p-ISSN 2615-787X e-ISSN 2615-790X
Accredited by Directorate General of Higher Education, Research, and Technology, Republic of Indonesia, No. 225/E/KPT/2022

Tropical Animal Science Journal, September 2024, 47(3):354-362
DOI: https://doi.org/10.5398/tasj.2024.47.3.354
Available online at https://journal.ipb.ac.id/index.php/tasj

Performance of Thin-Tailed Sheep Fed Cassava Peel Silage-Based Diet with Different Protein Supplements

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(Received 19-02-2024; Revised 20-06-2024; Accepted 21-06-2024)

ABSTRACT

Growing sheep using native grass or crop byproducts has been commonly practiced by farmers in East Java, Indonesia. Better growth rates can be achieved when protein and energy sources are combined in the ration. This study aimed to evaluate the effect of feeding cassava peel silage (CPS) and different protein sources on the growth of sheep fed a maize stover-based diet. Twenty-four growing sheep aged 8-10 months and weighing 17.24 ± 1.87 kg were used, and they were kept in individual cages that allowed the measurements of feed intake, feces, and urine secreted per animal. The treatments applied were T1: rice bran (0.75% BW)+Urea (2% CPS); T2: (50% rice bran + 50% copra meal in 1.5% BW); T3: cassava leaf hay (1% BW); and T4: sunflower leaf hay (1% BW). All treatments provided maize stover (MS) at 0.5% of body weight and CPS *ad libitum*. The variables measured were nutrient intake and digestibility, rumen fermentation, and live weight gain (LWG). The results revealed that the treatments had a significant increase ($p<0.01$) in the digestibility of CP, EE, CF, NDF, and ADF and reduced the amount of methane gas (CH_4). Additionally, the treatments had a significant increase ($p<0.01$) in some variables such as N retention, LWG, and reduced FCR. Furthermore, the treatments significantly increased ($p<0.05$) NH_3, propionic acid, and the C_2/C_3 ratio, but they did not have a significant effect on pH, acetic acid, or butyric acid content. In summary, the T3 treatment improved live weight gain (LWG) and decreased the feed conversion ratio (FCR) in thin-tailed sheep.

Keywords: cassava peel silage; protein source feed; sheep production; thin-tailed sheep

INTRODUCTION

Sheep and goat farming are the most popular animal production activities for smallholders in Indonesia, and this is related to the lower budget needed and greater tolerance to low-quality local feeds and diseases, especially sheep, than beef or dairy cattle (Retnaningrum *et al.*, 2021). This evidence indicates that a proper feeding system plays a very important role in accelerating animal growth and improving business operation efficiency. For this reason, it is necessary to explore available local feeds and evaluate their quality for use in sheep rations so that the feeds offered are nutritionally adequate to support the animals' growth, and the technology introduced is technically easy for farmers to use to provide nutrients for animals at low prices. One of the potential local feeds that are abundantly available at the farmer level is cassava peels as an energy supplement to foliage or poor-quality feed. However, the low crude protein content in fresh cassava peels (4.8%) (Heuzé *et al.*, 2016) will not be adequate unless they are combined with protein sources.

Cassava (*Manihot utilissima*) is a local plant that is widely cultivated by Indonesian farmers to produce tubers for the food processing industry, and its peels constitute 15% of the total tubers on average (Anyanwu *et al.*, 2015). One of the constraints in utilizing cassava peel as animal feed is the presence of an antinutritional agent called cyanic acid (HCN), and a water content of approximately 13% causes molds to develop easily (Retnaningrum *et al.*, 2021).

Therefore, a strategy is needed to overcome these problems, such as preserving feedstuffs using an ensilage process that can reduce the HCN content (Oni *et al.*, 2014). During the ensiling process, an aerobic phase is established, creating favourable conditions for HCN. As the pH of the silage decreases, enzyme activities become limited, slowing down the elimination of HCN during storage (Oni *et al.*, 2014). Niayale *et al.* (2020) reported that sheep fed additional feed in the form of a mixture of cassava peel silage and cottonseed (3:1) had a greater average daily gain (ADG) (98 g/head/day) than sheep fed native grass only (57 g/head/day).

Potential protein source feed ingredients for ruminant animal feed include urea, copra meal, cassava leaf, and sunflower (*Thitonia diversifolia*) leaf. The use of urea as a protein source in feed must be balanced with feed rich in soluble carbohydrates because urea can be dissolved and hydrolyzed quickly into ammonia in the rumen by urease-producing bacteria (Tadele & Amha,

2015). Fresh cassava leaves contain dry matter (DM) (17.3%), crude protein (CP) (24.6%), ash (6.8%), and organic matter (OM) (93.2%) (Kounayongsa *et al.,* 2010). Sunflower plants contain DM (11.00%), CP (20.60%), EE (4.0%-0%), and CF (18.90%), and sunflower leaves contain 26.72% CP (Villegas *et al.,* 2020), while copra meal contains 24.6% CP (Retnaningrum *et al.,* 2021). This article addresses a significant topic concerning the use of agricultural waste from the agro-industry as a renewable energy source, specifically focusing on cassava peel. These peels are processed into silage to decrease the presence of the antinutrient HCN. Additionally, this silage is enriched with local protein sources such as cassava leaf hay, sunflower leaf hay, copra meal, and urea to enhance the productivity of thin-tailed sheep. Therefore, this study was conducted to evaluate the effect of cassava peel silage (CPS) supplemented with different protein sources on the growth of sheep fed a maize stover-based diet.

MATERIALS AND METHODS

Ethical Approval

The experimental studies were approved by the Animal Ethics Committee of Universitas Brawijaya 024-KEP-UB-2022.

In Vivo Feeding Trial

Twenty-four growing sheep aged 8–10 months with an average body weight of 17.24 kg were used. The animals were placed in individual metabolic cages from which feces and urine could be collected. Before the study was executed, the sheep were dewormed using Nitrox nil at a dose of 0.5 mL/20 kg live weight. The treatments applied were as follows: T1: rice bran (0.75% BW)+Urea (2% CPS); T2: (50% rice bran + 50% copra meal in 1.5% BW); T3: cassava leaf hay (1% BW); and T4: Sunflower leaf hay (1% BW). All treatments provided maize stover (MS) at 0.5% of body weight and cassava peel silage (CPS) *ad libitum*. For daily feeding management, MS was given first, followed by CPS. Protein sources were offered twice daily at 10 a.m. and 3 p.m. Samples were taken when the feeds were offered, and refusals were used to calculate nutrient feed intake. The animals were weighed every two weeks before the morning feeding during the trial. The nutrient contents of the feed ingredients are shown in Table 1, while the ratios and chemical compositions of the experimental diets are shown in Table 2. The variables observed during the early stage included growth performance (initial body weight, LWG, final body weight, and feed intake). A representative sample of ensiled cassava peel was taken and analyzed for DM, CP, ether extract (EE), and CF following AOAC (1995). Dry matter and total ash contents were analyzed using a TGA-500 furnace (Leco Corporation, St. Joseph, MI, USA), heated at temperatures of 105 °C and 550 °C, respectively, following AOAC method no. 942.05. Kjeldahl nitrogen (N) and CP were determined by multiplying nitrogen content by 6.25, utilizing the UDK 149 automatic Kjeldahl nitrogen protein analyzer. EE was assessed using a Soxhlet extractor (Extractions system B-811, Büchi, Flawil, Switzerland), according to AOAC method no. 963.15. CF values are stated as exclusive of any residual ash. Non-fiber extract was computed by deducting CP, EE, and CF from 100%. NDF and ADF contents were measured following the method used by methods of Van Soest *et al.* (1991) (Table 2).

NDF and ADF contents were determined by weighing a crucible (a) and placing a 0.5 g sample (b) into a 500 mL beaker. Then, 100 mL of neutral detergent solution (NDS) was added, while acid detergent solution (ADS) was used for ADF, and the mixture was heated. The sample was left for extraction for 60 minutes from the onset of boiling and during reflux. The residue was rinsed with 150 mL of distilled water and 40 mL of acetone. Subsequently, the glass plate and residue were dried in a 105 °C oven for approximately 8 hours until the weight became stable. The sample was then removed, cooled in a desiccator, and the cup was weighed (c). Afterwards, the sample was placed in a muffle at 550 °C for 2 hours, followed by cooling in a desiccator before weighing. The percentage of the NDF and ADF expressed using the formula:

$$\%NDF \text{ and } ADF = \{[(a + c) - a] / b\} \times 100\%$$

where a was the crucible weight, b was the weight of samples, and c was the weight of residue.

Table 1. Nutrient contents of the feed ingredients during experimental

Ingredients	DM (%)	Nutrient contents (% DM)							
		OM	CP	EE	CF	NDF	ADF	NFE	TDN
MS	25.81	88.99	9.29	1.74	23.73	59.42	32.28	54.23	68.37
CM	91.08	92.14	24.65	2.99	18.00	60.05	29.32	46.50	67.83
RB	90.29	85.09	11.51	9.64	31.03	59.35	49.45	32.91	62.54
CPS	28.49	90.46	6.49	1.28	17.10	34.15	27.71	65.59	75.55
CLH	88.93	84.08	30.23	5.58	18.10	52.41	46.40	30.17	58.60
SLH	85.03	78.22	24.03	2.39	17.49	41.12	39.99	34.31	55.16
Urea	-	-	287.50	-	-	-	-		

Note: DM= dry matter, CP= crude protein, EE= ether extract, CF= crude fibre, NDF= neutral detergent fibre, ADF= acid detergent fibre, NFE= nitrogen-free extract, TDN= total digestible nutrient, MS= maize stover, CM= copra meal, RB= rice bran, CPS= cassava peel silage, CLH= cassava leaf hay, SLH= sunflower leaf hay.

Study Area

The experiment was conducted at the Sumber Sekar Research Station, Dau sub District, Malang Regency, East Java Province, Indonesia (latitude 7.9185° S, longitude 112.5757° E).

Preparation of Cassava Peel for Ensiling and Feeding Programmes

Fresh cassava peel was obtained from a cassava processing factory located approximately 20 km from the research station. The peel was then chopped, washed, and withered for one night (±12 hours). The preservative used for making CPS comprised cassava flour of up to 2% of the total DM of cassava peel. The ensilage process took place over 21 days, and observations of the physical conditions, pH, and nutrient content of the silage were conducted. The feeds were offered in a sequence of eight times/day at 07:30 a.m., 8 a.m., 9 a.m., 10 a.m., 1 p.m., 2 p.m., 3 p.m., and 4 p.m. The following feeds were used: 07:30 a.m., maize stover (50%); 8 a.m., cassava peel silage (*ad libitum*); 9 a.m., feed containing a protein source (50%); 10 a.m., CPS (*ad libitum*); 1 p.m., maize stover (50%); 2 p.m., CPS (*ad libitum*); 3 p.m., feed containing a protein source (50%); and at 4 p.m., *ad libitum (CPS*). Water was provided *ad libitum* during the experimental period. The feed was adapted over 14-day adaptation periods. The feed intake was recorded daily by measuring the amount of feed offered and refused. All of the sheep were weighed individually in the morning before feeding using a weighing scale (True Test, New Zealand). LWG was expressed as the difference between the final and initial weights of the sheep divided by the day on which the study was conducted.

Digestibility, N Balance, and Growth of Sheep

Digestibility values were assessed by collecting fecal samples from each animal, while for determining nitrogen balance, urine was collected from each animal using bottles supplemented with 0.1 N sulphuric acid to preserve the nitrogen in the urine, following the method outlined by Retnaningrum *et al.* (2021). Urine samples taken daily were pooled for each animal every week, and subsamples were taken for N analysis. The samples were then bulked for 7 days and subsamples (10%) were taken and dried in open air for 7 days prior to analysis.

Table 2. Ingredients and chemical compositions of the experimental diets

Item	Treatments			
	T1	T2	T3	T4
Maize stover	0.5% BW	0.5% BW	0.5% BW	0.5% BW
Cassava peel silage	*Ad libitum*	*Ad libitum*	*Ad libitum*	*Ad libitum*
Rice bran	0.75% BW	0.75% BW		
CM : RB (1:1)				
Protein source:				
Urea	2% CPS	-	-	-
Copra meal	-	0.75% BW	-	-
Cassava leaf hay	-	-	1% BW	-
Sunflower leaf hay	-	-	-	1% BW
Ingredients:				
Maize stover, %	12.3	12.4	12.4	12.4
Cassava peel silage, %	67.5	49.6	62.2	62.2
Rice bran, %	18.4	18.6	0.0	0.0
Urea, %	1.4	0.0	0.0	0.0
Copra meal	0.0	18.6	0.0	0.0
Cassava leaf hay, %	0.0	0.0	24.9	0.0
Sunflower leaf hay, %	0.0	0.0	0.0	24.9
Mineral, %	0.4	0.7	0.5	0.5
Total (%)	100	100	100	100
Chemical composition:				
DM, % DM	34.99	44.66	33.8	33.65
OM, % DM	89.41	89.58	88.68	87.21
CP, % DM	11.58	11.19	12.77	11.22
EE, % DM	2.86	3.22	2.41	1.61
CF, % DM	20.14	20.63	18.05	17.9
NDF, % DM	41.46	46.89	41.87	39.05
ADF, % DM	31.92	32.66	32.95	31.35
TDN, % DM	73.42	75.42	76.32	74.21

Note: BW= body weight, DM= dry matter, OM= organic matter, CP= crude protein, EE= ether extract, CF= crude fiber, NDF= neutral detergent fiber, ADF= acid detergent fiber, CM= copra meal, RB= rice bran. T1= rice bran (0.75% BW)+Urea (2% CPS), T2= (50% rice bran + 50% copra meal in 1.5% BW), T3= cassava leaf hay (1% BW), T4= Sunflower leaf hay (1% BW).

Ruminal Fluid Profile

Rumen fluid sampling was conducted on the final day of the data collection stage, 3 hours after the morning feeding. Samples of rumen fluid were taken orally from all 24 sheep, with each sample comprising 20 mL; the rumen pH was then directly measured using a pH meter. The rumen fluid samples were divided into 2 bottles; H_2SO_4 solution was added to each bottle until the rumen fluid pH reached 2–3 (acid pH). The samples in each bottle were tightly closed and labeled and then stored in a freezer at -20 °C before being used in the NH_3 and VFA analysis. Ammonia (NH3) concentrations were determined using the Conway microdiffusion technique (Conway, 1962). Initially, the Conway cup was prepared by coating both the cup and its lid with vaseline. Next, one milliliter of specified boric acid was placed in the cup's center, while one milliliter of supernatant was added to the right side and one milliliter of Na_2CO_3 to the left side of the cup. The cup was then sealed, gently mixed, and left to incubate at room temperature for 24 hours. Following this incubation period, the solution was titrated with 0.01 N H_2SO_4 until the color changed to pink, enabling the calculation of NH_3 content. VFA analysis was conducted according to the method outlined by Fernández *et al.* (2016). For sample preparation, 200 µL of a mixture containing 25% metaphosphoric acid and formic acid in a 3:1 ratio was added to 1 mL of rumen liquid. After centrifugation for 30 minutes, the clear supernatant was diluted tenfold in water and injected into the gas-liquid chromatograph (DW-GC1120).

Statistical Analysis

The data obtained were subjected to statistical analysis using the following model:

$$Y_{ij} = \mu + \beta_j + \delta_i + \varepsilon_{ij}$$

where Y_{ij} was the dependent variable, μ was the overall mean, β_j was the effect of the block, δ_i was the effect of the treatment, and ε_{ij} was the random error. All data obtained were subjected to a statistical analysis by ANOVA using the general linear model procedure of Minitab software in Minitab® 17.1.0 version. The treatment least square means showing significant differences at the probability level of $p<0.05$ were compared using Tukey's pairwise comparison procedure.

RESULTS

Nutrient Intake and Digestibility

The nutrient intake and digestibility data for DM, OM, CP, EE, CF, NDF, and ADF are shown in Table 3. Statistical analyses revealed that the treatments significantly increased ($p<0.01$) nutrient intake (DM, OM, CP, EE, CF, NDF, and ADF). Moreover, the treatments significantly increased ($p<0.01$) CP, EE, CF, NDF, and ADF digestibility. The highest nutrient intake and digestibility of DM and OM were observed in the sheep that received treatment T3 (Table 3).

Table 3. Feed consumption and nutrient digestibility of thin-tailed sheep fed cassava peel silage-based diet with different protein supplements

Variables	Treatments				SEM	p value	Note
VFI (g/kg LW0.75)/day	T1 (n=6)	T2 (n=6)	T3 (n=6)	T4 (n=6)			
DM	70.48^{ab}	80.91^{bc}	82.20^{c}	66.10^{a}	1.86	0.001	**
OM	63.07^{ab}	72.60^{b}	73.07^{b}	57.77^{a}	1.72	0.0006	**
CP	7.31^{a}	8.31^{a}	9.85^{b}	7.27^{a}	0.26	0.0001	**
EE	1.13^{a}	2.28^{c}	1.86^{b}	1.06^{a}	0.10	0.00001	**
CF	14.00^{b}	16.22^{c}	14.83^{bc}	11.95^{a}	0.386	0.0001	**
NDF	29.30^{a}	36.39^{b}	33.99^{b}	26.28^{a}	0.93	0.00001	**
ADF	22.25^{a}	25.67^{b}	26.58^{b}	20.67^{a}	0.61	0.0001	**
DM intake (%LW)							
Maize stover	0.50	0.50	0.50	0.50	0.0001	1.00	ns
Cassava peel silage	2.31^{b}	2.20^{ab}	2.55^{b}	1.92^{a}	0.07	0.018	**
Protein supplement	0.57^{a}	1.12^{c}	0.84^{b}	0.73^{ab}	0.04	0.00001	*
Total	3.37^{ab}	3.82^{b}	3.89^{b}	3.16^{a}	0.08	0.0019	**
Nutrients digestibility							
DM	59.79^{a}	60.50^{a}	63.09^{b}	59.37^{a}	0.58	0.02	*
OM	65.37	65.60	66.93	64.20	0.489	0.14	ns
CP	48.35^{c}	44.33^{c}	39.68^{b}	32.23^{a}	1.37	0.00001	**
EE	69.69^{b}	85.05^{c}	58.45^{a}	57.52^{a}	2.42	0.00001	**
CF	24.80^{a}	26.19^{a}	32.58^{b}	28.10^{a}	0.74	0.0001	**
NDF	33.82^{a}	40.36^{b}	44.38^{b}	34.12^{a}	1.03	0.00001	**
ADF	32.17^{a}	31.50^{a}	43.22^{b}	39.90^{b}	1.21	0.00001	**

Note: VFI= voluntary feed intake, n=number of animal used, SEM= standard error mean, T1= rice bran (0.75% BW)+Urea (2% CPS), T2= (50% rice bran + 50% copra meal in 1.5% BW), T3= cassava leaf hay (1% BW), T4= Sunflower leaf hay (1% BW), DM= dry matter, OM= organic matter, CP= crude protein, EE= ether extract, CF= crude fiber, NDF= neutral detergent fiber, ADF=acid detergent fiber, LW= live weight. *= Means in the same row with different superscripts differ significantly at $p<0.05$, **= Means in the same row with different superscripts differ significantly at $p<0.01$, ns= $p>0.05$ and $p>0.01$.

Digestible Nutrient Intake

The intakes of the digested nutrients (DM, OM, CP, EE, CF, NDF, and ADF) are shown in Table 4. Statistical analysis revealed that the treatments significantly increased ($p<0.01$) the intake of the digested nutrients (DM, OM, CP, EE, CF, NDF, and ADF). As stated earlier, the highest intake and digestibility values were recorded in the sheep that received treatment T3. As a result, the highest intakes of digested nutrients (DM, OM, and CP) were also recorded in T3.

N Retention, LWG, and FCR

The N balance, LWG, and FCR data are shown in Table 5. Statistical analysis revealed that the treatments significantly increased ($p<0.01$) the N retention, LWG, and reduced the FCR values. The highest N retention was recorded in the sheep that received treatment T3. The live weight gain of the sheep ranged between 58.10 and 92.62 g/head/day, where treatment T3 consistently had the highest LWG as a consequence of the relatively high intake, digestibility, and intake of digested nutrients and N retention achieved. As shown in Table 5, the lowest FCR was achieved in the T3 treatment group, followed by the T2, T1, and T4 treatment groups.

Rumen Fluid Profile

The rumen fluid profile of the sheep included in the study is shown in Table 6. Statistical analysis revealed that feed treatment significantly increased ($p<0.05$) the NH_3 concentration, propionic acid content, and C2/C3 ratio but did not affect ($p>0.05$) the pH or acetic or butyric acid content. The values of pH, NH_3, and VFA were within the normal range to support the activity of microorganisms in the rumen. The highest pH value and NH_3 concentration occurred in T3 (6.90 pH; 14.66 mg N-NH_3/l NH_3) and in T1 (6.85 pH; 20.05 mg N-NH_3/l NH_3) treatments, respectively. The highest propionic acid and acetic acid contents were attained by sheep given treatment T2 (15.41 propionic acid; 45.96 acetic acid). Through stoichiometric calculation, it can be deduced that increased production of acetic and butyric acids leads to greater CH_4 production.

DISCUSSION

Nutrient Intake of Thin-Tailed Sheep

The high nutrient intake of DM, OM, CP, and EE of the sheep that received T3 may have been related to the high cassava peel silage intake (2.55% BW), which

Table 4. Digested nutrient intake of thin-tailed sheep fed cassava peel silage-based diet with different protein supplements

Digested nutrients' intake (g/kg $BW^{0.75}$/d)	Treatments				SEM	p value	Note
	T1 (n=6)	T2 (n=6)	T3 (n=6)	T4 (n=6)			
DM	38.57^{ab}	44.27^{bc}	44.98^{c}	36.17^{a}	1.01	0.001	**
OM	38.97^{ab}	44.86^{b}	45.15^{b}	35.70^{a}	1.06	0.0006	**
CP	3.45^{a}	3.93^{a}	4.65^{b}	3.43^{a}	0.12	0.0001	**
EE	0.79^{a}	1.60^{c}	1.31^{b}	0.74^{a}	0.07	0.0001	**
CF	3.10^{b}	3.59^{c}	3.29^{bc}	2.65^{a}	0.08	0.0001	**
NDF	8.89^{a}	11.04^{b}	10.31^{b}	7.79^{a}	0.28	0.0001	**
ADF	6.38^{a}	7.36^{b}	7.63^{b}	5.93^{a}	0.177	0.0001	**

Note: BW=body weight, d=day, SEM=standard error mean, T1= rice bran (0.75% BW)+Urea (2% CPS), T2= (50% rice bran + 50% copra meal in 1.5% BW), T3= cassava leaf hay (1% BW), T4= Sunflower leaf hay (1% BW), DM= dry matter, OM= organic matter, CP= crude protein, EE= ether extract, CF= crude fiber, NDF= neutral detergent fiber, ADF=acid detergent fiber, **= Means in the same row with different superscripts differ significantly at $p<0.01$.

Table 5. Nitrogen retention, live weight gain, and feed conversion ratio of thin-tailed sheep fed cassava peel silage-based diet with different protein supplements

Variables	Treatments				SEM	p value	Note
	T1 (n=6)	T2 (n=6)	T3 (n=6)	T4 (n=6)			
N Intake, g/day	10.14^{a}	14.06^{ab}	16.40^{b}	9.71^{a}	0.78	0.001	**
Fecal N, g/day	5.24^{a}	7.90^{ab}	9.98^{b}	6.57^{b}	0.50	0.002	**
Urine N, g/day	1.71	1.55	1.63	1.1	0.16	0.651	ns
Total N emission, d/day	6.95^{a}	9.45^{ab}	11.61^{b}	7.67^{ab}	0.78	0.006	**
N Retention, g/day	3.19^{a}	4.61^{b}	4.79^{b}	2.38^{a}	0.25	0.0002	**
Fecal N, %	51.67^{a}	56.17^{ab}	60.86^{b}	67.68^{c}	1.36	0.0001	**
Urine N, %	16.91	11.04	9.94	11.33	1.10	0.20	ns
Total N emission, %	68.58^{a}	67.21^{a}	70.80^{a}	79.01^{b}	1.42	0.021	*
N Retention, %	31.42^{b}	32.79^{b}	29.20^{b}	20.99^{a}	1.427	0.02	*
LWG (g/head/day)	61.67^{a}	89.29^{b}	92.62^{b}	58.10^{a}	4.362	0.0012	**
FCR	10.25^{ab}	8.71^{a}	8.40^{a}	11.06^{b}	0.409	0.0264	*

Note: N= nitrogen, n= number of animal used, ns=nonsignificant, SEM= standard error mean, LWG= live weight gain, FCR= feed conversion ratio, T1= rice bran (0.75% BW) + Urea (2% CPS), T2= (50% rice bran + 50% copra meal in 1.5% BW), T3= cassava leaf hay (1% BW), T4= Sunflower leaf hay (1% BW). *= Means in the same row with different superscripts differ significantly at $p<0.05$, **= Means in the same row with different superscripts differ significantly at $p<0.01$, ns= $p>0.05$ and $p>0.01$.

Table 6. Ruminal fluid profile of thin-tailed sheep fed cassava peel silage-based diet with different protein supplements

Variables	Treatments				SEM	p value	Note
	T1 (n=6)	T2 (n=6)	T3 (n=6)	T4 (n=6)			
pH	6.85	6.72	6.9	7.02	0.047	0.1359	ns
NH_3 (mg N-NH_3/L)	20.05	7.44	14.66	13.39	1.132	0.0001	**
VFA partial (m Mol/L):							
Acetic acid (C2)	45.96	53.38	48.48	51.74	2.056	0.0500	ns
Propionic acid (C3)	15.41[a]	23.73[b]	12.51[a]	13.46[a]	1.239	0.0001	**
Butyric acid (C4)	9.32	9.47	9.56	9.23	0.618	0.9971	ns
C2/C3 ratio	3.06[a]	2.28[a]	3.92[b]	3.96[b]	0.170	0.0001	**
C2:C3:C4	65.16:21.81: 13.03	61.60:27.28:11.13	69.05:17.68:13.27	69.85:17.94:12.21			
CO_2 (Mol)	57.58	54.31	58.85	57.73	0.641	0.0726	ns
CH_4 (Mol)	33.64[b]	29.54[a]	36.74[b]	36.55[b]	0.696	0.0000	**

Note: n= number of animals used, VFA= volatile fatty acid, ns= nonsignificant, SEM= standard error mean, pH= potential of hydrogen, NH_3= ammonia, CO_2= carbon dioxide, CH_4= methane. T1= rice bran (0.75% BW) + Urea (2% CPS), T2= (50% rice bran + 50% copra meal in 1.5% BW), T3= cassava leaf hay (1% BW), T4= Sunflower leaf hay (1% BW). **= Means in the same row with different superscripts differ significantly at p<0.01, ns= p>0.05 and p>0.01.

implied that cassava leaf hay supplemented in this study had improved palatability compared to the other protein supplements used in the rations across the treatments. Nevertheless, cassava contains hydrocyanic acid (HCN), which can be diminished through chopping and sun-drying before being used as cassava hay (CH) (Wanapat & Kang, 2013). According to Wanapat & Kang (2013), the first harvesting time of the leaves started three months after planting. The plants were then regularly harvested every two months, involving hand-cutting the young stems about 20–30 cm above the ground, leaving 3–5 branches. The freshly harvested tops were then either directly sun-dried or chopped before sun-drying to achieve an 80%–90% dry matter content (Wanapat & Kang, 2013). This process may take 2–3 days, but chopping accelerates drying. Sun-drying also removes over 90% of the hydrogen cyanide (HCN), improving taste, and facilitating long-term storage (Wanapat & Kang, 2013).

Harvesting cassava leaves during the early growth stage (3 months) to produce hay could lower the condensed tannin (CT) content and increase the protein content (25% of DM), leading to enhanced nutritive value (Wanapat & Kang, 2015). If the entire plant is harvested for haymaking after 4 months of planting, it can be harvested at the one-year mark, albeit with a reduction in root yield of approximately 15% compared to the original yield (Wanapat & Kang, 2015). Research from Fasae *et al.* (2011) indicates that incorporating 75% cassava hay into sheep diets can enhance dry matter intake and promote better growth performance.

Jiwuba & Udemba (2019) stated that feed consumption by livestock is highly dependent upon feed palatability, and the results of the present study showed that feeding cassava plant products (leaves and cassava peels) did not reduce palatability and has high potential for sheep production, even though the feed consumption (DM, OM, and CP) values observed were lower than those reported earlier (Fadiyimu *et al.,* 2016; Santos *et al.,* 2015).

The presence of wild sunflower leaf hay in the T4 ration resulted in the lowest feed consumption (DM, OM, CP, and EE), which might have been related to the bitter taste of wild sunflower leaves caused by antinutritional factors such as tannins, saponins, alkaloids, phytic acid, polyphenols, and flavonoids (Fasuyi & Okeke, 2014). The cassava peel silage in this study had a low CP content (6.49%), but the high cassava peel silage intake combined with the use of protein supplements in the rations increased consumption to achieve nutrient balance. Guimarães *et al.* (2014) reported that the CP intake in sheep fed cassava leaf hay and concentrate (a mixture of soybean meal and corn) was 12.27 g/kg BW0.75/day, and this value decreased to 11.02-11.57 g/kg BW0.75/day when cassava peel was present in the concentrate mixture. A greater percentage of cassava peel in the concentrate was followed by a decrease in CP intake. The highest digestibility in sheep that received the T3 treatment was mainly due to the nutritional content (see Table 2), in which the CP value was the highest in T3 and the CF was lower than that in T1 and T2. The high CP digestibility of T1 was due to the type of protein source feed used in the form of urea, which has a high solubility in the rumen (Tadele & Amha, 2015). Moreover, the low CP digestibility of T4 could be caused by the presence of tannins in wild sunflower leaf hay (Olmo-González *et al.,* 2022). It is possible that complex binding between tannins and proteins occurred, which led to a slower process of decomposition and digestion (Olmo-González *et al.,* 2022). The consumption of digested nutrients is influenced by nutrient intake and digestibility. Ferreira *et al.* (2017) stated that chemical composition, feed intake, and digestibility are closely related to metabolic processes. Low feed palatability and high fiber content in wild sunflower leaf hay in T4 are factors that cause low digestibility, which affects the intake of low amounts of digested nutrients.

Ruminal Fluid Profile of Thin-tailed Sheep

The pH values of T3 and T4, which represent sheep fed cassava and sunflower leaf hay, were greater or even closer to the normal pH value than those of sheep fed concentrated feed (T1 and T2), which were slightly lower (Table 2). The difference in NH_3 concentration in each treatment could be due to the differences in the type of

feed and the level of protein digestibility in the rumen, in which T1 showed the highest CP digestibility and T4 showed the lowest. Reddy & Hyder (2023) reported that the concentration of ammonia (NH_3) in the rumen is influenced by several factors, including the level of protein intake and the degree of protein degradation in the rumen. Proteins with high levels of degradation will produce ammonia in the rumen.

The high NH_3 concentration in T1 was due to the type of protein source feed supplementation given in the form of urea. Abdoun *et al.* (2006) stated that the factor that affects the production of NH_3 in the rumen other than the type and level of feed degradation is nonprotein nitrogen (NPN), which can decompose quickly into NH_3 in the rumen. Table 2 shows that the NH_3 concentration in sheep during the study was within the normal range of 7.44-20.05 mMol. Mcdonald *et al.* (2022) reported that the optimal range of NH_3 concentration for rumen microbial protein synthesis ranged from 6-21 mMol. The NH_3 concentration is closely related to microbial protein synthesis because microbes utilize ammonia as the main source of N for microbial protein synthesis. Microbial protein synthesis will be optimal if there is a good synchrony between the release time of the nitrogen source and the carbon skeleton in the rumen (Zhu *et al*., 2023). The high concentration of propionic acid in T2 was caused by supplementary feed in the form of a mixture of copra meal and rice bran (1:1), a waste product of rice milling that is high in carbohydrates. First, copra meal has a higher organic matter content, amounting to 92.14% of dry matter (DM). Additionally, compared with rice bran, copra meal has a greater nitrogen-free extract (NFE) content. This NFE can be converted into volatile fatty acids (VFAs) in the rumen, thereby providing propionic acid to the sheep rumen. In contrast, urea is directly converted into nonprotein nitrogen (NPN) upon reaching the rumen without containing organic matter.

Table 2 shows that acetic acid levels were not significantly different among treatments ($p<0.05$). However, the highest concentration of acetic acid (C2) was found in T2, followed by T4, T3, and T1. This disparity can be attributed to the high proportion of acetic acid in T3 and T4, which was influenced by the type of additional feed provided in the form of hay.

Moreover, the treatments significantly reduced CH_4 levels ($p<0.01$). This reduction may have been influenced by rice bran, which belongs to the grain family. The greater the production of acetic and butyric acids, the greater the production of CH_4. This occurs because the formation of acetic and butyric acids generates H_2 and CO_2, which are the primary precursors for methane gas production. Wang *et al.* (2014) reported that a greater production of acetic acid is followed by an increase in the production of H_2, so methanogenic bacteria have a greater opportunity to utilize H_2 in the formation of methane gas (CH_4).

The lowest C_2/C_3 of T2 can be interpreted as indicating that this treatment provides a better value for energy use efficiency than other treatments. The total concentration of partial VFAs in the present study was still within the normal range, at 70.54–86.58 mMol. McDonald *et al.* (2022) reported that a good VFA concentration for rumen microbial growth ranges from 70-150 mMol or equivalent to 5-10 g/l. A normal VFA concentration is an indicator that livestock have an adequate supply of energy for their daily needs, and this condition, coupled with an adequate protein supply, may improve nutrient utilization, hence increasing animal production. The increase in fiber-degrading microbiota led to greater hydrogen production in the rumen of sheep. Conversely, the reduction in VFA-producing microbiota indicated increased methane emissions and greater energy consumption in the sheep rumen. A prior study suggested that methanogens attach to protozoa and fungi (which degrade fibers to produce hydrogen) to acquire hydrogen (Langda *et al.*, 2020). Volatile fatty acids (VFAs) play a crucial role in the growth and immunity of ruminants (Naeem *et al.*, 2012). VFAs can heavily keratinize intestinal epithelial cells, thereby establishing a physical barrier within the rumen environment (Langda *et al*., 2020).

N Balance, Live Weight Gain, and Feed Conversion Ratio of Thin-tailed Sheep

The results of the current study showed that the sheep given all feed treatments had a positive N balance and the highest N retention in T3 could be caused by the highest CP content and CP intake (Table 3 and Table 4). Moreover, the lowest N retention in T4 was related to the lower CP content of the ration. Tables 3, 4, and 5 show that the sheep that received the T3 treatment had the highest feed intake, digestibility, and intake of digested nutrients, which led to the LWG values of those sheep being greater than those of the other treatments (Figure 1). The addition of protein sources in the present study may also cause an increase in CP intake, leading to an increase in the LWG. Tadele & Amha (2015) reported that sheep fed a mixture of cassava peel silage and cottonseed (3:1) had a greater LWG (69 g/day) than did those given dried cassava peel (61 g/day) or only field grass (40 g/day). This can be interpreted as indicating that processing in the form of silage can increase the nutritive value of cassava peel, which is consistent with the findings of Anaeto *et al*. (2013), who reported that sheep fed field grass *ad libitum* with the addition of unfermented cassava peel at 1.5% BW had low LWG (47.6 g/day). In a study by Dos Santos Silva *et al*. (2020), it was found that sheep fed cassava hay gained an additional 70 grams per day compared to sheep fed different types of hay. This finding underscores the potential of agricultural residue as a substitute ingredient in sheep diets. This result is linked to feeding behavior, particularly with sheep consuming cassava hay up to four times (Dos Santos Silva *et al*., 2020).

Niayale *et al*. (2020) conducted a study involving 45 sheep aged 4-6 months, reared for 70 days in 9 communal pens, each containing five sheep (three males and two females) on- farm. The diet comprised cassava peels (either dried or ensiled) and whole cottonseed in a ratio of 3:1. The results indicated that dry matter intake was 230 g/day with ensiled cassava peel supplementation, resulting in a higher live weight gain (6.9 kg or 98.57 g/

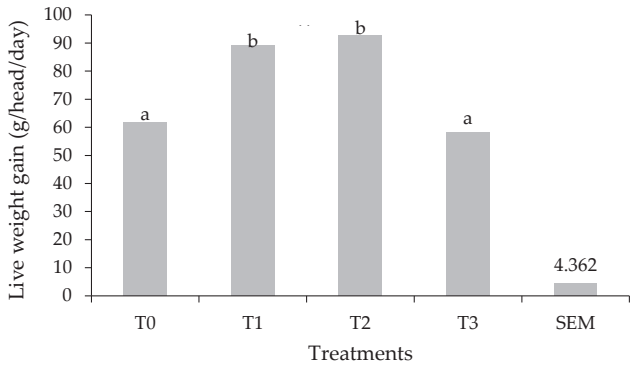

Figure 1. Live weight gain of thin-tailed sheep fed cassava peel silage-based diet with different protein supplements ($p<0.01$).

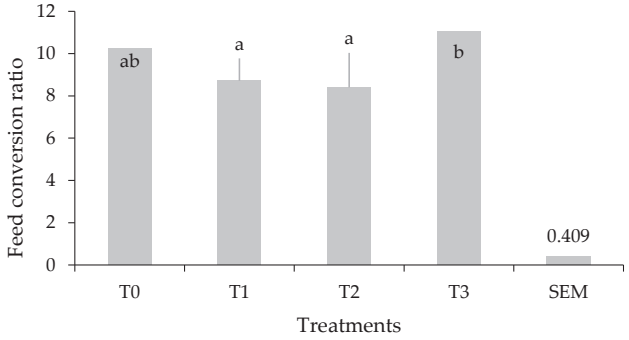

Figure 2. Feed conversion ratio of thin-tailed sheep fed cassava peel silage-based diet with different protein supplements ($p<0.01$).

day) compared to those fed dried cassava peels (6.1 kg or 87.14 g/day), where the dry matter intake was 180 g/day. Ensiled cassava peels had better LWG and FCR values than untreated cassava peels. The high FCR in T4 could indicate that the use of wild sunflower leaf hay as a protein source for sheep was not efficient, as high feed consumption was not followed by high LWG, and the T3 treatment was considered the most efficient compared to the other treatments because it had the lowest FCR (Figure 2).

The feed ingredients used in this study are available abundant and easy to be accessed by small farmers, so that utilizing those local feeds with the right strategy and management can be one of the efforts to develop smallholder farms. As cassava plants are grown by farmers in a wide range of climates and soil types in Indonesia, it is therefore highly possible to implement the feeding system based on cassava plant products for sheep production.

CONCLUSION

The use of cassava peel silage as a basal diet for growing sheep has great potential, and supplementation with different protein sources in sheep fed cassava peel silage-based diets improved total nutrient consumption, digestibility, the consumption of digested nutrients, ADG, and FCR. Cassava peel silage supplemented with 1% cassava leaves (T3) had the most efficient ratio, as indicated by the highest ADG and the lowest FCR. The use of cassava peel silage as a basal diet and as a suitable protein source for ruminants needs further study, especially with respect to animal growth and profits.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

ACKNOWLEDGEMENT

The authors express their gratitude to the Britannia Proofreading Service for editing the English language used in this manuscript. This research was funded by HGB 2019 from the Faculty of Animal Science, Universitas Brawijaya, Indonesia, with grant number 1726/UN10.F05/PG/2019.

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