et al.*[2] who reported that ramie leaves were palatable forages. Despal[9] also reported a high palatability of ramie leaves in sheep, although Ramirez-Torres *et al.*[20] found the palatability was not as high as tropical grasses or alfalfa. The amount of feed and nutrient refused by the goats tended to be higher in goats fed R2 than R1 and R3. This might be caused by the low palatability of ramie silage. Although Despal *et al.*[14]

Table 4: Feces, digested material and digestibility ration

| Parameters | R1 | R2 | R3 |
|---|---|---|---|
| **Feces (g)** | | | |
| DM | 248.07±29.92 | 245.35±19.90 | 306.30±72.12 |
| OM | 194.94±22.29 | 199.56±16.81 | 231.28±54.05 |
| Ash | 53.12±7.66[a] | 45.79±3.10[a] | 75.03±18.31[b] |
| CP | 31.83±7.40 | 36.45±2.66 | 45.12±11.29 |
| XL | 8.05±0.67 | 6.92±1.03 | 5.94±0.55 |
| CF | 52.25±6.67 | 46.34±8.05 | 50.43±12.47 |
| NFE | 102.81±11.61 | 109.84±11.03 | 129.79±30.91 |
| **Digested feed and nutrients (g)** | | | |
| DM | 470.67±48.59 | 394.91±132.85 | 477.79±157.02 |
| OM | 464.18±47.27 | 381.27±118.36 | 482.77±154.30 |
| TDN | 467.32±31.89 | 439.55±125.29 | 532.02±169.55 |
| Ash | 6.48±2.95 | 13.64±14.52 | -4.98±3.40 |
| CP | 60.96±0.94[b] | 32.04±10.23[a] | 54.42±17.05[b] |
| XL | 33.26±7.34[a] | 46.62±5.86[b] | 39.40±12.21[a] |
| CF | 82.19±16.53 | 78.33±40.04 | 100.77±33.87 |
| NFE | 287.78±26.03 | 224.27±63.15 | 288.17±92.11 |
| **Digestibility (%)** | | | |
| DMD | 65.61±1.01 | 60.52±9.98 | 60.54±2.07 |
| DOM | 70.49±0.78 | 64.60±9.02 | 67.28±1.72 |
| TDN | 69.54±1.01 | 67.78±7.50 | 67.53±1.64 |
| Ash | 11.09±4.59 | 20.43±19.83 | -8.22±6.87 |
| CP | 66.16±5.33[b] | 46.07±7.35[a] | 54.37±2.69[a] |
| XL | 79.56±3.68[a] | 86.89±2.97[b] | 86.46±2.32[b] |
| CF | 60.59±4.60 | 60.02±16.36 | 66.19±3.82 |
| NFE | 73.78±0.68 | 66.25±8.58 | 68.64±2.49 |

DMD: Dry matter digestibility, DOM: Digestibility organic matter, TDN: Total digestible nutrient, CP: Crude protein, XL: Crude lipid, CF: Crude fiber, NEF: Nitrogen free extract, [a,b]Values with different superscripts are significantly different ($p<0.05$)

successfully improved ramie silage quality by the addition of 20% (w/w DM) cassava extract meal to produce a bright greenish brown color, lactic acid odor and firm texture, the palatability *in vivo* by the goats was low. This might be caused by the eating habits of goats; they prefer to graze and consume fresh leaves[18] rather than conserved grass. This is different from cattle, which are accustomed to ensiled forage in their rations. Moreover, the best ramie silage produced[14] could not equal the quality of maize silage feed, which is consumed higher than[28] or similar[29] to non-silage contained rations.

The amount of feed intake in this experiment was higher than what was measured in non-lactating goats by Suparjo[30], at 434-560 g DMI, but it is lower than what was measured by Badarina *et al.*[31] on lactating local goats. The amounts of DMI relative to body weight were not influenced by the treatments. The amount of feed intake per kilograms body weight found in this experiment was comparable to what was measured by Novita *et al.*[32] on late-pregnancy local goats but lower than the formula that was predicted by Luo *et al.*[33] for goats with 27 kg average BW and ADG 100 g day$^{-1}$, which was estimated for 0.78 kg day$^{-1}$ or 2.89% b.wt.

Goats fed with R2 not only tended to consume lower DM but also lower nutrient quality in comparison to R1 and R3. Lower percentages of CP and NFE in rations consumed by the R2 goats were caused by the lower DMI and lower CP and NFE contents in the ration. The lower contents of CP and NFE in the R2 ration were also caused by the high degradation of OM and proteins during the ensiling process[14,15]. The high percentage of ash intake in the ration containing ramie leaves was due to the high amount of ash content in the ramie leaves[2,11,26].

Digestibility of the control ration (R1) tended to be higher for DMD, OMD and NFE or significantly higher for CP in comparison to the ration containing ramie leaves (R2 and R3). The finding showed that ramie leaves as forage cannot substitute concentrate with equal digestibility due to a higher content of ash[11,34]. The high crude fiber in ramie leaves did not lead to lower digestibility. The digestibility of crude fiber in rations containing ramie hay (R3) even tended to be higher than the control, which showed that CF was not the cause for the low DMD and OMD in rations containing ramie leaves. Veloso *et al.*[26] reported that NDF and ADF ramie leaves have higher solubility and total degradation in the rumen compared to the leucaena, pigeon pea, or perennial soybean leaves. Conto *et al.*[11] suspected low digestibility and energy values of ramie might be due to the existence of some anti-nutritional factors.

Although, Miranda *et al.*[35] reported that ramie leaves had a higher CP, soluble protein and total amino acids in comparison to leucaena, perennial soybean or pigeon pea leaves and less fiber fractions and similar RDP to perennial soybean, their total CP digestibility found in this experiment were lower than in R1. This showed that ramie leaf protein cannot substitute concentrate with equal protein digestibility, although when used as a concentrate substitute, it might reduce feed cost[10].

There were no statistical differences in the digestibility of rations and nutrients between R2 and R3. The coefficient digestibility of rations containing ramie leaves used in this experiment (60.5%) were lower than that found by Despal[9], which approached 65%, Badarina *et al.*[31] which reached 76%, Novita *et al.*[32] which found a DMD coefficient ranging from 64-72% or Despal *et al.*[14] which found DMD >72%.

The Total Digestible Nutrient (TDN) in grams per day tended to be lower in ration R2 compared to R1 and R3 (394.9 vs 470.7 and 477.8 g). This was due to the lower intake of R2 in comparison to R1 and R3. However, TDN in percentage of intake was quite similar among the treatments (67.5-69.5%). This finding was similar to Despal[9] but higher than Badarina *et al.*[31]. By using the conversion of ME (MJ $kg^{-1}$) = TDN (%)$\times$0.15104 according to the NRC[36] formula, it was found that the ME value of the rations were 10.57, 10.24 and 10.20 MJ $kg^{-1}$ for R1, R2 and R3, respectively or 2.51, 2.45 and 2.44 M cal $kg^{-1}$ for R1, R2 and R3, respectively. By multiplying the DMI into the ME value, the daily ME for the rations were found to be 7.60, 6.56 and 8.00 MJ $day^{-1}$ for R1, R2 and R3, respectively.

Zemmelink *et al.*[37] recommended a requirement of 384 kJ/$BW^{0.75}$ ME for maintenance and 38.1 kJ $g^{-1}$ daily body weight gain. By calculating the 27 kg average BW goat used in this experiment, the ME required for maintenance of the goats was 4.55 MJ, which left 3.05, 2.01 and 3.45 MJ ME for daily body weight gain in R1, R2 and R3, respectively. The ME can support 80.02, 52.70 and 90.51 g daily body weight gain for R1, R2 and R3, respectively.

The data showed that the hay technique conserved ramie leaf nutrients better than silage. Ramie leaf hay was also consumed better than silage by the goats. Therefore, it is recommended to use the hay technique to conserve ramie leaves. This study used goats, which are less likely to consume silage; therefore, further tests on larger ruminants, such as cattle, may find different results.

## CONCLUSION

From this experiment, it can be concluded that 20% of conventional Jawarandu goat concentrate can be substituted with ramie hay leaves. The utilization of ramie leaf silage produced a lower intake, digestibility and predicted daily weight gain.

## SIGNIFICANCE STATEMENTS

This study discovered the best conservation technique of ramie leaves that can be beneficial for ramie farmers in improving their profit margin and providing sustainable forage availability for livestock. Hay is a significantly better technique than silage in conserving ramie leaves and could replace the expensive concentrate feed currently used. This study will help researchers uncover the critical areas of ramie leaf conservation techniques that so far were not explored. Thus, a new focus on optimizing the hay technique for ramie leaves may be explored in the future.

## ACKNOWLEDGMENTS

We thank Koppontren Darussalam Garut for providing the ramie leaves. We are grateful to Hj. Aminah Mursadad (almh.) for encouragement and facilities and to the anonymous reviewers for their constructive support in revising the presentation and content of this manuscript. Financial support from Indonesian Directorate General of Higher Education through National Competitive Grant Program is thankfully acknowledged.

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