Short Communication

Comparative Nutritional Intake, Digestibility, and Rumen Fermentation Outcomes of Feeding Fresh or Ensiled Purple Napier Grass to Sheep

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Abstract | This study evaluated the effects of feeding purple Napier grass (*Pennisetum purpureum* cv. 'Prince') in fresh or ensiled form on feed intake, nutrient digestibility, growth performance, and rumen fermentation in sheep. Eighteen growing rams were used, allocated equally into two dietary treatments (n= 9 per group). Purple Napier silage was produced through a 100-day fermentation process prior to feeding. Feed intake, digestibility, body weight change, and rumen fluid parameters were measured to determine the nutritional response to each forage form. Feed intake, digestibility, and growth performance parameters did not differ significantly between treatments (P > 0.05). Dry matter and organic matter digestibility were numerically higher in sheep fed silage, but the differences were not significant (P > 0.05). Final body weight, ADG, and FCR also did not differ significantly between treatments. Rumen fermentation characteristics were largely similar between treatments, with no significant differences in rumen pH, NH_3–N, or butyrate concentration. In contrast, silage significantly decreased acetate, increased propionate, and reduced the acetate-to-propionate ratio (P < 0.05). In summary, feeding purple Napier silage altered certain rumen VFA proportions but did not significantly affect intake, digestibility, or growth performance compared with fresh forage under the conditions of this study.

Keywords | Purple Napier grass, Silage, Volatile fatty acids, Anthocyanins, Rumen fermentation profile, Sheep

Received | November 07, 2025; **Accepted** | January 26, 2026; **Published** | April 13, 2026
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Citation | R.M.Aprilia, Kusmartono, Hermanto, Kuswanto, Subagiyo (2026). Comparative nutritional intake, digestibility, and rumen fermentation outcomes of feeding fresh or ensiled purple napier grass to sheep. J. Anim. Health Prod. 14(2): 603-612.
DOI | https://dx.doi.org/10.17582/journal.jahp/2026/14.2.603.612
ISSN (Online) | 2308-2801

INTRODUCTION

Livestock production in tropical regions is strongly influenced by the availability and quality of forage. Napier grass (*Pennisetum purpureum*) is one of the most widely used tropical forages due to its high biomass yield throughout the year, surpassing many cultivated and wild grasses (Sinche *et al*., 2021). It grows well in tropical climates such as Indonesia, where annual rainfall averages around 1,000 mm. Napier grass also adapts to low-fertility soils, tolerates drought (Fukagawa and Ishii, 2018), propagates vegetatively, withstands repeated cutting, and regrows rapidly, making it highly preferred by livestock (Rabatseta *et al*., 2024). Moreover, it can be easily processed into silage (Mudhita *et al*., 2024) or hay (Kamruzali *et al*., 2021). When supplemented with legumes or protein concentrates, Napier grass provides an adequate fiber source for ruminants (Islam *et al*., 2024).

Purple Napier (*P. purpureum* 'Prince') is a semi-dwarf, purple-leafed cultivar developed by the United States Department of Agriculture (USDA) and the University of Georgia (UGA). It shares similar growth characteristics with common Napier grass but contains higher concentrations of anthocyanins (up to 4.34 g/kg DM), which may enhance animal performance and health (Yin *et al*., 2021). These bioactive compounds can exert functional effects beyond fiber supply, including modulation of rumen microbiota and antioxidant activity. Previous studies have shown that Purple Napier improves antioxidant capacity, milk yield (Onjai-uea *et al*., 2024), growth performance, rumen fermentation, and microbial diversity in goats (Paengkoum *et al*., 2025), as well as feed intake, digestibility, and plasma profiles in Saanen goats (Chaokaur *et al*., 2024).

In Indonesia, forage-based feeding systems dominate sheep production, but seasonal shortages of quality forage are common, particularly during the dry season (Landupari *et al*., 2020). Silage is therefore an important preservation method that helps maintain nutrient availability and support animal productivity during periods of feed scarcity (Chen *et al*., 2022). Silage made from Napier grass has been reported to enhance intake, digestibility, and rumen fermentation efficiency (Sanjaya *et al*., 2022). However, comparative evaluation of Purple Napier grass in fresh versus silage form for sheep remains very limited, particularly under Indonesian production conditions. Therefore, this study aimed to compare the effects of fresh and ensiled Purple Napier grass on feed intake, nutrient digestibility, growth performance, and rumen fermentation in sheep under Indonesian conditions.

MATERIALS AND METHODS

Study location and ethical statement

This research was conducted in the Experimental Cage of the Faculty of Animal Husbandry, Universitas Brawijaya, in Sumbersekar Village, Dau District, Malang Regency, East Java. The procedure for the care and handling of animals follows ethical guidelines approved by the Animal Care and Research Committee of the Institute of Biosciences, Universitas Brawijaya, Indonesia, with an ethics number (No 099-KEP-UB-2024).

Silage production

The forage used in this study was Purple Napier grass (*Pennisetum purpureum* 'Prince'), cultivated in the Sumbersekar Feed Garden, Faculty of Animal Husbandry, Universitas Brawijaya. The grass was harvested 60 days after regrowth for both fresh and silage treatments. The harvest age was selected based on agronomic best practices for optimal forage quality (Akbarillah *et al*., 2024).

Silage was prepared from Purple Napier grass harvested at 60 days of regrowth and chopped into 2–3 cm pieces using a forage cutter. No additives were applied during ensiling. The chopped material was tightly packed into large plastic bags, sealed using a vacuum sealer to remove oxygen, and stored at ambient temperature (27–30°C) until the feeding trial commenced. The ensiling period lasted for 100 days.

Feed composition

The experimental sheep were fed Purple Napier grass in two forms: Fresh (FPN) and silage (PN-silage). Each diet consisted of 60% forage and 40% concentrate. The concentrate was formulated to meet the nutritional requirements of growing sheep, particularly in terms of crude protein and energy, in accordance with the NRC (2007) recommendations. Locally available feed ingredients were used in the formulation, and the ingredient composition is presented in Table 1. The nutrient composition of fresh Purple Napier grass, Purple Napier silage, the concentrate, and the complete rations for each treatment is shown in Table 2.

Table 1: Ingredient proportion in the concentrate (% as feed basis).

Ingredients	Inclusion level (%)
Pollard	26.0
Distillers dried grains with solubles	10.0
Corn starch	14.0
Brown Skin	14.0
Palm Kernel Meal	13.0
Corn Gluten Feed	10.0
Coconut Meal	6.00
Soybean Meal	6.00
Molasses	1.00
Total	100.0

Table 2: Chemical composition of purple napier fresh, silage, concentrate, and experimental diets of sheep (% DM).

Composition	FPN	PN silage	Concentrate	Experimental diets	
				FPN	PN-silage
DM (%)	16.41	15.77	86.73	44.54	44.15
OM (%)	87.14	88.54	94.57	90.11	90.95
CP (%)	5.63	7.03	19.53	11.19	12.03
CF (%)	31.5	35.1	1.93	19.67	21.83
EE (%)	2.09	2.48	5.4	3.41	3.65
NFE (%)	57.55	52.95	67.46	61.51	58.75
TDN (%)	69.93	67.65	84.89	69.93	67.65

Note: TDN values of the experimental diets were recalculated as weighted means of forage (60%) and concentrate (40%) according to their respective TDN contents.

Feed treatments

This study used 18 male rams aged 6–8 months, with an average initial body weight of 16.77±0.80 kg. The sheep were housed individually in metabolic cages equipped with separate containers for feed and water, as well as devices for feces and urine collection to ensure accurate measurement of nutrient intake and excretion.

Figure 1: Purple napier (*Pennisetum purpureum* 'Prince') grass.

The animals were randomly assigned to two dietary treatments: Fresh Purple Napier grass (FPN) and Purple Napier grass silage (PN-silage), with nine sheep per treatment. Feeding was conducted twice daily at 08:00 and 15:00, using feed troughs placed at the front of each cage. Clean drinking water was provided ad libitum throughout the experiment. The feeding trial lasted for 90 days, consisting of a 14-day adaptation period followed by a 76-day data collection period. Each sheep was fed at 5% of its body weight per day on a dry matter basis, divided into two equal meals. The feed allocation was adjusted every two weeks in response to changes in body weight. Forage and feces from each animal were collected daily, weighed fresh, and then oven-dried at 60 °C until a constant weight was achieved.

Feed and fecal sampling

Throughout the trial, the amounts of feed offered and feed refusals were recorded daily. Samples of feed, refusals, and feces were collected from each sheep every morning before feeding. The samples were analyzed for dry matter (DM), ash, ether extract (EE), and crude protein (CP) following the AOAC (2005) procedures. All chemical analyses were conducted in duplicate.

Chemical analysis

The proximate composition of feed and feces (DM, ash, EE, crude fiber (CF), and nitrogen-free extract (NFE)) was determined according to the Indonesian National Standard (SNI, 2024). Total Digestible Nutrients (TDN) were calculated using the following equation (SNI, 2024):

$$TDN\ (\%) = 5.31 + 0.412\ (CP) + 0.249\ (CF) + 1.444\ (EE) + 0.937\ (NFE)$$

Feed intake and digestibility

Nutrient digestibility was determined using the acid-insoluble ash (AIA) marker method. Samples of fresh Purple Napier grass, Purple Napier silage, and feces were oven-dried at 65 °C for 72 hours and stored at −20 °C until analysis. Nutrient and energy digestibility coefficients were calculated using the following formula:

$$Digestibility\ coefficient\ (\%) = 100 - \{100 \times [(\%AIA\ in\ diet \times \%Nutrient\ in\ feces) / (\%AIA\ in\ feces \times \%Nutrient\ in\ diet)]\}$$

Growth performances

Body weight was recorded at the beginning and end of the study (day 90). Average daily gain (ADG) was calculated as the difference between final and initial body weight divided by the number of experimental days. Feed conversion ratio (FCR) was determined as the ratio of total feed intake to body weight gain during the experimental period.

Collection and analysis of rumen fluid

Rumen fluid samples were collected three hours after feeding on the final day using a stomach tube. The samples were immediately filtered anaerobically through four layers of cheesecloth, and pH was measured on-site using a portable pH meter. Ammonia nitrogen (NH_3-N) concentration was determined following the method described by Wrolstad *et al.* (2005). Filtered rumen fluid was then transferred to the laboratory in sterile thermos flasks. Volatile fatty acid (VFA) concentrations were analyzed by gas chromatography (Agilent Technologies, Santa Clara, CA, USA).

Statistical analysis

Data were analyzed using an independent t-test in SPSS (version 25). Normality (Shapiro–Wilk) and homogeneity of variance (Levene's test) were confirmed prior to analysis. No a priori power analysis was conducted; therefore, the present study may be underpowered to detect small to moderate treatment effects.

RESULTS

Feed consumption and digestibility

Feed intake variables did not differ significantly (P>0.05) between sheep fed fresh purple Napier grass (FPN) and those fed purple Napier silage (PN-silage) (Table 3). Total dry matter intake (DMI), forage intake, concentrate intake, metabolic body weight–adjusted intake, and percentage of body weight intake were all statistically similar, indicating that the physical form of purple Napier grass did not affect feed consumption. Organic matter intake (OMI) also showed no significant variation between treatments.

Table 3: Effect of fresh and ensiled purple napier grass on feed intake and nutrient digestibility in sheep.

Parameter	FPN	PN silage	SEM	P value
Total DMI (kg/day)	0.72	0.73	0.025	0.844
Forage intake (kg/day)	0.29	0.31	0.016	0.523
Concentrate intake (kg/day)	0.43	0.42	0.011	0.267
Total DMI (g/kg $BW^{0.75}$)	73.2	74.0	1.441	0.567
Total DMI (% of BW)	3.50	3.61	0.056	0.344
Total OMI (kg/day)	0.66	0.67	0.023	0.771
Purple Napier intake (kg/day)	0.25	0.27	0.014	0.413
Concentrate intake (kg/day)	0.41	0.40	0.010	0.616
DM digestibility (%)	63.11	66.10	0.874	0.086
OM digestibility (%)	65.83	68.88	0.921	0.098

Note: DMI= dry matter intake; OMI= organic matter intake; BW= body weight; SEM= standard error of the mean. Values within the same row without different superscripts do not differ significantly ($P > 0.05$).

Digestibility values showed a slight numerical increase in the silage group, with DM digestibility increasing from 63.11% to 66.10% and OM digestibility increasing from 65.83% to 68.88%. However, these differences were not statistically significant (DM: P= 0.086; OM: P= 0.098) and should therefore be interpreted only as non-significant trends rather than treatment effects. Overall, the results indicate that converting purple Napier grass into silage did not significantly improve feed intake or nutrient digestibility under the conditions of this study.

Growth performance

The growth performance of sheep is presented in Table 4. Final body weight did not differ significantly between treatments (P= 0.632), indicating that feeding purple Napier as silage or in fresh form resulted in comparable end-point weights. Average daily gain (ADG) was numerically higher in the PN-silage group (136.31 g/day) than in the FPN group (102.98 g/day), but this difference was not statistically significant (P=0.215). Similarly, the feed conversion ratio (FCR) showed no significant difference (P= 0.435), despite a numerical improvement in sheep fed silage (1.15 vs. 1.25).

Although some numerical trends suggest slightly better performance with silage, these trends lack statistical support and therefore cannot be interpreted as true treatment effects. The results clearly show that feeding purple Napier grass as silage did not significantly enhance animal growth or feed efficiency compared with feeding it fresh.

Table 4: Effect of fresh and ensiled purple napier grass on growth performance of sheep.

Parameter	Unit	FPN	PN silage	SEM	P value
Final body weight	kg	24.71	26.11	0.563	0.632
Average daily gain (ADG)	g/day	102.98	136.31	6.702	0.215
Feed conversion ratio (FCR)	—	1.25	1.15	0.052	0.435

Note: SEM = standard error of the mean. FCR = total DMI (kg) ÷ total weight gain (kg). No parameters differed significantly between treatments ($P > 0.05$).

Rumen fermentation characteristics

Rumen fermentation characteristics are summarized in Table 5. Rumen pH (P=0.062) and NH_3–N concentrations (P=0.401) did not differ significantly between treatments, indicating comparable ruminal conditions regardless of whether sheep were fed fresh or ensiled purple Napier grass. In contrast, significant differences were observed in the volatile fatty acid (VFA) profile. Sheep fed PN-silage produced significantly lower acetate (P=0.001) but higher propionate (P=0.013), leading to a markedly lower acetate-to-propionate ratio (P=0.004). However, butyrate concentration showed no significant difference between treatments (P= 0.342).

Table 5: Effect of fresh and ensiled purple napier grass on rumen fermentation parameters.

Parameter	Unit	FPN	PN silage	SEM	P value
Rumen pH	—	6.03	6.57	0.115	0.062
NH_3–N	mg/100mL	18.62	20.12	1.882	0.401
Acetate (C2)	mM	16.96^{b}	12.23^{a}	1.117	0.001
Propionate (C3)	mM	10.15^{b}	16.92^{a}	1.441	0.013
Butyrate (C4)	mM	6.47	7.37	0.504	0.342
C2:C3 ratio	—	1.92^{b}	0.81^{a}	0.611	0.004

Note: SEM= standard error of the mean. Different superscripts (a, b) indicate significant differences between treatments ($P < 0.05$). VFAs= volatile fatty acids. C2:C3:C4 molar ratios were removed because no inferential statistics were available.

These results indicate that, although overall rumen pH and ammonia production remained similar, ensiling purple Napier grass shifted the VFA pattern toward a more glucogenic fermentation profile characterized by increased propionate production. This shift occurred without altering total rumen fermentation intensity, as no significant differences were observed in pH, NH_3–N, or butyrate concentrations.

DISCUSSION

Intake and digestibility

Sheep fed Purple Napier grass silage showed numerically higher dry matter intake (DMI) and organic matter intake (OMI) than those fed the fresh form (Table 3). However, these differences were not statistically significant ($P > 0.05$). This suggests that ensiling tended to improve feed palatability and intake. The improvement can be attributed to the increased nutritional availability during the silage process, which enhances the concentration of essential nutrients for ruminants (Abo-Eid *et al*., 2016). Fermentation during ensiling increases volatile fatty acid (VFA) production (Kung *et al*., 2018) and the proportion of easily fermentable carbohydrates (Silva *et al*., 2022), while modifying the physical structure of forage (Barmaki *et al*., 2018), thereby potentially improving DMI, OMI, and feed efficiency. Moreover, lactic acid fermentation reduces the bitter and astringent taste of anthocyanins in fresh Purple Napier, enhancing palatability without compromising antioxidant activity. These findings agree with Onjai-Uea *et al*. (2024), who reported higher DMI in goats fed Purple Napier silage, and with Bureenok *et al*. (2012), who found that fermented Napier with molasses increased feed intake.

Dry matter digestibility (DMD) and organic matter digestibility (OMD) were also higher in sheep fed Purple Napier silage (66.10% and 68.88%, respectively) compared to fresh forage. Nevertheless, these improvements were not statistically significant ($P>0.05$), indicating that digestibility responses represent numerical tendencies rather than confirmed effects. This improvement is associated with the degradation of fibrous components during fermentation, resulting in a more digestible feed fraction (Valadares *et al*., 2019). Purple Napier typically has high neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents that limit digestibility (Rambau *et al*., 2022). After recalculating dietary TDN as weighted values of forage and concentrate, silage diets showed a slightly higher dietary energy density; however, these differences were not statistically significant (Table 2).

Growth performance

Growth performance results showed higher final body weight, average daily gain (ADG), and improved feed conversion ratio (FCR) in sheep fed Purple Napier silage (Table 4). Despite these numerical differences, none of the growth variables differed significantly ($P>0.05$), and therefore, the improvements should not be interpreted as definitive treatment effects. These numerical differences may reflect higher nutrient availability in silage; however, they were not statistically supported and should be interpreted as tendencies only. Increased DMI and OMI directly contribute to greater energy supply for tissue growth, leading to better performance. Similar findings were reported by Meethip *et al*. (2024) and Paengkoum *et al*. (2025), who noted that anthocyanins such as cyanidin-3-glucoside in Purple Napier enhance antioxidant status and reduce methanogenic and protozoal activity, resulting in improved energy efficiency and growth. The higher propionate concentration in silage-fed sheep (Rabatseta *et al*., 2024) also supports more efficient energy utilization. Given the relatively small sample size (n= 9 per treatment) and P-values approaching significance (e.g., DM digestibility $P= 0.086$; OM digestibility $P= 0.098$), the possibility of Type II error cannot be excluded.

Rumen fermentation and volatile fatty acids

Rumen fermentation parameters, including pH, ammonia nitrogen (NH_3-N), and butyrate concentrations, did not differ significantly between treatments ($P>0.05$; Table 5). However, acetate, propionate, and the acetate-to-propionate ratio differed significantly ($P<0.05$), indicating that ensiling altered specific components of the VFA profile rather than the overall fermentation environment. Fermentation of carbohydrate-rich silage produces VFAs that influence rumen pH stability. The anthocyanins in Purple Napier can modulate microbial fermentation dynamics, reducing excessive ammonia accumulation and maintaining a neutral rumen environment (Yin *et al*., 2021; Meethip *et al*., 2024; Tian *et al*., 2021). Although silage contained slightly higher crude protein, rumen NH_3–N concentrations were not increased, suggesting that the microbial capture of ammonia for protein synthesis was efficient rather than ammonia accumulation (Hassen *et al*., 2010; Gomes *et al*., 2016; Li *et al*., 2022; Nurjana *et al*., 2015). Enhanced digestibility in anthocyanin-rich silage can also elevate total gas and VFA production (Meethip *et al*., 2024; Onjai-Uea *et al*., 2024), indicating active microbial metabolism.

Volatile fatty acids serve as the primary energy source for ruminants, and anthocyanins may promote VFA production by influencing microbial populations. Differences in moisture and fiber composition between fresh and ensiled Purple Napier affect fermentation outcomes (Li *et al*., 2022). During ensiling, lactic acid production supports propionate formation an energy-efficient VFA in ruminant nutrition (Mikołajczyk *et al*., 2020; Navarro-Villa *et al*., 2012). Well-fermented silage helps maintain optimal rumen conditions and promotes balanced microbial activity (Prihambodo *et al*., 2025). In the present study, such shifts were indeed observed, as propionate increased and acetate decreased significantly in the silage group, confirming that ensiling influenced VFA proportions even though total fermentation activity (pH, NH_3-N, butyrate) remained unchanged.

Anthocyanins in Purple Napier act as bioactive compounds that modulate rumen microbial populations, favor propionate-producing pathways, and enhance antioxidant capacity (Meethip *et al*., 2024). These effects contribute to improved fermentation efficiency and energy utilization (Suong *et al*., 2022; Tian *et al*., 2021) while potentially reducing methanogenesis (Paengkoum *et al*., 2025), thereby supporting ruminant productivity without altering overall rumen stability.

Practical implications

For tropical smallholder systems, where dry-season forage scarcity is a major constraint, Purple Napier silage provides a reliable conserved forage that maintains intake, digestibility, and animal performance at levels comparable to fresh forage. Its use can reduce seasonal feed shortages, stabilize animal productivity, and lower dependency on purchased concentrates. Economically, silage preparation enables farmers to utilize surplus biomass from the rainy season, minimizing feed waste while enhancing year-round feed security.

CONCLUSION

Feeding purple Napier grass as silage or in fresh form resulted in comparable feed intake, nutrient digestibility, growth performance, and most rumen fermentation parameters in sheep. Although purple Napier silage produced significant shifts in specific volatile fatty acid proportions (lower acetate and higher propionate) the overall nutritional and productive responses did not differ significantly between treatments. Therefore, purple Napier silage can be considered an acceptable alternative to the fresh form, particularly where forage preservation is needed, but its advantages over fresh forage were not statistically confirmed in this study. Further research with larger sample sizes and longer feeding periods is recommended to fully determine its potential benefits in sheep production systems.

ACKNOWLEDGMENT

The authors gratefully acknowledge Brawijaya University for financial support through the Professor Grant Project, which funded this research.

NOVELTY STATEMENT

The novelty of this research lies in the comprehensive evaluation of the productivity of Indonesian local livestock through the provision of functional feed in the form of purple napier grass, offered both as fresh forage and silage, which has not been extensively and systematically studied under tropical conditions in Indonesia.

AUTHOR'S CONTRIBUTION

RMA and IS designed and coordinated the study. HM and KM supervised the experiment. KM, RMA and IS performed the experiment, analyzed the data, and drafted the manuscript. KW took part in preparing and critically checking this manuscript. All authors read and approved the final manuscript.

Generative AI and AI-assisted technology statement

The authors declare that no generative AI or AI-assisted technologies were used in the preparation, analysis, or writing of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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