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Enhancing Nutrient Intake, Digestibility, Rumen Fermentation, and Blood Metabolites in Kacang Goats Using Compost-Enriched Hydroponic Maize Fodder

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ABSTRACT

This study aimed to enhance nutrient intake, digestibility, rumen fermentation, and blood metabolites in Kacang goats by substituting grass silage with hydroponic maize fodder enriched with fermented compost tea. The compost tea, prepared by fermenting organic compost with sugared water + 40 mL EM4 for 3 days, was used to grow maize fodder hydroponically. Four male Kacang goats (13.05 ± 1.32 kg) were assigned to four dietary treatments in a 4x4 latin square design over four 15-day periods (10 days for adaption, 5 days for data collection). The treatments were: 60% grass silage + 10% *Leucaena leucocephala* + 30% concentrate (control, FCG0); 30% grass silage + 30% hydroponic maize fodder + 10% *L. leucocephala* + 30% concentrate (FCG1); 15% grass silage + 45% hydroponic maize fodder + 10% *L. leucocephala* + 30% concentrate (FCG2); and 60% hydroponic maize fodder + 10% *L. leucocephala* + 30% concentrate (FCG3). Goats on FCG3 had lower ($p<0.05$) dry matter intake (152.48 g/day) compared to FCG0 (226.83 g/day). Nutrient digestibility, including organic matter and crude fiber, improved ($p<0.05$) in FCG3 (77.21% and 66.12%) compared to FCG0 (76.62% and 52.27%). Total volatile fatty acids (VFA) increased in FCG3 (131.54 mM) compared to FCG0 (111.73 mM). However, no significant differences were observed in ruminal ammonia (NH_3-N), ruminal pH, or blood metabolites. In conclusion, substituting grass silage with hydroponic maize fodder enriched with fermented compost tea up to 75% of the diet improved digestibility and rumen fermentation without negatively affecting intake, digestibility, or blood metabolites in Kacang goats, suggesting its potential as an alternative feed. However, complete substitution (100%) reduced intake, indicating challenges at higher substitution levels.

Keywords: alternative green fodder; compost tea; Kacang goats; hydroponic maize fodder; ruminants

INTRODUCTION

Despite its significant contribution to both meat production and the economic livelihoods of smallholder farmers in East Nusa Tenggara Province, Indonesia, the productivity of Kacang goats remains stagnant due to year-round feed fluctuations (Benu *et al.*, 2024a), which pose a persistent challenge to the goat's nutritional intake and overall well-being. Conversely, ruminant nutrition plays a crucial role in ensuring optimal animal health, productivity, and sustainability in livestock production systems (Moorby & Fraser, 2021). Therefore, ensuring that Kacang goats receive adequate nutrition is essential for maximizing their growth, reproductive performance, and resistance to diseases.

Grass silage is a commonly used forage source in ruminant diets due to its high digestibility and availability. The conventional reliance on grass silage as a primary feed source for ruminants often encounters limitations such as reduced nutrient levels due to microbial degradation and insufficient vitamin presence (Nugroho *et al.*, 2015). In addition, variation in dry matter content of silage and inconsistent nutrient composition could reduce dry matter intake and consequently impact animal performance (Haselmann *et al.*, 2020). Furthermore, small-scale farmers struggle to preserve grass silage for extended periods during the dry season due to challenges in grass conservation (Benu *et al.*, 2024b), including limiting access to adequate storage facilities and the untimely harvesting of grass beyond its optimal stage of maturity (Gomes *et al.*, 2021). Hence, it is crucial to find strategies to provide forage for goats.

Hydroponic maize fodder could be utilized as an alternative feed source to grass or green forage. This is due to the year-round availability, predictable nutrient content, and rapid growth characteristics (Naik *et al.*, 2014). In addition, hydroponic maize fodder cultivation proves effective in conserving water and space, particularly beneficial for individuals with limited resources and marginal land. Furthermore, hydroponic maize fodder originates from maize seeds that undergo germination and brief cultivation (Sneath & Mcintosh, 2003). However, our previous study showed that the inclusion of hydroponic maize fodder reduced the intake of weaned Ongole x Brahman calves (Benu *et al.*, 2024b). Therefore, we speculated that this phenomenon could be due to the nutrient composition of maize, which was grown in planting media using only water and without the addition of any nutrients. The optimum growth and development of sprouted maize fodder is mostly affected by nutrition, such as nitrogen supplied to the planting media (Bhaumik *et al.*, 2023). Compost tea (CT) is an organic liquid fertilizer derived from high-quality compost, rich in beneficial microorganisms and compounds that can protect and enhance plant growth (Ingram & Milnerr, 2007). Compost tea is rich in microorganisms that support plant growth and suppress pathogens through various mechanisms, both direct and indirect. These include providing plant nutrients via biological nitrogen fixation, dissolving macro- and microelements, and controlling pathogens through biological antibiotic agents (Ashour *et al.*, 2023). The utilization of compost tea as organic fertilizer in plants such as *Cichorium intybus* has been reported to increase productivity, nutrient content, and *in vitro* digestibility (Amalyadi *et al.*, 2022). Hence, enriching hydroponic maize fodder with fermented compost tea could enhance nutrient bioavailability, stimulate rumen microbial activity, and improve the overall digestibility of rumen fermentation, as well as metabolic efficiency in ruminants. However, there is limited information regarding the use of fermented compost tea in hydroponic maize fodder and its effects on nutrient intake and digestibility, rumen fermentation variables, and blood metabolites in Kacang goats. The objective of this study was to investigate the impact of substituting grass silage with different levels of hydroponic maize fodder enriched with fermented compost tea on nutrient intake and digestibility, rumen fermentation variables, and blood metabolites in Kacang goats.

MATERIALS AND METHODS

Site of the Study

The present study was conducted at Oelomin, Kupang, West Timor, Indonesia for 3 months from October to December 2022. This study was approved by the Livestock Research Ethic Committee, Universitas Nusa Cendana No: 047/1. KT /KEPPKP/VI/2022

Experimental Design, Animals, and Diets

The experiment used four male goats (13.05 ± 1.32 kg) in four 15-day periods x four diets in a Latin Square Design experiment. Each period consisted of a 10-day dietary adaptation followed by 5 days of sample collection. The animals were randomly allocated to one of the four dietary treatments consisted of FCG0: 60% grass silage + 10% *Leucaena leucocephala* + 30% concentrate; FCG1: 30% grass silage + 30% maize fodder + 10% *L. leucocephala* + 30% concentrate; FCG2: 15% grass silage + 45% maize fodder 10% *L. leucocephala* + 30% concentrate; FCG3: 60% maize fodder + 10% *L. leucocephala* + 30% concentrate. The animals were familiarized with handling and sampling procedures before the start of the experiment. Throughout the experiment, the animals were housed in metabolic crates (1 x 1.5 m) within a naturally ventilated shed. The animals were fed their dietary treatments (Tables 1 and 2) twice daily (0800 and 1600h). Water was offered *ad libitum*.

Maize Fodder Production

The maize grains for this study were purchased from a local market. Five kilograms of maize were initially rinsed with tap water to eliminate any debris. Subsequently, the maize was treated with an antifungal solution (Antracol, Bayer Indonesia, Jakarta) at a concentration of 2 mL/L to reduce fungal contamination and then kept in a dark area to steep for 12 hours overnight. Following this, the maize was soaked in fresh tap water for 24 hours before being evenly distributed into planting trays. These trays were manually watered two to three times a day, depending on the weather conditions. The sprouted maize seeds were cultivated for 7 days before being harvested and used as animal feed based on the study of Naik *et al*. (2015). After harvesting, the fodder is thoroughly cleaned to remove any remnants of seeds or other contaminants to ensure that the feed is hygienic and free from mold or pathogens that could harm the goats. Hydroponic maize fodder was grown daily, and the production process was repeated daily. Samples of the harvested sprouted maize seeds were taken from each tray and dried in an oven at 60 °C for 48-72 hours. Representative samples were then taken for further proximate analysis according to the method outlined by (AOAC, 2005).

During the planting process, maize fodder is supplemented with compost tea mixed with water as a source of nutrients. The compost tea was prepared following the method of Amalyadi *et al*. (2022). Briefly, compost tea uses mature compost materials with the main components of animal manure/barnyard manure 2 kg + 120 mL sugared water + 40 mL EM4. EM4 (Effective Microorganisms 4) is a liquid microbial inoculant that contains beneficial microorganisms, including lactic acid bacteria, yeast, and photosynthetic bacteria. These microbes aid in the fermentation process, enhancing nutrient availability and decomposition. In this study, the compost tea was prepared using mature compost materials, primarily consisting of animal or barnyard manure (2 kg), mixed with 120 mL of sugared water and supplemented with 40 mL of EM4 to promote microbial activity and accelerate the fermentation process. All materials are put into a bucket containing 15 L of clean water and mixed evenly. Then, it is aerated with a pump or stirred frequently manually to multiply microbial growth. The mixture is left for 7 days, then filtered and diluted with clean water at 1:10 or 100 mL/L of clean water. Compost tea is then applied to the fodder every 2-3 times a day, preferably in the morning or evening, at a rate of 100 mL per application.

Variables Measured

Dry matter intake was determined by weighing the leftovers of each feed ingredient (concentrate, *L.*

Table 1. Chemical composition of experimental diets of Kacang goats treated with different levels of grass silage or hydroponic maize fodder

Chemical composition	Ingredients						
	Grass silage	Hydroponic maize fodder	*Leucaena leucocephala*	Corn meal	Fish meal	Pollard	Mineral mix
Dry matter (%)	22.11	10.63	32.33	87.07	87.59	87.86	97.11
Organic matter (%DM)	97.58	85.45	96.95	98.58	83.02	96.28	49.06
Crude protein (%DM)	6.86	9.90	25.36	8.04	51.96	12.28	0.00
Ash (%DM)	2.41	4.85	3.04	1.41	16.97	3.71	48.05
Crude fiber (%DM)	32.21	12.59	15.49	3.83	2.06	7.10	28.28
Carbohydrate (%DM)	86.78	69.72	64.95	88.99	23.95	75.78	47.50
Nitrogen free extract (%DM)	54.56	57.13	49.45	85.16	21.89	68.68	19.22
Ether extract (%DM)	3.93	5.82	6.64	1.54	7.10	8.21	1.55
Gross energy (MJ/Kg DM)	18.02	16.44	19.65	17.87	19.16	18.89	8.74

Table 2. Feed ingredients of Kacang goats fed grass silage and substituted with different levels of hydroponic maize fodder

Items	Treatments			
	FCG0	FCG1	FCG2	FCG3
Feed ingredients (%DM)				
Hydroponic maize fodder	0	30	45	60
Grass silage	60	30	15	0
Leucaena leucocephala	10	10	10	10
Corn meal	15	15	15	15
Pollard	12	12	12	12
Fish meal	2.43	2.43	2.43	2.43
Mineral mixture	0.3	0.3	0.3	0.3
Urea	0.27	0.27	0.27	0.27
Total	100	100	100	100
Calculated nutrient content, % of total DM				
Dry matter	42.23	38.79	37.300	35.349
Organic matter	96.6	92.96	91.388	89.325
Crude protein	10.600	11.510	11.905	12.420
Crude fiber	22.354	16.470	13.920	10.585
Ether extract	4.416	4.982	5.227	5.547
Total digestible nutrient	57.691	61.114	62.598	64.538

Note: FCG0: 60% grass silage + 10% *Leucaena leucocephala* + 30% concentrate; FCG1: 30% grass silage + 30% maize fodder + 10% *L. leucocephala* + 30% concentrate; FCG2: 15% grass silage + 45% maize fodder 10% *L. leucocephala* + 30% concentrate; FCG3: 60% maize fodder + 10% *L. leucocephala* + 30% concentrate.

leucocephala, grass silage, and maize fodder) after each meal. The feed ingredients were offered separately, with the concentrate provided in the morning, followed by *L. leucocephala*, grass silage, and maize fodder offered at regular intervals throughout the day, allowing the measurement of the intake of each feed ingredient. The diet preparation involved weighing and distributing each feed according to the dietary treatment. The dry matter intake, nutrient intake, and nutrient digestibility of the animals were calculated using the following equations:

Dry matter intake (DMI)= dry matter offered - dry matter refusal

Nutrient intake= DMI x % nutrient content

Nutrient digestibility= [(Nutrient intake - Nutrient in feces) / Nutrient intake] x 100

At the conclusion of the digestibility trial for each period, rumen fluid samples were collected from each goat 4 hours after the morning meal using a stomach tube following the method of Ramos-Morales *et al*. (2014). These samples were filtered through four layers of cheesecloth before measuring the pH with a digital pH meter (Hanna Instrument, Romania). Ammonia concentration was determined using micro diffusion plates according to Conway (1947). Total volatile fatty acids (VFA) were measured using the steam distillation method. Blood samples from each goat were taken the same day as rumen fluid collection, 4 hours after the morning meal. The samples were drawn from the jugular vein into two vacutainer tubes, with one containing 3 mL of EDTA for determining hematological variables and the other containing 5 mL without EDTA for determination of metabolite variables. The samples were immediately placed on ice and transported to the laboratory for later analysis. The blood samples were analyzed for red blood cells (RBC) and white blood cells (WBC) using a Neubauer counting chamber (hemocytometer). Packed cell volume (PCV) was determined using a hematocrit test, and hemoglobin (Hb) levels were measured using a hemoglobinometer.

Statistical Analysis

Data obtained in this study were statistically analyzed using the General Linear Model (GLM) procedure adapted by IBM SPSS Statistic for Windows, version 25 (IBM Corp Armonk, N.Y. USA, 2017) for user's guide with analysis of variance (ANOVA). Duncan's multiple range tests within the SPSS program were conducted to examine the degree of significance among means. Data were analyzed considering the Latin design 4x4 and the value of significant difference was set at p<0.05 and 0.05<p<0.01 was assigned as a tendency to be significant. The mathematic model used was:

$$Y_{ijk} = \mu + A_i + P_j + T_k + \varepsilon_{ijk}$$

Where Y_{ijk} is the observed variable; μ is the overall mean; A_i is the effect of animal *i* ranging between 1 and 4; P_j is the effect of *j* period between 1 and 4; T_k is treatment effect *k* between 1 and 4; and ε_{ijk} is random error.

RESULTS

Nutrient Intake and Digestibility

The nutrient intake of Kacang goats fed grass silage and substituted with different levels of hydroponic maize fodder enriched with fermented compost tea in growth media are presented in Table 3. The results demonstrate that nutrient intake variables were not significantly affected by substitution levels up to 75% (FCG2: 15% grass silage + 45% maize fodder 10% *L. leucocephala* + 30% concentrate; 223.85 g/h/d) when compared to the control group (FCG0: 60% grass silage + 10% *L. leucocephala* + 30% concentrate; 226.83 g/h/d). However, when substitution level was increased to 100% (FCG3: 60% maize fodder + 10% *L. leucocephala* + 30% concentrate), a significant (p<0.05) decrease in total dry matter intake (152.48 g/h/d), as well as the intakes of organic matter (125.18 g/h/d), crude protein (17.09 g/h/d), ether extract (6.54 g/h/d), crude fiber (25.31 g/h/d), carbohydrate (98.65 g/h/d), nitrogen free extract (73.43 g/h/d), and gross energy intake (5.41 MJ/h/d) were observed.

Nutrient digestibility in Kacang goats consuming grass silage and substituted with different levels of hydroponic maize fodder enriched with fermented compost tea in growth media are presented in Table 4. Dry matter (DM; 77.80%) and organic matter (OM; 77.02%), ether extract (EE; 78.83%), crude fiber (CF; 66.12%), carbohydrate (CHO; 74.57%), nitrogen free extract (NFE; 77.51%), and gross energy (GE; 90.19%) digestibility were improved (p<0.05) with higher substitution rates of hydroponic maize fodder. However, there was a significant decrease in crude protein (CP; 86.36%) digestibility when the substitution level was increased to 100% (FCG3).

Rumen Variables

Ruminal fermentation variables of Kacang goats treated with grass silage or increasing rates of hydroponic maize fodder are presented in Table 5. Feeding

Table 3. Nutrient intake of Kacang goats fed grass silage and substituted with different levels of hydroponic maize fodder enriched with fermented compost tea

Nutrient intake	Treatments				SEM	p-value
	FCG0	FCG1	FCG2	FCG3		
Total DMI (g/h/d)	226.83^{b}	177.20^{ab}	223.85^{b}	152.48^{a}	26.68	0.080
Organic matter (g/h/d)	219.29^{b}	162.97^{ab}	206.27^{b}	125.18^{a}	23.70	0.025
Crude protein (g/h/d)	55.47^{c}	34.50^{b}	43.29^{bc}	17.09^{a}	7.09	0.009
Ether extract (g/h/d)	15.28^{c}	10.37^{ab}	12.93^{bc}	6.54^{a}	1.76	0.012
Crude fiber (g/h/d)	34.17^{b}	28.01^{ab}	36.03^{b}	25.31^{a}	3.46	0.062
Carbohydrate (g/h/d)	145.66^{b}	115.27^{ab}	147.17^{b}	98.65^{a}	14.98	0.045
Nitrogen free extract (g/h/d)	111.58^{b}	87.35^{ab}	111.22^{b}	73.43^{a}	11.53	0.040
Gross energy (MJ/h/d)	7.43^{b}	6.17^{ab}	7.09^{b}	5.41a	0.50	0.025

Note: FCG0: 60% grass silage + 10% *Leucaena leucocephala* + 30% concentrate; FCG1: 30% grass silage + 30% maize fodder + 10% *L. leucocephala* + 30% concentrate; FCG2: 15% grass silage + 45% maize fodder 10% *L. leucocephala* + 30% concentrate; FCG3: 60% maize fodder + 10% *L. leucocephala* + 30% concentrate. DMI= dry matter intake. Values in the same row with different superscripts are significantly different (p<0.05).

Table 4. Nutrient digestibility in Kacang goats fed grass silage and substituted with different levels of hydroponic maize fodder enriched with fermented compost tea

Digestibility (%)	Treatments				SEM	p-value
	FCG0	FCG1	FCG2	FCG3		
Dry matter	72.43^{ab}	62.06^{a}	65.90^{a}	77.80^{b}	4.67	0.057
Organic matter	76.62^{b}	70.21^{ab}	68.01^{a}	77.02^{b}	2.86	0.045
Crude protein	92.30^{c}	90.47^{bc}	88.44^{ab}	86.36^{a}	1.50	0.033
Ether extract	84.60^{b}	74.21^{ab}	73.79^{a}	78.83^{ab}	4.15	0.120
Crude fiber	52.27^{ab}	45.94^{a}	45.51^{a}	66.12^{b}	6.33	0.053
Carbohydrate	69.36^{ab}	63.16^{a}	61.17^{a}	74.57^{b}	3.80	0.043
Nitrogen free extract	74.62^{ab}	68.73^{a}	66.31^{a}	77.51^{b}	3.29	0.047
Gross energy	86.86^{ab}	85.57^{a}	84.06^{a}	90.19^{b}	1.63	0.043

Note: FCG0: 60% grass silage + 10% *Leucaena leucocephala* + 30% concentrate; FCG1: 30% grass silage + 30% maize fodder + 10% *L. leucocephala* + 30% concentrate; FCG2: 15% grass silage + 45% maize fodder 10% *L. leucocephala* + 30% concentrate; FCG3: 60% maize fodder + 10% *L. leucocephala* + 30% concentrate. Values in the same row with different superscripts are significantly different (p<0.05).

goats with grass silage and substituted with increasing levels of hydroponic maize fodder enriched with fermented compost tea in growth media significantly increased ($p<0.05$) VFA concentration in the FCG3 (131.54 mM) compared to the other groups. The NH_3-N concentrations in this study remained relatively consistent across treatment (p= 0.395). The ruminal pH values did not show significant differences among the treatments (p= 0.526).

Blood Metabolites

Feeding goats with grass silage and substituted with increasing rates of hydroponic maize fodder enriched with fermented compost tea in growth media had no significant differences between treatments on blood metabolites, including blood urea nitrogen and blood glucose (Table 6).

DISCUSSION

In this study, Kacang goats fed grass silage alone had similar dry matter intakes compared to those fed diets with up to 75% substitution levels of hydroponic maize fodder. However, when the substitution level was increased to 100%, there was a significant decrease in total dry matter intake, as well as the intakes of organic matter, crude protein, ether extract, crude fiber, carbohydrate, nitrogen free extract, and gross energy. The findings of the present study were similar to those of other studies. Alharthi *et al.* (2023) reported a decreased organic matter intake of lambs fed sprouted barley compared to the control group. In addition, Ren *et al.* (2022) and Benu *et al*. (2024b) also observed a decrease in total dry matter intake of Holstein Dairy cow and weaned Ongole x Brahman calves, where the animals' basic diets were partially replaced by hydroponic barley fodder and hydroponic maize fodder, respectively. In contrast, Nugroho *et al.* (2015) found that the total intake of dairy cows improved when hydroponic maize fodder was enriched with bio slurry in growth media. In addition, Jediya *et al.* (2021) also observed an increase in dry matter intake of calves fed hydroponic maize fodder as a partial replacement of concentrate.

The reduction of total dry matter intake and nutrient intake observed in this study was surprising as it was not in line with our hypothesis that providing a diet with an increasing level of hydroponic maize fodder, which was supplemented with fermented compost tea in growth media would increase dry matter intake. Since the dietary CP increased and the CF decreased with the increasing level of hydroponic maize fodder substitution (Table 2), CP of the diet commonly has a positive correlation to DMI and vice versa, CF fraction decreased DMI of the animals *(Riaz et al.*, 2014). The decline of DMI of Kacang goats in this study can be attributed to several factors, including non-germinated seeds, roots in the hydroponic maize fodder, and high-water content (96.14%). Ren *et al.* (2022) found that a minor portion of non-germinated seeds mixed with sprouted barley was unpalatable, potentially contributing to the decreased DMI in cows that were fed a diet consisting of 50% hydroponically grown barley fodder. The proportion of roots in the hydroponic maize fodder may have also contributed to the reduced feed intake observed in this study. Ren *et al*. (2022) reported that roots in the sprouted barley decrease chewability and palatability. The high water content in hydroponic maize fodder might have been another factor leading to the reduced DMI observed in this study, as it contributes to rumen fill and consequently lowers DMI (Havekes *et al.*, 2020; Wu *et al*., 2024). A similar result was reported by Benu *et al.* (2024b) that high water content in hydroponic maize fodder contributed to lower DMI in weaned Ongole x Brahman calves.

The nutrient intake of goats is directly connected to their dry matter intake and the diet's nutritional quality. As previously mentioned, when maize grain germinates and grows into hydroponic maize, nutrient availability increases, leading to the improved rumen fermentation (Farghaly *et al.*, 2019). This might account for the increased dry matter, organic matter, crude fiber, carbohydrate, nitrogen free extract, and gross energy digestibility observed in goats fed hydroponic maize

Table 5. Rumen fermentation products of Kacang goats fed grass silage and substituted with different levels of hydroponic maize fodder enriched with fermented compost tea

Variables	Treatments				SEM	p-value
	FCG0	FCG1	FCG2	FCG3		
Total VFA (mM)	111.73[a]	112.95[a]	120.53[ab]	131.54[b]	5.19	0.029
NH_3-N (mg 100 mL)	204.91	209.10	204.91	216.41	7.07	0.395
Ruminal pH	7.65	7.25	7.15	7.45	0.34	0.526

Note: FCG0: 60% grass silage + 10% *Leucaena leucocephala* + 30% concentrate; FCG1: 30% grass silage + 30% maize fodder + 10% *L. leucocephala* + 30% concentrate; FCG2: 15% grass silage + 45% maize fodder 10% *L. leucocephala* + 30% concentrate; FCG3: 60% maize fodder + 10% *L. leucocephala* + 30% concentrate. Values in the same row with different superscripts are significantly different ($p<0.05$).

Table 6. Blood metabolites of Kacang goats fed grass silage and substituted with different levels of hydroponic maize fodder enriched with fermented compost tea

Variables	Treatments				SEM	p-value
	FCG0	FCG1	FCG2	FCG3		
Blood urea nitrogen concentration (mg/dL)	40.79	41.91	41.34	41.29	0.76	0.575
Blood glucose concentration (mg/dL)	73.82	70.85	69.76	72.59	3.03	0.584

Note: FCG0: 60% grass silage + 10% *Leucaena leucocephala* + 30% concentrate; FCG1: 30% grass silage + 30% maize fodder + 10% *L. leucocephala* + 30% concentrate; FCG2: 15% grass silage + 45% maize fodder 10% *L. leucocephala* + 30% concentrate; FCG3: 60% maize fodder + 10% *L. leucocephala* + 30% concentrate.

fodder at a high level in our study. Increasing nutrient digestibility in this study might also be due to the enhanced nutrient availability since hydroponic maize fodder often has more tenderness as harvested at lower age (7 days).

However, improving substitution rates of hydroponic maize fodder also resulted in a significant decrease in crude protein digestibility and ether extract digestibility as observed in this study. A previous study reported a similar result that increasing the amount of hydroponically grown barley fodder reduced CP levels in cows (Ren *et al.,* 2022). In contrast, Nugroho *et al.* (2015) and Lim *et al.* (2022) found that crude protein digestibility was increased in cows and goats offered hydroponic maize fodder, respectively. Similarly, Farghaly *et al.* (2019) and Arif *et al.* (2023) reported an improvement in nutrient digestibility in goats and sheep fed sprouted barley and hydroponic maize fodder, respectively. The decrease in CP digestibility in this study may be due to factors including high moisture content, fiber content and physical fill effect, and rumen fermentation dynamics. Hydroponic fodder typically contains high moisture. In this study, hydroponic maize fodder has a high-water content of 96.14%. This high-water content can dilute the nutrient concentration, leading to the reduced dry matter intake (DMI) and potentially decreasing the digestive efficiency for protein. The high moisture may also result in faster rumen fill, limiting the animal's ability to consume more feed, thus affecting nutrient absorption and overall digestibility (Chethan *et al.,* 2022). Hydroponic maize fodder contains both soluble and insoluble fibers, which may increase bulk and limit feed intake due to the physical rumen fill effect. The high fiber content, especially the root portion of the fodder, can slow down digestion and reduce the time available for protein breakdown in the rumen (Ebenezer *et al.,* 2021). Feeding hydroponic maize fodder may alter the rumen fermentation process, as observed in various studies. The rapid transit time of hydroponic fodder through the gastrointestinal tract, due to its high-water content, can result in less thorough microbial digestion of protein (Chethan *et al.,* 2022).

Soaking grains has been documented to enhance moisture content and enzymatic activity (Thakur *et al.,* 2021), which facilitates the degradation of storage compounds into simpler and more digestible fractions, such as the conversion of starch to sugars and proteins to amino acids. In addition, the germination of seeds into sprouts has been shown to increase the hydrolysis of nutrient reserves, releasing soluble compounds and enhancing the availability of nutrients for rumen microflora (Lei *et al.,* 2017). Moreover, sprouted maize fodder is a source of vitamins and enzymes that function as biocatalysts, aiding in feed metabolism and the release of energy (Farghaly *et al.,* 2019). The provision of a concentrate mixture along with sprouted maize fodder resulted in a significant increase in total volatile fatty acids (TVFA), presumably due to the heightened microbial activity (De Oliveira Franco *et al.,* 2017).

Volatile fatty acids (VFAs) play a crucial role in ruminant nutrition as they serve as a major energy source for ruminants, which is derived from carbohydrates fermentation in the rumen. The increase in total VFA concentrations was observed in FCG3 (100% substitution with hydroponic maize fodder; 131.54 mM) compared to the other treatments. A similar result was reported by Benu *et al.* (2024b), showing a significant increase in total VFA concentration with higher substitution levels of hydroponic maize fodder in the diet of weaned Ongole x Brahman calves. Additionally, Joshi *et al.* (2024) also observed an increase in total VFA concentration when hydroponic maize fodder was fed to calves. This suggests that hydroponic maize fodder supports enhanced microbial fermentation in the rumen. This could be due to its nutritional composition, including fermentable fibers and carbohydrates, which promote microbial activity and VFA production. Fayed (2011) noted that the rise in total VFA concentration from feeding hydroponic fodder was attributed to the presence of vitamins and enzymes, which function as biocatalysts to support feed metabolism. Another factor that contributes to the increase in VFA in this study could attributed to the difference in carbohydrate structures between hydroponic maize fodder and grass silage, which can impact how they are digested and fermented in the rumen, thereby influencing the production of VFAs.

Ammonia nitrogen (NH_3-N) concentration in the rumen is a key indicator of protein degradation and microbial protein synthesis. The lack of significant differences in NH_3-N concentrations across treatments indicates that the protein degradation and ammonia production in the rumen were not substantially influenced by the varying levels of hydroponic maize fodder. This stability suggests that the protein content and its degradability in the hydroponic fodder are comparable to those in the conventional feed, maintaining a consistent nitrogen balance in the rumen. The stability of rumen NH_3-N concentrations across treatments suggests that the rumen's initial protein degradation and ammonia production were not significantly impacted by the varying levels of hydroponic maize fodder. The lack of change in NH_3-N levels across FCG treatments, despite differences in CP digestibility, could be due to several factors. One possibility is that the microbial protein synthesis in the rumen was efficient enough to utilize the available ammonia, leading to stable NH_3-N levels regardless of variations in CP digestibility. Another explanation might be that the rate of protein degradation and ammonia absorption did not correspond directly to the observed differences in digestibility. Other factors like rumen pH, passage rate, or the balance between rumen-degradable and undegradable protein could also influence this relationship.

Ruminal pH is a critical parameter reflecting the balance between acid production and buffering capacity in the rumen. The ruminal pH values remained within the optimal range (7.15-7.65) for ruminal fermentation across all treatments, showing no significant variation. This stability is crucial as it indicates that the inclusion of hydroponic maize fodder did not induce any adverse effects on ruminal acid-base balance. Hydroponic maize fodder tends to have a high-water content and contains simple sugars that are rapidly fermentable. This could potentially lower rumen pH if overfed. However, when included at moderate levels, it seems to provide enough fermentable energy without causing a drop in pH. Hydroponic maize fodder also contains moderate amounts of fiber, particularly neutral detergent fiber (NDF), which stimulates chewing and saliva production, thereby contributing to the rumen's buffering capacity. Adequate fiber is essential to keep the rumen pH stable, as it promotes rumination and the production of bicarbonate-rich saliva (Chethan *et al.*, 2022).

Blood urea nitrogen (BUN) concentration is an important indicator of protein metabolism, dietary protein utilization, and nitrogen balance in ruminants. It reflects the amount of nitrogen being excreted as urea after protein catabolism. In this study, the mean levels of BUN ranged from 40.79-41.91 mg/dL, with no significant differences among treatments (p = 0.575). These levels remain above the normal range of 15 to 25 mg/dL (Okere *et al.*, 2022). This suggests that protein utilization and nitrogen balance were similar across the different dietary treatments. Despite variations in dietary composition, the goats maintained a stable nitrogen status, reflecting efficient utilization of dietary protein and nitrogen regardless of the level of hydroponic maize fodder substitution. Similar results were reported by Arif *et al*. (2023) indicating that no significant differences were observed when goats were fed barley and hydroponic maize fodder.

Blood glucose concentration reflects the availability and utilization of glucose, the primary energy substrate, in the bloodstream. Blood glucose levels in ruminants are primarily maintained through gluconeogenesis, the production of glucose from non-carbohydrate sources, mainly propionate (VFA) produced during fermentation. In this study, the blood glucose concentrations also did not show significant differences across the treatments (p= 0.584). The non-significant differences in blood glucose concentrations among treatments indicate that the substitution of conventional feed with hydroponic maize fodder did not adversely affect the animals' energy metabolism. The consistent glucose levels across treatments suggest that hydroponic maize fodder provides an adequate and stable source of carbohydrates. This is important for meeting the energy requirements of the animals, particularly in maintaining physiological functions and supporting productive performance. Normal blood glucose levels for goats range from 50 to 75 mg/dL (Fanta *et al*., 2024).

The consistent blood glucose concentrations observed across treatments suggest that substituting grass silage with hydroponic maize fodder enriched with fermented compost tea did not markedly affect glucose metabolism or energy utilization in Kacang goats. Stable blood glucose levels suggest that energy metabolism and glucose utilization remained relatively constant across the dietary treatments, reflecting a balanced energy status in the animals. The similar blood glucose levels across treatments indicate that the overall carbohydrate metabolism and gluconeogenic efficiency are unaffected by the different levels of hydroponic maize fodder substitution. A previous study also reported no significant differences between treatments on blood glucose when Beetal goats were offered barley and corn hydroponic (Arif *et al.*, 2023). In addition, Benu *et al*. (2024b) recorded similar results in weaned Ongole x Brahman calves maintained on grass silage and replaced with increasing levels of hydroponic maize fodder.

CONCLUSION

Substituting grass silage with hydroponic maize fodder enriched with fermented compost tea up to 75% of the diet improved digestibility and rumen fermentation without negatively affecting intake, digestibility, or blood metabolites in Kacang goats, suggesting its potential as an alternative feed. However, complete substitution (100%) reduced intake, indicating challenges at higher substitution levels.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

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